WEDC Developing knowledge and capacity in water and sanitation

Water, Engineering and Development Centre
Loughborough University

Using the Shit/Excreta Flow Diagrams – SFDs- for modelling future scenarios in Kumasi, Ghana

by

Lara Fernández Martínez

A research project submitted in partial fulfilment of the requirements for the award of the degree of Master of Science of Loughborough University

August 2016

Supervisors:
R.E. Scott
C. Furlong

Loughborough University

Acknowledgements

I would like to take the opportunity to thank some people for their contribution to this research and their support during this intense and fructiferous year

- First and foremost, my research supervisors at WEDC, Rebecca Scott and Claire Furlong. Their guidance, assistance, and enthusiasm for the project has enabled the past four months of research to run smoothly and without any major difficulties
- WEDC staff for their support and care during my trip to Kumasi and the WEDC Conference.
- People from Kumasi for their interest and contribution to this research.
- Special mention of gratitude goes to Richard Dewhurst for his friendship and for volunteering to do the proof reading of this research.
- All WEDC students this year, it has been a great year in your company sharing much more than knowledge and group projects
- Hayat Al-jabiry and Karla Enrique for their unconditional friendship and all their support during the whole year.
- My mother, always there and always inspiring me.
- And last, but not least Sergio, thank you for believing in me and give me perspective. I would not have been here without you.

“No hay cicatriz, por brutal que parezca,
que no encierre belleza.
Una historia puntual se cuenta en ella,
algún dolor. Pero también su fin.
Las cicatrices, pues, son las costuras
de la memoria,
un remate imperfecto que nos sana
dañándonos. La forma
que el tiempo encuentra
de que nunca olvidemos las heridas”

Las Cicatrices, Piedad Bonnett

Certificate of Authorship

I certify that:

(i) I am responsible for the work submitted in this dissertation, and that the original work is my own except as specified below. *(specify)*

(ii) I have not submitted this work to any other institution for the award of a degree

(iii) All laboratory work and statistical analyses have been carried out by me with no outside assistance except as noted below. *(specify)*

(iv) All information (including diagrams and tables) or other information which is copied from, or based on, the work of others has its source clearly acknowledged in the text at the place where it appears.

Signed:

Date:

Research Dissertation Access Form

Location: WEDC Resource Centre, Loughborough University

Title:

Status of access: **OPEN**

Author's declaration:

I agree to the following conditions:

OPEN This dissertation shall be made available within the WEDC Resource Centre, and may be borrowed by WEDC staff and students. Pages may be copied, subject to copyright regulations. It may also be copied by the British Library for supply to requesting libraries and individuals, subject to a written assurance that it will not be published in part or in full. The dissertation may also be made freely available electronically through the WEDC knowledge base and/or the Learn server subject to Terms and Conditions for electronic access described in the Research Dissertation Notes.

Author's Signature: Date:

Conditions of access approved by: Rebeca Scott and Claire Furlong

Supervisors' signatures:

Abstract

The high population density of the cities does not allow families to safely abandon onsite sanitation facilities. This creates a need for a sanitation service chain to safely manage the faecal waste. Hence, Shit/Excreta Flow Diagram (SFD) are being developed as an analysis tool, which illustrates excreta pathways along the sanitation service chain in a city. The main objective of this study is to use the SFD methodology to model four possible future scenarios in Kumasi and predict the changes in excreta flow patterns. Four different scenarios have been defined using the population growth rate, the number of public toilets, number of private toilets and the treatment plant capacity as main variable parameters. First, a "baseline scenario" was formed, in order to analyse the potential change in the SFD if there is no investment in the next years and the population continues to increase. Afterwards two more scenarios were studied regarding the on-going projects or those that are about to start in the city. Finally, a combination of second and third scenarios was defined to illustrate the total change in the SFD if all projects are implemented.

For each scenario a list of questions has been proposed to define the minimum data collection required from secondary data and interviews. Once the scenarios were produced, bottlenecks were identified throughout the sanitation service chain in Kumasi: **Private toilets**: are not expected to significantly increase in the next year, and considering the high population growth rate this creates a high dependency on the public toilets. **Public toilet capacity**: the current number of public toilets cannot meet the future demand. The new toilets that will be constructed next years can meet the demand up to 2022. **Trucks capacity**: If the number of trucks remains constant, the trucks will not be enough after 2017. **Treatment plant capacity**: The treatment plant will work over capacity and its efficiency will be reduced.

Changes from one scenario to another can be observed comparing the SFDs but only interventions that target a high percentage of population have visual impact. Additionally, trends and changes within the same scenario are not easily observed (regarding only the SFDs). For that reason trend graphs have been used to analyse and discuss the results, disclosing: When there are installations that are full but not emptied the percentage of people who safely managed their excreta in the SFDs increases. This situation cannot represent a risk for the environment because the faecal sludge (FS) is contained. However, the FS is not being managed. Additionally, SFDs do not show what is happening with those people who relied on these full installations, e.g. are they to come back to practise OD? Finally it was observed that SFDs show the percentage of FS that is treated in the plants, but analysing only the SFD it is not clear if the treatment plant is working under or over capacity.

<u>Key words:</u> SFD, faecal sludge, Kumasi, sanitation service chain, urban sanitation.

Executive Summary

On site sanitation technologies are the predominant technologies in cities. The high density of the cities does not usually allow families to safely abandon onsite sanitation solutions and construct other nearby. This creates a need for a sanitation service chain to hygienically removed and transport the faecal material (Hawkins, Blackett and Heymans, 2013). The movement of the faecal material trough the sanitation chain is illustrated by the Excreta/Shit Flow Diagrams – SFDs-, giving a strategic overview of the sanitation situation in a city to the stakeholders (Blackett and Evans, 2015).

Nowadays the SFD methodology is being applied in 50 different countries and cities around the world to evaluate the methodology and explore its potential beyond an advocacy purpose. This research explores that potential by illustrating the changes produced by ongoing or planned interventions in the excreta pathways by using the SFD methodology in Kumasi.

In 2015, an SFD for Kumasi was produce by WEDC and KMA, as part of the SFD Promotion Initiative (Furlong, 2015). Using this SFD and identifying the ongoing and planned projects in the city, four possible future scenarios were modeled to predict the changes in excreta flow patterns in Kumasi.

The scenarios have been defined using population growth and planned investments in the city as main variable parameters. For each scenario a list of questions has been proposed to define the minimum data collection required from secondary data and interviews. This study has relied on the available secondary data and primary data collected from personal communications, online interviews and a short visit to Kumasi during 39th WEDC International Conference where additional interviews and observations were completed.

Once the data were analysed, a quantitative summary for each scenario was presented. The SFD calculation tool was used and the SFDs were produced for **Year 1** as starting point, **Year 5** because the identified projects are planning to be finish within 5 years and **Year 10** to illustrate what would happen if no more investments are planned.

Finally, “trend graphs” have been produced to show the progress in different aspects of the sanitation service chain over the10 years. These graphs allowed analysing and discussing the SFD results.

The first step was to identify the planned and ongoing project:

- “A toilet in every compound”: and its objective is to increase the access to compound toilets for 100,000 low-income residents in Kumasi by 2019.
- Rehabilitation of the Faecal Sludge Treatment Plant (FSTP): Affecting only the efficiency of the treatment but not its treatment capacity.

- Public toilets Project: 108 new public toilets are expected to be constructed.

Based on these projects four scenarios were defined and modelled. In every scenario each part of the sanitation service chain has been analysed. Within each scenario, different values of key parameters can be considered because they are not accurately defined. Therefore the SFD would be different, having scenarios within the defined scenario. In this study, the worst case scenario was selected because it is when the major changes are produced.

Scenario 1

Considered as a “baseline” scenario in which public investments are not considered for the next 10 years and then the main infrastructure remains constant. The population growth rate is used as main variable parameter.

Trends of this scenario showed that open defecation (OD) is going to increase in the next 10 years (from 4% in 2016 to 18% in 2025) because after 2017 there are not enough public toilets to cope with the demand. However the percentage of population who safely manage their faecal sludge (FS) is going to decrease first (from 45% to 39% in 2019) and increase after 2019 up to 45%. This rise is because there are installations that, even when full, cannot be emptied because the trucks do not have the capacity to meet the demand. Therefore the amount of installations that contain the FS but are not emptied increase. This is considered as safely managed by the SFD Methodology because the FS is contained.

Finally the trend in treatment has been analysed. The FSTP is working over capacity, reducing its efficiency up to 33%, however the SFD does not show when the capacity of the plant is reached. After 2019, the efficacy of treatment is constant because the amount of FS arriving at FSTP is going to be constant (the trucks do not have capacity to deliver more FS to the FSTP).

Scenario 2

This scenario has been defined by considering the projects: “A toilet in every compound” and “Rehabilitation of the FSTP”. As a consequence the main variable parameters are the population growth rate, the percentage of population living in compounds that are going to use new private toilets and the treatment efficiency of the FSTP.

The project “a toilet in every compound” affects a small percentage of population having a small visual impact in the SFD. The OD is going to change from 4% in 2016 to 16% in 2025 and the truck will not have capacity to cope with the demand after 2018.

The total percentage of people who safely manage their FS will change from 19% in 2016 to 62% in 2025. The small percentage in 2016 is due to the FSTP is going to be out of service for two years due to the rehabilitation works. Afterwards, the percentage of FS treated will be 62%. This is going to be constant for the same reason as in scenario 1 (trucks cannot cope the demand).

Scenario 3:
This scenario has been defined considering the “Public Toilets Project”. As consequence the main variable parameters are the population growth rate and the number of the public toilets

The rise in the number of public toilets will stop the increase of OD. However after 2021 it increases again up to 9% because the public toilets cannot respond to the population growth. Trucks reach their maximum capacity in 2017, when the new toilets are constructed.

The percentage of population who safely manage their faecal sludge (FS) is going to increase after 2017 up to 53%. As in scenario 1, this rise is due to trucks not having the capacity to meet the demand.
The trend in the FS treated at the FSTP is the same as in scenario 1, because investments on have not been considered in this scenario.

Scenario 4:
This scenario has been defined as a combination of Scenario 2 and 3. As a consequence the main variable parameters are: Population growth rate, the percentage of population living in compounds who is going to use new private toilets, the number of the public toilets, the treatment capacity of the FSTP

The new private and public toilets will retain the OD at 3% until 2023 when public toilets cannot respond to the population growth. OD will increase up to 7% in 2025. Trucks reach their maximum capacity in 2017.

The total percentage of people who safely manage their FS will change from 19% in 2016 to 72% in 2023. Then it decreases down to 70% because the OD will increase as well. As in scenario 2, the small percentage in 2016 is because the FSTP is going to be out of service for two years due to the rehabilitation works. Afterwards, the percentage of FS treated will be 62%.

The accuracy of the results depends on the quality of the data. In this case study, the results could be used as an approximation. To use the modelling SFDs to make decisions about

future investment, more accurate data is needed, especially from the Vacuum Tankers Operators.
Once the scenarios were produced, changes from one scenario to another can be observed comparing the SFDs but only interventions that target a high percentage of population have visual impact. Additionally, trends and changes within the same scenario are not easily observed (regarding only the SFDs). For that reason trend graphs have been used to analyse and discuss the results.

After the trend analysis two main conclusions can be made about the SFD tool and methodology:

- When there is a rise on the FS that is contained but not emptied- this means installations that are full but not emptied- seems to be positive, increasing the percentage of people who safely managed their excreta in the SFDs. This situation cannot represent a risk for the environment because the FS is contained. However, the FS is not being managed. Therefore depending on what the SFD wants to represent, if the management of FS or the environmental risk of the FS, this should be considered as good or bad managed.
  Additionally, SFDs do not show what is happening with those people who relied on these full installations, e.g. are they to going back to practise OD?
- The SFD shows the percentage of FS that is treated in the plants, but analysing only the SFD it is not clear if the treatment plant is working under or over capacity.

Finally, some recommendations have been made to use the SFD methodology to develop future scenarios:

- Including "trend graphs" as part of the methodology to analyse future changes. These trend graphs make the analysis process easier and more visual, simplifying the data analysis to all type of users and decision makers.
- It can be useful to try to model the future scenarios at the same time as the SFD is being developed for the current situation. Most of the data used to model future scenarios can be collected at the same time, at least that needed to develop the "baseline scenario"
- Extend to some years after the planned project deadline to observe when new interventions will be needed.

References

BLACKETT, I. and EVANS, B., 2015. *Introducing the Fecal Waste Flow Diagram Approach* [online]. Available from: http://www.susana.org/_resources/documents/default/3-2211-7-1442219928.pdf.

FURLONG, C., 2015. *SFD Report Kumasi, Ghana, 2015.* SFD Promotion Inicitiative [online]. Avaliable from: http://www.susana.org/_resources/documents/default/3-2361-7-1447766816.pdf

HAWKINS, P., BLACKETT, I., and HEYMANS, C., 2013. *Poor-Inclusive Urban Sanitation: An Overview* [online]. Washington DC, United States. Available from: https://www.wsp.org/sites/wsp.org/files/publications/WSP-Poor-Inclusive-Urban-Sanitation-Overview.pdf.

Table of contents

List of figures

List of tables

Abbreviations

AMA	Accra Metropolitan Assembly
EAWAG	Swiss Federal Institute of Aquatic Science and Technology Department
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
GPOBA	Global Partnership on Output-Based Aid
IWMI	Integrated Water Management Institute
JMP	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation
KNUST	Kwame Nkrumah University of Science and Technology
KMA	Kumasi Metropolitan Assembly
KVIP	Kumasi Ventilated Improved Pit Latrine
MDG	Millennium Development Goals
NGO	Non-Governmental Organisation
OD	Open Defecation
PPP	Public-Private-Partnership
SANDEC	Water and Sanitation in Developing Countries in EAWAG
SDG	Sustainable Development Goals
SFD	Shit/Excreta Flow Diagram
STP	Septage Treatment Plant
SuSanA	Sustainable Sanitation Alliance
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
VTO	Vacuum Tankers Operators
WASH	Water, Sanitation and Hygiene
WB	World Bank
WC	Water Closet (Flush toilet)
WEDC	Water Engineering Development Centre
WHO	World Health Organization
WMD	Waste Management Department in KMA
WSP	Water and Sanitation Program, World Bank
WSUP	Water and Sanitation for the Urban Poor
WW	Wastewater
WWTP	Wastewater Treatment Plant

Chapter 1. Introduction

1.1 Urban Sanitation Challenge

If an average human produces about 1.5 litres of excreta per day then a city of 1 million people discharges 1500 cubic meters of waste per day (Lüthi et al., 2011) that has to be managed in order to reduce the negative environmental and health impacts. In 2015 there were 538 cities with a population bigger than 1 million (Brinkhoff, 2016).

Currently, more than 50% of the world's population live in cities and urban dwellings as well as the number of cities grows every day. This increase in population growth rate is concentrated in periurban areas and slums. According to the JPM(WHO/UNICEF, 2015) 494 million of urban population still lack of access to improved sanitation mainly in low income settlements in Asia, Africa and Latin-America where governments do not have either resources and capacity to provide adequate services to the population.

It is believed predominated sanitation technology in urban areas is sewerage but in reality on site sanitation technologies are more widely used than sewers, above all within poor settlements (Strande, Ronteltap and Brdjanovic, 2014). Governments have neglected this solution because it was viewed as a temporary solution until sewers arrive. However the trend of using onsite sanitation is far from decreasing; in fact it is increasing due mainly to the rapid urbanisation in the poorest areas of cities.,

1.2 Research topic

1.2.1 Focus on excreta pathways

The high density of the cities does not allow families to safely abandon a full pit latrine and construct other nearby, creating a need for a sanitation service chain to hygienically remove and transport the faecal material to the treatment (Hawkins, Blackett and Heymans, 2013). That movement of the faecal material trough the sanitation chain is illustrated by the Excreta/Shit Flow Diagrams – SFDs- (Figure 1)

The SFD represent the excreta pathways along the city. The width of the arrows and the percentage represent the proportion of the population whose faecal waste takes on each route (Blackett, Hawkins and Peal, 2014) The green arrows represent the well managed excreta whereas the red ones represent the badly managed excreta which is spread at different levels in the urban environment. (ibid)

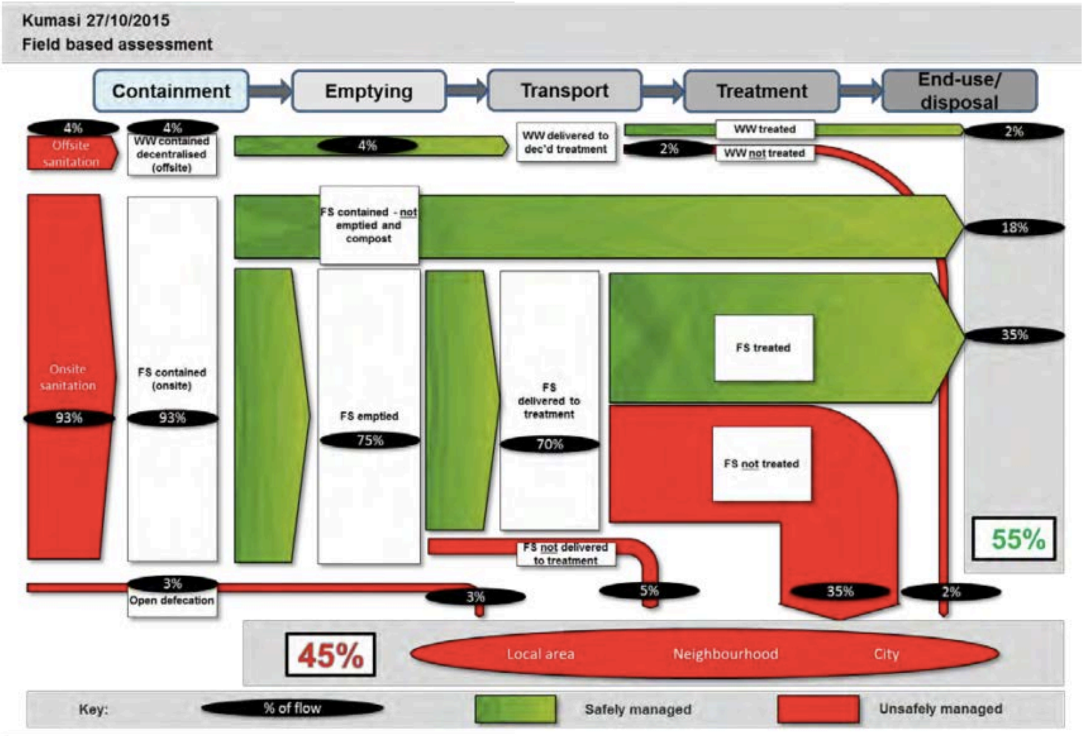


Figure 1: SFD Example. SFD of Kumasi, Ghana (Furlong, 2015a)

The SFD gives a strategic overview of the sanitation situation in a city to the stakeholders and it can point out the way towards specific tactical intervention along the sanitation chain (Peal and Evans, 2015). Nowadays, the tool is being applied in 50 different cities and cities to evaluate the methodology and explore its potential beyond an advocacy purpose. Exploring this potential by illustrating the changes in the sanitation service chain produced by ongoing or planned interventions in the excreta pathways is the central subject of this research.

1.2.2 Focus on small and medium cities in Africa

Over the last 20 years, Africa has been the part of the world most rapidly urbanising (UN-Habitat, 2016). This has been driven mainly by natural increase, rural–urban migration, spatial expansion of urban settlements through the annexation areas, and, in some countries, negative events such as conflicts and disasters (UN-Habitat, 2009)

This population growth has been concentrated in small and medium cities with less than 5 million of inhabitants where currently most of Africa's urban dwellers reside (United Nations, 2014).

Given that governmental efforts and investments have been focused on the largest cities services (UN-Habitat, 2016), small and medium cities with fewer resources and higher growth rates represent a challenge to achieve sustainable and affordable sanitation services..

1.2.3 Focus on Kumasi, Ghana

Kumasi is the second largest city in Ghana. It has a population of 2,8 million and a growth rate of 5.5% (Brinkhoff, 2012 and Farvacque-Vitkovic et al., 2008). This high rate is caused by a large transient and immigrant population through the city from all parts of the country, as well as from neighbouring West African countries (Maoulidi, 2010, Furlong, 2015a)

The research was focused on this city because, apart from being a secondary city with a high growth population rate, stakeholders were very involved and enthusiastic during the elaboration of the current SFD, making their participation more likely and facilitating the data collection process.

Figure 2 shows that Kumasi is located in South Ghana, 300 km north of the capital Accra (Maoulidi, 2010) covering an area of 254 km2 (Furlong, 2015a)

The city comprises nine sub-metropolitan areas (figure 3): Manhyia, Tafo, Suame, Asokwa, Oforikrom, Bantama, Kwadaso, Nhyiaeso, Asawase and Subin, (Maoulidi, 2010).

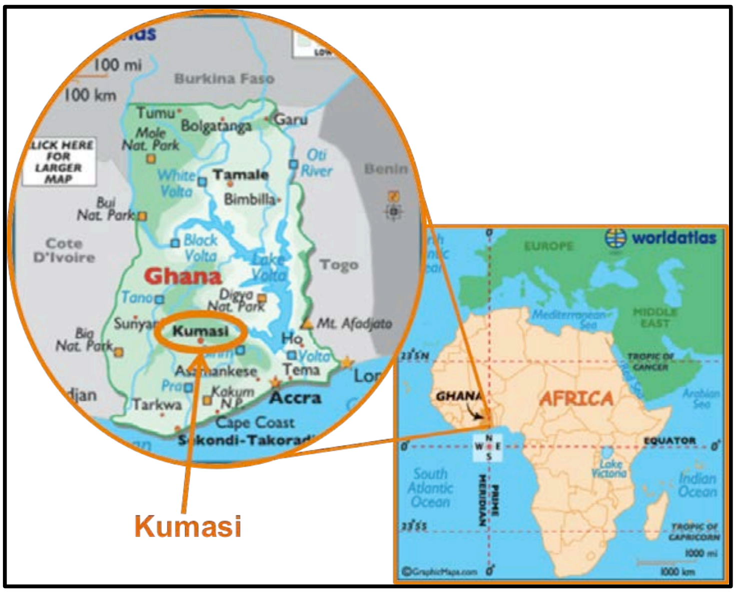


Figure 2: Kumasi Location, adapted from Worldatlas, 2016.

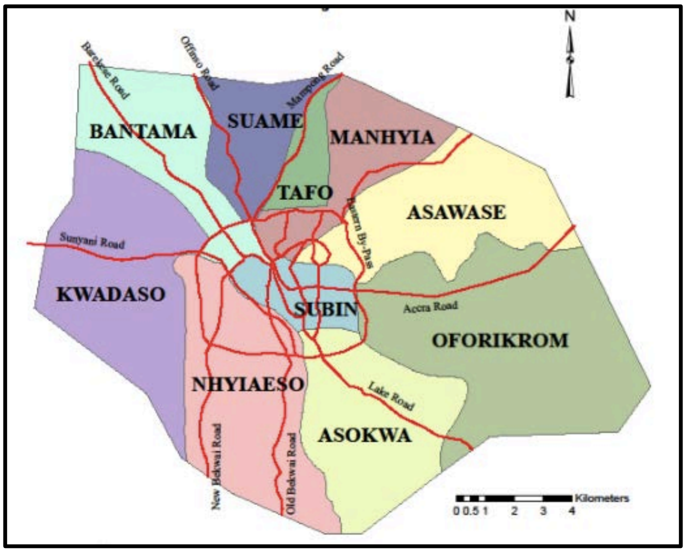


Figure 3. Kumasi Sub-metros (Maoulidi, 2010).

It is important to underline, Asawase that has been excluded from Kumasi and no longer falls within the KMA boundaries (Furlong, 2015a) but the data collected for this study includes this sub-metropolitan area.

The coverage of sanitation at household level is 97% (93% is considered onsite sanitation) and the total amount of excreta flow safely managed is 55% over the total produced by both, onsite and offsite sanitation (Furlong, 2015a)

1.3 Aim, objectives and research questions

The aim of this research is to answer the following question: How can the SFD methodology be used to model different scenarios and predict changes in faecal waste flow patterns as sanitation services change in a city?

Four main objectives have to be achieved to answer different research questions:

1. Outlined the contribution of SFD to urban sanitation
    a. What are the urban sanitation challenges?
    b. What is an SFD? What is it used for? What is its potential?
2. Defined future scenarios to be modelled in Kumasi, Ghana
    a. What variables have to be considered when modelling futures scenario?
    b. What are the questions to be answered through data collection?
3. Produced the SFD for the defined scenarios
    a. What data have to be collected to be able to produce the future SFD?
    b. How the SFD changes when an intervention is produced?
4. Appraised the SFD tool identifying the strengths and the weakness in relation to modelling future scenarios
    a. What are the limitations of SFD methodology?
    b. How the SFD tool or methodology can be improved?

1.4 Scope

This research will use the existing SFD tool and its methodology to predict changes in the excreta flow pathways.

1.5 Dissertation overview

The structure of this dissertation shows the process developed during the research in a chronological order.

Chapter 2 presents the literature review undertaken, starting with an explanation of the strategy (section 2.1) and the type of literature assessed (section 2.2) and followed by overview about urban sanitation from the MDG to the SDG (section 2.4). Afterwards the sanitation service chain is explained in order to introduce the SFD tool (section 2.5 and 2.6).

Finally a summary is exposed in section 2.7 and the gaps found out during the literature review listed up (section 2.8).

Chapter 3 describes the methodology. It consists of a brief explanation of the SFD tool (section 3.1) and how this has been used to model different scenarios (section 3.2). Section 3.2.2 describes how the scenarios have been defined followed by an explanation of the methods used to data collection (Section 3.2.3). Later the methodology to produce the SFDs and analyses the change in trends is presented (section 3.2.4 and section 5.2.5. This chapter finishes with a brief exposition about the ethical considerations of this study)

Chapter 4 contextualizes Kumasi, Ghana by a general background (section 4.1) additionally, explanations about the on-going and planned projects, which have been the base to define the scenarios, are presented (section 4.2)

Chapter 5 presents the scenarios. For each scenario a detailed explanation was made, explaining first each link of the sanitation service chain, and how the projections for the next years were calculated. Finally the SFD result for each year is exposed and the trend over the years analysed and discussed.

Chapter 6 exposes the conclusion and recommendations

Chapter 2: Literature Review

2.1 Introduction

The SFD is a new tool which is starting to be widely used by governments and institutions in developing countries to assess the situation of sanitation within the cities. However limited literature (very little publication and most of them from the same authors) has been found and as consequence this literature review was focused on getting an overview about how the SFD can contribute to the urban sanitation sector.

This chapter starts with an explanation of the methodology used to search for the information and the type of literature that has been used, detailed in section 2.2 and section 2.3 respectively. Then, section 2.4 presents how the urban sanitation vision has changed from an approach focused on household technology used by the MDG to a wider approach based on the services used by SDG. Afterwards, section 2.5 describes the sanitation service chain within a city and the factors to be considered: technology, stakeholders and an enabling environment. Section 2.6 explains the analytical tools for assessing the sanitation chain. Finally, section 2.7 sums up the main finding and section 2.8 underline the gaps in knowledge that have been found

2.2 Methodology

Firstly, documents recommended at the SFD Promotion Initiative website were analysed to understand the SFD and to have an overview of the main institutions which have been working in this field. Then, research at WEDC Resources Centre was carried out, there some general books about sanitation and urbanization have allowed the author to realise the global trend in sanitation.

After gaining an outline in the international situation of urban sanitation, more specific literature about the different sanitation approaches that have been developed over the last years (specially about the sanitation service chain) were sought using Catalogue Plus and Google Scholar, to find articles in specific journals. Some of the key words that have been used are included in table 1

Finally the literature has been complemented by personal contacts (expert lead), by searching on websites of the main institutions involved in urban sanitation in developing countries (UN, WSP, WSUP, Eawag/SANDEC) and by references found in books and articles (snowball effect)

The strategy used to develop the literature review and the results achieved have been summarised in Table 1. No major problems have been found to reach the articles and references used by other researchers.

Source of information	Justification	Results
SFD Promotion Initiative, SuSanA website	This is the website where most relevant information related to the SFDs can be found. It is the platform of the SFD Promotion initiative, which is doing SFD across 50 different cities.	Documents for understanding the SFD Methodology and its potential were found. A general overview of the main institutions working in FSM and sanitation chain was obtained.
WEDC Resources Centre	WEDC Resources Centre is a good starting point for getting a large number of references about any topic related to water and sanitation.	Book and journals related with sanitation and urbanization were found in the sections of sanitation and cities in the WEDC resources Centre
Catalogue plus /Loughborough Library	The main key words used were "sanitation service chain", "urban sanitation", "sanitation" + "SDG" or "MDG", "value chain", "sanitation ladder", "faecal sludge management" or "sanitation planning". The aim was to find the most relevant articles in journals/books, providing a starting point to find more specific information about sanitation service chain and new sanitation approaches	A preliminary research of 72 articles was done. After skimming the title and abstract of the articles around 27 articles were related to the topic of the dissertation. The articles are mainly from the journals: Environment and Infrastructure Journal and Journal of Water, Sanitation and Hygiene for Development.
Google Scholar/Google	Google has been used to locate references and articles, which could not have reached by others means. Additionally, this source has been used to make a general search about the SDGs and the sanitation service chain.	Some articles that could not be reached by the Catalogue Plus were found in Google Scholar. Additionally some general documents, flyers and brief notes related to "urban sanitation", "sanitation"+ "MDG" or "sanitation chain" were found.
WSP, WSUP, Eawag, WSUP, UN-Habitat, JMP-WHO/ UNICEF, IWMI	These institutions are a referent for the sector. As a consequence of browsing their websites some reports about their work in this field can be found as well as some projects that are being developed	Reports supporting the general knowledge about the sanitation chain and its failures were found, Additionally, some institution such as the UN and Eawag have a large number of publications about urban sanitation. The former related to urbanization, the MDG and the SDG the latter about FSM.
Personal Contacts	To have a better understanding about the SFD and the global trends of urban sanitation some people have been contacted	Grey literature and presentations related to the topic have been reached through these contacts
Other references	References in other articles and books can lead to specific information relating to a more general topic.	Articles published before 2011 have been found mainly from these sources because they do not use the key word or sanitation chain or FSM (relatively new concepts) but they were the starting point for this information

Table 1: Literature Review Strategy

2.3 Type of literature assessed

Due to SFD being a new tool that has been developed for international institutions and independent consultants, the literature is limited to reports from WSP or the SFD initiative. Only an article and a conference paper were found about SFDs, the rest of literature was presentations or reports from different institutions. Some grey literature has been gained through personal contacts.

Literature about the Sanitation Service Chain and Faecal Sludge Management, despite being relatively new concepts was found in some articles and books obtained through the sources of information. Additionally, there are many reports from NGOs or international institutions, which talk about urban sanitation and either its challenges or its planning.

A large amount of information was found about the MDGs in water and sanitation, within reports from the UN and the JMP being most comprehensive source of information. However, limited reports even from the UN were found analysing the new SDG and no articles and books have yet been published.

2.4 From the MDG to SDG

The Millennium Development Goals have been the framework for addressing the multidimensional problem of poverty for the past 15 years. Goal 7 included a target that defied the global community to halve, by 2015, the proportion of people without sustainable access to basic sanitation (WHO/UNICEF, 2015), The target has not been reached and currently there are still 2.1 billion people without access to basic sanitation, 700 million more than the aim of the MDG (ibid)

At the beginning, the JMP was focused on measuring ‘access’ or ‘no-access’ to basic sanitation at household level, Later approaches have been focused on expanding the concept to improve and unimproved sanitation using the sanitation ladder (Mehta and Mehta, 2013)

2.4.1 Sanitation Ladder

In 2008, the JMP developed the sanitation ladder shown in figure 4 to define in detail what is considered improved and unimproved sanitation giving information about the technology steps the population take from open defecation to improved sanitation in households (Kvarnström et al., 2011). The use of this sanitation ladder has facilitated the monitoring of the MDG, providing a more disaggregated analysis related to the type of sanitation facilities (Mehta and Mehta, 2013).

Lack of data about the sanitation services within the cities has made the use of statistics focused on improved facilities the most realistic and accurate option for monitoring the MDG (Allen and Hofmann, 2008) However, over the last few years some authors have underlined the limitations of this approach:

- The sanitation ladder is a technology-based approach, giving the expected solution to governments and reducing creativity to adapt services to meet the needs of the local context (Kvarnström et al., 2011)

- It is focused on households, hence It does not capture the service performance through different levels of the city - community, neighbourhood, zone, etc. (Kvarnström et al., 2011, Mehta and Mehta, 2013)
- The Sanitation Ladder does not measure if the system is adequate or sustainable to keep the surroundings free of excreta (Verhagen and Ryan, 2008, Kvarnström et al., 2011, Munamati, Nhapi and Misi, 2015)
- It does not consider the difference between rural and urban areas. Dense concentration of houses, which is far more common in urban areas (and increasingly common in informal settlements) (Kvarnström et al., 2011) also requires different sanitation solutions to single-storey housing. There, onsite solutions must be emptied and the faecal sludge managed (Jenkins et al., 2014, Satterthwaite, 2016)

Open Defecation when human faeces are disposed of in fields, forest, bushes, open bodies of water, beaches or other open spaces or disposed of with solid waste	Unimproved Sanitation
Unimproved sanitation facilities: do not ensure hygienic separation of human excreta from human contact. Unimproved facilities include pit latrine without slab or platform, hanging latrines and bucket latrines.	
Shared sanitation facilities: Sanitation facilities of an otherwise acceptable type shared between two or more household. Only facilities that are not shared or not public are considered improved	

Improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact. They include:
• Flush/pour flush to:
  ○ Piped sewer system
  ○ Septic tank
  ○ Pit latrine
• Improved ventilated pit (VIP) latrine
• Pit latrine with slab
• Composting toilet
	Improved Sanitation

Figure 4: Sanitation Ladder MDG, WHO/UNICEF JMP, 2015

Reviewed literature agrees about the need to understand, especially in the cities, what happens with human excreta beyond the point of containment (Williams and Overbo, 2015). The recommendation is to change from an approach based on technology which focuses on households to another that considers the safe management of faecal waste within the cities (Kvarnström et al., 2011, Kedam, 2012, Mehta and Mehta, 2013, WHO/UNICEF JMP, 2015b). This approach has been considered in the definition of the SDG.

2.4.2 SDGs

The SDGs are the new framework to continue the work started by the MDGs. Goal 6 is dedicated to water and sanitation, with a specific target about sanitation: "*6.2. By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation"* (WHO/UNICEF JMP, 2015b)

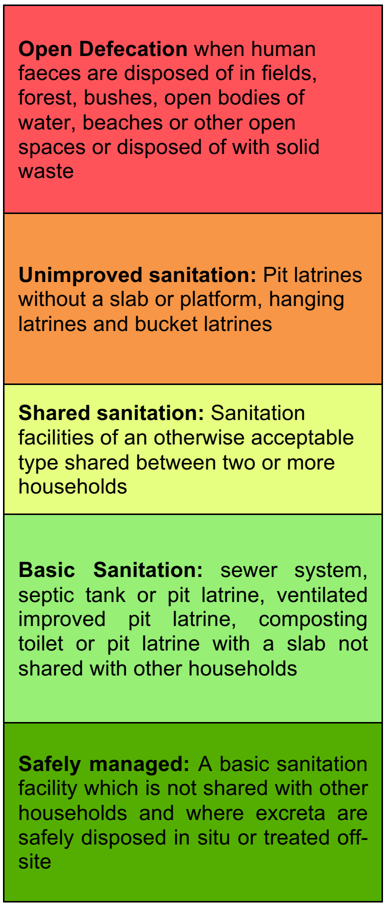


Figure 5: Sanitation Ladder SDG: WHO/UNICEF JMP, 2015b.

According to that wider perspective demanded by the institutions and experts around the world, the new key indicator proposed by the SDG related to sanitation is 'the percentage of population using safely managed sanitation services'. This indicator comprises three main elements (WHO/UNICEF JMP, 2015b):

- a basic sanitation facility (MDG 'improved' indicator),
- which is not shared, and
- where excreta are safely disposed in situ or transported and treated off-site.

Additionally the sanitation ladder is still proposed in order to underline the progressive improvement in sanitation access (figure 5). The indicators are going to be disaggregated at least by urban/rural, wealth and affordability

The collection of the required data to measure the safely managed sanitation services is still a challenge. The JMP has relied on household surveys to collect the data for monitoring the MDGs but this new perspective requires not only improving national sample surveys but also to generate data for sanitation for each city so SDGs can actually guide policy and investment (Satterthwaite, 2016).

2.5 Sanitation Service Chain[1]

This broader approach introduced by the SDG is illustrated and compared to that of the MDGs in figure 6 where sanitation is looked at as a service chain.

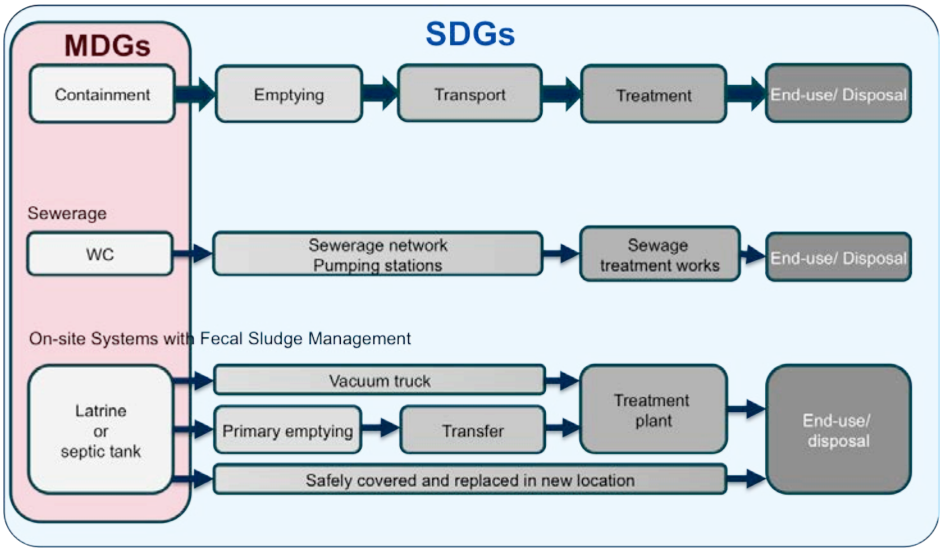


Figure 6: MDGs vs. SDGs approach (Hawkins, 2016)

Tilley et al. (2008) defined sanitation as a multi-step process from generation to disposal or reuse and Von Münch, (2008) described sanitation as a system that includes five elements: containment, collection, transport, treatment and disposal or reuse. This has enabled the illustration of sanitation as a chain of a series of separate activities or services (Mehta and Mehta, 2013, Hawkins, Blackett and Heymans, 2014) and studying the citywide sanitation service. At one end is the containment where wastewater and excreta is generated and stored and at the other end is treatment and disposal/reuse (Peal and Evans, 2015).

Offsite sanitation (or sewerage systems, figure 6) connects latrines to a treatment plant away from the plot where excreta and wastewater are generated, relying on sewers to empty and transport sewage from containments to a centralised treatment plant (Tilley et al., 2008)

Onsite sanitation (or non-sewered sanitation, figure 6), in which excreta and wastewater are collected and stored or treated on the plot where they are generated, entailing an FSM service (Strande, Ronteltap and Brdjanovic, 2014). Onsite sanitation is the most common solution within the cities of developing countries.

---

[1] The term ‘sanitation value chain’ is often used synonymously with ‘sanitation service chain’ (Trémolet, 2011) but in this research the term ‘sanitation service chain’ has been used.

Box 1
Sanitation Service Chain Vocabulary

Excreta – consists of urine and faeces that is not mixed with any flushed water. Excreta are small in volume, but concentrated in both nutrients and pathogens. Depending on the quality of the Faeces, it has a soft or runny consistency.

Faecal Sludge (FS) – is the general term given to undigested or partially digested slurry or solids containing mostly Excreta and water, in combination with sand, grit, metals, trash and/or various chemical compounds. Faecal Sludge comes from onsite sanitation technologies, resulting from the collection and storage of excreta or blackwater, with or without greywater.

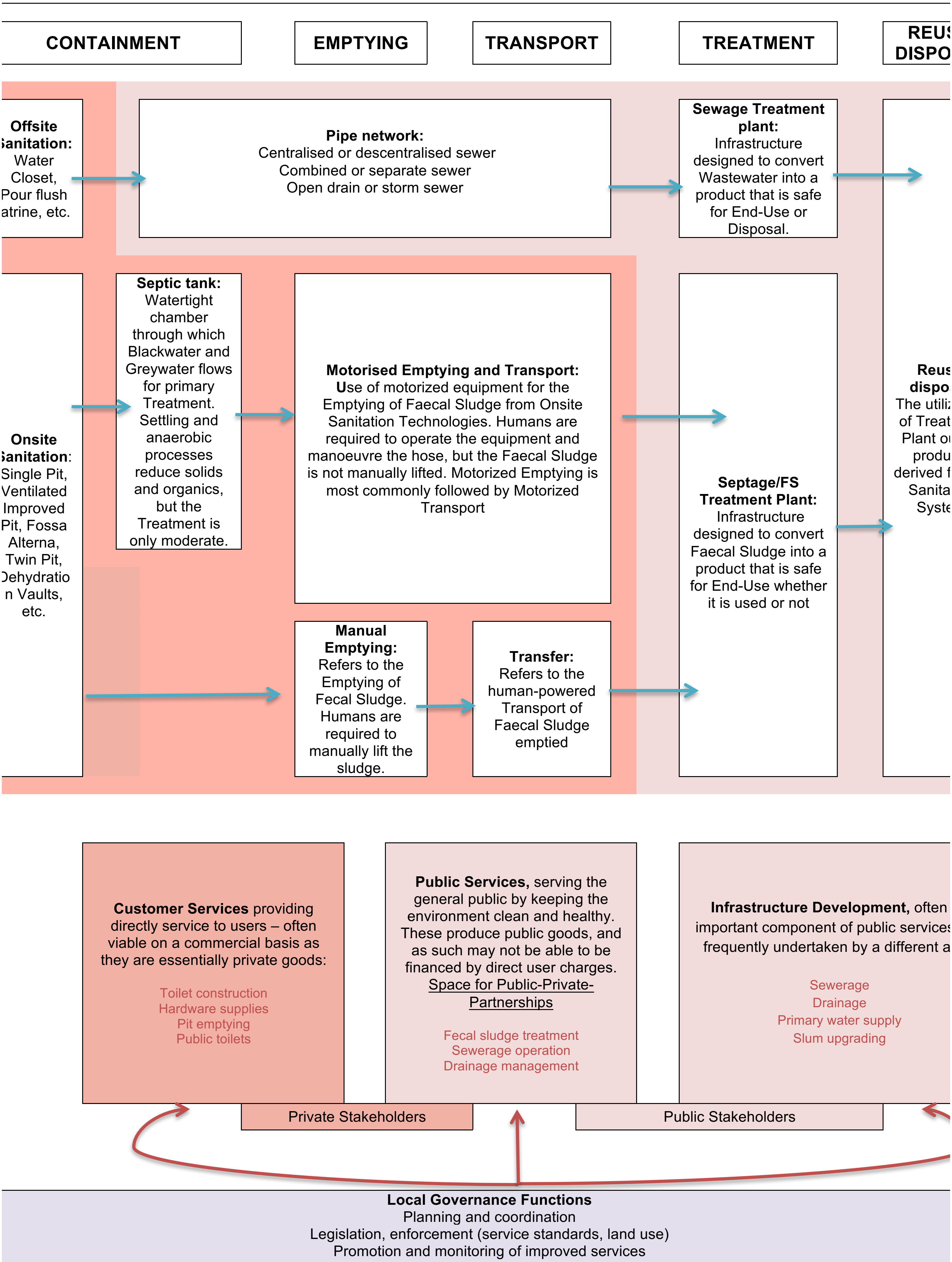
Faecal Sludge Management – FSM includes the storage, collection, transport, treatment and safe end-use or disposal of FS

Adapted from Tilley et al., (2008) and Strande, Ronteltap and Brdjanovic, (2014).

A safely managed sanitation service (what the SDG is looking for) requires that all the stages of the chain work properly (Scott, 2012). If there is a break at some point in the chain the excreta can get out into the environment, with the resulting risks to health and water sources contamination (ibid)

2.5.1 Weak links in the Sanitation Service Chain

Figure 7 illustrates the complexity of the sanitation chain in cities where onsite sanitation is present. In each stage (containment, emptying, transport, treatment and disposal or reuse) appropriate technology has to be developed and the wide range of different service providers (public and private) coordinated. In addition, the participation of national and local governments defining the legal and institutional framework would strengthen the links of the chain.


CONTAINMENT
EMPTYING
TRANSPORT
TREATMENT
REUS
DISPO
Offsite
anitation:
Water
Closet,
Pour flush
atrine, etc.
Pipe network:
Centralised or descentralised sewer
Combined or separate sewer
Open drain or storm sewer
Sewage Treatment plant:
Infrastructure designed to convert Wastewater into a product that is safe for End-Use or Disposal.
Septic tank:
Watertight chamber through which Blackwater and Greywater flows for primary Treatment. Settling and anaerobic processes reduce solids and organics, but the Treatment is only moderate.
Motorised Emptying and Transport:
Use of motorized equipment for the Emptying of Faecal Sludge from Onsite Sanitation Technologies. Humans are required to operate the equipment and manoeuvre the hose, but the Faecal Sludge is not manually lifted. Motorized Emptying is most commonly followed by Motorized Transport
Onsite
anitation:
Single Pit,
Ventilated
Improved
Pit, Fossa
Alterna,
Twin Pit,
ehydratio
n Vaults,
etc.
Septage/FS Treatment Plant:
Infrastructure designed to convert Faecal Sludge into a product that is safe for End-Use whether it is used or not
Reus
dispo
The utili
of Treat
Plant o
produ
derived
Sanita
Syste
Manual Emptying:
Refers to the Emptying of Fecal Sludge. Humans are required to manually lift the sludge.
Transfer:
Refers to the human-powered Transport of Faecal Sludge emptied
Customer Services providing directly service to users – often viable on a commercial basis as they are essentially private goods:
Toilet construction
Hardware supplies
Pit emptying
Public toilets
Public Services, serving the general public by keeping the environment clean and healthy. These produce public goods, and as such may not be able to be financed by direct user charges.
Space for Public-Private-Partnerships
Fecal sludge treatment
Sewerage operation
Drainage management
Infrastructure Development, often
important component of public services
frequently undertaken by a different a
Sewerage
Drainage
Primary water supply
Slum upgrading
Private Stakeholders
Public Stakeholders
Local Governance Functions
Planning and coordination
Legislation, enforcement (service standards, land use)
Promotion and monitoring of improved services

The most common weak links along the chain have been identified though data available from developing countries. The data on sanitation chain are very limited and only few institutions (WSP, Eawag/Sandec and Bill and Melinda Gates Foundation mainly) have researched and documented this. Those weak links can be described under three main concepts:

- Inadequate management of services, either with offsite and onsite sanitation.
    - Poor operation and maintenance of sewer networks by the sanitation utility (usually public), causing problems in pumping stations, leakage in sewer pipes, and/or non-functional wastewater treatment plants (Hawkins, Blackett and Heymans, 2013) Usually cities do not have a designated place to dispose of the faecal sludge and some have reported the ocean as a disposal site (Williams and Overbo, 2015)
    - Regarding the onsite sanitation and the FSM, the service tends to be informal and outside public sector control (Hawkins, Blackett and Heymans, 2014). Septic tanks and some latrines may be emptied by public and/or privately operated vacuum tankers, while other latrines are emptied by various unhygienic methods; large proportion of faecal sludge collected is buried in backyards or dumped illegally. (Hawkins, Blackett and Heymans, 2013).
- Lack of enabling environment, which ensures policy guidance, and incentives to engage stakeholders and prioritize sanitation, guaranteeing accountability, and promoting the development of adequate capacity to deliver the necessary services (Hawkins, Blackett and Heymans, 2013)
    - Richest areas have been always prioritised over the poorer areas, resulting in inequitable coverage where sewerage has been seen as the “proper” form or urban sanitation, considering the FSM as a temporary solution or illegal or informal settlements (Hawkins, Blackett and Heymans, 2013, 2014)
    - Limited knowledge for sanitation planning and stakeholders participation, at institutions and communities, leading to deficient coordination in sharing responsibilities and in developing business models (Hawkins, Blackett and Heymans, 2013, Medland, Cotton and Scott, 2015)
    - Lack of secure tenure, tenants rely on landlords to provide facilities but they usually prefer to invest in more profitable rent-generating buildings than latrines and usually tenants are not allowed to build permanent structures on a landlord’s property (Medland, Cotton and Scott, 2015)

- Technical issues
    - The containment is usually not well designed and collection and transport trucks are not able to access narrow road and paths leading to houses because the emptying is not taking into account when the latrines are constructed (Hawkins, Blackett and Heymans, 2014, Strande, Ronteltap and Brdjanovic, 2014).
    - There is not enough faecal sludge treatment plants in the cities, being the wastewater treatment plants the place where the FS is dumped, which may reduce the efficiency of the plant (Hawkins, Blackett and Heymans, 2014, Strande, Ronteltap and Brdjanovic, 2014)
    - The reuse of treated sludge is still not considered for most of the cities (Hawkins, Blackett and Heymans, 2014)
    - Sewers, septic tanks and latrines are usually situated in flooding areas increasing the risk of contamination and spreading diseases by releasing excreta directly into the environment (Hawkins, Blackett and Heymans, 2013, Williams and Overbo, 2015)

Overcoming all these issues requires not only to have an understanding about the overall status of FSM in developing countries but also a comprehensive analysis of the sanitation service chain in each city to define the specific challenges (Peal et al., 2014).

2.6 Assessing the sanitation service chain in a city

Considering the new challenge set up by the SDG, FS is likely to play an important role in managing public and environmental health as a long term solution or, at least, during the next few years because most of the cities do not have the capacity to provide networked sanitation for all and they will not obtain it in a sort term (Peal et al., 2014). Therefore, more systematic approaches to analysis and understanding the FSM and the sanitation service chain as a whole in the cities are needed in order to identify and design effective operations in urban sanitation (Peal and Evans, 2015)

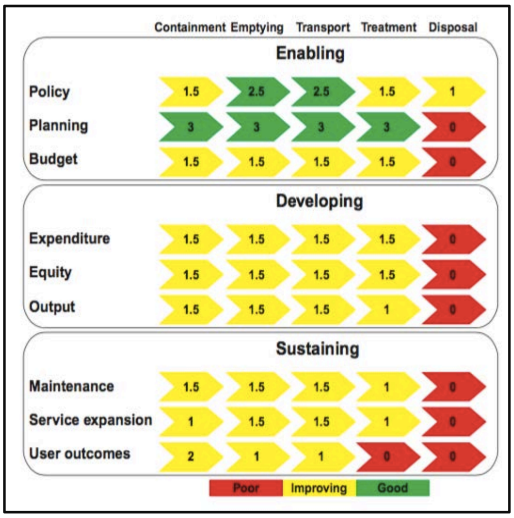


Figure 8: Scorecard for Dakar, Senegal (Hawkins, Blackett and Heymans, 2014)

Based on these considerations, the World Bank, through the WSP, studied the trends in FSM using 12 cities in order to "develop analysis tools that can be used to asses FSM at the city level and identify appropriate operational intervention" (Peal and Evans, 2015). This resulting in two tools, one assesses the enabling environment using a Service Delivery Assessment Scorecard (figure 8). The other tool, called Shit Flow Diagram (figure 9) shows the percentage of people whose FS is safely managed across the sanitation services chain.

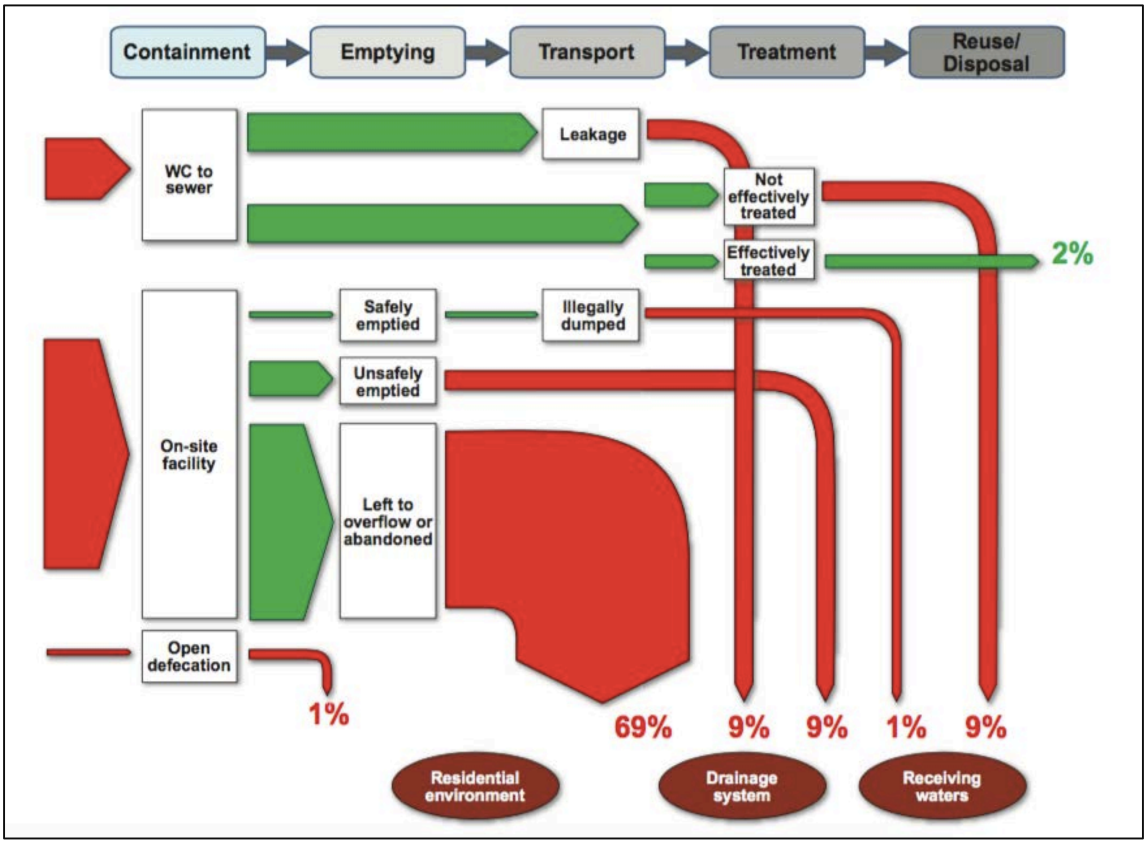


Figure 9: Example, Shit Flow Diagram. Dakar, Senegal (Hawkins, Blackett and Heymans, 2014)

Building on this work, a group of institutions supported by the Bill and Melinda Gates Foundation have been developing the SFD Promotion Initiative, testing the excreta flow diagrams (SFDs) and the service delivery context tool in 50 different cities of Africa, Asia and Latin America (Sustainable Sanitation Alliance, 2015).

2.6.1 The SFD Promotion Initiative

The SFD Promotion Initiative includes standardized guidance – a methodology and tools - for the easy production (once the data is colleted) of standardized SFDs, supported by a description of information sources and the sanitation delivery chain in the city concerned (Sustainable Sanitation Alliance, 2015).

The SFD tool illustrates the excreta flow pathways along the sanitation service chain in a city. The arrows represent the percentage of population (not the volume of excreta) and for each stage the proportion of population who is either effectively or not effectively managing the excreta can be seen (Furlong et al., 2016). This allows you to observe that even when a city effectively contains at household level (having a high coverage of "improved" sanitation according to the MDG) a poor FSM and operation problems in the sewerage leads to having faecal waste widely distributed throughout the environment (Hawkins, Blackett and Heymans, 2014).

Supporting this tool a report explaining the context of the services delivery is produced, which includes a waste flow matrix (figure 10) to summarise the information given by the SFD.

Fecal waste flow matrix Type of system	% of FW	*of which safely collected*	*of which safely delivered*	*of which safely treated*	**Safe: 46%**
Sewered (off site centralised or decentralised)	9%	100%	25%	50%	**1%**
On-site containment - permanent/emptiable	47%	20%	48%	50%	**2%**
On-site contanment - single-use/not emptied/safely abandoned	43%	100%	100%	100%	**43%**
Open defecation	1%	0%			
Unsafe: 56%		**39%**	**12%**	**3%**	
Affected zones		*local area & drainage*	*drainage system*	*receiving waters*	

Figure 10 Example of waste flow matrix. Maputo, Mozambique (Peal and Evans, 2015)

The data collected to elaborate these reports and the SFD have been gathered from available documents, interviewing expert informants, focus groups and field observation (SFD Promotion Initiative, 2015). According to the SFD Manual the selected methods of data collection depend on whether the study has been desk-based or field-based (figure 11)

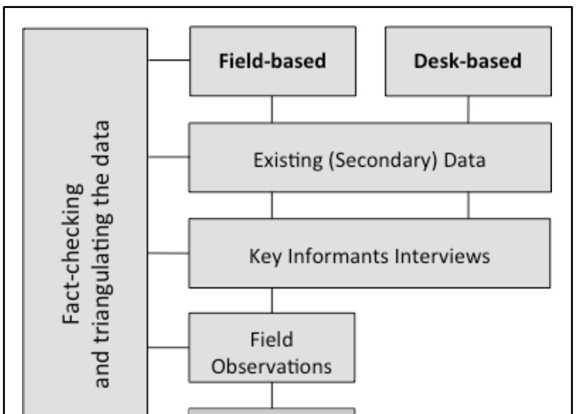


Figure 11: Methods of data collection, Furlong et al., 2016.

The limited data available when developing an SFD make researchers face multiple challenges. For instance, Furlong et al. (2016) have identified 5 major challenges when they developed the SFD in Kumasi:

1. The definition of the city boundary because the boundary of the city changed in 2013 as consequence the data collected could not be disaggregated. Therefore the study area was based on the old city boundary.
2. 2015 was a transition period for the sector, moving from the MDGs to the SDGs meaning that most plans were being updated when the study was undertaken
3. Terms of sanitation technologies used. It was found that many terms were used interchangeably to describe different technologies i.e. septic tank and aqua privy.
4. It was found that data has been collected across the sanitation service chain by stakeholders but it is not in the public domain.
5. The SFD does not include data from schools; however their facilities can be used by up to 35% of the population. If you considered this school population you would be considering the students twice (as part household and as part of the schools). Therefore a better knowledge of the use of school and home sanitation facilities is required in order to avoid a misrepresentation of the SFD.

To date limited attention has been paid to the data used to produce the SFDs (Furlong et al., 2016). Despite SFDs are usually produced with limited and not totally accurate data, they give to stakeholders an overview of the situation and point out the challenges of sanitation service (Peal et al., 2014, Peal and Evans, 2015). This tool has been really effective for communications and advocacy activities with governments and international institutions, (Blackett and Evans, 2015)

2.6.2 SFD Potential

When good data is available, the SFD could be modified to indicate how volume, mass and even nutrient value flow through the FS network, helping decision-makers to identify parts of the FSM system with the potential to derive value through down-stream processes and reuse (Peal et al., 2014)

Figure 12 shows how the potential of the SFD is related to the amount and quality of data available. The methodology has been successfully used as an advocacy tool but if more data are available it can be a good planning or monitoring tool.

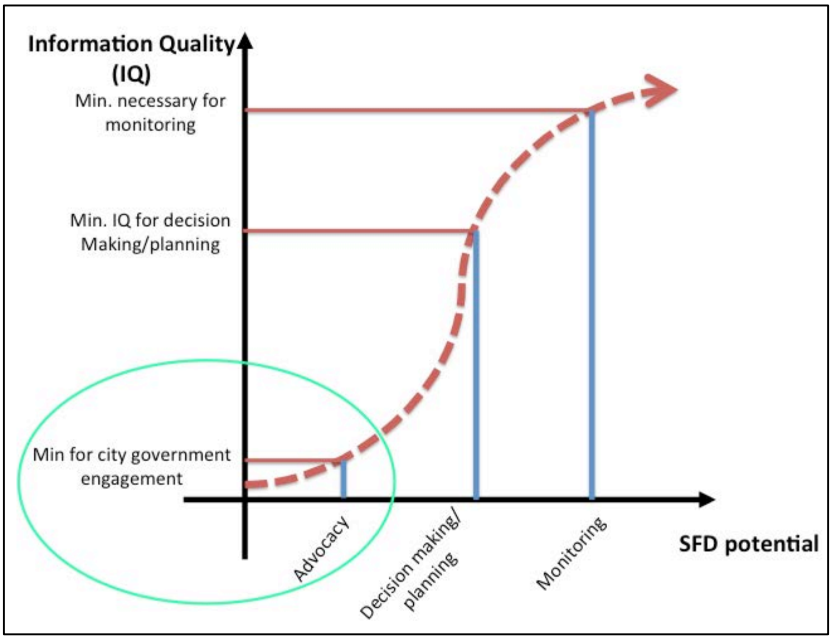


Figure 12: SFD potential in relation to information quality (Rodrigues, 2016)

2.6.3 Using the SFD as an analysis tool for future interventions

The SFD shows the relative importance of the different pathways the FS can take in the city. This allows stakeholders to make rapid assessments and to identify the strong and weak links along the chain, pointing out where the future interventions are required (Hawkins, Blackett and Heymans, 2014, Peal et al., 2014)

Once the current SFD has been developed and the future projects identified, the SFD methodology can be used to illustrate the future scenarios, measuring how the current SFD is going to change in the next few years if those projects are implemented and the population continues to increase. This new use of the tool has been developed by IWMI in Accra in 2015. They calculated the SFD for 3 different years, 2000, 2010 and 2025 relying on primary data (when available), estimations and expert interviews (Nikiema, 2015) First they calculated the SFD for years 2000 and 2015 and afterwards they used that trend to estimate the changes between 2015 and 2025, taking into account the growth rates and the expected or upcoming projects that can affect the operation/construction of treatment plants (Nikiema, 2015). The methodology and learnt lessons used to develop these SFDs has not been published.

2.7 Summary

The MDGs focused on the urban sanitation determining the levels improved or unimproved facilities at household level. This approach has been widely criticised by different experts because the poorest people in cities live in high density areas and most of them rely on onsite sanitation, needing a sanitation service to empty their facilities and not only improved facilities.

Recently, the SDGs pointed out the need for changing to a wider perspective, which ensures that not only improved facilities at the households exist but also that safe faecal waste management along the sanitation service chain exists within the city.

The sanitation service chain is defined by five main stages: containment, emptying, transport, treatment and disposal or reuse. Ensuring safe faecal waste management requires that all the stages of the chain must to work properly and that no link is broken. This means that it is needed to develop appropriate technology, services and an enabling environment for each stage of the chain.

As a consequence a comprehensive analysis tool of the chain to define the specific challenges in a city is being developed by the SFD Promotion Initiative. The SFD tool physically shows the excreta pathways across the sanitation service chain and it is supported by a report that explains in detail the delivery sanitation context. Once a SFD has been produced the broken or weak links in the chain can be appreciated, identifying where the future investments are required.
One of the potential uses of this tool is to model the future scenarios in a city incorporating the expected investments and the population growth. This has been explored by IWMI using the trends in a period of 5 years to model the future in Accra, Ghana.

2.8 Gaps in Literature review

This wider urban sanitation approach, which considers the entire sanitation chain along a particular city, is relatively new and as consequence further research in this area has to be done. Some knowledge gaps have been identified during this literature review; all of them are related to the lack of knowledge on how the FSM works in the cities:

- The SDG has established as key indicator 'the percentage of population using safely managed sanitation services' but how the data is going to be generated to measure this still a challenge
- It has been highlighted the limited knowledge about how to coordinate and develop business models with stakeholders (public and private). Also the lack of appropriate

technologies for some services of the sanitation chain (emptying, treatment and reuse) has been emphasised.

- SFDs are being developed in different cities but further research is needed to explore its potential.

This dissertation has been focused on the use of the SFD to model future scenarios based on upcoming projects and the population growth in Kumasi, Ghana. In Kumasi, a good opportunity evolved because WEDC has developed the current SFD for Kumasi (Furlong, 2015a), making the contact process and the gathering of information easier. The dissertation seeks to contribute to the enhancement of the SFD methodology and to explore its potential.

Chapter 3: Methodology

In the last few years, as underlined in the literature review, the urban sanitation approaches have changed from a vision focused on the users and formal providers of sanitation (mainly sewerage) to a wider perspective that considers all the stakeholders involved in FSM across the sanitation service chain. As a consequence, during 2012-2013 the WSP carried out an analysis of excreta flow along the sanitation chain in 12 cities using a range of methods for data collection, resulting in a variety of styles, definitions and levels of reliability of the output (SFD Promotion Initiative, 2015a). Following this standardized guidance –incorporating a methodology and tools - for the easy production of standardized SFDs has been developed and currently it is being tested in more than 50 cities in Africa, Asia and Latin America (SFD Promotion Iniciative, 2015b). The methodology of this research uses the Manual for SFD production (2015) as a framework.

This study relied on available secondary data, personal communication and in a visit to Kumasi to better understand the city context and to conduct unstructured and semi structured interviews with key informants. Additionally during the field trip informal observations were carried out by the author.

This chapter explains the way in which the SFD methodology has been used as well as the research design developed. Firstly, section 3.1 describes the SFD tool and how it has been used to model the scenarios; afterwards the research design process is presented (section 3.2), describing the scenarios definitions, the methods of data collection and the production and discussion of the SFD for each scenario. Finally section 3.3 expounds the ethical considerations for this research.

3.1 Description of SFD Methodology

The SFD is a quantitative analysis tool, which illustrates the excreta flow pathways along the sanitation chain in a city. This SFD is supported by a report that collects all the data used to elaborate the SFD and explains the situation of the sanitation service chain in a qualitative way.

Desk-based SFDs rely on literature review and online interviews with key informants as methods for data collection, whilst field-based SFDs add observation and focus groups as methods of data collection. Therefore field-based SFDs not only describe the services delivery context but also analyses its situation.

The SFD Methodology also describes the minimum data to be collected and its protocols, a method to assess the groundwater risk in the city and it gives recommendations to ensure the stakeholders' engagement in order to facilitate the data gathering process.

The methodology is explained in the Manual for SFD production (SFD Promotion Iniciative, 2015) and it can be found on SuSanA website (www. susana.org)

3.2 Using the current SFD to model future scenarios

An SFD for Kumasi has already been produced in October 2015 (Furlong, 2015a). This study was field-based; producing a detailed city report. Both the SFD and the city report have been used as a starting point to model the future scenarios.

According to the SFD methodology, some important aspects of the service delivery chain have been explained:

- National policies, laws and regulations for excreta management in Ghana
- Local bylaws for excreta management in Kumasi,
- Institutional roles and responsibilities
- Services standards set up by the Ghanaian government
- Drinking water supplies in the city

These aspects have likely not changed since the publication of that report (October 2015) and additionally they are not considered as having a direct influence on the excreta flows. Therefore they have not been included as part of this research.

The SFD methodology defines a range of technologies to be used in the SFD production. This research assumes the same type of containment sanitation systems (onsite and offsite) used in the SFD already produced for Kumasi (see table 2).

Technologies	Further breakdown	How is defined in the SFD
No facilities	N/A	Open Defecation
Private WC	Sewered	Decentralize foul sewer –separate sewer
	Septic tank	Septic tank outlet to soakaway
		Sealed tank with no outlet to overflow
Private pit latrine	Basic latrine	Unlined pit with no outlet no overflow
		Abandoned and covered in soil
Private Improved pit latrine	Improved pit latrine	Lined pit with semipermeable walls open bottom with no outlet no overflow
		Abandoned and covered in soil
Public toilet	WC/Aqua privy	Sealed tank with no outlet no overflow
	WC/Septic tank	Septic tank outlet to soakaway
	KVIP	Lined pit with semipermeable walls open bottom with no outlet no overflow
		Abandoned and covered in soil
	Enviroloo	Sealed tank with no outlet no overflow
	Basic Latrine	Unlined pit with no outlet no overflow

Table 2: Type of Sanitation Containment Systems/technonology in Kumasi, adapted from (Furlong, 2015a)

In order to understand the current situation of the sanitation service chain and identified the main stakeholders, the SFD produced for Kumasi was analysed and briefly explained in chapter 4. Afterwards, four main steps have been developed to define the most realistic future scenarios to be modelled and to produce the corresponding SFDs.

3.2.1 Identifying the on-going and planned projects in Kumasi

The first step was to identify the main on-going and planned projects in Kumasi in order to define the most realistic future scenarios. These projects, explained in Chapter 4, have been identified by the secondary data available from the SFD study and discussed with the KMA during the visit to Kumasi.

3.2.2 Defining the scenarios to be modelled

Four different scenarios were defined in order to assess how the SFD is going to change for the next years. These changes have been measured using the population growth and the intended investments in the city as the known parameters

Firstly, a “baseline scenario” was proposed, in order to analyse the potential change in the SFD if there is no investment in the next few years and the population continues to increase. In this case the main known variable is the population growth rate.

Secondly, considering the on-going projects or those that were about to start in the city two more scenarios have been studied, both considering the population growth rate and the future investments as known variables. Modelling these scenarios the potential change resulting from the planned investments was showed.

Finally, a fourth scenario has been defined to illustrate the total change in the SFD if both projects are implemented and to measure the total change produced.

All the scenarios were discussed and agreed with the main stakeholders ensuring they are representative enough of the city. They have been explained in detail in chapter 5 and for each scenario a list of questions has been proposed to define the minimum data collection required.

3.2.3 Data collection

According to Denscombe (2007) there are two types of data that can be collected during the research process:

- Secondary data coming from documents such as government reports, other research, official documents or field studies.
- Primary data gathering from:
    - Observation in the field, gathering qualitative data from measurements of service provision and facilities through the sanitation and FSM service chain and qualitative data from visiting the service providers and facilities through the sanitation and FSM service chain (SFD Promotion Initiative, 2015a)
    - Interviews, including Focus Groups, with key stakeholder such as community leaders or people in charge of sanitation in` the city.
    - Questionnaires, used when standardized data is required from a large number of respondents

Selecting the appropriate methods depends on the amount and quality of available secondary data, the kinds of data needed and how the collection of these data can give a different perspective of the subject to the researcher (Denscombe, 2007)

As mentioned previously, this study has relied on the available secondary data and primary data collected from personal communications, online interviews and a short visit to Kumasi during 39th WEDC International Conference where additional interviews and observations were completed. Focus Groups were not considered due to a lack of time of the researcher in the field.

The methods of data collection contributed in different ways to answer the research questions and reach the outcomes of this research. This can be found in detail in appendix 1.

3.2.3.1 Desk review

This involves the analysis of documents from different sources as websites, governmental documents, key informants, previous researcher or NGO working in Kumasi

The first stage was to understand the Kumasi SFD background, the methodology used to develop it and the situation of the sanitation service chain in Kumasi. This allowed the collection of the most relevant and useful information to define the scenarios, to answer some of the proposed questions for each scenario and to model the SFDs.

Once the interviews and the trip to Kumasi were finished, a second stage was carried out to complete the gaps in data. Between these phases new documents were found and the literature review updated.

3.2.3.2 Key Informant Identification

Prior to travelling to the field, key informants were identified and contacted to find out if they were going to be present in Kumasi during the conference. These contacts were first introduced by the dissertation supervisors (Claire Furlong and Rebecca Scott). Two types of key informants have been contacted for this research:

- People from Kumasi with responsibility in relation to the sanitation services chain as the Clean Team Toilet and staff from KMA. The principal objectives of these interviews were to validate the data collected and to understand their perception of possible future changes in the service.
- People from institutions, which are participating in the SFD promotion initiative and in the elaboration of the Manual for SFD production such as WSP or Leeds University. The purpose was to have their expert opinion about the tool and the issues that were found in the research process.

In appendix 2 a table can be found indicating the institution, its role in the sanitation service chain in Kumasi, its relevance, the possible questions and the method of data collected.

Additionally a flyer (appendix 3) was developed in order to attract the attention of potential informants during the WEDC conference in Kumasi.

3.2.3.3 Personal Correspondence with Key Informants

Personal correspondence with the key informants allowed collecting further specific documents, grey literature, and makes other contacts with organizations or individuals. A detailed list of people who were contacted is in appendix 4.

3.2.3.4 Key Informants Interviews

Semi-structured interviews were held to consider the opinion and perception of the people involved in the sanitation service chain and to ensure the reliability of the collected data. The questions can be found in the formularies in appendix 5. The questions were established depending on the institution that was interviewed and its responsibilities in the sanitation chain. It is important to underline that in this type of interviews the questions can be slightly changed or further explained.

The interviews were carried out by different techniques depending on the informants' availability and the time they had to talk. Some interviews were held online (audio calls) because the informants were not going to be available during the visit to Kumasi. This kind of interviews entails a loss of visual clues preventing the interviewer from picking up on non-verbal communication that could be valuable for understanding the informant thought (Denscombe, 2007). The rest of the interviews were one to one meetings in a formal or more informal way depending on the timing and availability of the informants during the conference.

Semi-structure and face to face interviews are easy to arrange because only two people have to coincide and makes the process for the interviewer fairly straightforward to locate specific ideas (Denscombe, 2007). However this kind of interviews involves disadvantages (Denscombe, 2007):

- the process of data analysis is more complicated because the collated data is not standardised
- The effect on the data quality due to the interaction between the participants. This can be even bigger in studies like this research because cultural and languages differences take place

3.2.3.5 Visit to the going projects in Kumasi

The author visited the projects that are being implementing by the KMA and supported by WSUP. These visits were part of the 39th WEDC International Conference and allowed the researcher to ask some question to the WSUP and KMA staff about the projects, they expected results and the installations performance.

3.2.3.6 Observations

One of the most important tools for researchers in developing countries are observations (Scheyvens and Storey, 2003). They may result in both the generation of hard data or impressions, helping to shape and interpret the research (ibid)

During the field trip to the KMA projects in Kumasi the researcher had the opportunity of talking to people and seeing the installations. As a consequence a personal opinion of the city context and the projects was built up based on observations and analysis of the human behaviour

3.2.3.7 Dealing with uncertainty in the data

Triangulation is the practise of viewing things from more than one perspective (Denscombe, 2007). Data presented in this research has been collected from different sources and with different methods in order to crosscheck the data and reduce the bias. However during the data collection process it was found that some data is different depending on whom is reporting it, for example data from NGOs and data on governmental documents. Additionally gaps in data have been found all along the sanitation service chain. These uncertainty data as well as assumptions made have been highlighted for each scenario.

When the level of uncertainty was considered relatively high by the author different SFDs have been produced and analysed with the key informants and reported in Chapter 4.

3.2.4 SFDs production on for each scenario

Once the data were analysed, a quantitative resume for each scenario was presented by the table shows in appendix 6. With this data the SFDs were produced for:

- **Year 1** as starting point
- **Year 5** because the identified projects are planning to be finish within 5 years
- **Year 10** to illustrate what would happen if not more investments are planning.

The SFD calculation tool was used to produce the SFDs. This is an Excel spread sheet, which use the collected data to create a matrix showing all sanitation containment systems, the total percentages of excreta for all variables in the SFD diagram and then automatically produces the SFD (SFD Promotion Iniciative, 2015). This spread sheet can be found in SuSanA website.

3.2.5 Trend Analysis and discussion of SFD Results

To complement to the SFDs, different graphs have been produced to show the progress in different aspects of the sanitation service chain along the 10 years. For instance the figure 13 shows the percentage of population who rely on onsite or offsite sanitation solutions and the presence of OD.

These graphs allowed to analyses the SFD results and trends over the years

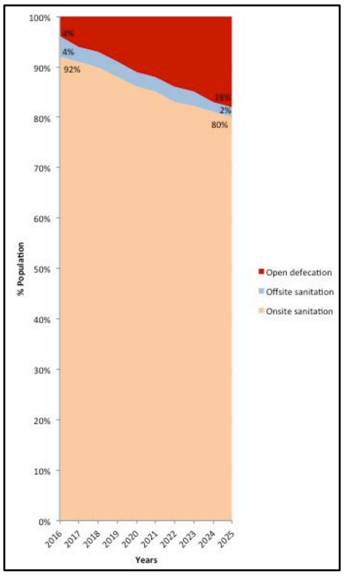


Figure 13: Graphic example [Flow Excreta management along 10 years] (source: the author)

3.3 Ethical Considerations

Ethical Clarence was obtained by Loughborough University, Ethical Approval (Human participants) Subcommittee (see appendix 11). Some major ethical issues considered in this research are listed below:

- **Informed voluntary participation**: During and after the research process all the participants have been able to ask questions about their participation in the research or about the research. Participants were not under any obligation to take part in this research and they were well informed before starting the process of data collection and all gave the author oral consent to conduct the data collection.
- **Confidentiality and privacy:** All the participants have been informed about the purpose of the research and they agreed in that the information provided was used in this study.
- **Personal Risk**: there is a minimal personal risk involved in developing of this study.
- **Data Management**: All the documents used for the data collection as well as interviews and communication with key informants were recorded by the author (by notes or by a digital record of the conversation) and they are kept securely by the next years.

Chapter 4: Case study: Kumasi, Ghana.

The following findings are as a consequence not only of one week in Kumasi but also as a result of reviewing the collected secondary data. As explained in the chapter previous chapter, the methodology consisted mainly of secondary data, semi-structured interviews and observations.

Not all the interviews planned prior to travelling were carried out. Table 3 shows the stakeholders who were finally interviewed.

Name	Organization	Role	Methodology
Anthony Mensah	KMA- WMD	Old Director of WMD in Kumasi (until June 2016)	Semi-structured Interview
John Donkor	KMA	Head of Sanitation at WMD	Unstructured Interview during field trip
Ps Michael Morrisson	KMA	FS treatment plant manager	Visit to the treatment plant- unstructured interview
Fifi Boadi	AMA	Student who want to do their final research about SFDs	Personal Unstructured Interviews
Frank R. Kettey	WSUP	Project manager WSUP Kumasi	Semi-structured Interview
Edward Anim	Clean Toilet	CEO Clean Team	Semi-structured Interview
Abigail Aruna	Clean toilet	Social responsibility	Unstructured Interview
Harold Esseku	World Bank	External Consultant - WASH Expert	Semi-structured Interview
Joseine Nikiema	IWMI Ghana	Responsible IWMI Ghana	Semi-structured Interview

Table 3: Stakeholders interviewed, their roles and the methodology used.

Not conducting all the interviews that were planned did not stop the research process but it did make the crosschecking of the data weaker. Collected data came from the different parts of the sanitation chain where the stakeholders participate; however the author did not have access to the emptying and transport stakeholders

This chapter presents a brief background of Kumasi and its sanitation situation. Afterwards the on-going or planned projects that have been identified are explained. Based on those projects the scenarios have been defined and explained in chapter 5

4.1 Background

Kumasi is the second largest city in Ghana. It is a city characterised by its huge market, the largest single market in West Africa (figure 14). This makes Kumasi the commercial centre where people from the whole country and beyond come to visit (Adarkwa, 2011).

Figure 14: Kumasi Central Market

Additionally, Kumasi area is a strategic point of connection between the south and north of Ghana as well as for the other surrounding countries (MCI, 2013). It is estimated that there is 21% of floating population (Tiberghien, 2016),

4.1.1 Climate and Geography

Kumasi is situated in a rainforest area (Tiberghien, 2016), in the wet sub-equatorial region. Kumasi has two wet seasons per year, the first one from May to July and the second one from September to November (Adarkwa, 2011) and the climate is defined as tropical wet and dry with more or less constant temperature throughout the year. During rainy seasons flooding is frequent (Tiberghien, 2016).

The topography of the city varies from 250 meters to 300 metres above the sea level (Adarkwa, 2011). Much of the city drains south to the Sisa-Oda river system, but there is a part of the city which drains west to the Offin and Owaabi river systems, the latter being the main source of drinking water for the city (Furlong, 2015a).

4.1.2 Population

Kumasi's population was 2 million in 2010 (GSS, 2013). The population growth is at a rate 5.5% (Brinkhoff, 2012 and Farvacque-Vitkovic et al., 2008). As a consequence the estimated population in 2016 is 2.8 million people. A large transient and immigrant population through the city causes this high rate, with people mainly coming from rural areas of Ghana and other West African countries (Tiberghien, 2016). Currently, over a third of the population are migrants (Furlong, 2015a).

Kumasi Metropolis consists of 48% urban, 46% peri-urban and 6% rural areas (Tiberghien, 2016). The administrative institution of this metropolis is the Kumasi Municipality Assembly.

The KMA until 2015 consisted of ten Sub Metropolitan District Councils but nowadays only nine Sub Metropolitan District are part of the KMA (Furlong, 2015a) Data on this study considers the ten Submetropolitan District Councils because no disaggregated data was found.

The Waste Management Department is the branch of the KMA responsible for both solid waste and liquid waste, having a subsection responsible for the Liquid Waste Management.

4.1.3 Sanitation situation

As outlined throughout this document, in 2015 as part of the SFD Promotion Initiative a report with a detailed explanation about the current situation was developed by Furlong (2015) and the corresponding SFD produced. This study uses that SFD as starting point to develop the scenarios in chapter 5, see SFD in figure 15.

Kumasi has a small sewerage system, which serves 4% of the population. It discharges to small wastewater treatment plants. (Furlong, 2015a)

The coverage of onsite sanitation is 93%: 39% of the population still relies on public toilets whereas 54% of population have private toilets (usually shared facilities in compound housing) (Furlong, 2015a).). The Emptying and transport system to disposal is working well at the moment, transporting 70% of the total excreta produced by the population to the Septage Treatment Plant[2] (Furlong, 2015a). The STPs works most of the time close to or above of its capacity. Figure 16 illustrate when the STP has been working over capacity depending on the treatment capacity considered and mean truck size. The STP is only treating the 50% faecal sludge arriving at the plant due to lack of maintenance (Furlong, 2015a).

[2] Faecal Sludge Treatment Plant (FSTP) or Septage Treatment Plant (STP) are used indistinctly along this document.

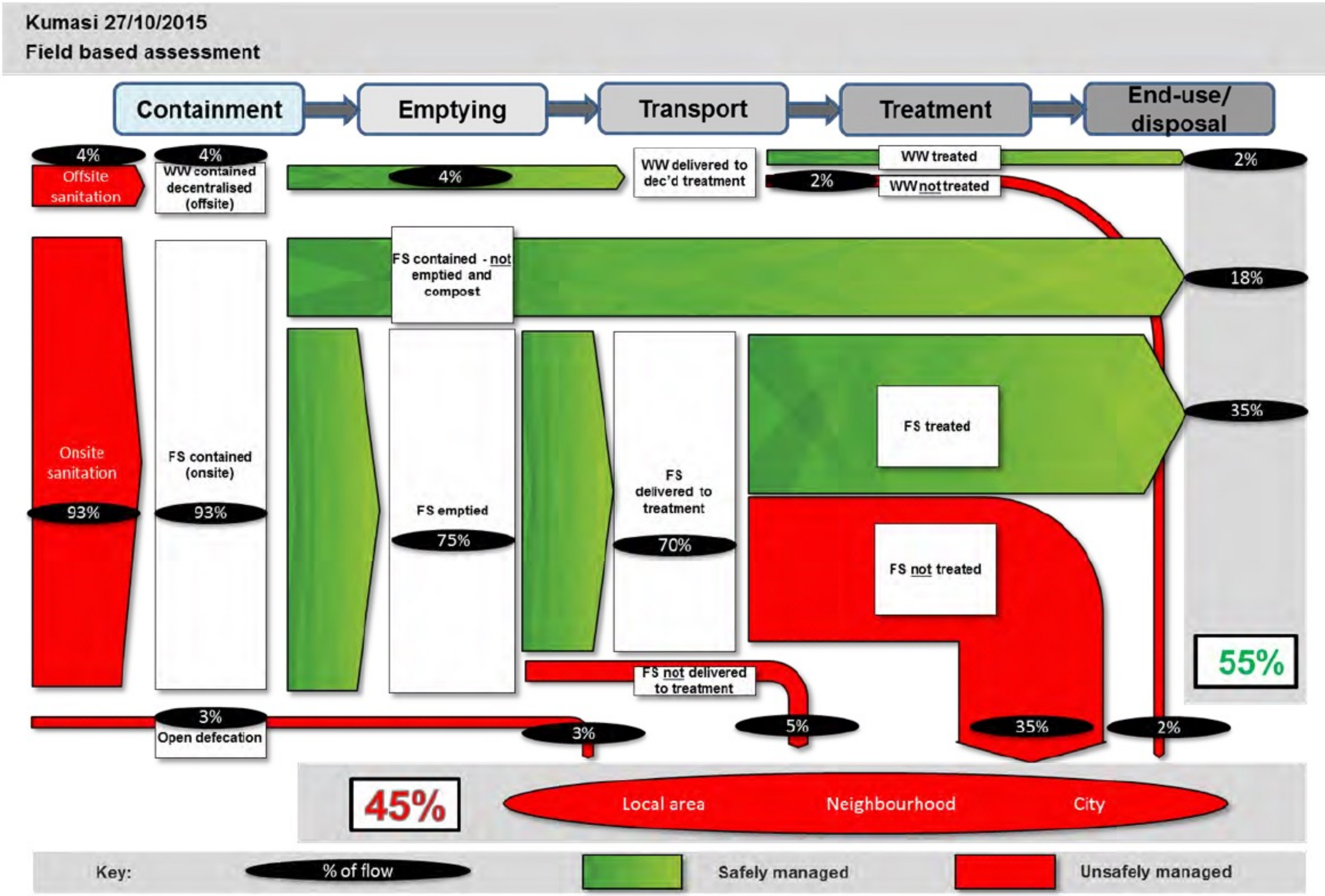


Figure 15: SFDS for Kumasi Ghana(Furlong, 2015a).

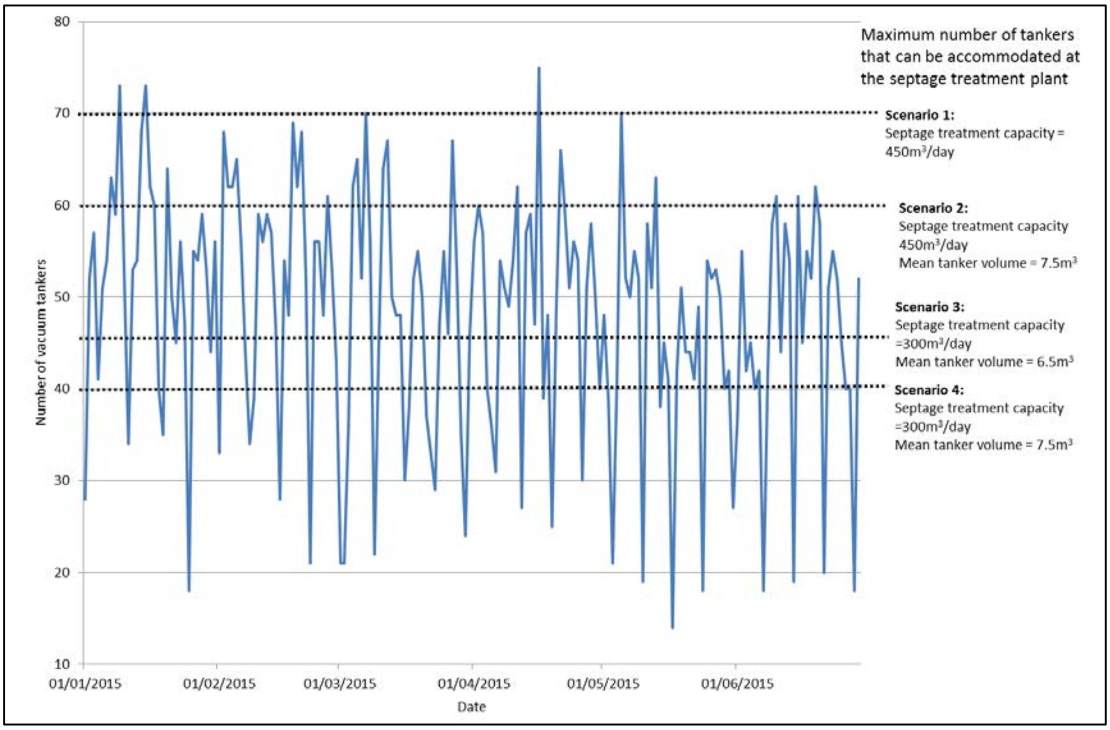


Figure 16: Number of tankers discharging to Dompease STP over six months in 2015, compared with the number of tankers that can be accommodated under 4 different scenarios (Furlong, 2015a).

Open Defecation is up to 3% (Furlong, 2015a), whereas if the whole country is considered, this figure increases to 19%. (WHO/UNICEF JMP, 2015b).This is relevant because of the amount of people coming to stay in Kumasi from other part of the country is high (see section 4.1.2)

According to the SFD developed in Kumasi in 2015, the total amount of safely managed excreta flow was 55% of the total produced by both, onsite and offsite sanitation and including OD (Furlong, 2015a).

4.2 Ongoing and planned projects in Sanitation

Ghana is now considered a middle-income country and therefore international organizations are probably going to reduce their support in the next few years, including in sanitation (WB, 2016a). Due to the sanitation situation in Kumasi being better than the rest of the country, this decrease in International aid could be more notable. In fact, the projects identified by the author for the forthcoming years in Kumasi include little investment.

4.2.1 Clean Team Toilets - Supported by WSUP

Figure 17: Clean Team Toilets (source: the author)

Kumasi has a diverse sanitation technology landscape and new systems are currently being introduced, one of which is the Clean Team toilet (Furlong, 2015a). This toilet is a portable toilet with urine diversion (figure 17). Clients, most from low-income areas in Kumasi, can choose between two types: a wet toilet with chemicals or a dry solution with scented sawdust (Clean Team Toilets, 2016a, WSUP, 2016a)

The toilet is leased to the consumers who are charged a monthly tariff fee including emptying 3 times per week (Clean Team Toilets, 2016b). Most of the costumers used public toilets before, and they report that some people who are using the clean toilets are old people or people with some kind of disability (Clean Team Toilets, 2016a) Currently they have 1030 customers (households) and they are planning to increase their number of clients up to 3800 in 2018 (Clean Team Toilets, 2016a, WSUP, 2016a)

The toilet has a bucket inside (figure 8) and once it is removed from the client it is transported to a transfer point. This transfer station is situated next to the STP. There, the waste is removed and deposited in a tank or on drying beds (depending on the type of toilet, dry or wet). The buckets are cleaned and re-used. The tank, where the waste from wet Clean Team toilets is stored, is emptied directly to the STP.

Figure 18: Buckets which go within the Clean Team Toilets (source: the author)

4.2.2 A toilet in every compound - Supported by WSUP

Compound housing[3] is the most common form of habitation in low-Income areas in Kumasi (Mazeau et al., 2014, Furlong, 2015a Mikhael, Musah and Craig, 2016). There, tenants are usually sharing the same living space with more than 20 people (Mazeau et al., 2014)

The levels of sanitation and access to private toilets are low in Kumasi. Instead low-income communities rely on the high number of public toilets (Mikhael, Craig and Musah, 2016)To address this challenge WSUP is supporting the KMA with long term strategies focused on strengthening the public sector role by (Mikhael, Musah and Craig, 2016):

- **Better enforcement by Local Government**: The process begins with an inspection to confirm the compound has a safe toilet. If this is lacking, the compound's residents will be informed of by-laws and support for getting a toilet will also be offered to them. If they fail to comply they will be warned and finally prosecuted
- **Trained and Certified Business:** The KMA ensures that those involved in the construction of toilet facilities have been adequately trained, and that the facilities constructed are safe to use.
- **Advocacy by traditional Leaders:** Environmental Health Officers engage with traditional leaders to secure buy-in to the strategy
- **Monitoring-Learning-Adaption**: A monitoring framework will be set up to allow for learning and ongoing adaptation of the strategy.

The strategy was formed by the KMA in 2015 and its objective is to increase the access to compound toilets for 100,000 low-income residents in Kumasi by 2019 (KMA and WSUP, 2014, WSUP, 2016b).

4.2.3 Rehabilitation of the Septage Treatment Plant– Supported by WSUP

Kumasi has the only STP in the whole country (see figure 19). It has been constructed in 2004 supported by the World Bank with a 15-years capacity life (Tiberghien, 2016). The plant comprises two parallel systems of three anaerobic ponds connected to a facultative pond followed by other two aerobic ponds (STP/KMA, 2016a) The treatment capacity is not clear: according to the design documents the design capacity is 300m^3/day for sludge, but it is believed that capacity was modified during the construction up to 450m^3/day for sludge (Furlong, 2015a).

---

[3] Compound housing: Multi-room dwellings where a number of households live together around central courtyard and often sharing the same bathroom and common spaces.

As pointed out in section 4.1.3 the STP is effectively treating only 50% of the volume of waste that is arriving due to a lack of regular maintenance (Furlong, 2015a. Siltation of the first pond reduces retention time leading to the discharge of partially treated effluent (Tiberghien, 2016). In order to solve that problem the KMA, supported by WSUP, is going to desilt the ponds and the efficiency of the STP will be recovered (STP/KMA, 2016a, WSUP, 2016b). The project is expected to be finished at the end of 2017 (STP/KMA, 2016b).

Figure 19: Dompease Septage Treatment Plant, Kumasi, Ghana. 2016. (source: the author)

4.2.4 Public Toilets Project – supported by the World Bank

In 2015 there were in Kumasi 360 public toilets blocks in Kumasi (KMA, 2015a). Other public toilets are not working because they need to be rehabilitated: according to data shared by the KMA public toilets were abandoned (KMA, 2015a). Around 68% of these public toilets are operated by the KMA, 24% are under private ownership and the remaining toiles are owned by unit committees, chiefs of communities in which they are located, schools, etc. (WB, 2016b).

The World Bank has planned a project in the framework of the GPOBA. They have planned to construct 108 new public toilets (38 rehabilitation and 70 new public toilets), employing private stakeholders to build and operate the new infrastructure in Kumasi though a PPP arrangement (WB, 2016b). The size of the new water closet toilets is envisaged to range from 10, 16, 20, 24 to a maximum of 26 facilities[4] depending on their location (ibid)

The construction of these new toilets will start in 2017 and it is expected that the construction will finish in the same year (KMA, 2016, WB, 2016b).

4.3 Conclusions

These identified projects in Kumasi have served as a basis to define the scenarios to model the SFDs.

[4] Single seat or cubicle, sitting or squatting

Chapter 5: Scenarios: Collected Data and Discussion

As explained in the methodology (section 3.2.2) four different scenarios have been considered regarding the ongoing and planned projects. They were also discussed with the KMA.

In this chapter a detailed definition of scenarios is presented and the questions to be addressed in each one listed. Afterwards, each link of the sanitation chain for the next 10 years is discussed based on the collected data and the SFD is built up for each scenario. Finally a discussion of the trends over the 10 years is presented for each scenario.

5.1 Scenario 1

This is considered as a “baseline” scenario in which public investments are not considered for the next 10 years and then the main infrastructure remains constant.
The 5.5% population growth rate is used as main variable parameter.
Some questions have been established in order to define the minimum data to be collected, and these questions are as follow:

Open defecation

- Is the OD going to increase if there are no public investments?

Offsite sanitation

- What is the capacity of sewer network to absorb the new connections?

Onsite sanitation-Containment

- With the Clean Team Toilets, are they going to increase their coverage up to more than 1% of the population?
- What is going to be the trend in the number of private toilets in compound housings?
- How many people can the current public toilets service? Can they respond to the future demand?

Onsite sanitation-Emptying and transport service

- Can the current emptying and transport system cope with the future demand?

Onsite sanitation-Treatment and Disposal

- How much faecal sludge will arrive at the STP?
- When is the current STP going to surpass its capacity?

In order to discuss the collected data and produce the SFDs each part of the sanitation service chain has been analysed and finally the SFD will be produced.

5.1.1 Open defecation

Open defecation in Kumasi has been significantly reduced in recent years, decreasing from 6% in 2008 (Mazeau et al., 2014) to 3% in 2010 (GSS, 2013) whereas the prevalence of OD in Ghana is still high: 19% over the whole country (WHO/UNICEF JMP, 2015a) and 45% in Accra (Tiberghien, 2016). This difference between Kumasi and he rest of the country is mainly due to the long tradition of using public toilets among the Kumasi population (Furlong, 2015a and Tiberghien, 2016).

In Kumasi, this positive trend is jeopardized by the high population growth rate because immigration usually involves poor people coming from other parts of the country (see section 4.1.2)Therefore the immigrants are used to practicing open defecation and have no habit of paying for using public toilets. Expert interviews have reported that in their perception OD is decreasing but flying toilets are increasing and 2 out of 7 experts have observed an increase of OD on the outskirts of the city; however none of them could provide any evidence to the author.

More research is needed to determine how migration can affect OD habits in a city like Kumasi but considering the available data in table 4 the percentage of OD is being slowly reduced. According to Hopewell and Graham (2014) the reduction rate is 0.05% each year, meaning that the percentage of OD in Kumasi is going to be reduced really slowly. There is usually a residual OD that is difficult to eliminate, cities that are near to achieving 0% OD are unable to make significant progress in OD reduction (Hopewell and Graham, 2014).

Year	2003	2008		2010	2015
Percentage OD	3.95%	3.65%	6.00%	3.00%	3.00%
Source	Hopewell and Graham, 2014		Mazeau, 2014	GSS, 2013	Furlong, 2015

Table 4: OD in Kumasi over the past years

For this study a trend of 0.05% (Hopewell and Graham, 2014) has been assumed for the OD reduction. Table 5 shows the prevalence of OD for the next 10 years. It is important to point out that the total number of people practising OD is going to increase until 2025, whilst the percentage of the population will be reduced. This is because the population increases faster that the OD is reduced

Year	2015	2016	2020	2025
Population Growth Rate (section 4.1.2)	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
Population OD	79,792	82,778	95,595	113,581
Percentage OD	3.0%	2.95%	2.75%	2.50%

Table 5: OD projection for the next 10 years in Kumasi (Scenario 1)

This projection would be used to produce the SFD as long as the public toilets can meet the future demand. In the forthcoming years OD will increase even more due to a lack of sanitation facilities (Furlong, 2015a). This will be discussed in section 5.1.3.2.

.

5.1.2 Offsite sanitation

Mazeau et al.(2014) estimated that 8.1% of people in Kumasi were connected to the sewers in 2008 whereas 2010 official census (GSS, 2013) establishes that 5% of Kumasi population is connected to sewers, that means approximately 102,000 connexions were active by then. As this network has not been expanded since its construction, the percentage of population connected is decreasing over the years because the number of connections has remained constant (Furlong, 2015a).

Table 6 shows the trend in sewerage connection in Kumasi and its projection calculated for the next 10 years considering that the number of connections is not going to change. It is important to point out that the absolute number of connection estimated by (Mazeau et al., 2014) in 2008 is bigger than one in 2010 census, this is probably due to errors in the estimated population connected to the sewerage, but still the trend confirms that the percentage of connection to the sewerage in Kumasi is decreasing over last years.

Year	**2008**	**2010**	**2015**	**Year 1**	**Year 5**	**Year 10**
				2016	**2020**	**2025**
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	1,817,363	2,035,064	2,659,747	2,806,033	3,476,183	4,543,233
Population Connected to the sewer	147,206	101,753	101,753	101,753	101,753	101,753
Percentage of the population Connected to the sewer	8%	5%	4%	4%	3%	2%
Source	Mazeau et al., 2014	GSS, 2013	Furlong, 2015a	Projection		

Table 6: Sewerage connexions for the next 10 years in Kumasi (Scenario 1)

In 2015 only 80% of the sewage produced went to the small and decentralised sewage treatment plants (Furlong, 2015a), which corresponds to 20% leakage. No data is available about the operation and maintenance plans of the network, so as a consequence the percentage of leakage assumed is the same (20%), but it is probable that without good operation and maintenance this leakage will increase.

According to Furlong (2015) and STP/KMA (2016b) these plants are partially treating (50%) the sewage. Assuming that the plants are going to continue partially treating the influent, table 7 shows the projection made for the next 10 years. As before, operation and maintenance has not been considered.

Year	2015	Year 1	Year 5	Year 10
		2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
DELIVERED TO SEWAGE TREATMWENT PLANTS				
Percentage of generated sewage that is delivered to treatment	80%	80%	80%	80%
SEWAGE TREATED				
Percentage delivered sewage that is treated	50%	50%	50%	50%

Table 7: Transport and Treatment in Kumasi for the next 10 years (Scenario 1)

5.1.3 Onsite sanitation

As explained in the methodology (section 3.2) the containment technologies are not going to be analysed. The same types of containment sanitation systems (onsite and offsite) used in the SFD already produced for Kumasi are assume. The types of technologies are explained in table 2 in section 3.2.

New infrastructure, either private or public will be assumed as WC toilets, (connected to a septic tank or a sealed tank) because it is the current trend of new infrastructure in Kumasi (KMA, 2016a, WSUP, 2016b). That means the number of people using basic latrines or improved pit latrine is going to be constant. Table 8 shows this projection. The rest of people are going to be connected to a septic tank or a sealed tank.

Year		2015	2016	2020	2025
Population Growth Rate		5.5%	5.5%	5.5%	5.5%
Population		2,659,747	2,806,033	3,476,183	4,543,233
Type of facility	**Technology considered in the SFD**				
Basic Latrine	Unlined it with no outlet no overflow	5%	5%	4%	3%
		132,987	132,987	132,987	132,987
	Abandoned and covered in soil	6%	6%	5%	4%
		159,585	159,585	159,585	159,585
Improved pit latrines	Lined pit with semipermeable walls open bottom with no outlet no overflow	2%	2%	2%	1%
		53,195	53,195	53,195	53,195
	Abandoned and covered in soil	5%	5%	4%	3%
		132,987	132,987	132,987	132,987
WC	Sewerage	4%	4%	3%	2%
WC/Aqua Privy/ Enviroloo	Sealed tank with no outlet no overflow	=100% - the sum of all other technologies (22%) – OD(3%)=75%	=100% - the sum of all other technologie s (22%) – OD (depends on the scenario)	=100% - the sum of all other technologi es (18%) – OD (depends on the scenario)	=100% - the sum of all other technologies (13%) – OD (depends on the scenario)
	Septic tank outlet to soakaway				
Source		Furlong, 2015	Projection (calculated)		

Table 8: Basic Latrines and Improved pit Latrines user in Kumasi from the next 10 years.

The only technology that is being used in Kumasi that was not analysed within the 2015 SFD report was the Clean Team Toilets (see section 4.2.1), because they gave service to less than 1% of the population. Table 9 shows that even considering the projection base on the number of clients expected by the Clean Team for 2018 (best case scenario) this technology is going to be used by less than 1% of the population at least until 2023. From 2023 to 2025, the number of clients could represent more than 1% of population as long as the business continues to increase at the same rate from the beginning. This is not probable because usually businesses have a ceiling of clients after some years. Therefore this technology has not been analysed in this study.

Year	2015	2016	2017	2018	2023	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	2,960,365	3,123,185	4,081,876	4,543,233
People per household (GSS, 2013)	4	4	4	4	4	4
% of population served by the Clean Team Toilets	0.15%	0.15%	0.33%	0.49%	1.05%	1.19%
Number of people served by the C3lean Team Toilets	4,032	4,120	9,660	15,200	42,900	53,980
Clean team clients	1,008	1,030	2,415	3,800	10,725	13,495
Source	(Furlong, 2015a)	Clean Team Toilets, 2016 and WSUP, 2016b	Projection (calculated)	Clean Team Toilets, 2016 and WSUP, 2016b	Projection (calculated)	

Table 9: Clients of the Clean Team Toilets for the next 10 years

The containment in this research is analysed by categories of origin, in order to project the proportion of the population who are going to rely on each one of them.

5.1.3.1 Private toilets – compound housings

It is estimated that 75% of Kumasi's population live in compound housing (Amoako and Korbow, 2011) and as a consequence this study assumes as Furlong (2015) did, that the majority of private toilets in Kumasi are located in compounds and shared by the people living in them.

Even if there is no public investment, the private toilets will increase due to private investments made by households. The available data to calculate the percentage of population using private toilets over the next 10 years in Kumasi are:

- According to Mazeau et al. (2014) the percentage of the population with toilets without connection to the sewerage network was 48% in 2008 and it is expected to decrease in the coming years.
- According to a 2010 census the percentage of the population relying on private toilets without connection to the sewerage network was 53%.
- According to Furlong (2015) the percentage of the population having a private toilet was 54%.

These data are not totally consistent; the growth rate of private toilets has risen moderately between 2008 and 2010 (2.5% each year) whereas between 2010 and 2015 it has slightly increased (0.2% each year). Additionally, the KMA reported that the number of toilets in compound is increasing slowly (KMA, 2016a) However, this contradicts Mazeau's decreasing expectations due to the increasing demand of people to live in compounds (reducing the space to construct toilets) and because bucket toilets have been discouraged in Ghana since 2010 (Mazeau et al., 2014).

Therefore the most conservative rate (0.2% increasing each year) has been selected to project the data for the next 10 years and produced the SFD. This projection is shown in table 10. This ensures that trend continues increasing like in recent years; however the number of compounds without access to private toilets increases due to the population growth.

Year	2008	2010	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	1,817,363	2,035,064	2,659,747	2,806,033	3,476,183	4,543,233
Population using private toilets	870,153	1,078,584	1,436,264	1,520,870	1,911,901	2,544,210
Percentage of the population using private toilets	48%	53%	54%	54.20%	55.00%	56.00%
Source	Mazeau et al., 2014	GSS, 2013	Furlong, 2015a	Projection (calculated)		

Table 10: Percentage of population relying on private toilets (Scenario 1)

5.1.3.2 Public toilets

In 2015 39% of Kumasi used public toilets (Furlong, 2015a). The number of toilets blocks was 360, with approximately 5792 facilities (KMA, 2015a) meaning that the number of users per facility was 179[5]. 16 toilets (260 more facilities) were under construction in 2015 (KMA, 2015a) and then number of toilets blocks expected in 2016 is 376 and 6052 facilities. This number of facilities is going to be constant for the next 10 years if there is no public investment in Kumasi (see table 11).

Based on the expected trends on the practise of OD (section 5.1.1), using offsite sanitation (section 5.1.2) and using private toilets (section 5.1.3.1) the demand for public toilets has been calculated in table 11. Adding the all these trends (% of people practicing open defecation % of people using offsite sanitation and private toilets) it is assumed that the rest of the population is going to demand public toilets.

[5] According to (WSUP, 2014) the Ministry of Local Government and Rural Development (MLGRD) of Ghana recommends no more than 50 users per facility (this reference could not be confirmed)

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OPEN DEFECATION				
Population practicing OD	79,792	82,778	95,595	113,581
Percentage of population practicing OD	3.0%	2.95%	2.40%	2.50%
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	3%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,436,264	1,520,870	1,911,901	2,544,210
Percentage of the population using PRIVATE TOILETS	54.00%	54.20%	55.00%	56.00%
PUBLIC TOILETS				
Population demanding Public Toilets	**1,041,938**	**1,100,632**	**1,366,934**	**1,783,688**
Percentage of population demanding public toilets	**39.2%**	**39.2%**	**39.3%**	**39.3%**

Table 11: Public toilets demand (Scenario 1)

WSUP (2014) estimated that the population use public toilets 1-2 times a day on average. This study assumes that on average people use the public toilets just once a day. The capacity to cope the demand of those 6052 facilities depends on the time that each user spends in a facility:

- Scenario 1 A:

  Table 12 shows the average number of minutes that a public toilet user spent in a facility in 2015: knowing the number of facilities (5792) and users (39% of the population) it is possible to calculate the number of minutes that each user would spend on average in each facility, considering public toilets will be open 19 hours per day.

SCENARIO 1A	2015	Source
Population Growth Rate	5.5%	Furlong, 2015a
Total Population	2,659,747	
Percentage of population that could use the public toilets: CAPACITY	39%	
Number of Public Toilets	360	
Number of facilities (based on data the KMA)	5792	
Users per facilities per day (assuming that all people used the facility at least once per day)	179	Calculated
Users per facilities per hour (assuming they open from 4am to 11pm (19 hours)]	9	
Minutes per user as average	6.4	

Table 12: Minutes that each public toilets user spends on average in each facility in 2015

Assuming that public toilets in the next 10 years will give the same level of service (6.4 minutes per user in each facility as an average) that they did in 2015, it is possible to calculate the capacity of the public toilets to respond to the demand; table 13

SCENARIO 1A	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%
Total Population	2,806,033	3,476,183	4,543,233
Minutes per user as average	6.4	6.4	6.4
Users per facilities per hour	9	9	9
Users per facilities per day assuming they open from 4am to 11pm (19 hours)]	179	179	179
Number of facilities (based on KMA data)	6052	6052	6052
Number of people who could use the facility per day	1,083,308	1,083,308	1,083,308
Percentage of population that could use the public toilets: CAPACITY	**38.6%**	**31.2%**	**23.9%**

Table 13: Public toilets capacity if each person spends on average 6.4 min per facility (Scenario 1A)

Comparing the projected demand for public toilets in table 11 and the capacity of the public toilets in table 13 it can be concluded that the public toilets cannot cope with the future demand,

As a result, OD will increase more than expected in Kumasi (section 5.1.1) because after 2016 the toilets would not have the capacity to respond to the demand of the growing population. Table 14 shows this rise.

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	3%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,436,264	1,513,662	1,867,023	2,426,171
Percentage of the population using PRIVATE TOILETS	54.0%	54.20%	55.00%	56.00%
PUBLIC TOILETS				
Population using Public Toilets	1,041,938	1,083,865	1,083,865	1,083,865
Percentage of population using Public Toilets	39.0%	38.6%	31.2%	23.9%
OPEN DEFECATION				
Population practicing OD	79,792	99,545	378,664	813,404
Percentage of population practicing OD	3%	3.55%	10.9%	17.9%

Table 14: Public toilets use and OD practise if each public toilet user spends 6 min on average per facility (Scenario 1A)

- Scenario 1B

  Another way of calculates the capacity of the toilets is to define the minimum time that a person needs to use a toilet. This minimum time has been calculated based on data collected by WSUP, (2014)- table 15,in which they estimated the ratio of user per facility in each district. In this case the minimum time has been calculated in 4 minutes.

	Submetro in Kumasi	Number of Toilets	Number of facilities	Users per day	Opening Hours	Person per hour	Minutes per person
1	ASAWASE	20	264	212	19	11	5
2	BATAMA	20	388	267	19	14	4
3	KWADASO	30	465	216	19	11	5
4	MANHYIA	58	931	65	19	3	18
5	NHYESO	20	301	179	19	9	6
6	OFORIKROM	52	749	162	19	9	7
7	SUAME	31	538	120	19	6	10
8	SUBIN	57	925	75	19	4	15
9	TAFO	33	440	133	19	7	9
	Total	321	5001	159	19	8	7

Table 15: Time spend per person in each facility in 9 submetros of Kumasi (adapted from WSUP, 2014).

If this minimum time is considered the capacity of the toilets would be more, as it is shown in table 16, In this case public toilets could deal with the demand.

SCENARIO 1B	**2016**	**2020**	**2025**
Population Growth Rate	5.5%	5.5%	5.5%
Total Population	2,792,735	3,394,586	4,332,448
Minimum amount of minutes per user as average	4	4	4
Users per facilities per hour	15	15	15
Users per facilities per day assuming they open from 4am to 11pm (19 hours)]	285	285	285
Number of facilities	6052	6052	6052
Number of people who could use the facility per day	1,724,820	1,724,820	1,724,820
Percentage of population that could use the public toilets: CAPACITY	**62%**	**51%**	**40%**

Table 16: Public toilets capacity if each person spends 4 min on average per facility (Scenario 1B)

The total opening hours of public toilets per day in both scenarios was assumed to be 19 hours; public toilets are not open24 hours per day (KMA, 2016a). Opening hours vary from one to another (Mazeau, 2013) and those owned by the KMA are usually open from 4am to 11pm (Nyarko, 2015) .

No considerations have been made about operation and maintenance because no data is available.

5.1.3.3 Institutional Toilets

People using institutional toilets in Kumasi (such as prisons, military bases, hospitals and schools) are included in the baseline data and projections already made for private and public toilets. Thus institutional toilets are not analysed in this research as people would otherwise be included twice since SFDs work with percentages of the population and not with the volume of excreta. This as explained in the literature review (section 2.6.1) is one of the difficulties when modelling SFD due to not being considered all the flow produced. Therefore consequences the flow which is arriving to the treatment plant can be bigger than considered in the SFDs calculation.

5.1.3.4 Emptying onsite sanitation systems

In 2015 95% of onsite sanitation systems are emptied (Furlong, 2015a), by either motorised or manual methods.

No data has been found about manual emptying but Furlong (2015) estimated that 11% of the population who have basic latrines or improved pit latrines used either this method or abandoned the latrine, covering it in soil in 2015. It is assumed that the proportion of the population relying on these methods is going to be constant over the next 10 years because the new sanitation facilities constructed in Kumasi are mostly WC's (KMA, 2016a, WSUP, 2016b).

The rest of the onsite sanitation facilities are emptied by vacuum tankers (mainly private providers) and transported to the STP. The number of vacuum trucks working in Kumasi nowadays is 48 (Tiberghien, 2016). Each truck has capacity to service 5 to 8 customers per day, giving a total capacity to service 312 installations (private toilets or public toilets per day) as shown in table 17.

Vacuum Trucks Capacity		**Source**
Number of trucks (37-42 companies)	48	Furlong 2015a and Tiberghien, 2016.
Mean capacity of tankers (m³)	7.5	Furlong, 2015b
	6.5	KMA, 2015b
Average number of customers/installations that each truck is able to empty per day	6.5	Furlong. 2015a
Total number of customers/installations that all the trucks can empty per day.	312	Calculated
Number of customers/installations that all trucks have capacity to emptying per year	113,880	

Table 17: Vacuum tankers capacity (currently)

No data was found about the vacuum trucks plans, hence it is assumed that the number of trucks and their capacity (calculated in table 17) is going to be the same now as it will be in the future, but this should be investigated more.

The public toilets need to be emptied up to twice per week (Furlong, 2015a, KMA, 2016b) It is assumed that toilets are going to need to be emptied with this frequency in the future. Table 18 presents the number of times that public toilets need to be emptied over the next 10 years.

Year	2015	2016	2020	2025
Number of public toilets	360	376	376	376
Number of times on average that one public toilets have to empty per week	2			
Number of times that one public toilets has to be emptied per year	104	104	104	104
Number of times that all public toilets have to be emptied per year	**37,440**	**39,104**	**39,104**	**39,104**

Table 18: Emptying needs of Public Toilets (Scenario 1)

The amount of private toilets, which have to be emptied, is shown in table 19. The number of people per compound is not clearly established by the available data but there is an agreement that there are more than 20 people on average (Mikhael, Craig and Musah, 2016, WSUP, 2016b) . Therefore 20 people per compound were considered as a conservative assumption.

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,792,735	3,394,586	4,332,448
People per household in Kumasi (GSS, 2013)	4	4	4	4
Percentage of people relying in private toilets (see section 5.1.3.1)	54.0%	54.2%	55.0%	56.0%
Number of people relying in private toilets	1,436,264	1,520,870	1,911,901	2,544,210
Number of people per compound (at least)	20	20	20	20
Number of compounds with toilets that have to be emptied	71,813	76,004	95,595	127,211

Table 19: Number of compounds that have to empty their installations (Scenario 1)

As explained before, 11% of the population in 2015 who have basic latrines or pit latrines (and as consequence of compounds, assuming the number of 20 people constant per compound) used manually emptiers or abandoned the latrines covering it in soil. The number of compounds having this type of latrines is assuming constant due to the trend in Kumasi being to construct WC toilets (KMA, 2016a, WSUP, 2016b).

Subtracting this amount of compounds (7899) from the total of compound that have to be emptied, the number of compound with toilets to be emptied by tankers has been calculated in table 20

Year	2015	2016	2020	2025
Number of compounds with toilets that have to be emptied	71,813	76,004	95,595	127,211
Number of compound empting manually disposed safely or not emptied	7,899	7,899	7,899	7,899
Percentage of compound empting manually and disposed safely or abandoned and covered in soil	11%	10%	8%	6%
Number of compound with toilets to be emptied by tankers	**63,914**	**68,144**	**87,695**	**119,311**

Table 20: Number of compounds that have to empty their installations (Scenario 1)

No data was found about the how frequently these installations have to be emptied, as consequence this study is going to assume that each compound has to empty their sanitation facilities once per year as average. Pits and septic tanks that are emptied may require emptying less frequently, while basic latrines are likely to require more frequent emptying – especially given the average of 20 users per compound.

Table 21 shows the demand to empty installations and the capacity of the current number of vacuum trucks to cope with the future demand. If the number of trucks does not increase after 2019 they will not be able to respond customers' demands. As no information could be collected about vacuum tankers business plan for future years the data presented in table 21 will be used to produce the SFDs.

Year	2015	2016	2019	2020	2025
Number of times that all public toilets have to be emptied per year	37,440	39,104	39,104	39,104	39,104
Number of compound with toilets to be emptied by tankers	63,914	68,144	82,382	87,695	119,311
Total of installations to be emptied	**101,354**	**107,248**	**121,486**	**126,799**	**158,415**
Percentage of installation emptied with trucks (Furlong, 2015a))	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	101,886	115,412	120,460	150,494
Tanker capacity (emptying actions per year)	113,880				
Number of installation that trucks can ACTUALLY empty	96,286	101,886	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	**95%**	**95%**	**94%**	**90%**	**72%**

Table 21: Percentage of onsite sanitation facilities emptied by tankers (Scenario 1)

5.1.3.5 Transport

The current system set up by the tankers is working well (Furlong, 2015a and KMA, 2016). Therefore it is assumed that 95% of the collected waste is delivered to the treatment plant.

5.1.3.6 Treatment

At the time of writing, the STP is not being used and the vacuum trucks are discharging the FS into the environment at a set point next to the STP (see figure 20). The reason is that the KMA (with the support of WSUP) is going to rehabilitate the plant next year and they need to empty the ponds. However in this scenario, it is considered that this septage treatment plant will not be rehabilitated – or that any rehabilitation will not significantly alter the current treatment capability.

Figure 20: Vacuum truck discharging into the environment next to STP

As a consequence it is assumed that the STP would still be working and treating at maximum efficiency 50% of the incoming faecal sludge (Furlong, 2015a). This reported efficiency was based on the operation and maintenance reality of the plant, not only on its volumetric capacity.

To calculate the capacity of the plant in the future the following points have to be considered:

- The capacity of the treatment plant is not clear. Initially it was designed to cope with an inflow of 300m^3 of sludge per day but it is believed that this capacity was increased to 450m^3/day during the construction (Furlong, 2015a. Calculations will be undertaken to consider both capacities.
- The official mean size of the tankers is but 6.5m^3 however according to Furlong's observation (2015) the mean size is 7.5 m^3. Calculations will be undertaken to consider both sizes.
- The number of trucks arriving at the plant each day varies from 48-51 (KMA, 2015b) to 59-71 (Furlong, 2015b). 51 tankers per day are going to be assumed by this study because it is an average from the daily records from the six first months of 2015.

  To calculate the required capacity of the plant to deal with future demand, an estimation of the daily volume of FS arriving at the plant is needed. There is a lack of information about the volume of the installations (either public as public toilets or private as compound toilets)

Additionally only household installations and public toilets are considered, not institutional installation (as schools or government building) or costumers of the trucks who are outside of city limits. As consequence the volume arriving at the plant is probably going to be more than calculated.

Therefore, regarding the capacity of 51 tankers the number of trucks arriving at the SPT in 2015 and that they should cope with 96,286 installations, the number of trucks needed to cope the demand has been calculated by proportionality (knowing three values enables a fourth to be projected) knowing the number of installations emptied by them. The calculated projection for the next 10 year is shown in table 22.

Year	2015	2016	2020	2025
Number of installations emptied by the trucks per year (see section 5.1.3.4)	96,286	101,886	113,880	113,880
Trucks arriving at the STP per day	51	54	60	60

Table 22: Tanker per day arriving at the STP (Scenario 1)

Based on the different possibilities (of treatment capacity and truck size) four scenarios can be considered as shown in table 23:

SCENARIO 1i/ Year	2015	2016	2020	2025
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	6.5			
Volume arriving m^3/day	331.50	349.60	390.83	390.83
Capacity of treatment plant (m^3/day)	450			
Treated (to SFD)	50%	50%	50%	50%
SCENARIO 1ii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	6.5			
Volume arriving m^3/day	331.50	349.60	390.83	390.83
Capacity of treatment	300			
Treated (to SFD)	45%	43%	38%	38%
SCENARIO 1iii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	7.5			
Volume arriving m^3/day	382.50	403.38	450.96	450.96
Capacity of treatment plant (m^3/day)	450			
Treated (to SFD)	50%	50%	50%	50%
SCENARIO 1iv/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck size	7.5			
Volume arriving m^3/day	382.50	403.38	450.96	450.96
Capacity of treatment plant (m^3/day)	300			
Treated (to SFD)	39%	37%	33%	33%

Table 23: FS treated depending on the STP capacity and mean size of trucks arriving at the STP (Scenario 1)

There is no method to calculate the amount of FS that the STP is going to treat when it is working over capacity. In this study it was assumed that if the efficiency of the treatment plant is 50% and the capacity is 300m^3/day, then the STP is going to treat up to 150m3/day. The rest is considered untreated as shown in the table below.

Efficiency when it is working under capacity	**50%**		
Capacity (m^3/day)	**300**		
Arriving at the STP (m3/day)	200	300	400
Treated (m3/day)	100	150	150
Not Treated (m3/day)	100	150	250
% of FS treated	50%	50%	25%

Table 24: Example of how the % of FS treated was calculated

5.1.4 SFD Production

The data obtained from the analysis made before has been used to produce the SFDs. By introducing the data for each year in an Excel spreadsheet that can be found in SUSANA website (see section 3.2.4 in the methodology), the SFD for each of the next 10 years can be produced to illustrate scenario 1.

In this section only the worst-case scenario has been modelled, because it is in this scenario in which most of the relevant changes can be observed over the years. As a consequence, the SFDs produced for this scenario consider:

- Public toilets users will spend on average of 6 minutes in each facility (see section 5.1.3.2)
- The mean size of sludge tankers arriving at the STP is 7.5 m^3 (see section 5.1.3.6)
- The intake capacity of STP is 300m^3/day of septage (see section 5.1.3.6)

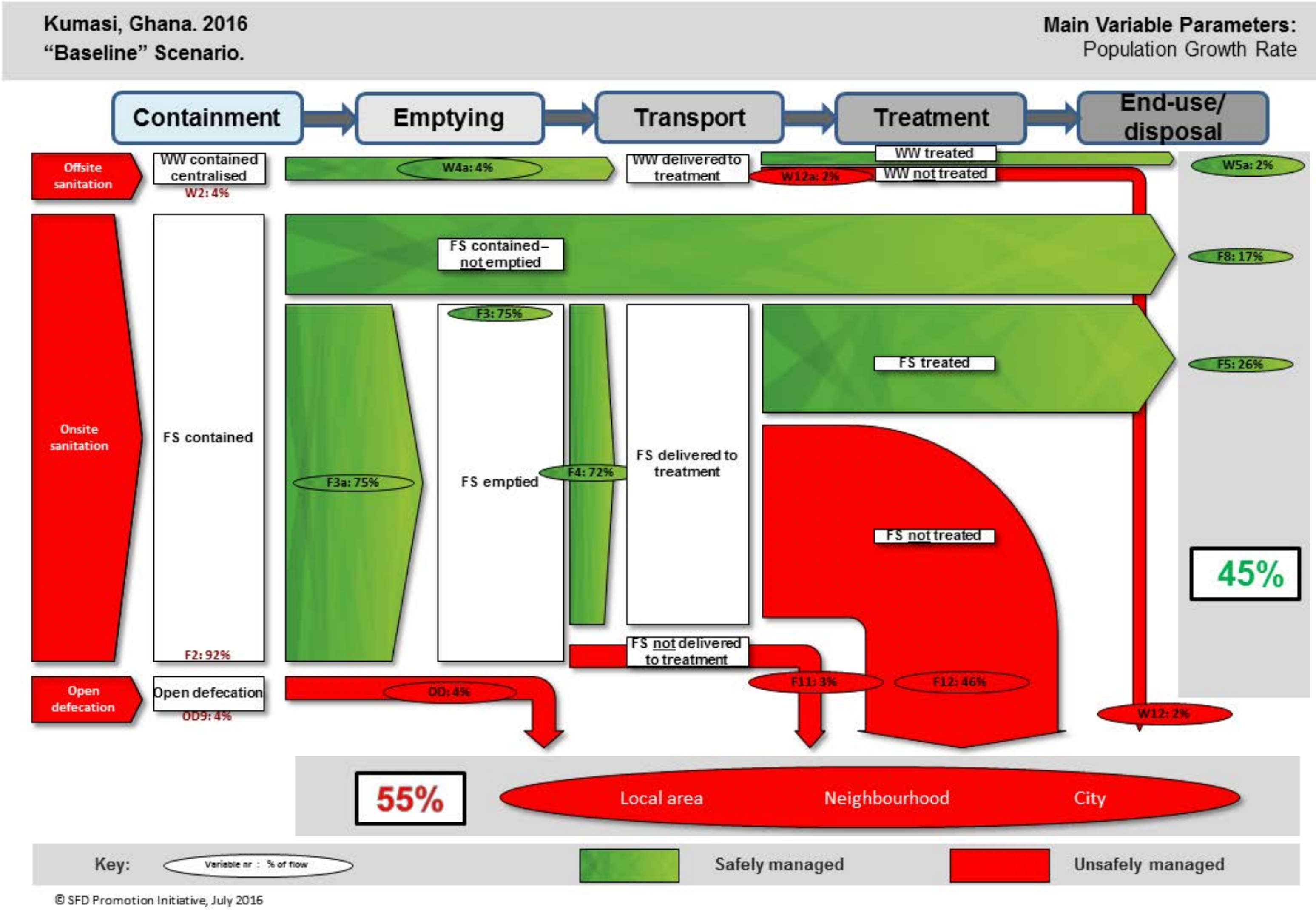
The detailed data to produce the SFDs for this scenario can be found in appendix 7.

5.1.4.1 SFD results for each year, baseline scenario

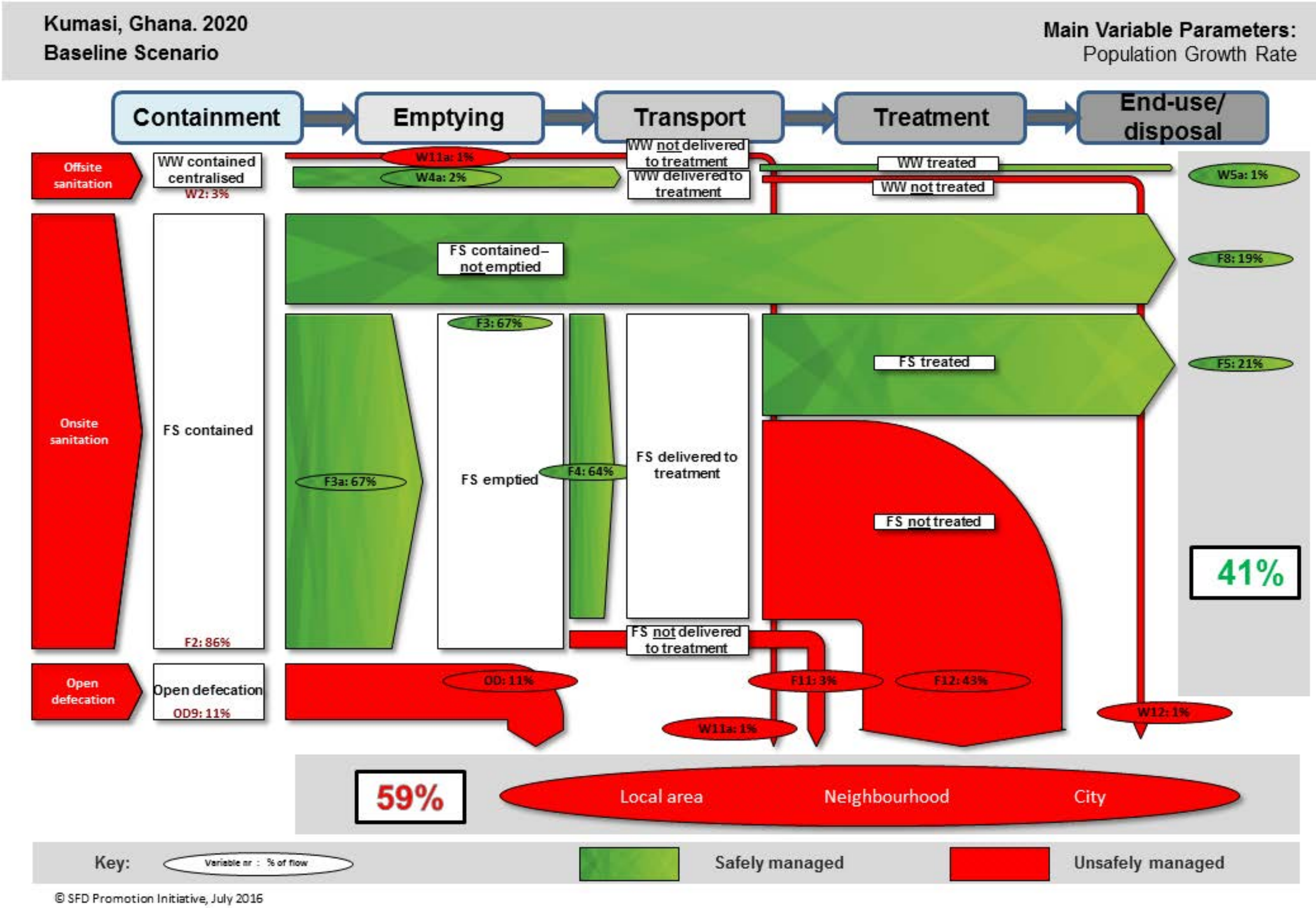
Scenario 1 / PARAMETERS	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Population growth rate	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%
Population	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	3,667,373	3,869,079	4,081,878	4,306,381	4,543,232
Households	701,508	740,091	780,796	823,740	869,046	916,843	967,270	1,020,469	1,076,595	1,135,808
People/per household	4	4	4	4	4	4	4	4	4	4
OFFSITE SANITATION										
Containment										
WW Contained Decentralised	4%	3%	3%	3%	3%	3%	3%	3%	2%	2%
Transport										
WW delivered to treatment	4%	2%	2%	2%	2%	2%	2%	2%	2%	2%
WW NOT delivered to treatment	0%	1%	1%	1%	1%	1%	1%	1%	0%	0%
Treatment										
WW treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
WW not treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Disposal										
Safely Disposed	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
ONSITE SANITATION										
Containment										
FS Contained	92%	91%	90%	88%	86%	85%	83%	83%	81%	80%
Emptying										
FS contained and not emptied	17%	15%	15%	15%	18%	21%	22%	24%	26%	29%
FS emptied	75%	76%	75%	73%	68%	64%	61%	59%	55%	51%
Transport										
FS delivered to treatment	72%	72%	72%	69%	65%	61%	58%	56%	52%	48%
FS not delivered to treatment	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%
Treatment										
FS treated	26%	26%	24%	23%	22%	20%	19%	18%	17%	18%
FS not treated	45%	46%	47%	46%	43%	41%	39%	37%	35%	30%
Disposal										
Safely Disposed	26%	26%	24%	23%	22%	20%	19%	18%	17%	18%
OPEN DEFECATION										
Open defecation	4%	6%	7%	9%	11%	12%	14%	15%	17%	18%
EXCRETA FLOW MANGAMENT										
Safely Management	45%	42%	40%	39%	41%	42%	42%	43%	44%	48%
Unsafely Management	55%	58%	60%	61%	59%	58%	58%	57%	56%	52%

Table 25: SFD results for each year, baseline scenario

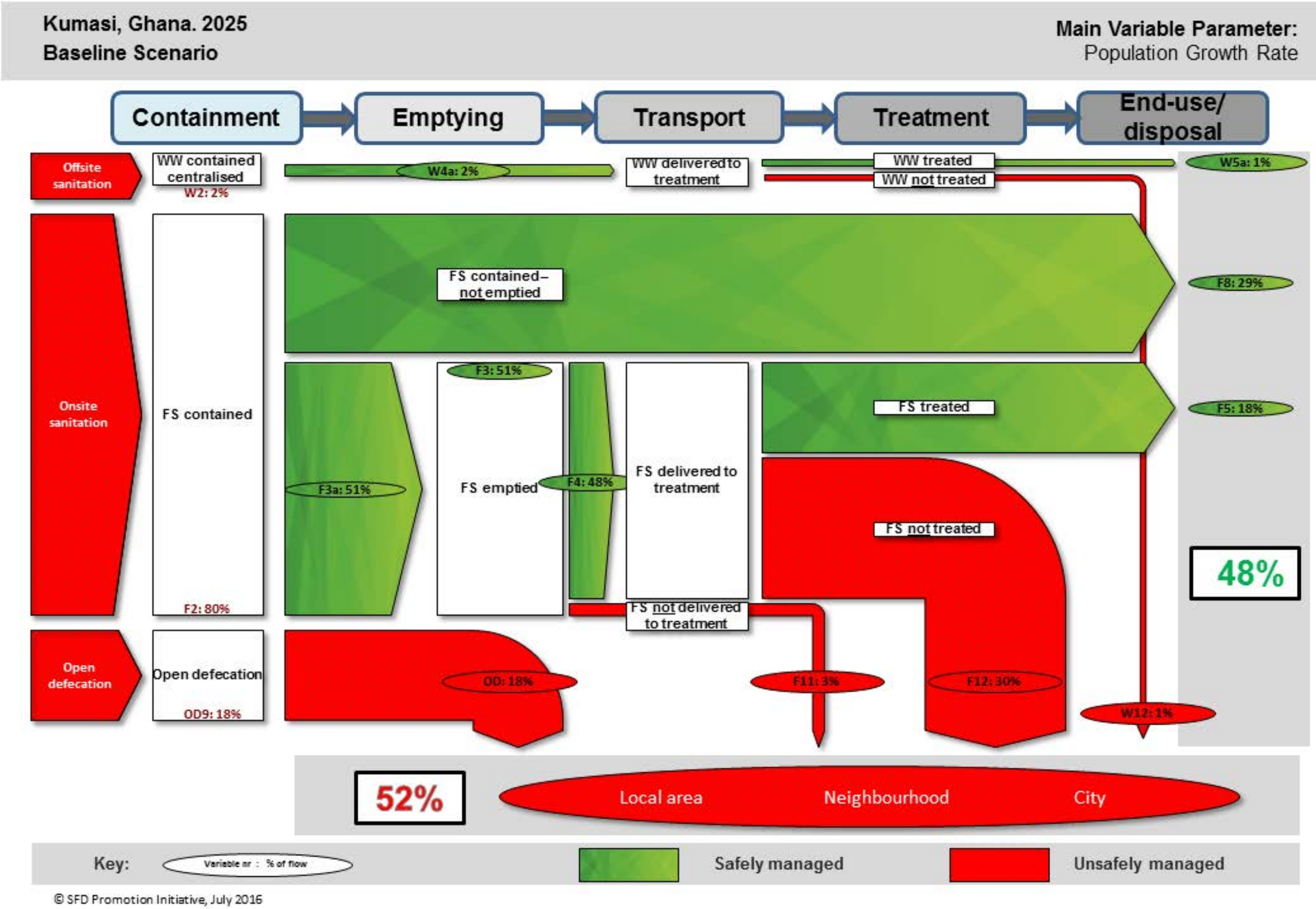
5.1.4.2 Baseline Scenario Year 2016.



5.1.4.3 Baseline Scenario Year 2020.



5.1.4.4 Baseline Scenario Year 2025



5.1.5 Trend Analysis and discussion

As explained in the methodology, as a complement to the SFD, a trend analysis was made. First the graphs showing the results of the SFDs (section 5.1.4.1) were produced.

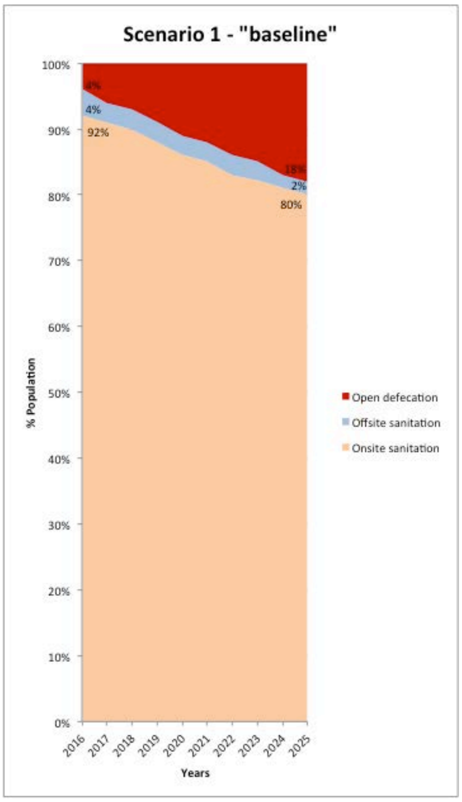


Figure 21 shows the trend in the type of sanitation in Kumasi for the next ten years. Due to the capacity of toilets not being enough to cope the demand, the percentage of population using onsite sanitation is decreasing and the open defecation is going to increase at the same rate as the population growth does (see section 5.1.3.2, scenario 1A) .

Figure 21: Trend in the type of sanitation in Kumasi for the next 10 years (scenario 1).

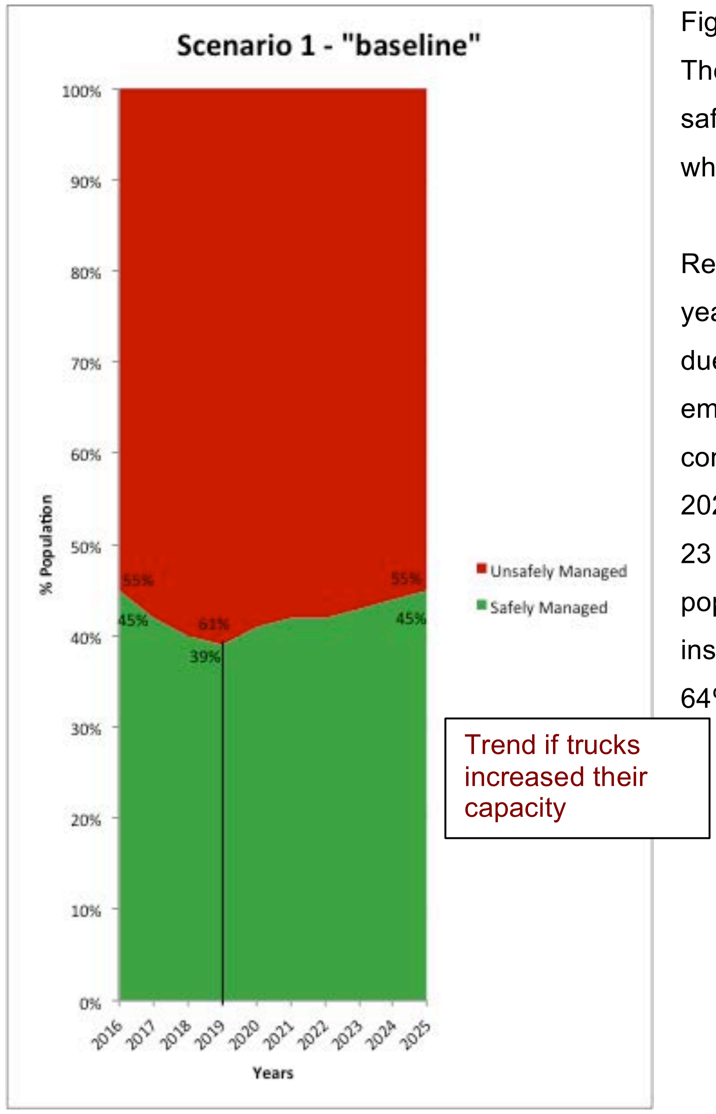


Figure 22: % of population whose excreta is safely managed along 10 years (scenario 1)

Figure 22 shows the overall result for scenario 1. The proportion of the population whose excreta is safely managed increases after year 2019, even when there is no investment considered.

Regarding the SFDs produced (section 5.1.4) for years 1, 5 and 10, it is observed that this increase is due to the proportion of the population who do not empty their contained FS. The width of the arrow “FS contained but not emptied” increases from 19% in 2020 up to 29% in 2025. This is illustrated in figure 23 over the 10 years. The percentage of the population (who use onsite sanitation) emptying their installations in 2015 was 82% whilst in 2019 it is 64%.

This is because the SFD methodology considers that if FS is well contained it is safe for the environment (avoiding to contaminate the ground water) and as a consequence it is safely managed.

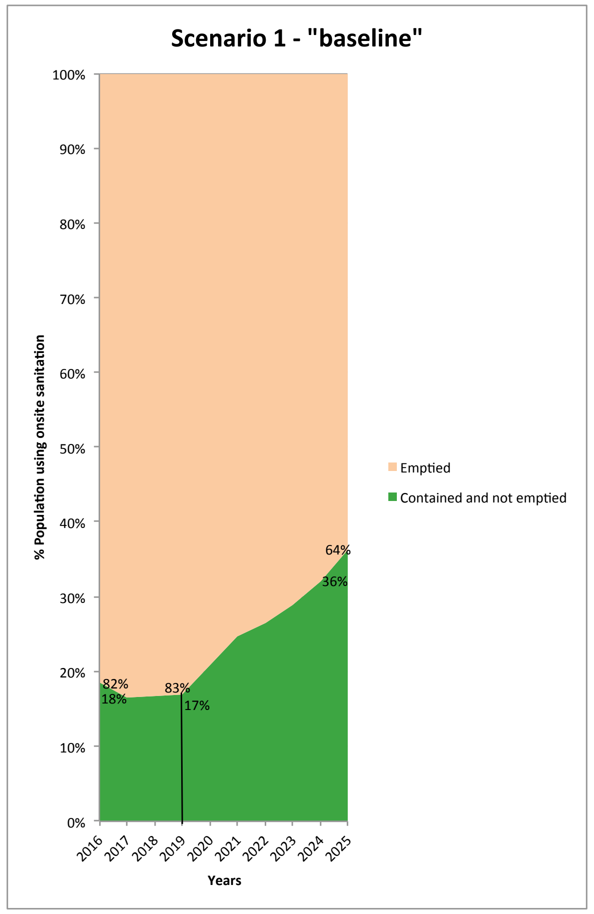


Figure 23: % of population who empty their installations (scenario 1)

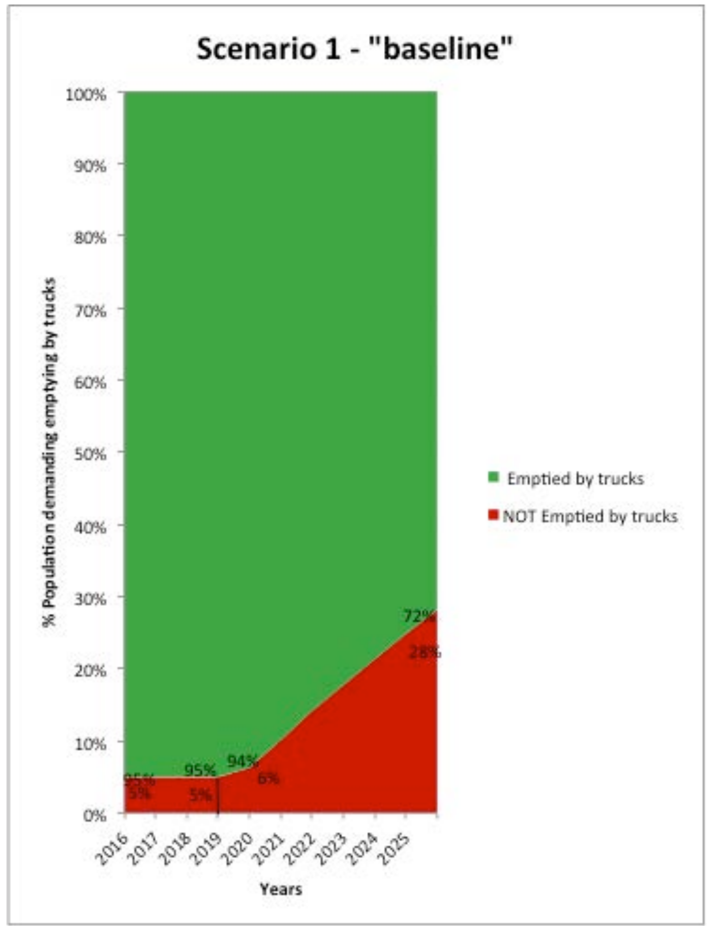


Figure 24: % of installations that cannot be emptied by trucks(scenario 1)

To understand why the population stops emptying their installations it is important to analyse the collected data concerning emptying (section 5.1.3.4, detailed data are in appendix 7)). Figure 24 shows that people stop emptying their installations because trucks reach their maximum capacity in 2019. However, as shown in table 21 (“Total of installations to be emptied”) the demand for emptying installations by trucks increases over the years.

Considering the three trends in the graphs, it can be concluded that the rise in the percentage of population who safely managed the FS after 2019 is because there are installations that, even when full, cannot be emptied because the trucks do not have the capacity to meet the demand.

After 2019, some installations need to be emptied and trucks do not have the capacity to do it. This issue in the sanitation service chain seems to be positive when it is modelled in the SFDs because the proportion of population who safely managed their installation increases (figure 21). This is due to SFD methodology considering that if an installation contains the FS there is no risk of environmental contamination

Having FS contained but not emptied means that FS is not being managed (there is no emptying service). If the objective of the SFDs is to illustrate the percentage of people who well manage their FS this lack of emptying service should be considered as a bad practise. Additionally, once the installations are full people cannot longer use them and SFD does not illustrate what would happen in this case, e.g. would those people return to OD?

Finally the trend in treatment has been analysed. Figure 25 shows the percentage of FS arriving at the STP treated and not treated. After 2019, the efficacy of treatment is constant, this is due to the amount of FS arriving at STP is going to be constant because the number of trucks arriving at the treatment plant is going to be constant because they do not have more capacity to delivered more FS to the STP.

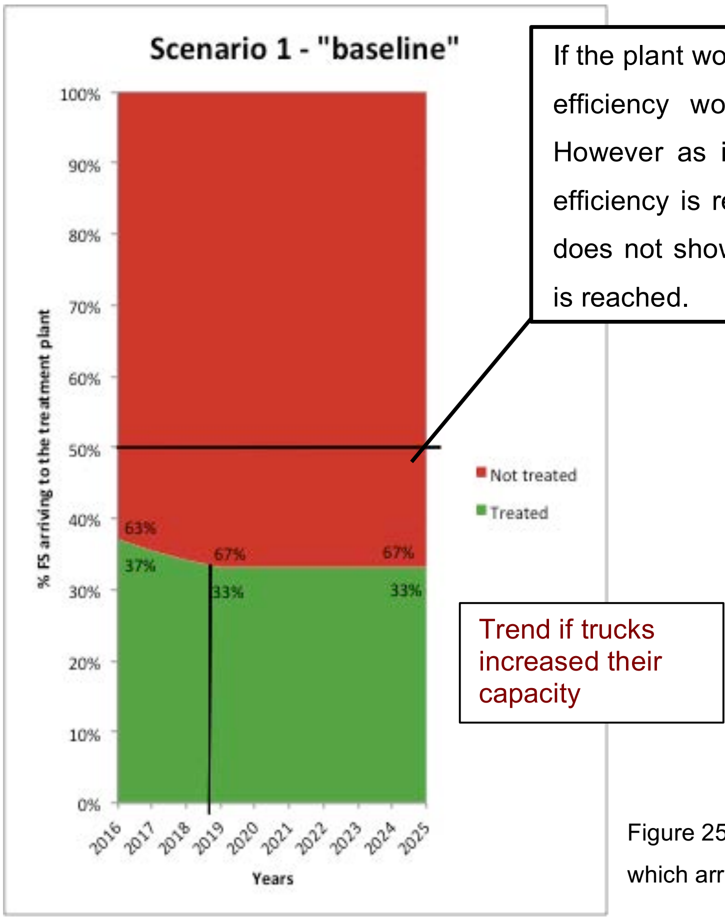


Figure 25: % treated and not treated of FS which arrive at the STP (scenario 1)

5.2 Scenario 2

Using as a starting point Scenario 1, this scenario has been defined by considering the projects supported by WSUP as (see section 4.):

- A toilet in every compound, see section 4.2.2
- Rehabilitation of the treatment plant, see section 4.2.3

As a consequence the main variable parameters are:

- Population growth rate, which is 5,5%
- The amount of population living in compounds who are going to use new private toilets
- The treatment capacity of the STP.

Questions have been established in order to define the minimum data to be collected. Some of these questions have been already answered by Scenario 1. The questions are as follows:

Open defecation

- Is the OD going to increase more than the trend calculated in the baseline scenario (section 5.1.1) if the number of public toilets increase?

Offsite sanitation

- What is the capacity of the sewer network to absorb new connections?

Onsite sanitation-Containment

- Are the Clean Team Toilets going to increase to 1%?
- What is going to be the trend in the number of private toilets in compound housing?
- How many people can the current public toilets service? Can they respond to the future demand?

Onsite sanitation-Emptying and transport service

- Can the current emptying and transport system cope with the future demand?

Onsite sanitation-Treatment and Disposal

- How much faecal sludge will arrive to the STP?
- When is the current STP going to work over its capacity if it is rehabilitated?

In order to discuss the collected data and produce the SFDs again, each part of the sanitation service chain has been analysed and finally the SFDs have been produced.

5.2.1 Open defecation

The trend of open defecation if the public toilets and the compound toilets are able to respond to the future demand has been discussed in Scenario 1 (5.1.1). The same trend is assumed for this scenario, see table 5

As in scenario 1, this projection would be used to produce the SFD as long as the public toilets can meet the future demand. This will be discussed in section 5.2.3.1.

5.2.2 Offsite sanitation

This part of the sanitation chain is not going to be affected by WSUP project, therefore the same trends and figures in scenario 1 (section 5.1.2) are assumed, see table 6 and 7

5.2.3 Onsite sanitation

Technologies (including Clean Team Toilets) and their trends do not change in this Scenario being the same as presented in Scenario 1 section 5.1.3: table 8 and 9

5.2.3.1 Private toilets – compound housings

According to the project "A toilet in every compound" (see section 4.2.2) it is expected that 100,000 more new compound residents will have access to private toilets by 2019. Assuming at least 20 people live in each compound, the number of compounds reached and the percentage of the population benefitting from the project can be calculated.

No data have been provided about the number of toilets expected for each implementation of the project. Usually, implementation starts slow and increases from the middle to the end of the project. In this case it has been assumed:

- Year 1, 2015: It has been reported as a preparation year to narrow down the strategy.
- Year 2, 2016: the implementation has started and some compounds have already constructed new facilities. It is assumed that at least 10% of the expected results are going to be achieved

Figure 26: Duraplast Septic Tank installed in a compound in the first semester of 2016 in the frame of the project "A toilet in every compound"

- Year 3, 2017: It is assumed that at least 20% of the expected results are going to be achieved

- Year 4, 2018: This is assumed to be the year in which most of the population are going to implement new facilities in their compounds, reaching up to 40% of the expected installations by the end of the project
- Year 5, 2019: This is the last year of the project and it is assumed that 30% of the expected population is going to be reached

Table 26 shows all these assumptions and the percentage of population benefitting from the project

Year	2015	2016	2017	2018	2019	2020	2025
Growth Population rate	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Population	2,659,747	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	4,543,233
Population constructing new facilities in compounds	-	10,000	20,000	40,000	30,000	-	-
Total of population with new facilities in compounds (accumulated)	-	10,000	30,000	70,000	100,000	100,000	100,000
% population benefited by the project	**-**	**0.4%**	**1.0%**	**2.2%**	**3.0%**	**2.9%**	**2.2%**
People living in each compounds (at least)	-	20	20	20	20	20	20
Number of compounds constructing new facilities	**-**	**500**	**1,500**	**3,500**	**5,000**	**5,000**	**5,000**

Table 26: % of population expected to be benefited by the project "A toilet in every compound" (scenario 2)

This population has been added to the population calculated in scenario 1, section 5.1.3.1 and it is illustrated in table 27

	Year	2015	2016	2017	2018	2019	2020	2025
	Growth Population rate	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
	Population	2,659,747	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	4,543,233
	Total of population with new facilities in compounds (accumulated)	-	10,000	40,000	70,000	100,000	100,000	100,000
	% population benefited by the project	-	0.36%	1.01%	2.24%	3.03%	2.88%	2.20%
calculated in scenario 1	Population trend in construction of public toilets-without project	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,544,210
	Trend in construction of public toilets-without project	54.0%	54.2%	54.4%	54.6%	54.8%	55.0%	56.0%
	Population using PRIVATE TOILETS	**1,436,264**	**1,530,870**	**1,640,439**	**1,775,259**	**1,905,638**	**2,011,901**	**2,644,210**
	Percentage of the population using PRIVATE TOILETS	**54.00%**	**54.56%**	**55.41%**	**56.84%**	**57.83%**	**57.88%**	**58.20%**

Table 27: % of population using private toilets (scenario 2)

5.2.3.2 Public toilets

The demand for public toilets has been calculated in the same way has in scenario 1, section 5.1.3.2: based on the expected trends on the practising of OD (section 5.2.1), on using offsite sanitation (section 5.2.2) and on using private toilets (section 5.2.3.1). Table 28 shows the result.

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OPEN DEFECATION				
Population practicing OD	79,792	82,778	95,595	113,581
Percentage of population practicing OD	3.0%	2.95%	2.40%	2.50%
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	3%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,436,264	1,530,870	2,011,901	2,644,210
Percentage of the population using PRIVATE TOILETS	54.00%	54.56%	57.88%	58.20%
PUBLIC TOILETS				
Population demanding Public Toilets	**1,041,938**	**1,090,632**	**1,266,934**	**1,683,688**
Percentage of population demanding public toilets	**39.17%**	**38.87%**	**36.45%**	**37.06%**

Table 28: Public toilets demand (Scenario 2)

This, as scenario 1 has to be compared with the capacity of the current number of public toilets (6052) to cope with the demand depending on the time that each user spends in a facility:

- Scenario 2A: Assuming 6.4 min per user on average as calculated in scenario 1A, 1,083,308 people per year could use the 6052 facilities. (see table 12)

  Comparing the demand for public toilets projected in table 28 and the capacity of the public toilets in table 12, it can be concluded that the public toilets cannot cope with the future demand,

  Consequently, OD will still increase more than expected (section 5.2.1) after 2016 but less than in scenario 1B because the number of private toilets has increased. Therefore the toilets would not have the capacity to respond to the demand for the growing population. Table 29 shows this rise.

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	3%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,436,264	1,530,870	2,011,901	2,644,210
Percentage of the population using PRIVATE TOILETS	54.00%	54.56%	57.88%	58.20%
PUBLIC TOILETS				
Population using Public Toilets	1,041,938	1,083,865	1,083,865	1,083,865
Percentage of population using Public Toilets	39.0%	38.6%	31.2%	23.9%
OPEN DEFECATION				
Population practicing OD	79,792	89,545	278,664	713,404
Percentage of population practicing OD	3.0%	3.2%	8.0%	15.7%

Table 29: Public toilets use and OD practise if each public toilet user spends 6 min on average per facility (scenario 2A)

- Scenario 2B: Assuming 4 min per user on average as calculated in scenario 1B, 1,724,820 people per year could use the 6052 facilities (see table 16) In this case as, as in scenario 1B, the public toilets could deal with the demand.

5.2.3.3 **Institutional Toilets** (see section 5.1.3.3)

5.2.3.4 Emptying onsite sanitation systems

The capacity of the trucks is the same as scenario 1 (see 5.1.3.4): All trucks have capacity to empty 113,880 customers/installations per year (see table 17). In the same way, the emptying needs of the public toilets are going to remain constant from 2016 until 2025 and will be equal to scenario 1, table 18.

Nonetheless, the amount of private toilets, which have to be emptied, will be different from scenario 1. Table 30 shows the needs for emptying private toilets. This has been calculated in the same way as in section 5.1.2.3, assuming again 20 people per compound as a conservative assumption.

Year	2015	2016	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,792,735	3,394,586	4,332,448
Percentage of people relying in private toilets (see section 5.2.3.1)	54.00%	54.56%	57.88%	58.20%
Number of people relying in private toilets	1,436,264	1,530,870	2,011,901	2,644,210
Number of people per compound (at least)	**20**	**20**	**20**	**20**
Number of compounds with toilets that have to be emptied	**71,813**	**76,544**	**100,595**	**132,211**

Table 30: Number of compounds that have to empty their installations (scenario 2)

The number of compounds with toilets/installations that need to be emptied by tankers has been calculated as in scenario 1 (see section 5.1.3.4). The result is in table 31.

Year	2015	2016	2020	2025
Number of compounds with toilets that have to be emptied	71,813	76,544	100,595	132,211
Percentage of compounds emptied manually, disposed of safely or abandoned and covered in soil	11%	10%	8%	6%
Number of compounds emptied manually, disposed of safely or not emptied	7,899	7,899	7,899	7,899
Number of compounds with toilets to be emptied by tankers	63,914	68,644	92,696	124,311

Table 31: Number of compounds with toilets to be emptied by tankers (scenario 2)

As in scenario 1, it is assumed that each compound has to empty their sanitation facilities once per year on average.

Table 32 shows the demand to empty installations compared with the capacity of the current number of vacuum trucks to cope with the future demand. If the number of trucks does not increase after 2018 they will not be able to respond to the customers' demands. As no information could be collected about vacuum tankers business plans for the forthcoming years the data presented in table 32 will be used to produce the SFDs.

Year	2015	2016	2018	2020	2025
Number of times that all public toilets have to be emptied per year	37,440	39,104	39,104	39,104	39,104
Number of compound with toilets to be emptied by tankers	63,914	68,644	80,863.51	92,695.59	124,311.06
Total of installations to be emptied	101,354	107,748	119,968	131,800	163,415
Percentage of installation emptied with trucks (Furlong, 2015a	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	102,361	113,969	125,210	155,244
Tanker capacity (emptying actions per year)	113,880				
Number of installation that truck can ACTUALLY empty	96,286	101,886	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	**95%**	**95%**	**94.9%**	**86%**	**70%**

Table 32: Percentage of onsite sanitation facilities emptied by tankers (scenario 2)

5.2.3.5 **Transport** (see section 5.1.3.5)

5.2.3.6 Treatment

As explained in section 5.1.3.6, when the STP was visited the vacuum trucks were discharging the FS into the environment at a set point next to the STP (see figure 19 in that section). The reason is that the KMA (with the support of WSUP, see section 4.2.3) is going to rehabilitate the plant in 2017 and they need to empty the ponds to desilt them.

As a consequence it is assumed, the STP will not be working during 2016 and 2017. Once it starts working again, in 2018, it is assumed that the efficiency is going to be up to 95% due to its rehabilitation but no data has been provided by WSUP or KMA.

The same consideration made in scenario 1 was done in this case (see section 5.1.3.6 and tables table 17 and 18) to calculate the capacity of the plant in the future. The result is shown in table 33

SCENARIO 2i/ Year	2015	2016	2020	2025
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment plant (m^3/day)	450			
Treated (to SFD)	50%	0%	95%	95%
SCENARIO 2ii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment	300			
Treated (to SFD)	45%	0%	73%	73%
SCENARIO 2iii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m^3) - average	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m^3/day)	450			
Treated (to SFD)	50%	0%	95%	95%
SCENARIO 2iv/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck size	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m^3/day)	300			
Treated (to SFD)	39%	0%	63%	63%

Table 33: FS treated depending on the STP capacity and mean size of trucks arriving at the STP (scenario 2)

5.2.4 SFD Production

As in scenario 1, based on the collected data, the SFD for each of the next 10 years can be produced to illustrate scenario 2.

In this section only the worst-case scenario has been modelled, because it is in which most relevant changes can be observed over the years. As consequence, the produced SFDs for this scenario consider:

- Public toilets users will spend on average 6 minutes in each facility (see section 5.2.3.2)
- The mean size of sludge tankers arriving at the STP is 7.5 m^3 (see section 5.2.3.6)
- The intake capacity of STP is 300m^3/day of septage (Scenario, 2iv, see section 5.2.3.6)

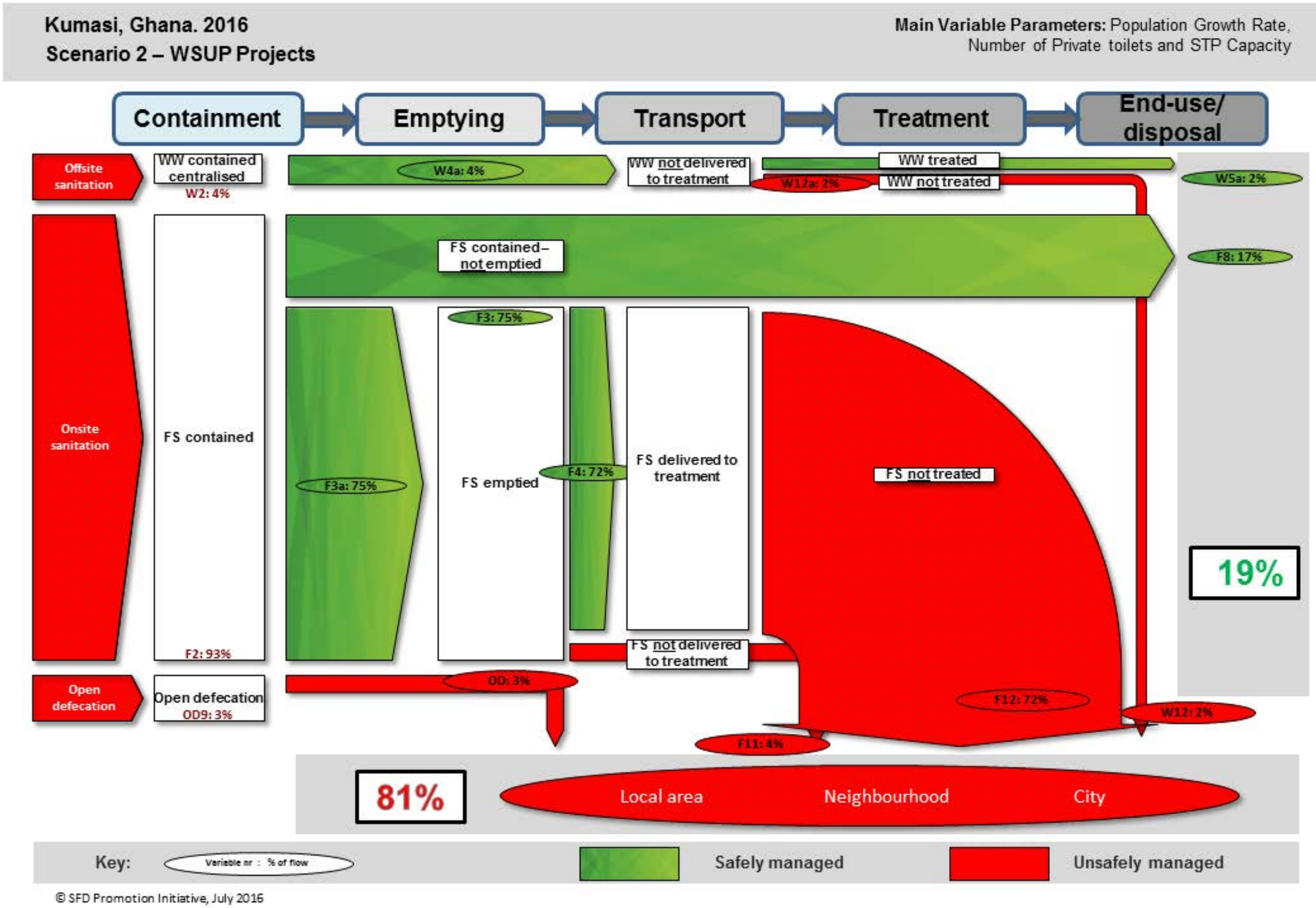
The detailed data to produce the SFDs for this scenario can be found in appendix 8.

5.2.4.1 SFD results for each year, scenario 2

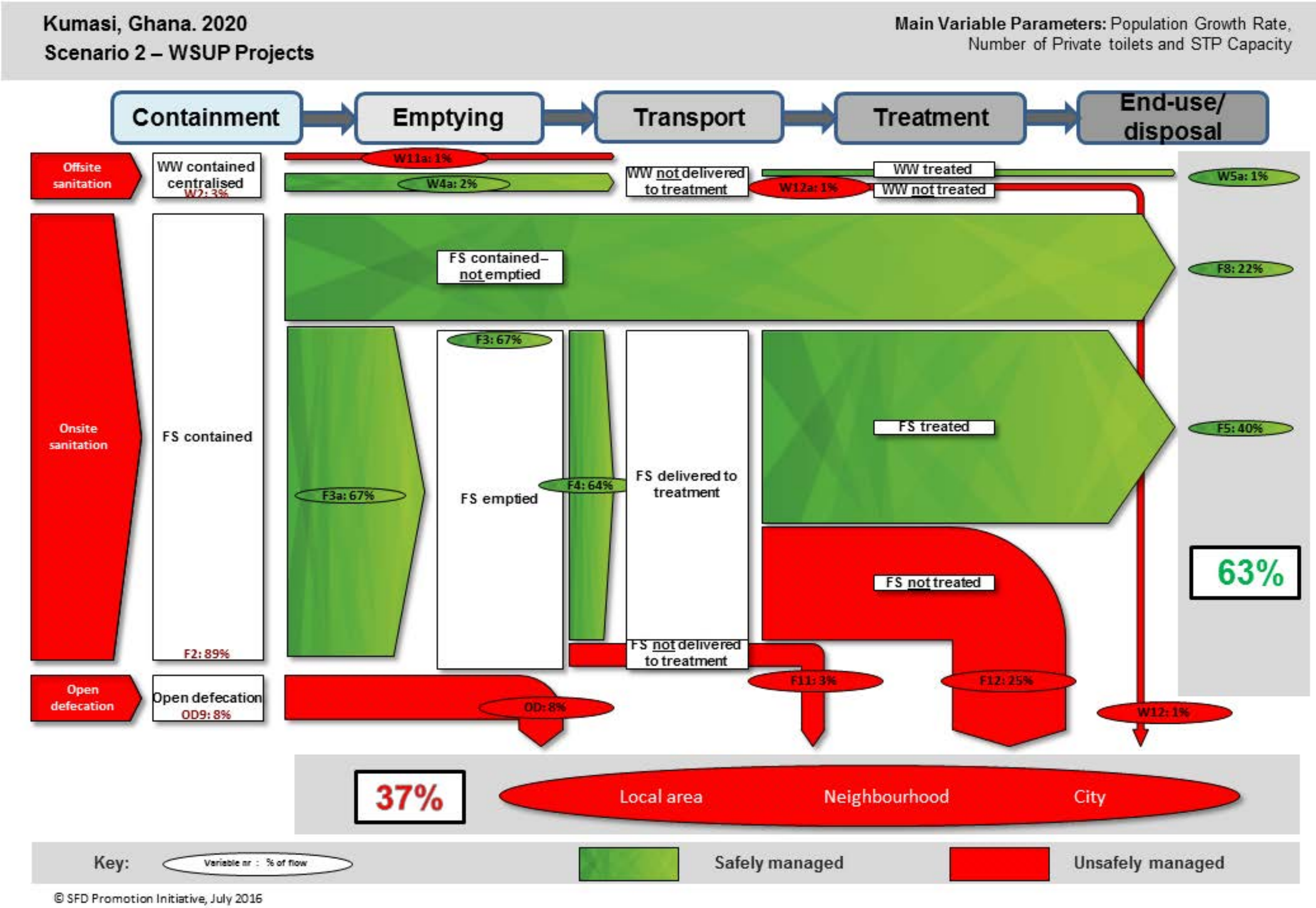
SCENARIO 2/PARAMETERS	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Population growth rate	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%
Population	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	3,667,373	3,869,079	4,081,878	4,306,381	4,543,232
Households	701,508	740,091	780,796	823,740	869,046	916,843	967,270	1,020,469	1,076,595	1,135,808
People/per household	4	4	4	4	4	4	4	4	4	4
OFFSITE SANITATION										
Containment										
WW Contained Descentralised	4%	3%	3%	3%	3%	3%	3%	2%	2%	2%
Transport										
WW delivered to treatment	4%	2%	2%	2%	2%	2%	2%	2%	2%	2%
WW NOT delivered to treatment	0%	1%	1%	1%	1%	1%	1%	0%	0%	0%
Treatment										
WW treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
WW not treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Disposal										
Safely Disposed	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
ONSITE SANITATION										
Containment										
FS Contained	93%	92%	92%	91%	89%	87%	86%	85%	84%	82%
Emptying										
FS contained (safely disposed)	17%	15%	15%	19%	22%	24%	25%	27%	29%	30%
FS emptied	76%	77%	77%	72%	67%	63%	61%	58%	55%	52%
Transport										
FS delivered to treatment	72%	73%	73%	68%	64%	60%	58%	55%	52%	49%
FS not delivered to treatment	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%
Treatment										
FS treated	0%	0%	46%	43%	40%	38%	37%	35%	33%	31%
FS not treated	72%	73%	27%	25%	24%	22%	21%	20%	19%	18%
Disposal										
Safely Disposed	0%	0%	46%	43%	40%	38%	37%	35%	33%	31%
OPEN DEFECATION										
Open defecation	3%	5%	5%	6%	8%	10%	11%	13%	14%	16%
EXCRETA FLOW MANGAMENT										
Safely Management	19%	16%	62%	63%	63%	63%	63%	63%	63%	62%
Unsafely Management	81%	84%	38%	37%	37%	37%	37%	37%	37%	38%

Table 34: SFD results for each year, scenario 2

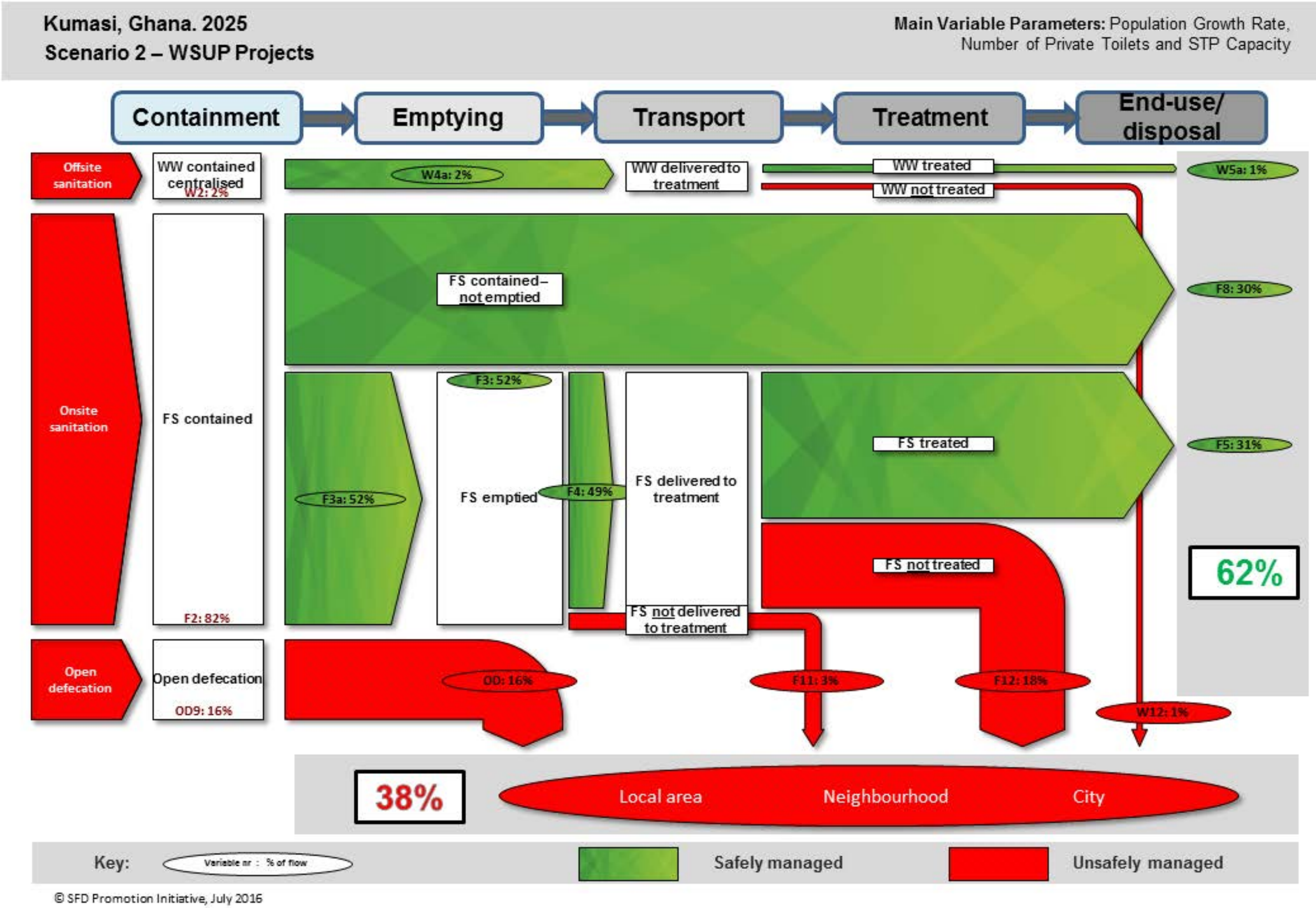
5.2.4.2 Scenario 2 Year 2016.



5.2.4.3 Scenario 2 Year 2020.



5.2.4.4 Scenario 2 Year 2025.



5.2.5 Trend Analysis

Again a trend analysis was made for this scenario. Firstly, the graphs showing the results of the SFDs (section 5.2.4.1) were produce.

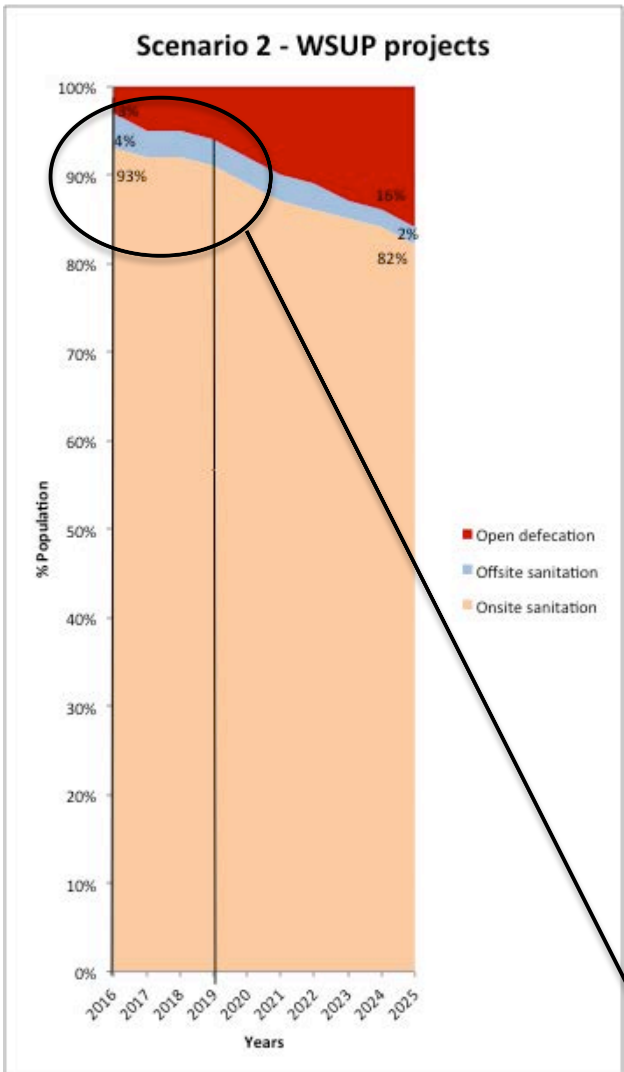


Figure 27: Trend in the type of sanitation in Kumasi for the next 10 years (scenario 2).

Figure 27 shows the trend in the type of sanitation in Kumasi for the next ten years, when WSUP projects are considered Due to the capacity of the toilets not being enough to cope the demand, the percentage of the population using onsite sanitation is decreasing and open defecation is going to increase. (See section 5.2.3.2, scenario 2A)

The change cannot be easily observed because it affects a small percentage of population. If a detailed view is considered (figure 28)it can be seen that when the WSUP project "A toilet in every compound" is implement the trend of people practising OD is reduced, especially between 2017 and 2018 when the project is expected to reach more compounds.

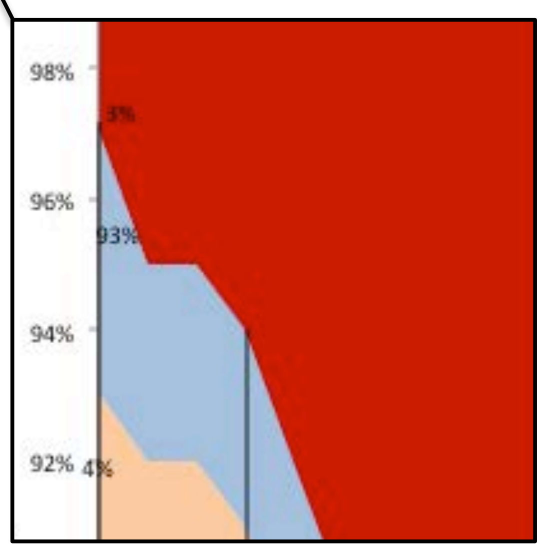


Figure 28: Focus on Trend in the type of sanitation in Kumasi (between year 2017 and 2019) Scenario 2

After the investment is finished as the amount of toilets are not enough to cope with the demand. OD continues to increase at the same rate as the population growth (the same as in scenario 1)

Figure 29 shows the overall result for scenario 2. The amount of population who safely manage their excreta flow increases after year 2017 because it is when the STP is expected to work again. After that the percentage is practically constant.

Regarding the SFDs produced (section 5.2.4) for years 1, 5 and 10, it is observed that this increase is due to the amount of population who do not empty their contained FS. The width of the arrow “FS contained but not emptied” increases from 17% in 2016 up to 30% in 2025. This is illustrated in figure 32 over the 10 years. The percentage of population (who use onsite sanitation) emptying their installations in 2015 is 82% whilst in 2025 it is 63%.

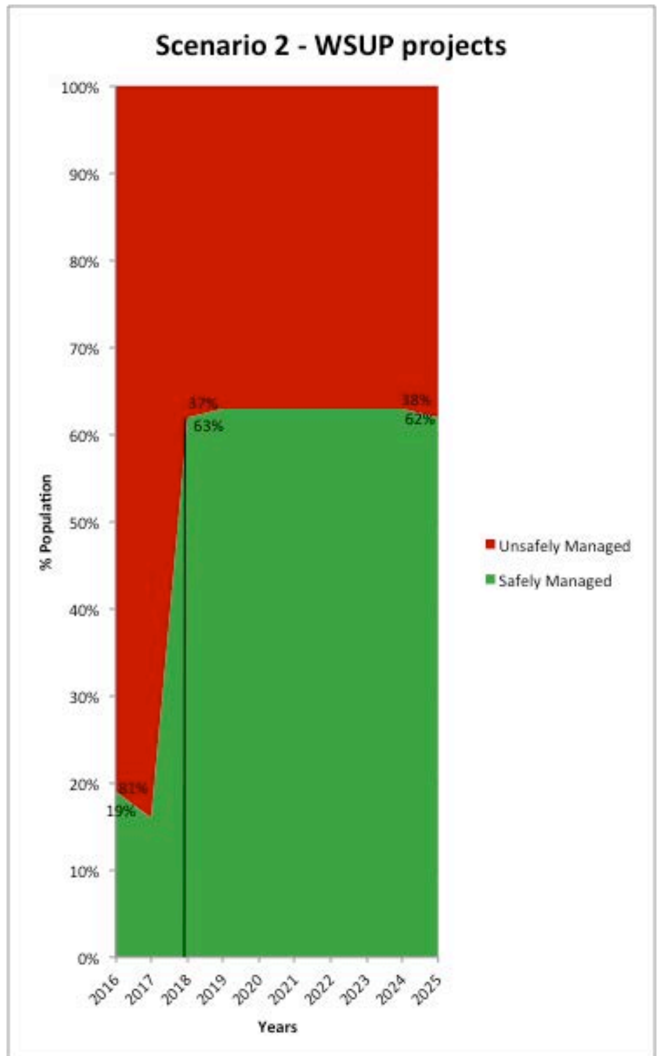


Figure 29: % of population whose excreta is safely managed along 10 years (scenario 2)

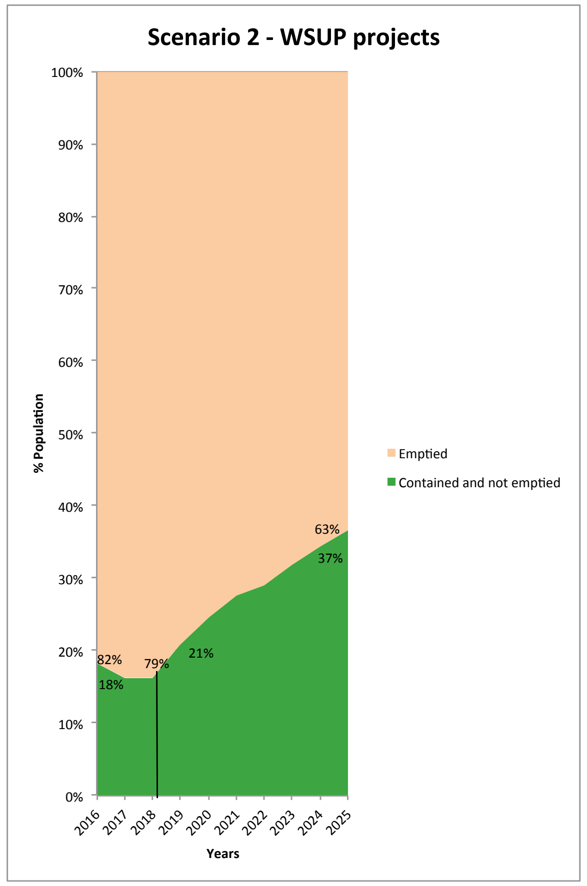


Figure 32: of population who empty their installations (scenario 2)

It is important to underline that in this scenario the percentage of compounds does not increase once the trucks reach their capacity because the percentage of population treating the FS is bigger than in scenario 1. These trends, (of both, scenarios), are show in figure 30.

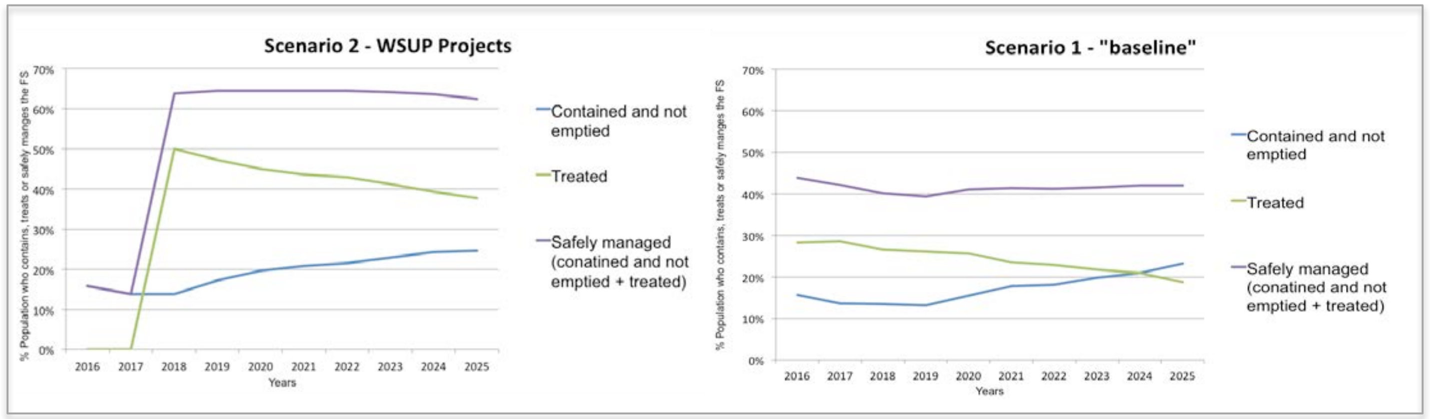


Figure 30: Trends in scenario 1 and 2. The main difference is the % of FS treated.

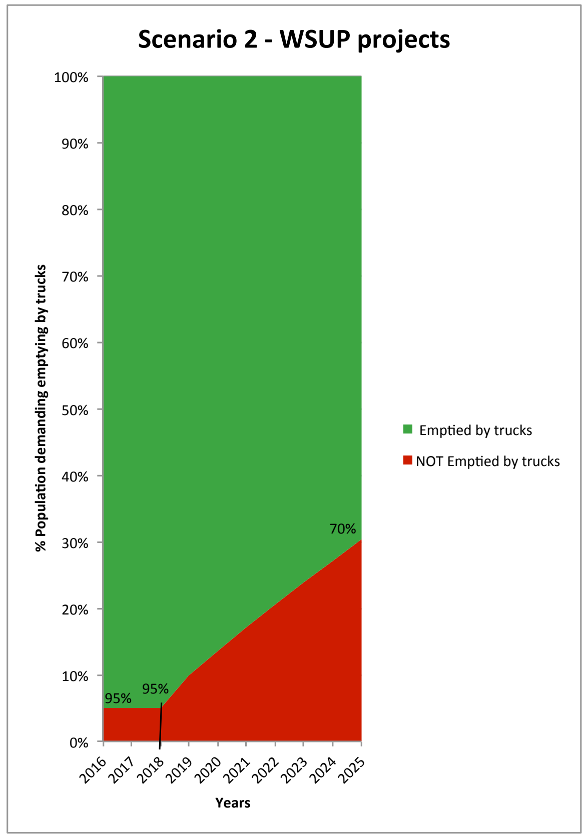


Figure 31: % of installations that cannot be emptied by trucks (scenario 2)

As in scenario 1, figure 31 shows that people stop emptying their installation because the trucks reach their maximum capacity in 2018. In scenario 1 this happens in 2019 but in scenario 2, the new installation in compounds (due to the project) increases the demand. However, as shows in table 31 the demand for emptying installations increases over the years.

Regarding these three trends in the graphs, it can be concluded that as in scenario 1, the percentage of the population whose excreta is safely managed after 2018 is practically constant because there are installations that, though full, they cannot be emptied because the trucks do not have the capacity to meet the demand.

The same issue explained in scenario 1 (section 5.1.5) appears in this case.

Finally the trend in treatment has been analysed. Figure 33 shows the percentage of FS arriving at the STP being treated and not treated. The plant is not working until 2018 due to the rehabilitation works. As in scenario 1, after 2018, the efficacy of treatment is constant. This is due to the amount of FS being constant as the number of trucks arriving at the treatment plant will also be constant as they do not have more capacity to deliver more FS to the STP. The percentage of Fs treated is higher than in scenario 1 after 2018 because of the rehabilitation of the STP.

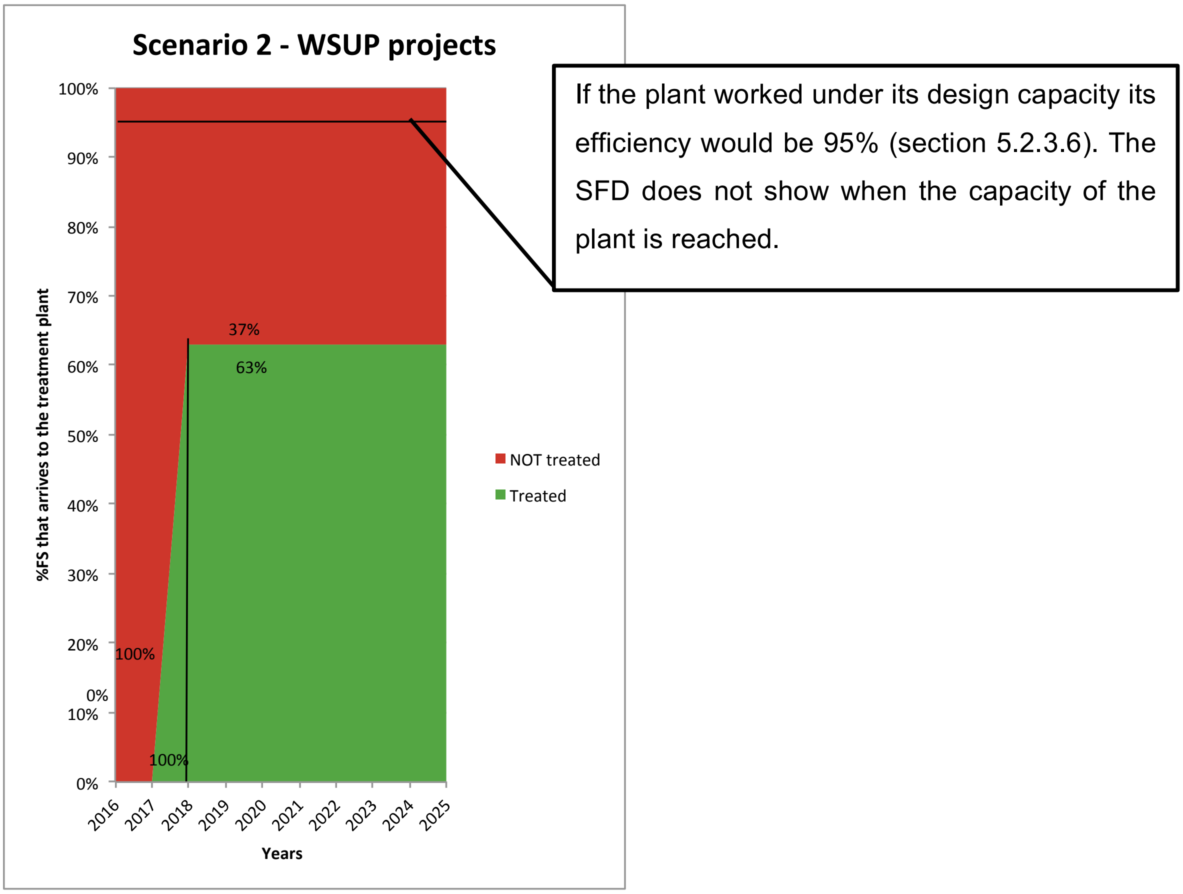


Figure 33: % treated and not treated of FS which arrive at the STP (scenario 2)

5.3 Scenario 3

Using scenario 1 as a starting point, this scenario has been defined by considering the project supported by WB (see section 4.): GPOBA Public toilets Project

As a consequence the main variable parameters are:

- Population growth rate, which is 5,5%
- The number of the public toilets

Questions have been established in order to define the minimum data to be collected. Scenario 1 has already answered some of these questions. The questions are as follows:

Open defecation

- Is OD going to increase more than the trend calculated in the baseline scenario (section 5.1.1) if the number of public toilets increases?

Offsite sanitation

- What is the capacity of the sewer network to absorb new connections?

Onsite sanitation-Containment

- The Clean Team Toilets; are they going to increase up to 1%?
- What is going to be the trend in the number of private toilets in compound housing?
- How many people can the public toilets (the current ones and the new ones) serve? Can they respond to the future demand?

Onsite sanitation-Emptying and transport service

- Can the current emptying and transport system cope with the future demand?

Onsite sanitation-Treatment and Disposal

- How much faecal sludge will arrive at the STP?
- When will the current STP reach its capacity?

In order to discuss the collected data and produce the SFDs again each part of the sanitation service chain has been analysed and the resultant SFDs produced.

.

5.3.1 Open defecation

The trend of open defecation if the public toilets and the compound toilets are able to respond to the future demand has been discussed in Scenario 1 (5.1.1). The same trend is assumed for this scenario, see table 5

As in scenario 1, this projection would be used to produce the SFD as long as the public toilets can meet the future demand. This will be discussed in section 5.3.3.1

5.3.2 Offsite sanitation

This part of the sanitation chain is not going to be affected by WSUP project, therefore the same trends and figures in scenario 1 (section 5.1.2) are assumed, see table 6 and 7

5.3.3 Onsite sanitation

Technologies (including Clean Team Toilets) and their trends do not change in this Scenario being the same as presented in Scenario 1 section 5.1.3: table 8 and 9

5.3.3.1 Private toilets – compound housings

This part of the sanitation service chain is not going to be affected by GPOBA project, and as a consequence the same trends and figures that are in scenario 1 (section 5.1.2) are assumed, see table 10.

5.3.3.2 Public toilets

The demand for public toilets is the same as that calculated in scenario 1 and section 5.1.3.2 because off site sanitation, open defecation and the use of public toilets is also the same as shown in table 11.

According to the GPOBA project (see section 4.2.4) in 2017 private stakeholders will be hired to construct 108 new public toilets (WB, 2016a, 2016b). These new blocks will have 10, 16, 20, 22 or 26 facilities depending on the location; therefore, 20 (the median) facilities will be considered by each new block of public toilets. In table 35 the number of public toilets and facilities for each has been calculated.

Year	**2015**	**2016**	**2017**	**2020**	**2025**
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,032	2,960,364	3,476,183	4,543,233
Number of Public Toilets without the project	360	376	376	376	376
New Public toilets			108	108	108
Total number of Public Toilets	**360**	**376**	**484**	**484**	**484**
Number of facilities without the project	5792	6052	6052	6052	6052
Number of new facilities			2160	2160	2160
Total Number of Facilities	**5792**	**6052**	**8212**	**8212**	**8212**

Table 35: Number of public toilets (scenario 3).

The demand for public toilets, as in scenario 1, has to be compared with their capacity to know if they can cope with the demand. That capacity is going to depend on the time that each user spends in a facility:

- Scenario 2A: Assuming that each user spends 6.4 min per facility on average as calculated in scenario 1A, it is possible to calculate the number of people that public toilets can serve, as shown in table 36

SCENARIO 3A	2016	2017	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,806,033	2,960,364	3,476,183	4,543,233
Number of facilities	6052	8212	8212	8212
Minutes per person	6.4	6.4	6.4	6.4
Users per facilities per hour[assuming as in scenario 1 they open from 4am to 11pm (19 hours)]	9	9	9	9
Users per facilities per day	179	179	179	179
Number of people who could use the facility per day (calculated)	1,083,308	1,470,704	1,470,704	1,470,704
Percentage of the population that could use the public toilets: CAPACITY	**38.6%**	**49.7%**	**42.3%**	**32.4%**

Table 36: Public toilets capacity (scenario 3A)

Comparing the projected demand for public toilets and the capacity of the public toilets in table 37 it can be concluded that the public toilets can cope with the future demand until 2022

SCENARIO 3A	2016	2017	2020	2022	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	2,806,033	2,960,364	3,476,183	3,869,079	4,543,233
Population demanding Public Toilets	1,100,632	1,162,323	1,366,934	1,521,325	1,783,688
Percentage of the population demanding public toilets	39.2%	39.3%	39.3%	38.0%	39.3%
Number of people who could use the facility per day (calculated)	1,083,308	1,470,704	1,470,704	1,470,704	1,470,704
Percentage of population that could use the public toilets: CAPACITY	38.6%	49.7%	42.3%	38%	32.4%
Population using Public Toilets	**1,083,308**	**1,162,323**	**1,366,934**	**1,470,704**	**1,470,704**
Percentage of population using Public Toilets	**38.6%**	**39.3%**	**39.3%**	**38.0%**	**32.4%**

Table 37: Public toilets capacity vs. demand (scenario 3A)

Consequently, OD will still increase more than expected (section 5.3.1) after 2021 but much less than in scenario 1 because the number of public toilets has notably increased. Table 38 shows this rise.

SCENARIO 3A/Year	2016	2017	2020	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the Population connected to the sewerage	4%	4%	3%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,436,264	1,520,870	1,911,901	2,544,210
Percentage of the Population using PRIVATE TOILETS	54.00%	54.20%	55.00%	56.00%
PUBLIC TOILETS				
Population using Public Toilets	1,041,938	1,083,308	1,366,934	1,470,704
Percentage of the population using Public Toilets	39.2%	38.6%	39.3%	32.4%
OPEN DEFECATION				
Population practicing OD	79,792	99,545	95,595	426,565
Percentage of the population practicing OD	3%	3.55%	2.8%	9.4%

Table 38: OD practise if each public toilet user spends 6 min on average per facility (scenario 3A)

- Scenario 3B: Assuming 4 min per user on average as calculated in scenario 1B, it can be calculated the amount of people who could use the facilities. Table 39 shows the capacity of the toilets in this case

SCENARIO 3B	2016	2017	2020	2025
Population Growth Rate	5.50%	5.50%	5.50%	5.50%
Total Population	2,806,033	2,960,364	3,476,183	4,543,233
Number of facilities	6052	8212	8212	8212
Minutes per person	4	4	4	4
Users per facilities per hour[assuming as scenario 1 they open from 4am to 11pm (19 hours)]	15	15	15	15
Users per facilities per day	285	285	285	285
Number of people who could use the facility per day (calculated)	1,724,820	2,340,420	2,340,420	2,340,420
Percentage of population that could use the public toilets: CAPACITY	**61%**	**79%**	**67%**	**51 %**

Table 39: Public toilets capacity (scenario 3A)

In this case, as in scenario 1B, public toilets could deal with the demand.

5.3.3.3 **Institutional Toilets** (see section 5.1.3.3)

5.3.3.4 Emptying onsite sanitation systems

The capacity of the trucks is the same as scenario 1 (see 5.1.3.4): All trucks have capacity to empty 113,880 customers/installations per year (see table 17).

The emptying needs of public toilets have been calculated in the same way as in scenario 1 (see 5.1.3.4) and are shown in table 40.

Year	2015	2016	2020	2025
Number of public toilets	360	376	484	484
Number of times on average that one public toilet has to be emptied per week	2			
Number of times that one public toilets has to be emptied per year	104	104	104	104
Number of times that all public toilets have to be emptied per year	**37,440**	**39,104**	**50,336**	**50,336**

Table 40: Emptying needs of Public Toilets (Scenario 3).

The number of private toilets, which have to be emptied, is the same as in scenario 1, and it is presented in table 20, section 5.1.3.4

Assuming a demand of 95% (as in scenario 1) and comparing the demand (public and private), with the capacity of the trucks, the percentage of installations actually emptied with trucks can be calculated as in table 41

Year	2015	2016	2017	2020	2025
Number of times that all public toilets have to be emptied per year	37,440	39,104	39,104	50,336	50,336
Number of compound with toilets to be emptied by tankers	63,914	68,144	83,854	87,695	119,311
Total of installations to be emptied	**101,354**	**107,248**	**122,958**	**138,031**	**169,647**
Percentage of installation emptied with trucks (Furlong, 2015a	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	101,886	116,811	131,130	161,165
Tanker capacity (emptying actions per year)	113,880				
Number of installation that truck can ACTUALLY empty	96,286	101,886	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	**95%**	**95%**	**93%**	**83%**	**67%**

Table 41: Percentage of onsite sanitation facilities emptied by tankers (scenario 3)

5.3.3.5 **Transport** (see section 5.1.3.5)

5.3.3.6 Treatment

As in scenario 1, in this case it is assumed the STP would still be working and treating a maximum efficiency of 50% of the incoming faecal sludge (Furlong, 2015a)

The same consideration made in scenario 1 was done in this case (see section 5.1.3.6 and tables table 17 and 18) to calculate the capacity of the plant in the future. The result is shown in table 42.

SCENARIO 3i/ Year	2015	2016	2020	2025
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment plant (m³/day)	450			
Treated (to SFD)	50%	50	50%	50%
SCENARIO 3ii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment	300			
Treated (to SFD)	45%	43%	38%	38%
SCENARIO 3iii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m³/day)	450			
Treated (to SFD)	50%	50%	50%	50%
SCENARIO 3iv/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck size	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m³/day)	300			
Treated (to SFD)	39%	37%	33%	33%

Table 42: FS treated depending on the STP capacity and mean size of trucks arriving at the STP (scenario 3)

5.3.4 SFD Production

Based on the analysis made before, different SFDs can be produced for this third scenario. As in scenario 1, based on the collected data, the SFD for each of the next 10 years can be produced to illustrate scenario 2.

In this section only the worst-case scenario has been modelled, because it is in which most relevant changes can be observed over the years. As consequence, the produced SFDs for this scenario consider:

- Public toilets users will spend on average 6 minutes in each facility (see section 5.3.3.2)
- The mean size of sludge tankers arriving at the STP is 7.5 m³ (see section 5.3.3.6)
- The intake capacity of STP is 300m^3/day of septage (Scenario, 3iv, see section 5.3.3.6)

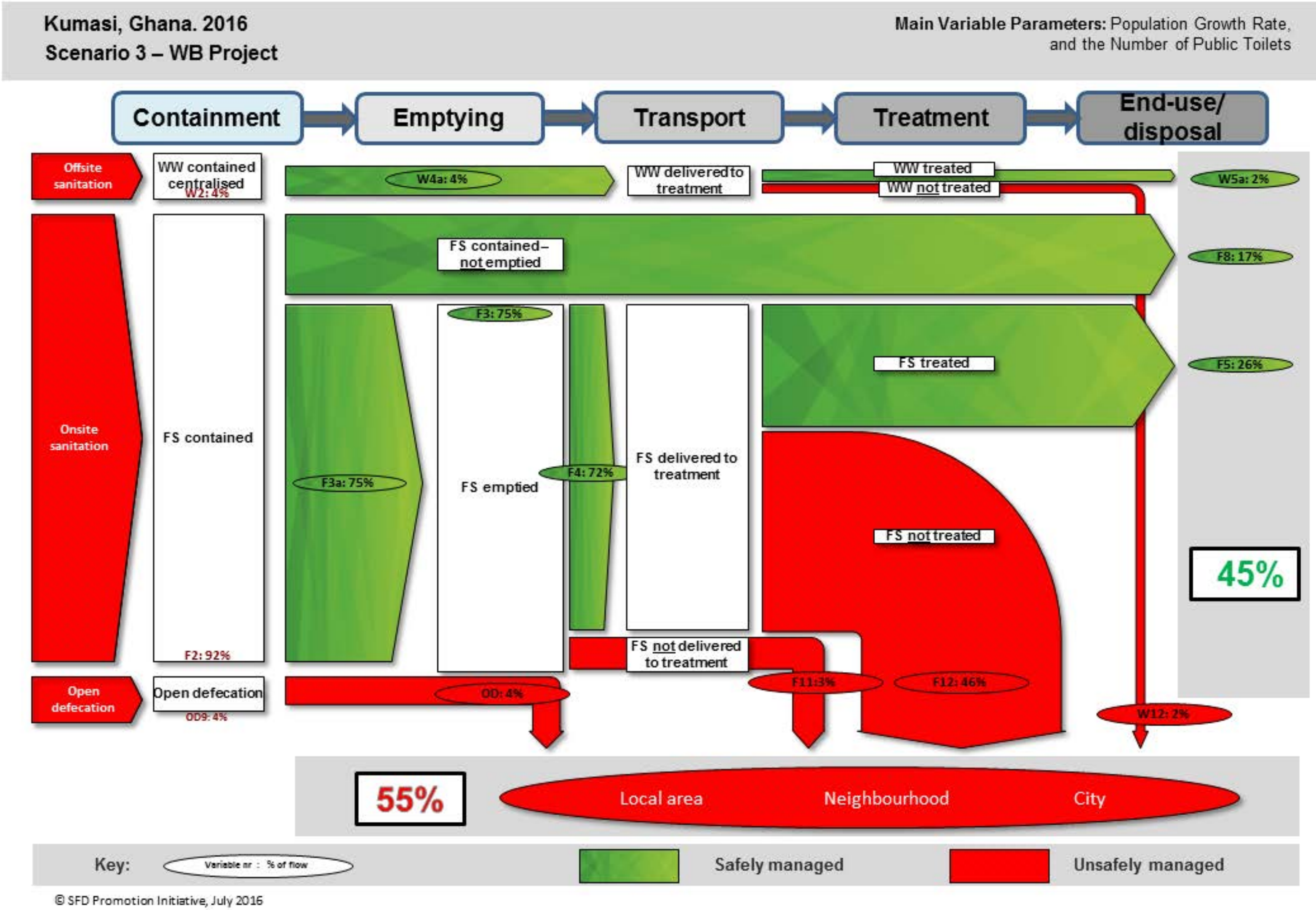
The detailed data to produce the SFDs for this scenario can be found in appendix 9.

5.3.4.1 SFD results for each year, baseline scenario

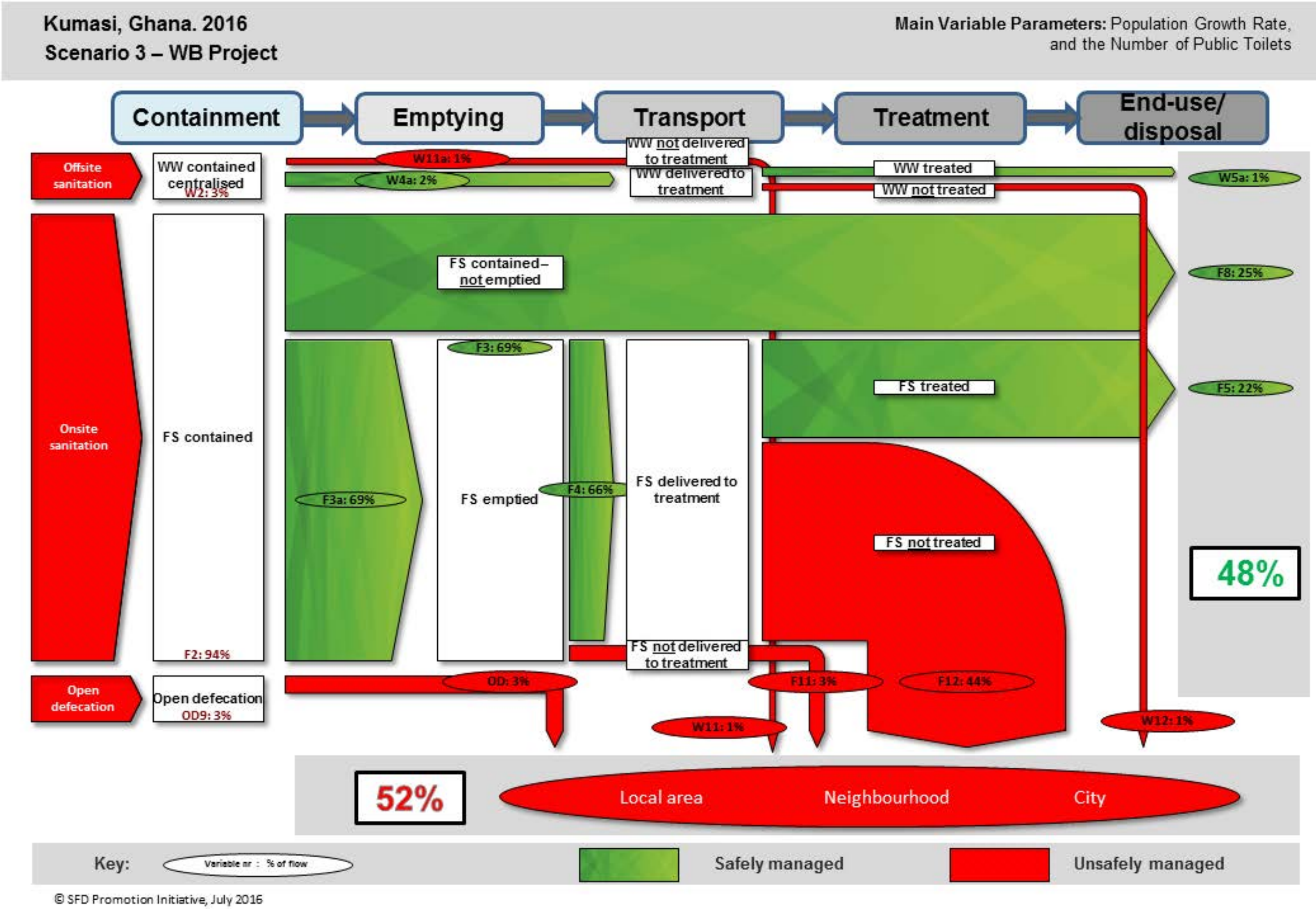
PARAMETERS	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Population growth rate	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%
Population	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	3,667,373	3,869,079	4,081,878	4,306,381	4,543,232
Households	701,508	740,091	780,796	823,740	869,046	916,843	967,270	1,020,469	1,076,595	1,135,808
People/per household	4	4	4	4	4	4	4	4	4	4
OFFSITE SANITATION										
Containment										
WW Contained Descentralised	4%	3%	3%	3%	3%	3%	3%	2%	2%	2%
Transport										
WW delivered to treatment	4%	2%	2%	2%	2%	2%	2%	2%	2%	2%
WW NOT delivered to treatment	0%	1%	1%	1%	1%	1%	1%	0%	0%	0%
Treatment										
WW treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
WW not treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Disposal										
Safely Disposed	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
ONSITE SANITATION										
Containment										
FS Contained	92%	94%	94%	94%	94%	94%	93%	92%	90%	89%
Emptying										
FS contained (safely disposed)	17%	18%	19%	23%	25%	28%	29%	31%	33%	35%
FS emptied	75%	76%	75%	71%	69%	66%	64%	61%	57%	54%
Transport										
FS delivered to treatment	72%	72%	71%	68%	66%	63%	61%	58%	54%	51%
FS not delivered to treatment	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%
Treatment										
FS treated	26%	24%	23%	22%	22%	21%	20%	19%	18%	17%
FS not treated	45%	48%	48%	45%	44%	42%	41%	39%	36%	34%
Disposal										
Safely Disposed	26%	24%	23%	22%	22%	21%	20%	19%	18%	17%
OPEN DEFECATION										
Open defecation	4%	3%	3%	3%	3%	3%	4%	6%	8%	9%
EXCRETA FLOW MANGAMENT										
Safely Management	**45%**	**43%**	**43%**	**46%**	**48%**	**50%**	**50%**	**51%**	**52%**	**53%**
Unsafely Management	**55%**	**57%**	**57%**	**54%**	**52%**	**50%**	**50%**	**49%**	**48%**	**47%**

Table 43: SFD results for each year, baseline scenario

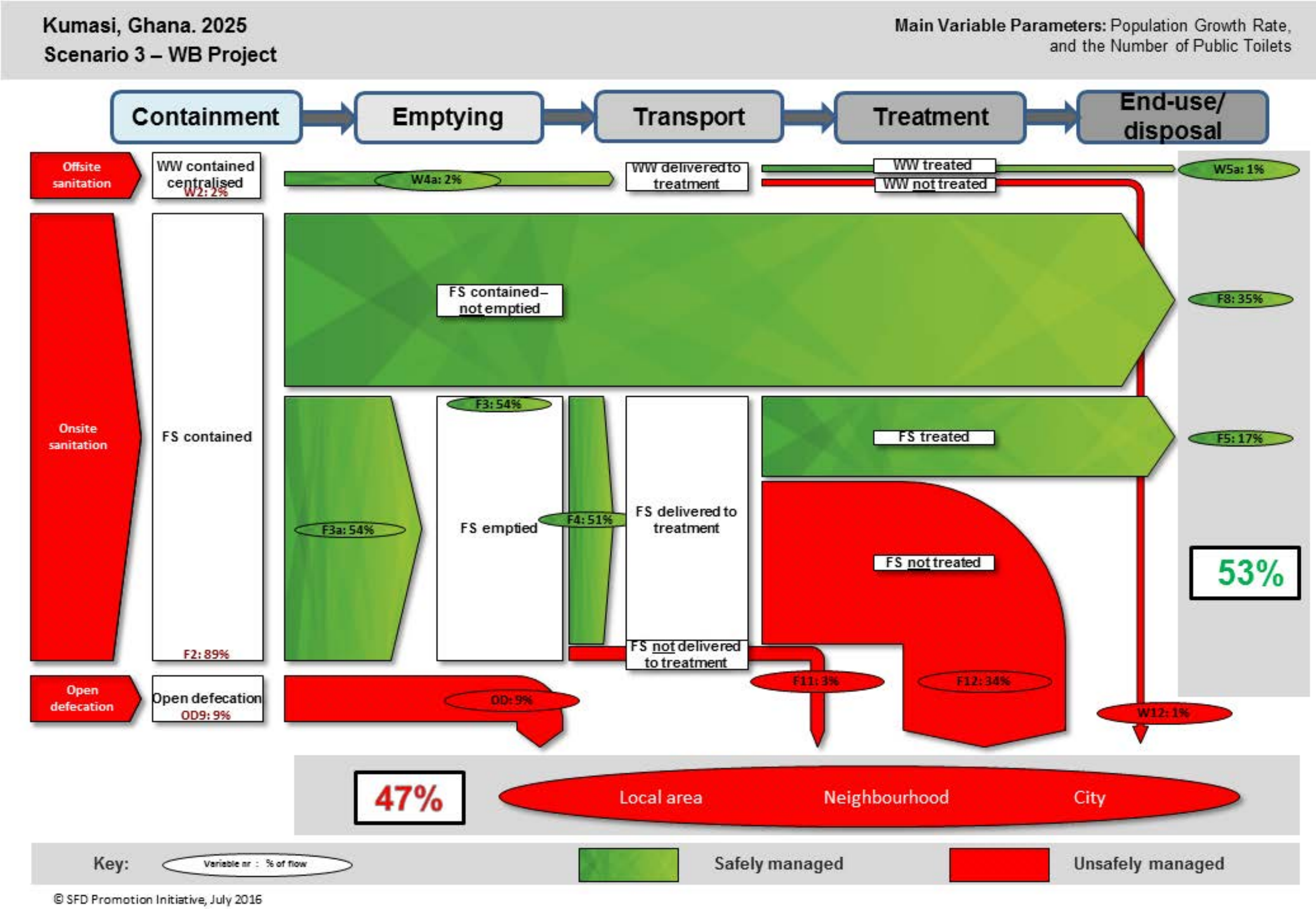
5.3.4.2 Scenario 3 Year 2016.



5.3.4.3 Scenario 3 Year 2020.



5.3.4.4 Scenario 3 Year 2025.



5.3.5 Trend Analysis

Following the same structure as the scenarios above first, the graphs showing the results of the SFDs (section 5.3.4) were produced.

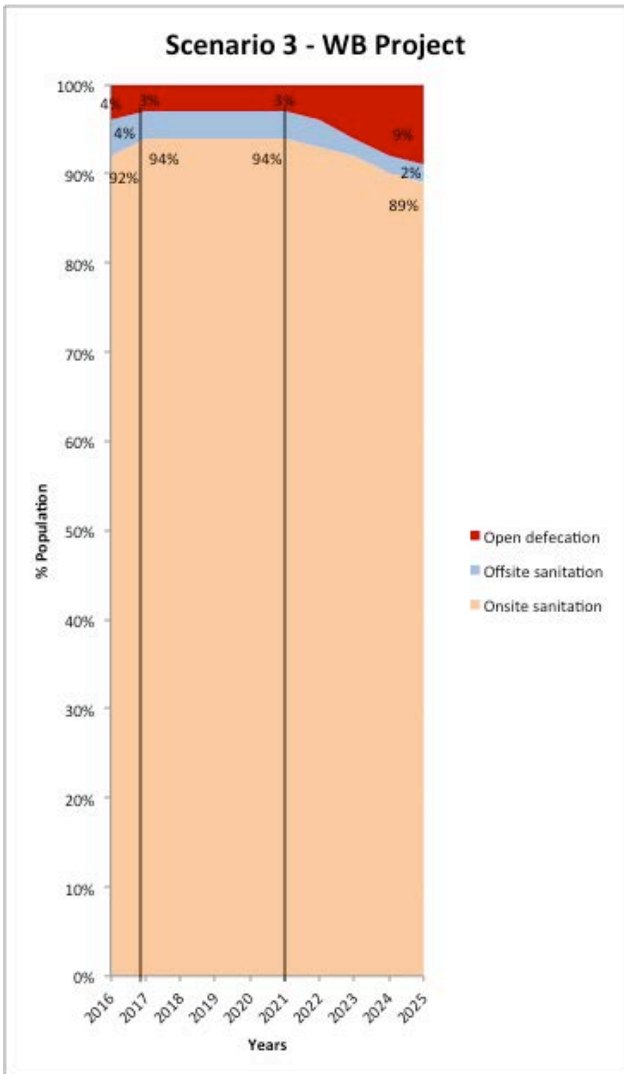


Figure 34: Trend in the type of sanitation in Kumasi for the next 10 years (scenario 3)

Figure 34 shows the trend in the type of sanitation in Kumasi for the next ten years. Due to the fact that in 2017 the number of toilets is expected to increase because of the forthcoming project, the percentage of the population using onsite sanitation will increase and the open defecation will fall to a minimum (see section 5.5.3.1, scenario 3A).

After 2021, when the toilets constructed by the project cannot cope with the demand due to the population growth, the OD increase again.

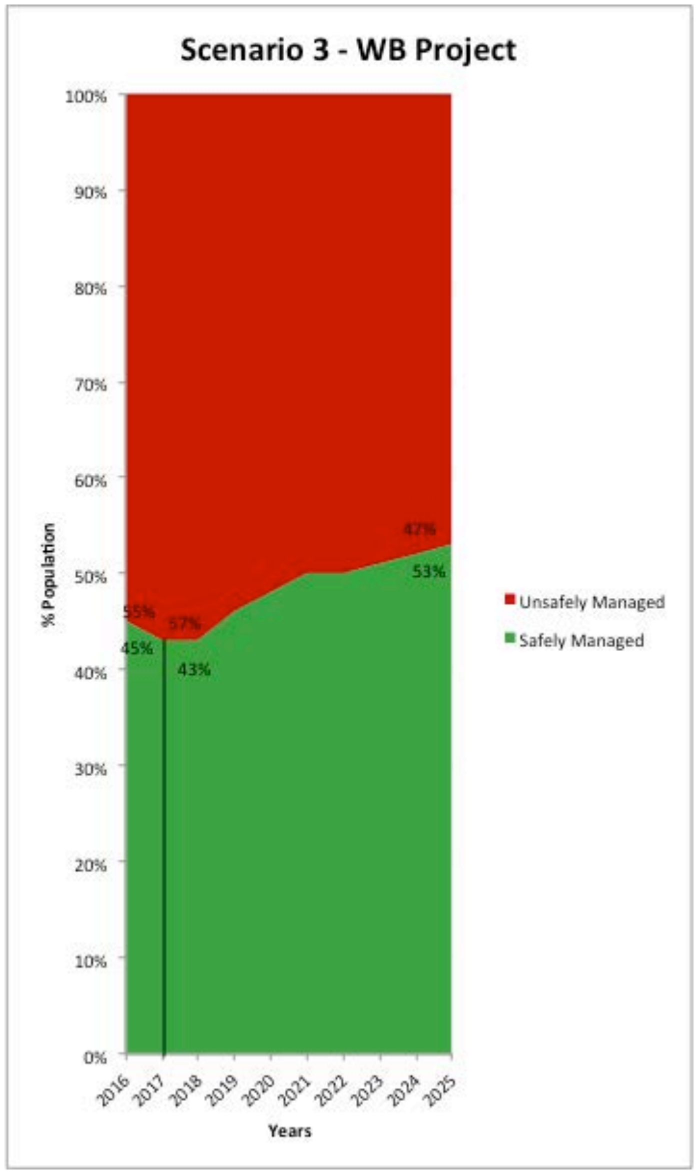


Figure 35: % of population who safely manages their excreta along 10 years, scenario 3

Figure 35 shows the overall result for scenario 3. The amount of the population who safely manage their excreta flow increases after year 2018.

Regarding the SFDs produced (section 5.3.4) for years 1, 5 and 10, it is observed that this increase is due to the proportion of population who not empty their contained FS. The width of the arrow "FS contained but not emptied" increases from 18% in 2020 up to 39% in 2025. This is illustrated in figure 36 over the 10 years. The percentage of the population (who use onsite sanitation) emptying their installations in 2016 is 82% whilst in 2025 is 61%.

The reduction in the percentage of installations emptied is because of the rising in the number of public toilets. In this scenario there are more installations to be emptied but the trucks have the same capacity. This is also shown in figure 36

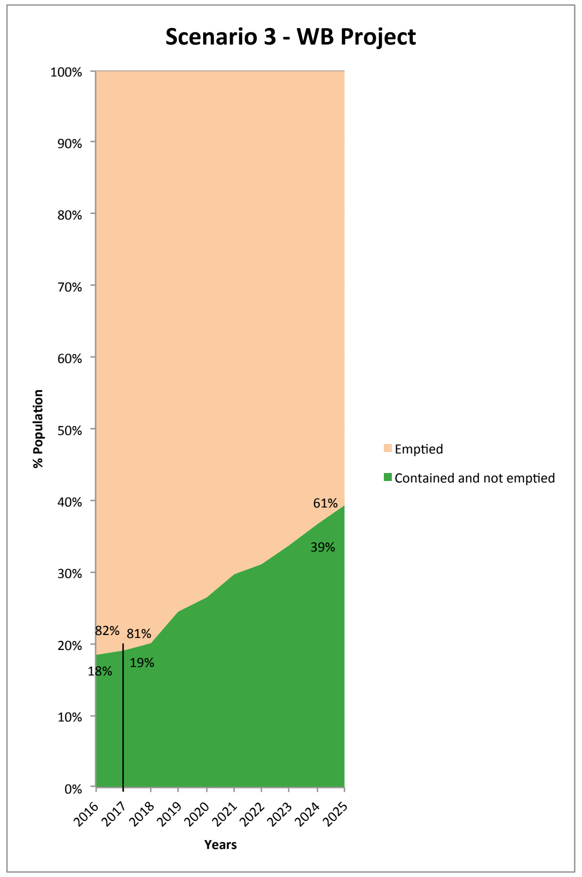


Figure 36: of population who empty their installations (scenario 3)

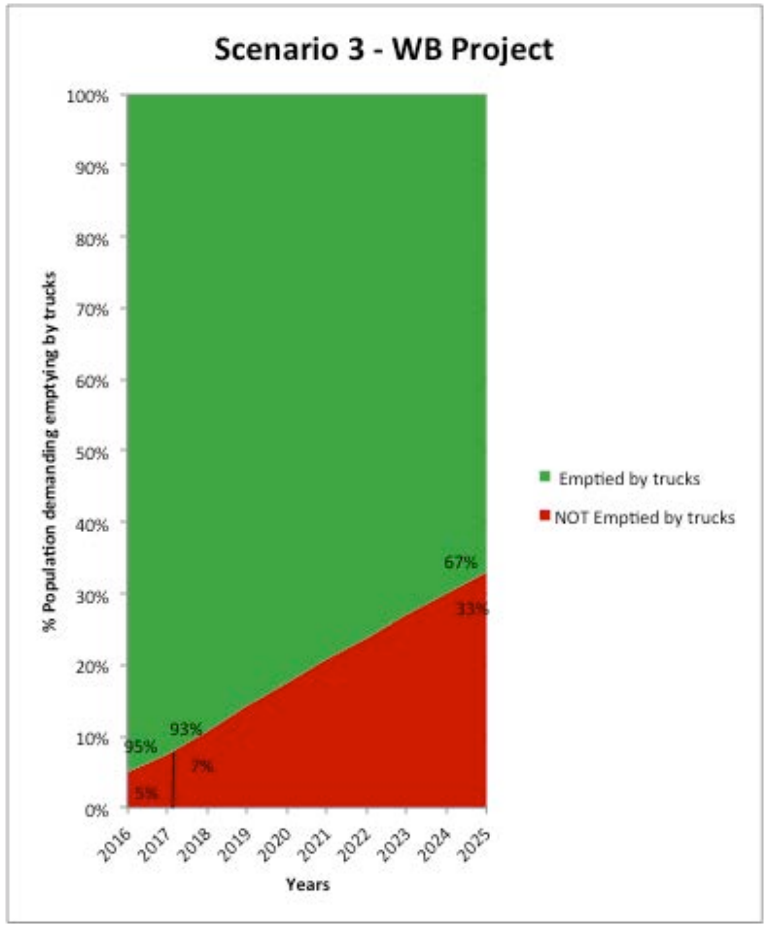
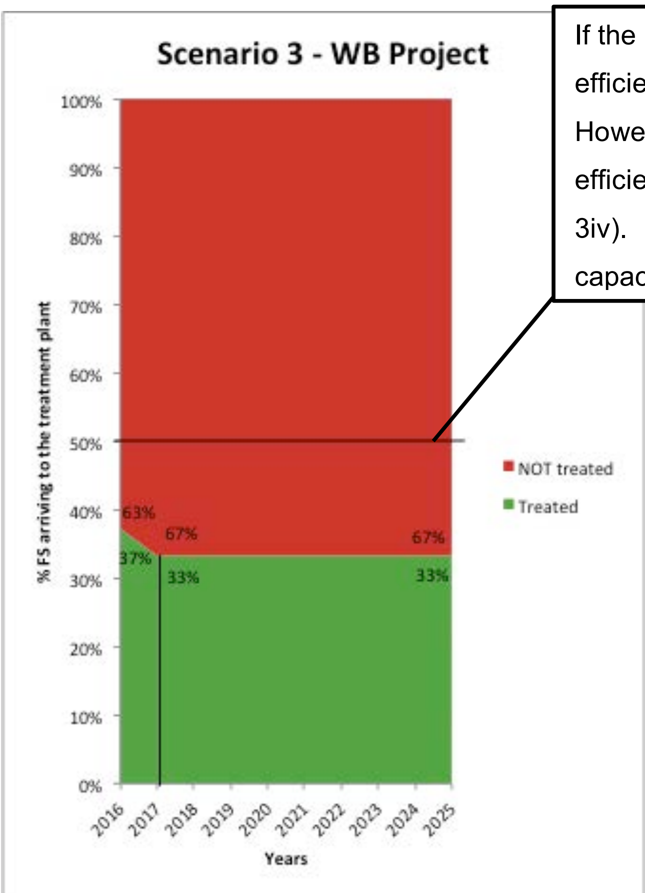


Figure 37: % of installations that trucks cannot be emptied (scenario 3)

Trucks reach their maximum capacity in 2017, when the new toilets are constructed and before that scenario 1 and 2. However, as shown in table 41 the demand for emptying installations increases over the years. From that year, as explained in scenario 1, the amount of population who safely managed their excreta is going to increase since the tool consider that FS contained is not a risk to the environment, and as a consequence is safely managed

Figure 38 shows the percentage of FS arriving at the STP that is treated and not treated. After 2017, the efficacy of treatment is constant: less that in scenario 2 but the same as in scenario 1. It is the same because the amount of FS is going to be constant due to the number of trucks arriving at the treatment plant also remains constant as they do not have more capacity.



If the plant worked under its design capacity its efficiency would be 50% (section 5.3.3.6). However as it is working over capacity their efficiency is reduced (see table 42, scenario 3iv). The SFD does not show when the capacity of the plant is reached.

Figure 38: % treated and not treated of FS arriving at the STP (scenario3)

5.4 Scenario 4

This scenario has been defined as a combination of Scenarios 2 and 3. As a consequence the main variable parameters are:

- Population growth rate, which is 5,5%
- The amount of the population living in compounds who are going to use new private toilets
- The number of public toilets
- The treatment capacity of the STP

Questions have been established in order to determine the minimum data required to be collected. Scenarios 1, 2 or 3 have already answered some of these questions. The questions are as follows:

Open defecation

- Is OD going to increase more than the trend calculated in the baseline scenario (section 5.1.1) if the number of public toilets and the number of private toilets increases?

Offsite sanitation

- What is the capacity of the sewer network to absorb new connections?

Onsite sanitation-Containment

- The Clean Team Toilets; are they going to increase up to 1%?
- What is going to be the trend in the number of private toilets in compound housing?
- How many people can the public toilets (the current ones and the new ones) serve? Can they respond to the future demand?

Onsite sanitation-Emptying and transport service

- Can the current emptying and transport system cope with the future demand?

Onsite sanitation-Treatment and Disposal

- How much faecal sludge will arrive at the STP?
- When is the current STP going to reach its capacity if it is rehabilitated?

A complementary question has been formed for this scenario: is there any synergy in implementing both projects?

In order to discuss the collected data and produce the SFDs again each part of the sanitation service chain has been analysed and the resultant SFDs produced.

5.4.1 Open defecation

The trend of open defecation if the public toilets and the compound toilets are able to respond to the future demand has been discussed in Scenario 1 (5.1.1). The same trend is assumed for this scenario, see table 5

As in scenario 1, this projection would be used to produce the SFD as long as the public toilets can meet the future demand. This will be discussed in section 5.4.3.1.

5.4.2 Offsite sanitation

This part of the sanitation chain is not going to be affected by WSUP project, therefore the same trends and figures in scenario 1 (section 5.1.2) are assumed, see table 6 and 7

5.4.3 Onsite sanitation

Technologies (including Clean Team Toilets) and their trends do not change in this Scenario being the same as those presented in Scenario 1 section 5.1.3: table 8 and 9.

5.4.3.1 Private toilets – compound housings

This part of the sanitation service chain is going to be affected in the same way as in scenario 2, and therefore the same figures are assumed (see section 5.2.3.1 and tables 26 and 27)

5.4.3.2 Public toilets

The demand for public toilets is the same as calculated in scenario 2, section 5.2.3.2 because the coverage of offsite sanitation, the prevalence of open defecation and the use of private toilets is also the same. Table 28 shows this demand.

The number of public toilets is the same as in scenario 3 (section 5.2.3.2, table 35)

The demand for public toilets has to be compared with their capacity. Their capacity is going to be the same as that calculated for scenario 3.

- Scenario 4A: Assuming that each user is going to spend 6.4 min per facility on average as calculated in scenario 1A. The capacity will be the same as in scenario 3A, because the number of facilities is also the same. See table 36.

Comparing the projected demand for public toilets and the capacity of the public toilets in table 44. It can be concluded that the public toilets can cope with the future demand until 2022

SCENARIO 4A	2016	2017	2020	2024	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%	5.5%
Total Population	2,806,033	2,960,364	3,476,183	3,869,079	4,543,233
Population demanding Public Toilets	1,041,938	1,090,632	1,266,934	1,470,704	1,683,688
Percentage of population demanding public toilets	39.17%	38.25 %	36.45%	36.97 %	39.06%
Number of people who could use the facility per day (calculated)	1,083,308	1,470,704	1,470,704	1,470,704	1,470,704
Percentage of population that could use the public toilets: CAPACITY	38.6%	49.7%	42.3%	34.2%	32.4%
Population using Public Toilets	**1,083,308**	**1,090,632**	**1,266,934**	**1,470,704**	**1,470,704**
Percentage of population using Public Toilets	**38.6%**	**38.87%**	**36.5%**	**34.2%**	**32.4%**

Table 44: Public toilets capacity vs. demand (scenario 3A)

Consequently, the OD will not increase more than expected (section 5.4.1) until 2024. It increases much less than in scenarios 1 and 2, because the number of public toilets has a notable influence on reducing the OD. Table 45 shows this rise from 2023.

Year	2016	2020	2024	2025
Population Growth Rate	5.5%	5.5%	5.5%	5.5%
Total Population	2,659,747	2,806,033	3,476,183	4,543,233
OFFSITE SANITATION				
Population connected to the sewerage	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	2%	2%
ONSITE SANITATION				
PRIVATE TOILETS				
Population using PRIVATE TOILETS	1,530,870	2,011,901	2,502,961	2,644,210
Percentage of the population using PRIVATE TOILETS	54.56%	57.88%	58.12%	58.20%
PUBLIC TOILETS				
Population using Public Toilets	1,083,308	1,266,934	1,470,704	1,470,704
Percentage of population using Public Toilets	38.6%	36.5%	34.2%	32.4%
OPEN DEFECATION				
Population practicing OD	79,792	99,545	95,595	426,565
Percentage of population practicing OD	3%	3.55%	2.8%	9.4%

Table 45: OD practise if each public toilet user spends 6 min on average per facility (scenario 4A)

- Scenario 4B: Assuming 4 min per user on average as calculated in scenario 1B, it the amount of people who could use the facilities can be calculated. In this case it is the same as that calculated for scenario 3B (table 39). Therefore Public toilets could deal with the demand.

5.4.3.3 **Institutional Toilets** (see section 5.1.3.3)

5.4.3.4 Emptying onsite sanitation systems

The capacity of the trucks is the same as scenario 1 (see 5.1.3.4): All trucks have capacity to empty 113,880 customers/installations per year (see table 17)

The emptying needs of public toilets are the same as in scenario 3 and are shown in table 40.

The number of private toilets, which have to be emptied, is the same as in scenario 2 and I is presented in tables 30 and 31.

Assuming a demand of 95% and comparing demand (public and private), with the capacity of the trucks, the percentage of installations actually emptied with trucks has been calculated as shown table 46.

Year	**2015**	**2016**	**2017**	**2020**	**2025**
Number of times that all public toilets have to be emptied per year	37,440	39,104	50,336.00	50,336.00	50,336.00
Number of compound with toilets to be emptied by tankers	63,914	68,644	74,122.48	92,695.59	124,311.06
Total of installations to be emptied	**101,354**	**107,748**	124,458	**143,032**	**174,647**
Percentage of installation emptied with trucks (Furlong, 2015a	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	101,886	118,236	135,880	165,915
Tanker capacity (emptying actions per year)	113,880				
Number of installation that truck can ACTUALLY empty	96,286	101,886	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	**95%**	**95%**	**92%**	**83%**	**67%**

Table 46: Percentage of onsite sanitation facilities emptied by tankers (scenario 4)

5.4.3.5 **Transport** (see section 5.1.3.5)

5.4.3.6 Treatment

As explained in section 5.1.3.6, when the STP was visited, the vacuum trucks were discharging the FS into the environment at a set point next to the STP (see figure 19).

As a consequence, as in scenario 2, it is assumed that the STP will not be working during 2016 and 2017. Once it starts working again in 2018, it is assumed that the efficiency will be up to 95% due to its rehabilitation.

.

The same considerations made in scenario 1 were done in this case (see section 5.1.3.6 and tables table 17 and 18) to calculate the capacity of the STP in the future. The result is shown in table 47.

SCENARIO 4i/ Year	2015	2016	2020	2025
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment plant (m³/day)	450			
Treated (to SFD)	50%	0%	95%	95%
SCENARIO 4ii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	6.5			
Volume arriving m^3/day	331.50	350.78	390.83	390.83
Capacity of treatment	300			
Treated (to SFD)	45%	0%	73%	73%
SCENARIO 4iii/ Year	**2015**	**2016**	**2020**	**2025**
Truck arriving at the STP per day	51	54	60	60
Truck capacity (m³) - average	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m³/day)	450			
Treated (to SFD)	50%	0%	95%	95%
SCENARIO 4iv/ Year	**2015**	**2016**	**2020**	**2025**
Trucks arriving at the STP per day	51	54	60	60
Truck size	7.5			
Volume arriving m^3/day	382.50	404.74	450.96	450.96
Capacity of treatment plant (m³/day)	300			
Treated (to SFD)	39%	0%	63%	63%

Table 47: FS treated depending on the STP capacity and mean size of trucks arriving at the STP (scenario 4)

5.4.4 SFD Production

Based on the previous analysis, different SFDs can be produced for this fourth scenario.

In this section only the worst-case scenario has been modelled, because it is in this case that most relevant changes can be observed over the years. As a consequence, the SFD's produced for this scenario consider:

- Public toilets users will spend on average 6 minutes in each facility (see section 5.4.3.2)
- The mean size of sludge tankers arriving at the STP is 7.5 m³ (see section 5.4.3.6)
- The intake capacity of the STP is 300m^3/day of septage (see section 5.4.3.6)

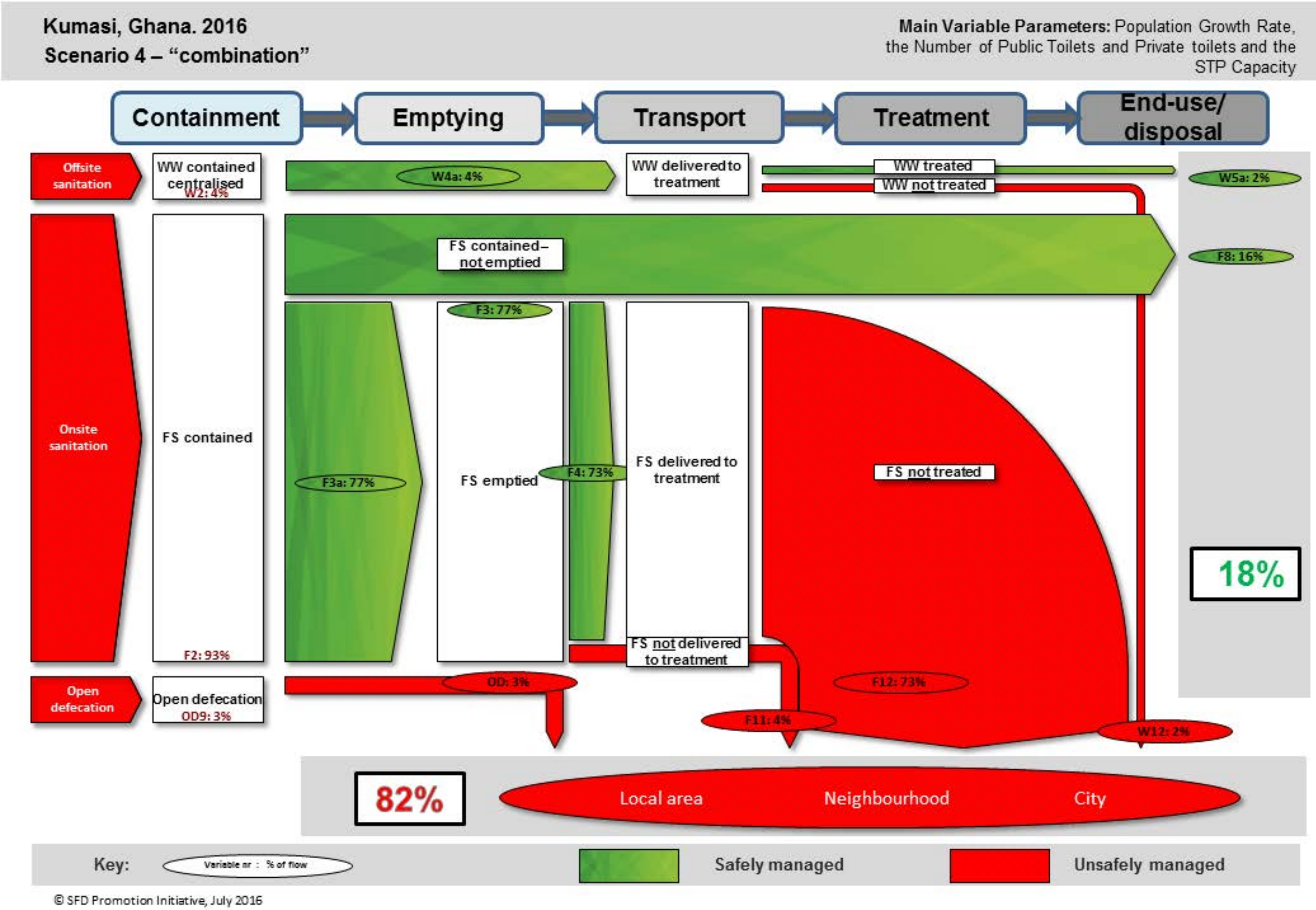
The detailed data to produce the SFDs for this scenario can be found in appendix 10

5.4.4.1 SFS results for each year, scenario 4

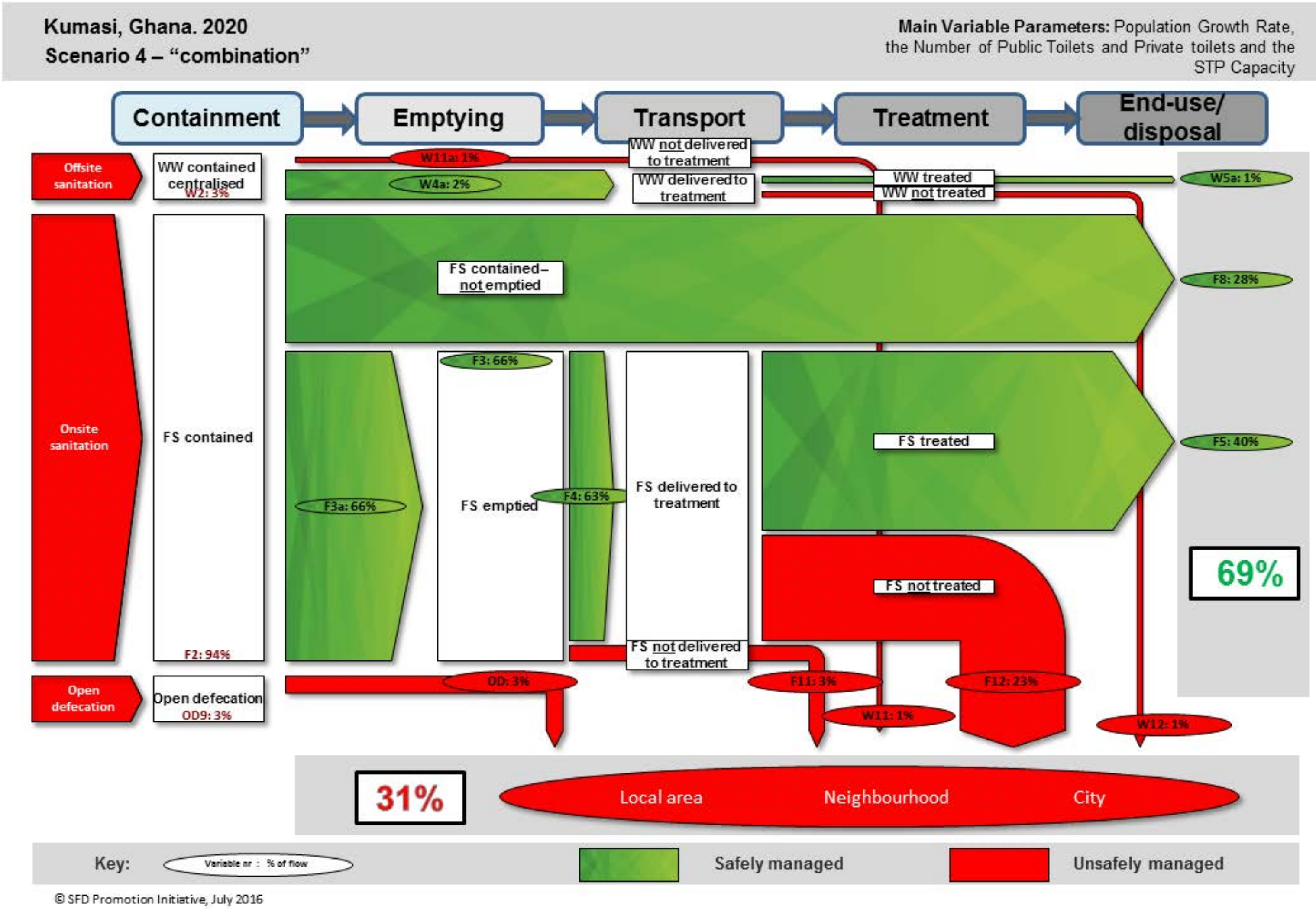
Scenario 4/PARAMETERS	2016	2017	2018	2019	2020	2921	2022	2023	2024	2025
Population growth rate	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%	5.50%
Population	2,806,033	2,960,365	3,123,185	3,294,960	3,476,183	3,667,373	3,869,079	4,081,878	4,306,381	4,543,232
Households	701,508	740,091	780,796	823,740	869,046	916,843	967,270	1,020,469	1,076,595	1,135,808
People/per household	4	4	4	4	4	4	4	4	4	4
OFFSITE SANITATION										
Containment										
WW Contained Decentralised	4%	3%	3%	3%	3%	3%	3%	2%	2%	2%
Transport										
WW delivered to treatment	4%	2%	2%	2%	2%	2%	2%	2%	2%	2%
WW NOT delivered to treatment	0%	1%	1%	1%	1%	1%	1%	0%	0%	0%
Treatment										
WW treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
WW not treated	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Disposal										
Safely Disposed	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
ONSITE SANITATION										
Containment										
FS Contained	93%	94%	94%	94%	94%	94%	94%	95%	93%	91%
Emptying										
FS contained (safely disposed)	17%	19%	22%	25%	28%	30%	31%	34%	36%	38%
FS emptied	76%	75%	72%	69%	66%	64%	63%	61%	57%	53%
Transport										
FS delivered to treatment	72%	71%	69%	66%	63%	61%	60%	58%	54%	50%
FS not delivered to treatment	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%
Treatment										
FS treated	0%	0%	43%	42%	40%	38%	38%	37%	34%	31%
FS not treated	72%	71%	25%	24%	23%	23%	22%	21%	20%	19%
Disposal										
Safely Disposed	0%	0%	43%	42%	40%	38%	38%	37%	34%	31%
OPEN DEFECATION										
Open defecation	3%	3%	3%	3%	3%	3%	3%	3%	5%	7%
EXCRETA FLOW MANGAMENT										
Safely Management	**19%**	**20%**	**66%**	**68%**	**69%**	**69%**	**70%**	**72%**	**71%**	**70%**
Unsafely Management	**81%**	**80%**	**34%**	**32%**	**31%**	**31%**	**30%**	**28%**	**29%**	**30%**

Table 48: SFD results for each year, scenario 4

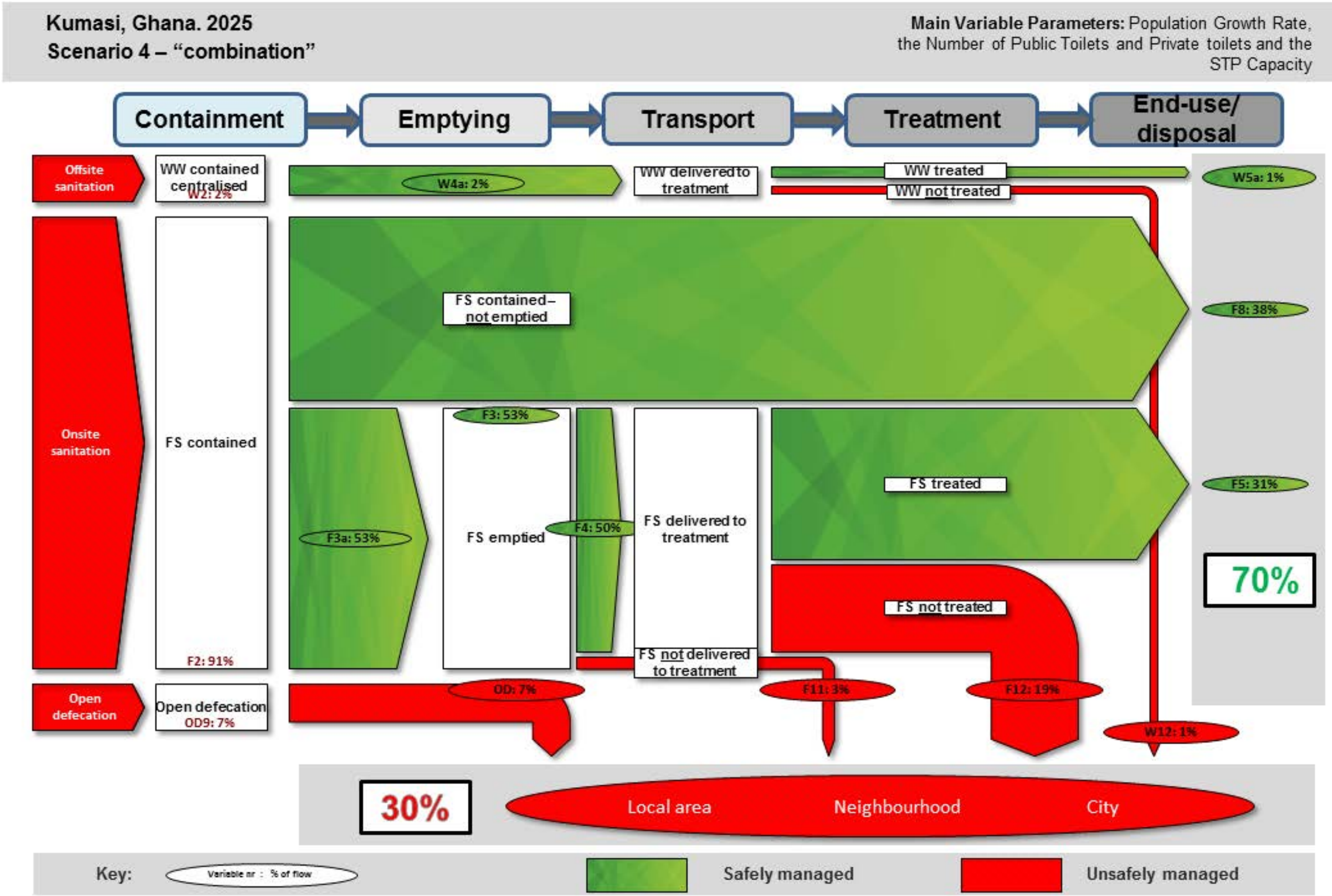
5.4.4.2 Scenario 4 Year 2016.



5.4.4.3 Scenario 4 Year 2020.



5.4.4.4 Scenario 4 Year 2025.



5.4.5 Trend Analysis

This last scenario was analysed in the same way as the scenarios above. Firstly, the graphs showing the results of the SFDs (section 5.4.4.1) were produced.

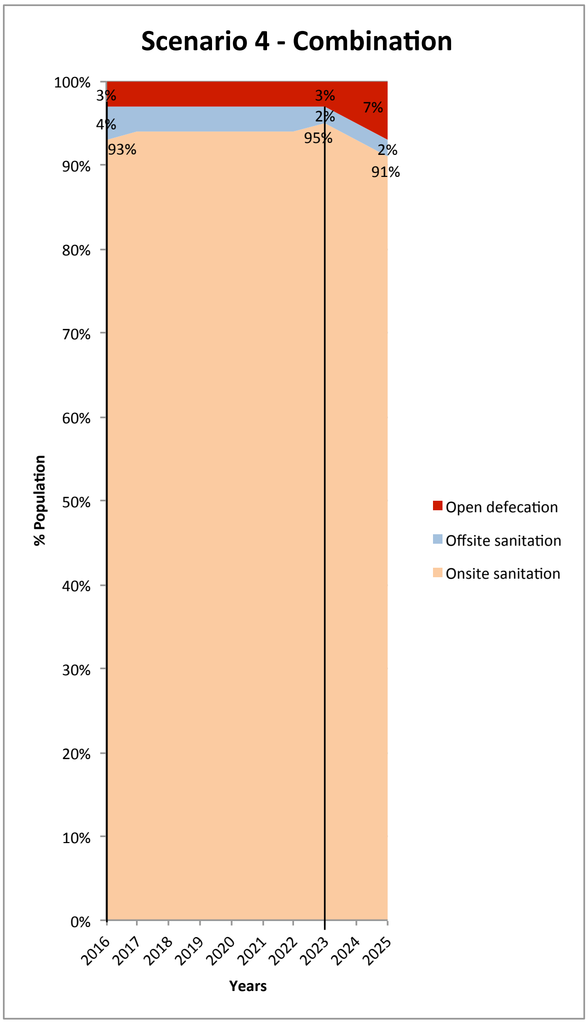


Figure 39: Trend in the type of sanitation in Kumasi for the next 10 years (scenario 4)

Figure 38 shows the trend in the type of sanitation in Kumasi over the next ten years. The new toilets (private and public) stop the rise in OD until 2023 when the public toilets will reach their capacity if new toilets are not constructed, (see section 5.4.3.2, scenario 4A).

After 2023 OD grows increases again because of the lack of toilets for the population which is growing at a rate of 5.5% per year.

In this case, OD starts increasing a year later than in scenario 3 due to the effect of the private toilets in compounds.

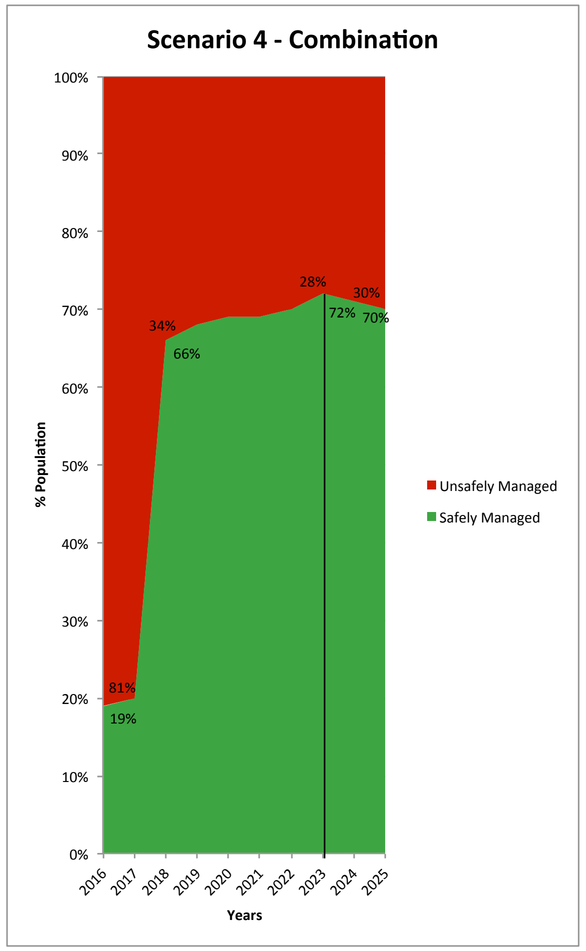


Figure 40: % of population who excreta is safely managed along 10 years (scenario 4)

Figure 40 shows the overall result for scenario 4. Between 2016 and 2018 the amount of population who safely manage their excreta flow is low due to the treatment plant is out of service. This amount increases when the STP starts working again and continues to increase until 2023. Then, the percentage of population who safely manage their FS is reduced because the OD increases.

Regarding the SFDs produced (section 5.4.4) for years 1, 5 and 10, it is observed that this increase is due to the proportion of the population who do not empty their contained FS. The width of the arrow "FS contained but not emptied" increases from 18% in 2020 up to 42% in 2025. This is illustrated in figure 41 over the 10 years. The percentage of population (who use onsite sanitation) emptying their installations in 2015 is 82% whilst in 2025 is 58%.

In this case the amount of installations that are contained at not emptied increase from 2016, and as a consequence the same behaviour can be observed in the percentage of population who safely manage their excreta.

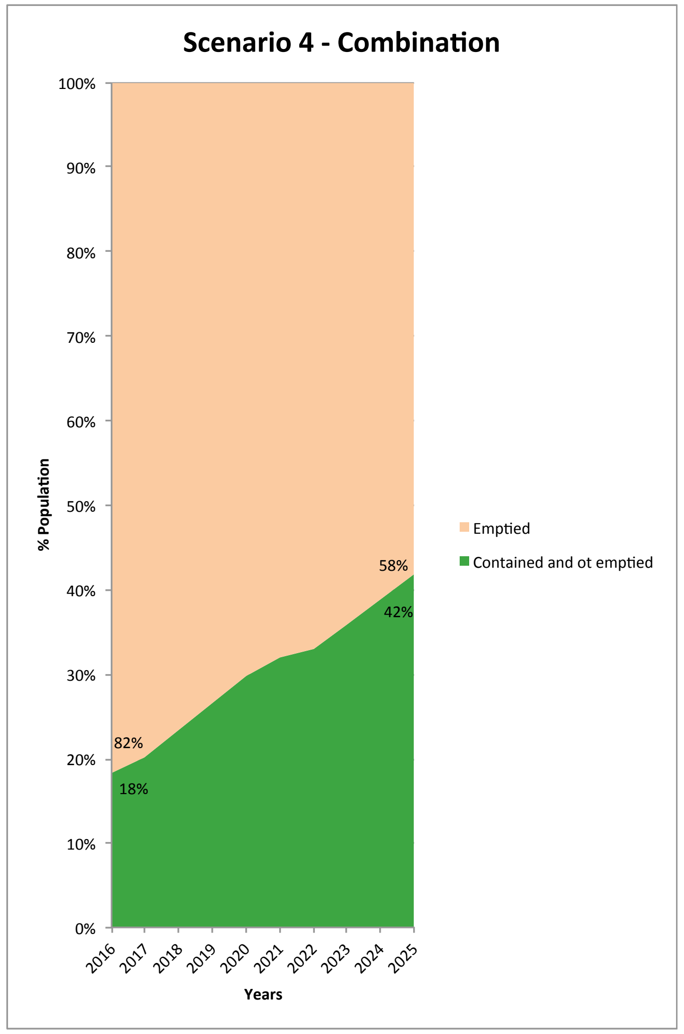


Figure 41: of population who empty their installations (scenario 4)

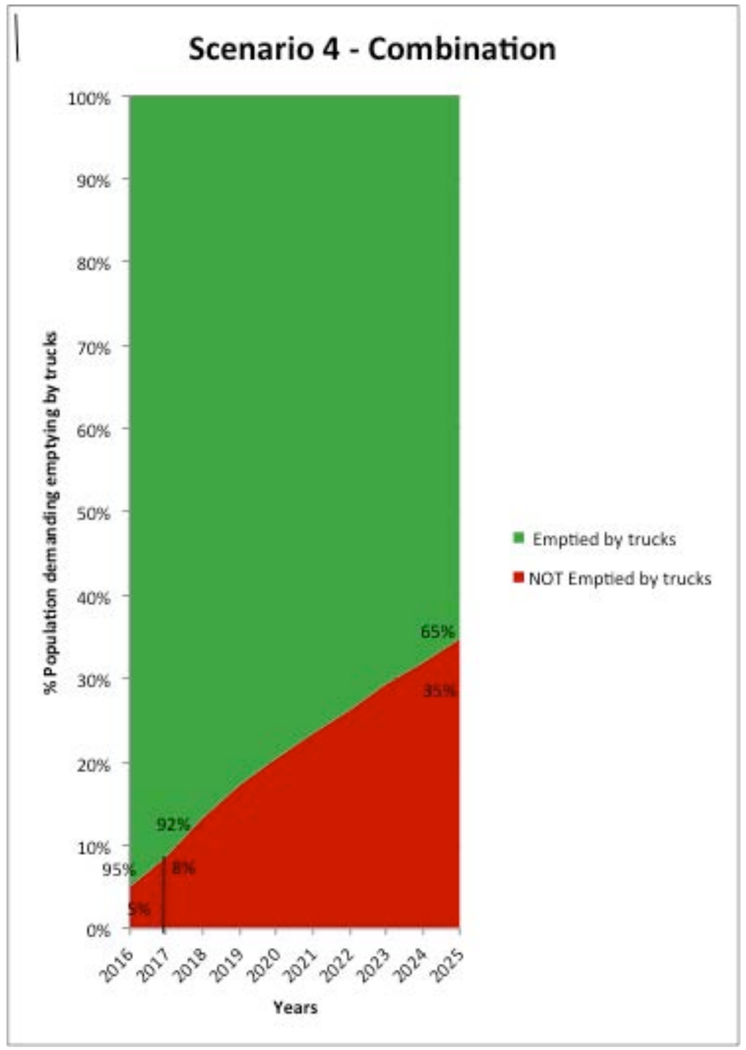


Figure 42: % of installations that cannot be emptied by trucks (scenario 4)

Analysing the data collected concerning emptying (section 5.4.3.4). Figure 41 shows that people stop emptying their installation because trucks reach their maximum capacity in 2017. However, as shown in table 46 the demand for emptying installations increases over the years.

Regarding the three trends in the graphs, it can be concluded that the rise in the percentage of population who safety manage their FS between 2017 and 2023 is partially because there are installations that, even when full, cannot be emptied because the trucks do not have the capacity to meet the demand.

Finally the trend in treatment has been analysed. Figure 43 shows the percentage of FS arriving at the STP treated and not treated. At first the plant is not working. In 2018 the rehabilitation will be finished, increasing the percentage treated. The efficiency of treatment is constant due to the trucks not having additional capacity to deliver FS to the treatment plant

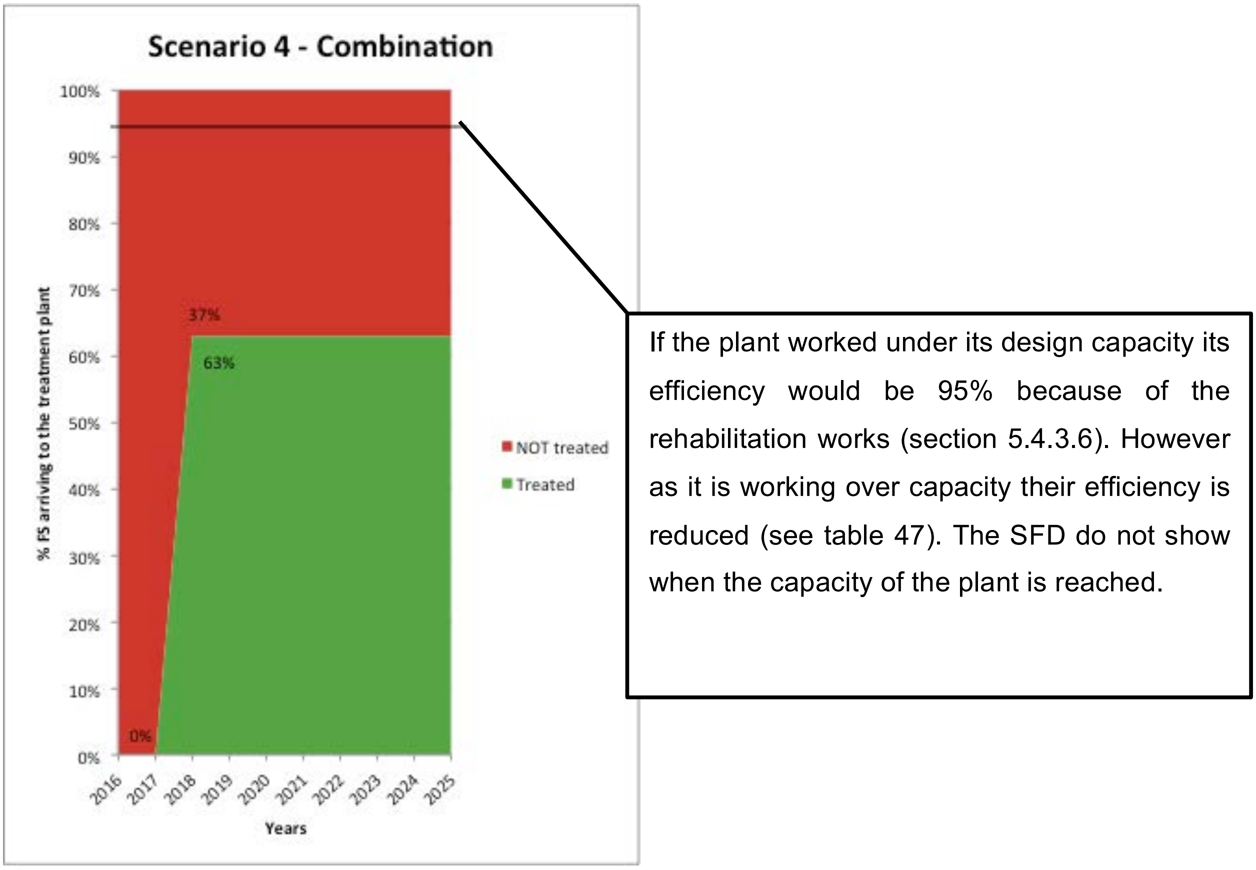


Figure 43: % treated and not treated of FS arriving at the STP (scenario 4)

Chapter 6: Conclusions and recommendations

The objectives set out on chapter 1 have been largely fulfilled. However some aspects concerning the sanitation service chain in Kumasi require more research in order to confirm the results presented. Recalling the objectives will aid to summarise the conclusions:

1. Outline the contribution of SFD to urban sanitation

   In an urbanised world, where onsite technologies are more widely used than sewers, there is a need, identified by the SDG, to safely manage the faecal sludge throughout the service sanitation chain within cities.

   SFD methodology has been demonstrated to be a good tool to track the excreta flow within a city, highlighting the weakest links in the sanitation service chain. It has been successfully used as an advocacy tool, however its potential as a planning or monitoring tool is not still clearly defined, and exploring it has been the main objective of this study.

2. Define future scenarios to be modelled in Kumasi, Ghana.

   Four scenarios have been defined, using population growth, new infrastructure (the number of public toilets and private toilet in the case of Kumasi) and changes in the capacity of the current infrastructure (capacity treatment of the STP in Kumasi) as the main variable parameters.

   Firstly, a "baseline scenario" was proposed in order to analyse the potential change in the SFD if there is no investment over the next few years, while the population continues to increase. Afterwards, on-going investment projects, or those that are about to start in the city were considered, to define two further scenarios. Finally, a combination of two scenarios was defined to illustrate the total change in the SFD if both investment projects are implemented.

   For each scenario, a list of questions was developed to define the minimum data collection required from secondary data, interviews and observations. These questions were mainly focused on:

   - The future trend in OD and private investments (i.e. compound toilets)
   - Future demand for services by the population
   - Capacity of the infrastructure (current and planned) to meet the demand

3. Produce the SFDs for future Scenarios

   This objective has been fulfilled. However, during the data collection process not all the stakeholders were interviewed, resulting in a reduction in data and opinions.

Within each scenario, different values of key parameters are considered because they are not accurately defined. Therefore the SFD would be different (having scenarios within the defined scenario). In the case of Kumasi this affected the capacity of public toilets (depending on the minimum average time that a user spent in a facility) and the capacity of the treatment plant (depending on the average size of trucks considered and the design capacity of the plant). In this study the worst case for each scenario has been modelled because it is when the greatest changes are produced from one year to another. The data examined in chapter 5 allows all the other possibilities to be easily analysed.

4. Appraise the SFD tool to identify strengths and weakness in relation to modelling future scenarios.
   Following the third result, this study has demonstrated that is possible to model futures scenario using the SFD methodology if minimum data is available. It is important to highlight that Kumasi is a special case as a high percentage of the population rely in public toilets and there is a lot of available data on this service (because it is centrally controlled by KMA). Data about private users and investment is more complicated to obtain.

   Changing data and making new scenarios, once the baseline scenario is produced is easy, making the tool flexible.

   As identified in the literature, the accuracy of the results depends on the quality of the data. In this case study, the results could be used as an approximation. To use the modelling SFDs to make decisions about future investment more accurate data is needed, not only to model the baseline scenario (as information about private toilets and OD) but also about the planned projects. Operation and maintenance have not been considered either because public and private stakeholders do not plan these actions.

   Once the scenarios were produced, changes from one scenario to another can be observed comparing the SFDs. However only interventions that target a high percentage of population have visual impact (see scenario 2, section 5.2.5) Additionally, trends and changes within the same scenario are not easily observed (regarding only the SFDs) because there is too much information present in each SFD and only two colours are used. For that reason, trend graphs have been used to analyse and discuss the results.

   After the trend analysis two main conclusions can be made about the SFD tool and methodology:

- When there is a rise in the FS that is contained but not emptied (this means installations not being emptied), there is an increase in the percentage of people who safely managed their excreta. This rise could be due to the number of latrines that are abandoned and covered with soil increasing or because the installations that need to be emptied cannot be due to vacuum tankers not having sufficient emptying capacity. The latter is the case in Kumasi.

  In both cases, whilst this contained FS does not present a risk to the environment, the FS is not being managed. Therefore depending on what the SFD wants to represent this could be considered as good or bad practice. Good if the SFD evaluate the environment risk and the FS is really contained and bad if the SFD evaluate the FS management.

  Additionally, there are people who have been using installations which they cannot use anymore because they are full: will there be sufficient space/resources (especially in cities with a high population density, like Kumasi) to construct new installations? or will these people revert back to practicing OD or using public toilets? SFDs do not show what is happening with those people who relied upon these full installations.
- The SFD shows the percentage of FS that is treated in the plants, but in analysing only the SFD it is not clear if the treatment plant is working under or over capacity.

Finally, it is important to list the bottlenecks identified throughout the sanitation service chain in Kumasi over the next 10 years:

- Compound toilets: As identified in the literature the number of toilets in Kumasi is not expected to significantly increase in the next year, and considering the high growth in the population rate this creates a currentlyhigh dependency on the public toilets,
- Public toilet capacity According to scenario 1, the current number of public toilets cannot meet the future demand. The new toilets planned to be constructed next years can meet the demand up to 2022 (scenario 4)
- Trucks capacity: If the number of trucks remains constant, the trucks will not to be able to meet the demand in a couple of years.
- Treatment plant capacity: the new rehabilitation does not consider increasing the STP capacity. If the capacity of the plant is 300m^3/day, even after it is rehabilitated the treatment plant is going to work over capacity and its efficiency is going to be reduced.

6.1 Limitations faced during the research process

As explained before, the SFDs produced are credible but not accurate; this is mainly due to the limitations faced during the process of data collection:

- No data was obtained from the Vacuum Truck Operators. Interviewed stakeholders did not have enough knowledge about their business plan, and it was not possible to interview them. Therefore, in this study it was assumed that VTO are not going to increase the number of trucks in the future, but this information required more research in order to confirm the scenarios produced.

  Due to this assumption, it was observed in chapter 5 (in the trend analysis for each scenario) that truck capacity is a bottleneck in the sanitation service chain for the next 10 years. Regarding this, it was intended by the author to develop a fifth scenario assuming that the trucks have the capacity to respond to the demand in the next 10 years; however due to a lack of time this could not be undertaken.
- Other data difficult to interpret was that relating to Open Defecation. In Kumasi where migration is determinant in the population growth rate, it is not clear if the trend is going to be the same as in previous years (which has been slowly reduced) or is going to increase. Even the key stakeholders' perceptions were not uniform. No literature was found about how OD changes in cities with a high migration rate.
- There is a lack of data about private investment (e.g. compound toilets), even when data from recent years is considered.
- Finally, due to lack of time the results were not discussed with SFD experts as planned at the beginning.

6.2 Recommendations

Conclusions and limitation have enable recommendations to be made for both SFD methodology and future research:

6.2.1 Recommendation for SFD methodology

The following points are recommended to be considered if SFD methodology is used to model future scenarios in cities:

- Including the trend graphs as part of the methodology to analyse future changes. These trend graphs make the analysis process easier and more visual. Simplifying the data analysis to all type of users and decision makers.

  Also, these kinds of graphs are starting to be used by some governments to illustrate their sanitation strategies. Figure 30 shows the "trajectory of change" over time for city-wide sanitation in Hawassaa, Ethiopia (Blackett and Hawkins, 2016). Both graphs (showing the strategy and future scenarios modelled using the SFDs) can be compared and decisions then made based on the comparison.

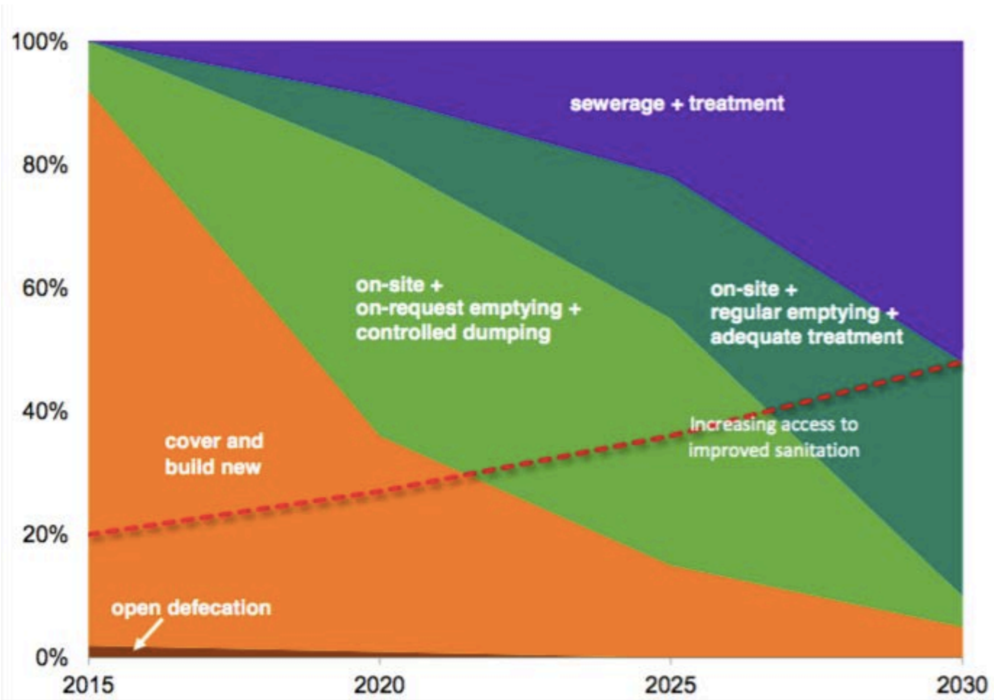


Figure 44: City-wide sanitation strategy for Hawassa, Ethiopia: a graphical representation (Blackett and Hawkins, 2016).

- It can be useful to try to model the future scenarios at the same time as the SFD is being developed for the current situation. Most of the data used to model future scenarios can be collected at the same time, at least that needed to develop the “baseline scenario”
- Extend to some years after the planned project deadline to observe when new intervention will be needed.

6.2.2 Recommendation for Future Research

The following points are recommended to be considered if additional research want to be developed in relation to FSM, SFD and Kumasi.

- Try to model future scenarios in other cities and compare the results and the consistency of the method.
- Explore the viability of modelling SFDs for a specific area of the city (i.e. in the case of Kumasi, one submetro) in order to make more visual changes produced by a small project focused on one area (usually low income area)
- Establish how a project should be formed to provide the information required to model future scenarios using SFDs
- Study how OD can by affected by high rates of growth population in secondary cities

References

ADARKWA, K.K., 2011. The role of Kumasi in National Development - Kumasi as a Central Place. In: *Future of the Treee: Toward growth and development of Kumasi*. Kumasi, Ghana: University Priting Press. pp. 14–34.

ALLEN, A. and HOFMANN, P., 2008. Moving down the ladder: Governance and sanitation that works for the urban poor. In: *IRC Symposium on Urban Sanitation*. Delft, The Netherlands: IRC International Water and Sanitation Centre.

AMOAKO, C. and KORBOW, D., 2011. Historical Development, Population Growth and Present Structure of Kumasi. In: *Future of the Treee: Toward growth and development of Kumasi*. Kumasi, Ghana: University Priting Press. pp. 35–54.

BLACKETT, I. and EVANS, B., 2015. *Introducing the Fecal Waste Flow Diagram Approach* WSP-WB and University of Leeds. [online]. Available from: http://www.susana.org/_resources/documents/default/3-2211-7-1442219928.pdf.

BLACKETT, I. and HAWKINS, P., 2016. *Fecal Sludge Management Tools: Case Study in Hawassa , Ethiopia [online]*. Water and Sanitation Program: Technical Paper. Available from: http://documentos.bancomundial.org/curated/es/430511468343408972/pdf/106810-WP-P146128-PUBLIC-05c-FSM-Diagnostics-Urban-Case-Study-Hawassa.pdf

BLACKETT, I., HAWKINS, P., and PEAL, A., 2014. Why faecal sludge managemeant matters and what needs to be done to serve poor communities better. n: *37th WEDC International Conference,: SUSTAINABLE WATER AND SANITATION SERVICES FOR ALL IN A FAST CHANGING WORLD*. Hanoi, Vietnam. pp. 1–7.

BRINKHOFF, T., 2012. *City population* [online]. Available from: http://www.citypopulation.de/Ghana-Cities.html?cityid=2327.

BRINKHOFF, T., 2016. *Major Agglomerations of the World - Population Statistics and Maps* [online]. Available from: http://www.citypopulation.de/world/Agglomerations.html [Accessed 31 May 2016].

CLEAN TEAM TOILETS, 2016a. *Project Field Visit*.

CLEAN TEAM TOILETS, 2016b. *Semi-Structured Interview*.

DENSCOMBE, M., 2007. *The good research guide for small-scale social research projects*. 3th ed. Maidenhead, UK.: Open University Press.

FARVACQUE-VITKOVIC, C., RAGHUNATH, M., EGHOFF, C., and BOAKYE, C., 2008. Development of the Cities of Ghana: Challenges, Priorities and Tools. *Africa Region Working Paper*. (110), pp. 1–157.

FURLONG, C., 2015a. *SFD Report Kumasi, Ghana, 2015.* SFD Promotion Inicitiative. Avaliable from: http://www.susana.org/_resources/documents/default/3-2361-7-1447766816.pdf

FURLONG, C., 2015b. *STP Observation*s. Unpublished.

FURLONG, C., MENSAH, A., DONKOR, J., and SCOTT, R.., 2016. Learnings from implementing the excreta flow diagram (SFD) process in Kumasi. In: *39th WEDC International Conference: Ensuring Availability and Sustainable Management of Water and Sanitation for All.* Kumasi, Ghana.

GSS, 2013. Report 2010 Population and Housing Report. Regional Analytical Report. Ashanti Region. p. 3.

HAWKINS, P., 2016. *Personal Communication*.

HAWKINS, P., BLACKETT, I., and HEYMANS, C., 2013. *Poor-Inclusive Urban Sanitation: An Overview* [online] WATER AND SANITATION PROGRAM: STUDY. Washington DC, United States. Available from: https://www.wsp.org/sites/wsp.org/files/publications/WSP-Poor-Inclusive-Urban-Sanitation-Overview.pdf.

HAWKINS, P., BLACKETT, I., and HEYMANS, C., 2014. *The Missing Link in Sanitation Service Delivery : a review of Fecal Sludge Management in 12 cities* [online]. Water and Sanitation Program: Research Brief. Available from: http://documents.worldbank.org/curated/en/2014/04/19549016/targeting-urban-poor-improving-services-small-towns-missing-link-sanitation-service-delivery-review-fecal-sludge-management-12-cities.

HOPEWELL, M.R. and GRAHAM, J.P., 2014. Trends in access to water supply and sanitation in 31 major sub-Saharan African cities : an analysis of DHS data from 2000 to 2012. *BMC Public Health* [online]. 14 (1), pp. 1–12. Available from: http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-208

JENKINS, M.W., CUMMING, O., SCOTT, B., and CAIRNCROSS, S., 2014. Beyond 'improved' towards 'safe and sustainable' urban sanitation: assessing the design, management and functionality of sanitation in poor communities of Dar es Salaam, Tanzania. *Journal of Water, Sanitation and Hygiene for Development* [online]. 4 (1), p. 131. Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896455780&partnerID=tZOtx3y1.

KEDAM, T.R., 2012. Meeting report. In: *Indian journal of biochemistry & biophysics*. pp. 134–135.

KMA, 2015a. *Public toilets data*.Unpublised

KMA, 2015b. *Daily Records - 6 months at the Dompoase STP*. Unpublished

KMA, 2016a. *Semi-Structured Intervew*.

KMA, 2016b. *Public Toilets Visit*.

KMA and WSUP, 2014. *A toilet in every Compound Strategy document*. Unpublished

KVARNSTRÖM, E., MCCONVILLE, J., BRACKEN, P., JOHANSSON, M., and FOGDE, M., 2011. The sanitation ladder – a need for a revamp? *Journal of Water, Sanitation and Hygiene for Development* [online]. 1 (1), p. 3. Available from: http://washdev.iwaponline.com/cgi/doi/10.2166/washdev.2011.014.

LÜTHI, C., PANESAR, A., SCHÜTZE, T., NORSTRÖM, A., MCCONVILLE, J.R., PARKINSON, J., SAYWELL, D., and INGLE, R., 2011. *Sustainable Sanitation in Cities*: A frame for action. Papiroz Publishing House. Rijswijk, The Netherlands. Avaliable from: http://www.susana.org/_resources/documents/default/3-1019-37-1430323810.pdf

MAOULIDI, M., 2010. A water and sanitation needs assessment for Kumasi, Ghana. *MCI Social Sector Working Paper* [online]. 16 (September), pp. 1–32. Available from: mci.ei.columbia.edu.

MAZEAU, A., 2013. *No toilet at home: implementation, usage and acceptability of shared toilets in urban Ghana*. [online]. Loighborough University. Available from: https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/13135.

MAZEAU, A.P., WELLINGTON, N., DRABBLE, S., ASANTE, F., and AWANTUNGO, D., 2014. Bringing toilets back to Kumasi's compound houses: landlord and tenant behaviours and motivators. In: *37th WEDC International Conference,: SUSTAINABLE WATER AND SANITATION SERVICES FOR ALL IN A FAST CHANGING WORLD*. Hanoi, Vietnam. pp. 1–6.

MCI, 2013. *Kumasi: Investment Guide 2013* [online]. Available from: http://mci.ei.columbia.edu/files/2014/05/Kumasi-Abbreviated-Investors-Guide.pdf

MEDLAND, L., COTTON, A.., and SCOTT, R.E., 2015. *SPLASH Urban Sanitation Research Programme Briefing Note 3: Understanding and addressing vulnerability in the sanitation service chain*. Loughborough, UK.

MEHTA, M. and MEHTA, D., 2013. City sanitation ladder: moving from household to citywide sanitation assessment. *Journal of Water, Sanitation and Hygiene for Development* [online]. 3 (4), p. 481. Available from: http://washdev.iwaponline.com/cgi/doi/10.2166/washdev.2013.134.

MIKHAEL, G., CRAIG, R., and MUSAH, I.B., 2016. A toilet in every compound: improving access to compound toilets in Kumasi and Ga West, Ghana. In: *39th WEDC International Conference: ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL*. Kumasi, Ghana.

MIKHAEL, G., MUSAH, I.B., and CRAIG, R., 2016. *A toilet in every compound : improving access to compound sanitation in Kumasi and Ga West.*Unpublised.

MUNAMATI, M., NHAPI, I., and MISI, S.N., 2015. Monitoring sanitation performance: unpacking the figures on sanitation coverage. *Journal of Water, Sanitation and Hygiene for Development* [online]. 5 (3), p. 341. Available from: http://washdev.iwaponline.com/cgi/doi/10.2166/washdev.2015.180.

VON MÜNCH, E., 2008. Sanitation and related sustainability criteria – How to indicate the quality of sanitation?. In: *IWA World Water Congress and Exhibition.* Vienna, Austria [online] Avaliable from: *http://www.susana.org/_resources/documents/default/2-1652-en-iwa-vienna-sustainability-criteria-muench-2008.pdf*

NIKIEMA, J., 2015. The Excreta Flow Diagram: A tool for advocasy and awake-up call for all! In: *The World Toilet Day 2015 : Conference on Sanitation*. London, UK: IWMI.

NYARKO, K.B., 2015. Partnerships in sanitation service management and infrastructure provision in Kumasi , Ghana. In: *38th WEDC International Conference: WATER, SANITATION AND HYGIENE SERVICES BEYOND 2015: IMPROVING ACCESS AND SUSTAINABILITY.* Loughborough, UK. pp. 1–7.

PEAL, A. and EVANS, B., 2015. *A Review of Fecal Sludge Management in 12 Cities* [online]. WSP. Available from: http://www.susana.org/en/resources/library/details/2212.

PEAL, A., EVANS, B., BLACKETT, I., HAWKINS, P., and HEYMANS, C., 2014. Fecal sludge management (FSM): analytical tools for assessing FSM in cities. *Journal of Water, Sanitation and Hygiene for Development* [online]. 4 (3), p. 371. Available from: http://www.iwaponline.com/washdev/004/washdev0040371.htm.

RODRIGUES, C., 2016. *SFD Promotion Incitaive Workshop*. In: *39th WEDC International Conference: Ensuring Availability and Sustainable Management of Water and Sanitation for All.* Kumasi, Ghana. Unpublished.

SATTERTHWAITE, D., 2016. Missing the Millennium Development Goal targets for water and sanitation in urban areas. *Environment and Urbanization* [online]. 28 (1), pp. 99–118. Available from: http://eau.sagepub.com/cgi/doi/10.1177/0956247816628435.

SCHEYVENS, R. and STOREY, D., 2003. *Development Fieldwork: A practical guide*. SAGE Publications Ltd. London, UK.

SCOTT, R.E., 2012. Management of Urban Sanitation Services. In: *Water Utilities Management - A WEDC Module*. Loughborough, UK. p. 31.

SFD PROMOTION INICIATIVE, 2015. *The SFD Promotion Iniciative* [online]. Available from: http://sfd.susana.org/about/the-sfd-promotion-initiative [Accessed 24 May 2015].

SFD PROMOTION INICIATIVE, 2015. *Manual for SFD Production* [online]. Sustainable Sanitation Alliance. Available from: http://www.susana.org/_resources/documents/default/3-2357-17-1446824434.pdf.

STP/KMA, 2016a. *STP Field visit*.

STP/KMA, 2016b. *Semi-Strutured Intervew*.

STRANDE, L., RONTELTAP, M., and BRDJANOVIC, D., 2014. *Faecal sludge management: Systems approach for implementation and operation* [online]. London: IWA Publishing. Available from: http://www.susana.org/_resources/documents/default/3-2100-7-1415357124.pdf.

SUSTAINABLE SANITATION ALLIANCE, 2015. *SFD Promotion Iniciative website* . [online]. Available from: http://sfd.susana.org [Accessed 1 Jul 2016].

TIBERGHIEN, J.-E., 2016. *A tale of clean cities: Insights for planning urban sanitation from Kumasi, Ghana* [online]. Available from: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwihgpy69q_OAhXLDcAKHah7CFQQFggwMAE&url=http://www.wateraid.org/~/media/Publications/A-tale-of-clean-cities--Kumasi-case-study.pdf?la=en&usg=AFQjCNFkvf1GwJXuGY6qJ7l9y2DtRN0hmA&sig2.

TILLEY, E., LÜTHI, C., MOREL, A., ZURBRÜGG, C., and SCHERTENLEIB, R., 2008. *Compendium of Sanitation Systems and Technologies* [online]. Development. Available from: http://www.susana.org/en/resources/library/details/454.

TRÉMOLET, S., 2011. Scaling Up Rural Sanitation : Identifying the Potential for Results-Based Financing for Sanitation. (November), pp. 1–38.

UN-HABITAT, 2009. *Planning sustainable cities: Global Report on Human Settlements. 2009*. Earthscan, London.

UN-HABITAT, 2016. *Urbanization and Development: Emerging Futures* [online]. Fist. Nairobi, Kenya: United Nations Human Settlements Programme (UN-Habitat). Available from: http://unhabitat.org/books/world-cities-report/.

UNITED NATIONS, 2014. *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)* [online]. New York, United. Available from: http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf.

VERHAGEN, J. and RYAN, P., 2008. Sanitation Services for the Urban Poor: Symposium Background Paper. *IRC International Water and Sanitation Centre*. (November 2008), pp. 1–20.

WB, 2016a. *Semi-structure Inteview*.

WB, 2016b. *GPOBA PROJECT CONCEPT NOTE*.Unpublished.

WHO/UNICEF, 2015. *2015 Update and MDG Assessment* [online]. World Health Organization. Available from: http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-Update-report-2015_English.pdf.

WHO/UNICEF JMP, 2015a. *WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation* [online]. Available from: http://www.wssinfo.org/definitions-methods/watsan-categories/ [Accessed 20 Jun 2016].

WHO/UNICEF JMP, 2015b. *Proposed indicators for drinking water, sanitation and hygiene.* WASH Post-2015.

WILLIAMS, A.R. and OVERBO, A., 2015. *Unsafe return of human excreta to the environment: a literature review* [online]. Chapel Hill, NC, USA: The Water Institute at UNC. Available from: https://waterinstitute.unc.edu/files/2015/07/BMGF_UnsafeReturn_LitReview_UNC_16June15.pdf.

WORLDATLAS, 2016. *Ghana Map* [online]. [online]. Available from: http://www.worldatlas.com/webimage/countrys/africa/gh.htm [Accessed 15 Jun 2016].

WSUP, 2014. *Baseline Market Study – Assessing PPP options to improve provision of public toilets in Kumasi.* Unpublished

WSUP, 2016a. Briefing Note: Clean Team Toilet. Unpublished

WSUP, 2016b. *Semi-Structured Intervew*.

Appendix 1: Methods of data collection used to answer the research questions

Research Objectives	Research Questions	Sources of information		
		Document that have been analysed	Secondary data from Literature review	Primary Data: Interviews, Correspondences and Observations
Outlined the contribution of SFD to urban sanitation	What are the urban sanitation challenges?	Journal articles, presentations, reports from WSP and SFD Promotion Initiative, books, Conferences Proceedings and grey literature.	X	
	What is a SFD? What is use for? What is its potential?		X	
Defined future scenarios to be modelled in Kumasi, Ghana	What variables have to be considered when modelling futures scenario?	Kumasi SFD, documents from SFD promotion Initiative, Panning Documents from KMA, WSUP and WB about Kumasi, etc.	X	X
	What are questions to be answered trough data collection?		X	X
Produced the SFD for the defined scenarios	What data have to be collected to be able to produce the future SFD?	Different Conference proceedings about compound toiles and public toilets in Kumasi, journal articles about OD, planned project documents in Kumasi, etc.	X	X
	How the SFD changes when an intervention is produced?		X	X
Appraised the SFD tool identifying the strengths and the weakness in relation to modelling future scenarios	What are the limitations of SFD methodology?	Reports and brief notes from WSP about an study in 12 cities and unpublished literature from IWIMI	X	
	How could the tool or methodology be improved?		X	

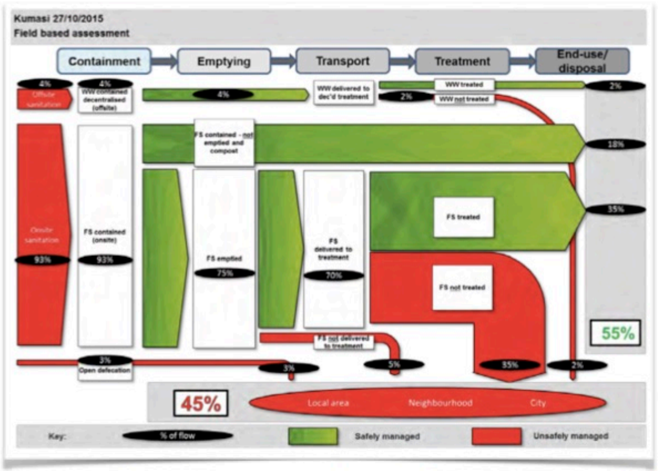
Appendix 2: Key Institutions with presence in Kumasi, their role and methodologies used (prior to travel)

Institution	Role	Relevancy	Possible Questions	Methodology
KMA	The WMD is responsible of sanitation facilities (schools included) and services provision in Kumasi city.	The opinion and perspective of this institution has a special interest. In specific, it is important to know their plans for the next years their perspective about the habits of population (specially of the poorest people and immigrants) and their opinion about the public toilets and compound toilets	• What are the projects being developed by KMA? • How public Toilets work? • Who empty the onsite facilities? • How is the STP working? • What are the habits of poorest people (and immigrants) in Kumasi • Is the OD increasing or decreasing in Kumasi?	Semi-structured interviews Two people from the WMD are going to be present in Kumasi and they have been contacted
Clean Team	Clients use toilets units inside their house and the waste is transported into a tank. The number of clients in 2015 was 4,032 and it is expected that increase	In the current SFD this model of onsite sanitation was not considered because their clients represented less than 1% of the total population but if the business continue to increase this type of onsite sanitation has to be included in the future SFDs.	• What is your business about? What type of clients do you have? • How do you manage the faecal waste? • When has the business started? • How many clients did you have last years? Do you have records? • How many clients do you have now? • How many clients are you expecting to have next years? Do you have any business plan?	Semi-structure interviews Contacted the CEO by Skype.
WSUP	It is the main international NGO working in sanitation in Kumasi	They have two on-going projects in coloration with KMA: rehabilitation of the Septage Treatment Plant and encouraging toilets construction in private compounds. Additionally it is interesting to know their perspectives about the OD because they work in slums.	• What is the work of WSUP in Kumasi? Where are you working? • What projects have you implemented or are you planning? • What are the results that you expected from those projects? • What are the habits (related to sanitation) of poorest people (and immigrants) in Kumasi • Is the OD increasing or decreasing in Kumasi? Why?	Semi-structure interviews Two people from the WSUP are going to be present in Kumasi have been contacted

Institution	Role	Relevancy	Possible Questions	Methodology
Vacuum Tankers Operators	It is the association where different tankers owners are.	Most of the installations in Kumasi are emptied trough Vacuum tankers	• How many Vacuum tankers are there in Kumasi? • Do they have any business plan? • Do they have the capacity to cope future demand?	Semi structured interviews or unstructured interviews
KNUST	This is the civil Engineering University with a campus in Kumasi	It is relevant to know their perspective about public toilets, clean toilet team and toilets in compound.	• Is the KNUST supporting the KMA work? How? • What is the main research that KNUST is carrying on in Kumasi related to sanitation? • Who empty the onsite facilities? • How is the STP working? • What are the habits of poorest people (and immigrants) in Kumasi • Is the OD increasing or decreasing in Kumasi?	Semi structured interviews or Unstructured interviews A person who is going to be in the WEDC conference has been contacted
World Bank	There are one of the main donors in Sanitation within the country	They are supporting a project to implement public toilets by a PPP in Kumasi	• What sanitation projects have the WB in Kumasi? • Do you have any other projects planning? • Who is implementing these projects? • What is the role of the KMA? • What are the expected results?	Semi structured interviews A external consultant has been contacted
SFD Experts (IWMI, WSP, other universities)	They have experience working on SFD and modelling them in different cities		• What is your experience with SFD? • Have been used the SFD for modelling different scenarios? Which ones and where? What methodology have you used? • What parameters are to be considered important for future scenarios?	Semi structured interviews or Informal interviews Six different people have been contacted, two of them are going to be in Kumasi (a student from Accra and someone from IWMI)

Appendix 3: Flyer to attract the attention of potential informants during the 39th WEDC International Conference

WEDC-MSc Dissertation



Using the SFD Methodology to model future scenarios in Kumasi, Ghana

SFD Promotion initiative provides standardized guidance for the easy production of standardized SFDs, supported by a description of information sources and the sanitation service chain in the city concerned

http://sfd.susana.org

Onsite sanitation technologies are more widely used than sewers, and the trend of using onsite sanitation far from decreasing is, in fact, increasing due to mainly the rapid urbanisation in the poorest areas of the city

Families living in high density settlement lack space to safely abandon a full pit or tank and construct other nearby. This creates a need for a sanitation service chain to hygienically remove and transport the faecal sludge. That movement of the faecal material through the sanitation chain is illustrate by the Excreta/Shit Flow Diagrams (SFD)

What are we researching?

Recently, an SFD for Kumasi was produce by WEDC and KMA, as part of the SDF Promotion Initiative. The objective go this research is to use the current SFD and the SFD methodology,to model four possible future scenarios in Kumasi and predict the changes in excreta flow patterns.

The scenarios have been defined using population growth and the planned investments in the city as main parameters.

For each scenario a list of questions has been proposed to define the minimum data collection required from secondary data and interviews. The process of data collection is being carried out and later the SFD for each scenario will be modeled. This will allow to assess the value of the SFD and tools to model future scenarios, its strengths and weakness and how it can be improved in the future.

Dissertation timing:

- June 2016: Literature review and methodology definition
- July 2016: Data collection and analysis
- August 2016: Conclusions and submission of final report

Are you interested in participate or find out more information?

Contact with Lara Fernandez;

larazedf@gmail.com

Telephone number:

PHOTO

Or you can find me at the WEDC conference

Appendix 4: List of Key Informants, personal communications

Institution	List of Key Informants who participated in the research	Date of communication	Purpose of the contact	Summary of the outcomes
WMD/ KMA	Mr Anthony Mensah (ancient head of WMD) and Mr John Donkor (Head of sanitation)	17/05/2016	Introduction	Introductory mail sent by Claire Furlong
	Mr Anthony Mensah	17/05/2016	Replied to email	Prosing and date for first call
	Mr Anthony Mensah	18 /05/2016	Setting introductory call	Date: 21th June.
	Mr Anthony Mensah and Mr John Donkor	19/05/2016	Document to discuss during the call	Proposal of scenarios to be modelled in Kumasi
	Mr Anthony Mensah	21/05/2016	First call	Introduced research and unstructured interview to discuss the scenarios to be modelled.
	Mr Anthony Mensah and Mr John Donkor	25/05/2016	Scenarios	The new proposal after the discussion with Anthony Mensah
	Mr Anthony Mensah and Mr John Donkor	30/06/2016	Set up meeting at Kumasi	Informed and asked for an interview during the WEDC conference and asked for a contact of the Vacuum Tankers Operator Association
	Ps Michael Morrison (FS Treatment Plant manager)	30/06/2016	Introduction	Introductory mail sent by Claire Furlong
	Ps Michael Morrison	30/06/2016	Set up meeting at Kumasi	Informed and asked for an interview during the WEDC conference and asked for a contact of the Vacuum Tankers Operator Association
	Anthony Mensah	29/07/2016	Document GPOBA project, Public Toilets	Reception of document about the GPOBA public toilets Project
Clean Team	Asantewa Gyamfi (head)	3/06/2016	Introduction	Introductory mail sent by Claire Furlong
	Asantewa Gyamfi	9/06/2016	Introduction	Introduced research
	Asantewa Gyamfi	9/06/2016	Replied to mail	Another contact has been given: Eddy Anim
	Eddy Anim (CEO)	14 /06/2016	Set up meeting	Date for interview
	Eddy Anim	30/06/2016	Set up meeting at Kumasi	Informed and asked for an interview during the WEDC conference at Kumasi
	Eddy Anim	30/06/2016	Set up meeting at Kumasi	Proposed date for Skype interview because he is not going to be present at Kumasi
WSUP Kumasi	Samwel Adjel (public toilets facilitator) and Ebenezer Astugah	30/06/2016	Introduction	Introductory mail sent by Claire Furlong
	Samwel Adjel and Ebenezer Astugah	30/06/2016	Set up meeting at Kumasi	Informed and asked for an interview during the WEDC conference at Kumasi
	Frank Romeo Kettey	25/07/2016	WSUP Projects	Documents about WSUP projects that are planned in Kumasi

Institution	List of Key Informants who participated in the research	Date of communication	Purpose of the contact	Summary of the outcomes
IMWI/ Ghana	Josiane Nikiema	30/06/2016	Instruction and Set up meeting at Kumasi	Introduction of the research and set up a meeting in WEDC conference at Kumasi to know IWMI experiences in modelling future scenarios to Accra.
	Josiane Nikiema (CC: Philip Amoah)	30/06/2016	Replied to email	Setting up a meeting 12th July in Kumasi
	Josiane Nikiema	08/08/2016	Document IWMI Project	Reception of document about the work that IWMI did about SFDs in Accra
AMA	Fiifi Boadi (Public Health Engineer, trying to model future impacts in Accra)	30/06/2016	Introduction	Introductory mail sent by Claire Furlong
	Fiifi Boadi	30/06/2016	Replied to mail	Informed and asked for a meeting during the WEDC conference at Kumasi
	Fiifi Boadi	30/06/2016	Confirmed meeting	Confirmed availability for a meeting at Kumasi during the WEDC Conference
SFDs Experts	Peter M. Hawkins, Isabel C. Blackett, Barbara Evans, Andrew Peal and Pippa Scott	17/06/2016 and 21/06/2016	Introduction	Introductory mails explaining the research and thank them availability sent by Rebecca Scott and Lara Fernandez
	Peter M. Hawkins	17/06/2016	Replied to mail	Confirmed availability
	Barbara Evans	17/06/2016	Replied to mail	Confirmed availability
	Andrew Peal	20/06/2016	Replied to mail	Confirmed availability
	Isabel C. Blackett	21/06/2016	Replied to mail	Confirmed availability
	Pippa Scott	21/06/2016	Replied to mail	Confirmed availability

Appendix 5: Interviews forms

A.5.1 SEMI-STRUCTURE INTERVIEW FORM, KMA

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To identified the sanitation projects for the next years (their objectives and expected results)
- The perspective about the kind sanitation facilities used by population (especially of the poorest people and immigrants).
- How the FSM is done in public toilets and compound toilets
- To know the types of onsite sanitation and how is the FSM (capacity to empty and transport)

Questions

1. What are the challenges of the KMA about sanitation? What is its experience in sanitation? What kind of projects have KMA implemented?
2. What projects have the KMA developed in the last years related to sanitation?
3. What are the ongoing or planned sanitation projects for the next years in Kumasi? What are the expected results?
    - Number of new public toilets and number of seats per block?
    - Number of new compounds with toilets
    - Capacity of the Septage Treatment Plant.
    - Capacity and number of vacuum trucks
4. How many public toilets are in Kumasi? How is the FS managed?
5. Do the compounds have private toilets or shared toilets? How do you management the fecal sludge?
6. Who empty the onsite facilities? Do they have the capacity to cope the future demand?
7. How is the STP working from the point of view of capacity, operation and effluent quality?
8. In your opinion, the number of clients at Clean Team Toilets is going to increase during next years?
9. What are the sanitation habits of poorest people (and immigrants) in Kumasi
10. In your opinion, is the OD going to increase or decrease in Kumasi? Do you have any evidence? To what extent, percentage? What areas are going to be more affected?
11. Do you have any useful documents that can provide more information?

A.5.2 SEMI-STRUCTURE INTERVIEW FORM, KMA/ SEPTAGE TREATMENT PLANT

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To identified the sanitation projects for the next years
  - Their objectives and expected results
- To know how the STP is working and its capacity

Questions

1. What are your responsibilities at the STP?
2. How is the operation and maintenance of the plan in each stage? Inlet, treatment and effluent?
3. What are the ongoing or planned sanitation projects for the next years in the STP? How will this affect capacity to treatment?
4. Who empty the onsite facilities? Do they come here for disposing the faecal waste? To what extend do they have the capacity to cope the future demand?
5. How is the STP working? What is its capacity? Do you analyse the effluent? What are the results comparing with standards?
6. Do you have record of the number of truck and volume of faecal sludge arriving at the plant? Does it can cope with the demand? For how long?
7. Do you have any useful documents that can provide more information?

A.5.3 SEMI-STRUCTURE INTERVIEW FORM, CLEAN TEAM

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To know the history of this initiative and the number of clients
- To know how they manage the faecal waste.
- To know the business plan

Questions

1. Can you explain how the service delivery by the clean team toilets is? When has the business started?
2. How do you manage the faecal sludge? At all stage of the sanitation chain collection emptying, transport, treatment.
3. What type of clients do you have? Where are they living? What were their previous sanitation habits, dis they use public toilet or practise OD?
4. How many clients did you have last years? Have they increased? Do you have record of the number of clients per year?
5. How many clients do you have now?
6. How many clients are you expecting to have next years (2016-2026)? Do you have any business plan?
7. How do you intend to ensure capacity to cope the future demand? At all stage of the sanitation chain collection emptying, transport, treatment.
8. In your opinion, is the OD going to increase or decrease in Kumasi? Do you have any evidence? To what extent, percentage? What areas are going to be more affected?
9. Do you have any useful documents that can provide more information?

A.5.4 SEMI-STRUCTURE INTERVIEW FORM, WSUP

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To know their experience in Kumasi
- Identify the ongoing and future projects.

Questions

1. What type of projects have WSUP implemented in Kumasi? Where?
2. What are the ongoing or planned sanitation projects related to service improvement for the next years in Kumasi? What are the expected results?
    - Number of new public toilets and number of seats per block?
    - Number of compounds with toilets
    - Capacity of the Septage Treatment Plant.
3. Are there toilets in the compounds? What kind? Are they private toilets or shared toilets? What kind of toilets? Are they improving from dry toilets to wet toilets? How do they work?
4. How is the STP working in term of effluent? Does it have the capacity to cope with the future demand?
5. In your opinion, the number of clients of the Clean Team Toilets is going to increase during next years?
6. What are the sanitation habits of poorest people (and immigrants) in Kumasi?
7. In your opinion, is the OD going to increase or decrease in Kumasi? Do you have any evidence? To what extent, percentage? What areas are going to be more affected?
8. Do you have any useful documents that can provide more information?

A.5.5 SEMI-STRUCTURE INTERVIEW FORM, WB

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To know their experience in Kumasi
- Identify the on-going and future projects.

Questions

1. What type of sanitation projects has the WB implemented in Kumasi over the last years?
2. What are the ongoing and planned sanitation projects affecting service delivery for the next years in Kumasi? What results are expected? Who is going to implement those projects? What is the role of the KMA in the faecal sludge management?
    - Number of new public toilets and number of seats per block?
    - Number of compounds with toilets
    - Capacity of the Septage Treatment Plant.
3. How is the faecal sludge going to be emptied and transport?
4. What are the sanitation habits of poorest people (and immigrants) in Kumasi
5. In your opinion, is the OD going to increase or decrease in Kumasi?
6. Do you have any useful documents that can provide more information?

A.5.6 SEMI-STRUCTURE INTERVIEW FORM, KNUST

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- Identify their research in sanitation
- To know their opinion about sanitation in Kumasi.

Questions

1. Is the KNUST supporting the KMA work? How?
2. What are the main researches that KNUST is carrying on or has carried on in Kumasi related to sanitation?
3. In your opinion, how do the public toilets work, are they emptied? And the private sanitation in compounds?
4. Who is emptying the onsite facilities in the city? How effective are they? Now and in the future
5. How is the STP working?
6. What are the sanitation habits of poorest people (and immigrants) in Kumasi
7. In your opinion, is the OD going to increase or decrease in Kumasi? Do you have any evidence? To what extent, percentage? What areas are going to be more affected?
8. Do you have any useful documents that can provide more information?

A.5.7 SEMI-STRUCTURE INTERVIEW FORM, SFD EXPERTS

Date	
Name	
Institution	
Position	

Approval to continue the Interview

☐ The interviewee has been informed about the research, he/she agrees on participate in this study and he/she has given their consent to record this conversation.

Purpose of this interview

- To know their experience working on SFDs

Questions

1. What is your experience with SFDs?
2. Have been used the SFD for modelling different scenarios? Which ones and where? What methodology have you used?
3. What parameters are to be considered important for modelling future scenarios?
4. Do you have any useful documents that can provide more information?

Appendix 6: Table showing a quantitative analyse for each scenario

PARAMETERS	2015	2016	2017	2018	2019	2020	2921	2022	2023	2024	2025
Population growth rate	0										
Population	2,659,747										
Households	665,000										
People/per household	4										
OFFSITE SANITATION											
Containment											
WW Contained Descentralised	4%										
Transport											
WW delivered to treatment	4%										
Treatment											
WW treated	2%										
WW not treated	2%										
Disposal											
Safely Disposed	2%										
ONSITE SANITATION											
Containment											
FS Contained	93%										
Emptying											
FS contained (safely disposed)	18%										
FS emptied	75%										
Transport											
FS delivered to treatment	70%										
FS not delivered to treatment	5%										
Treatment											
FS treated	35%										
FS not treated	35%										
Disposal											
Safely Disposed	35%										
OPEN DEFECATION											
Open defecation	3%										
EXCRETA FLOW MANGAMENT											
Safely Management	**55%**										
Unsafely Management	**45%**										

OFFSITE SANITATION								
Population connected to the sewerage	101,753	101,753	101,753	101,753	101,753	101,753	101,753	101,7
Percentage of the population connected to the sewerage	4%	4%	3%	3%	3%	3%	3%	3%
DELIVERY WWTP								
Percentage delivery to treatment	80%	80%	80%	80%	80%	80%	80%	80%
WW TREATED								
Percentage treated	50%	50%	50%	50%	50%	50%	50%	50%
OPEN DEFECATION								
Population OD (if public toilets can meet the demand)	79,792	82,778	85,851	89,011	92,259	95,595	99,019	102,5
Percentage OD (if public toilets can meet the demand)	3.0%	2.95%	2.90%	2.85%	2.80%	2.75%	2.70%	2.65
Population OD (if public toilets CANNOT meet the demand)	79,792	99,545	164,308	232,308	303,704	378,664	457,365	539,9
Percentage OD (if public toilets CANNOT meet the demand)	3%	4%	6%	7%	9%	11%	12%	14%
ONSITE SANITATION								
PRIVATE TOILETS								
Population using PRIVATE TOILETS	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390	2,143,
Percentage of the population using PRIVATE TOILETS	54.0%	54.20%	54.40%	54.60%	54.80%	55.00%	55.20%	55.40
PUBLIC TOILETS								
Percentage of population using Public Toilets (SFD)	39%	38.6%	37%	35%	33%	31.2%	30%	28%
Population using Public Toilets	1,041,938	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,
Percentage of the public Toilet demand	39.17%	39.22%	39.26%	39.29%	39.31%	39.32%	39.33%	39.32
Population demanding public toilets	1,041,938	1,100,632	1,162,323	1,227,162	1,295,310	1,366,934	1,442,211	1,521,
Public toilet CAPACITY	39%	38.6%	36.6%	34.7%	32.9%	31.2%	29.6%	28.0
Maximum amount of People who could use the public toilets		1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,
Number of Public Toilets	360	376	376	376	376	376	376	376
Number of facilities	5792	6052	6052	6052	6052	6052	6052	605
Users per facilities per day	179	179	179	179	179	179	179	179
Users per facilities per hour[assuming they open from 4am to 11pm (19 hours)]	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Minutes per person	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Average min per person using the toilets						6.4		
Percentage of population relying on onsite sanitation (SFD)	93%	93%	91%	89%	88%	86%	85%	83%
EMPTYING								
number of public toilets	360	376	376	376	376	376	376	376
number of time emptying the public toilets per week	2	2	2	2	2	2	2	2
number of times that one public toilets have to be emptied per year	104	104	104	104	104	104	104	104
number of times that public toilets have to be emptied per year	37,440.00	39,104.00	39,104.00	39,104.00	39,104.00	39,104.00	39,104.00	39,104
percentage of private	54.0%	54.2%	54.4%	54.6%	54.8%	55.0%	55.2%	55.4
number of people relying in private toilets	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390	2,143,
number of people per compound	20	20	20	20	20	20	20	20
number of compound with toilets	71,813	76,044	80,522	85,263	90,282	95,595	101,220	107,1
Percentage of compound empting manually disposed safely or not emptied and covered in soil (5.11)	11%	10%	10%	9%	9%	8%	8%	7%
Number of compound empting manually disposed safely or not emptied and released into the environment)	7,899	7,899	7,899	7,899	7,899	7,899	7,899	7,89
Number of compound with toilets to be emptied by tankers	63,913.73	68,144.05	72,622.48	77,363.51	82,382.47	87,695.59	93,320.06	99,274
Total of installations to be emptied	101,353.73	107,248.05	111,726.48	116,467.51	121,486.47	126,799.59	132,424.06	138,37
Percentage of installation emptied with trucks (Furlong, 2015a)	95%	95%	95%	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	101,886	106,140	110,644	115,412	120,460	125,803	131,4
Tanker capacity	113,880	113,880	113,880	113,880	113,880	113,880	113,880	113,8
Number of installation that truck can ACTUALLY empty	96,286	101,886	106,140	110,644	113,880	113,880	113,880	113,8
Number of installation that remain without emptied	-	-	-	-	1,532	6,580	11,923	17,5
Percentage of installation emptied with trucks (SFD)	95%	95%	95%	95%	94%	90%	86%	82%
TREATMENT-truck size 7.5, treatment volume capacity 350m3/day								
Truck arriving at the TP per day	51	54	56	59	60	60	60	60
number of installations emptying by the trucks	96,286	101,886	106,140	110,644	113,880	113,880	113,880	113,8
Truck size	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Volume arriving m3/day	382.50	404.74	421.65	439.54	452.39	452.39	452.39	452.

Percentage of the population connected to the sewerage	4%	4%	5%	5%	5%	5%	5%
DELIVERY WWTP							
Percentage delivery to treatment	80%	80%	80%	80%	80%	80%	80%
WW TREATED							
Percentage treated	50%	50%	50%	50%	50%	50%	50%
OPEN DEFECATION							
Population OD (if public toilets can meet the demand)	79,792	82,778	85,851	89,011	92,259	95,595	99,019
Percentage OD (if public toilets can meet the demand)	3.0%	2.95%	2.90%	2.85%	2.80%	2.75%	2.70%
Population OD (if public toilets CANNOT meet the demand)	79,792	89,545	134,308	162,308	203,704	278,664	357,365
Percentage OD (if public toilets CANNOT meet the demand)	3.00%	3.19%	5%	5%	6%	8.0%	10%
ONSITE SANITATION							
PRIVATE TOILETS							
Population using PRIVATE TOILETS	1,436,264	1,530,870	1,640,439	1,775,259	1,905,638	2,011,901	2,124,390
Percentage of the population using PRIVATE TOILETS	54.0%	54.56%	55.41%	56.84%	57.83%	57.88%	57.93%
Population constructing new facilities in compounds	-	10,000	20,000	40,000	30,000	-	-
Total of population with new facilities in compound (accumulated)		10,000	30,000	70,000	100,000	100,000	100,000
% population benefited by the project		0.36%	1.01%	2.24%	3.03%	2.88%	2.73%
People living in each compound (at least)		20	20	20	20	20	20
Number of compounds constructing new facilities		500	1,500	3,500	5,000	5,000	5,000
Population trend in construction of public toilets-without project	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390
Trend in construction of public toilets-without project	54.0%	54.20%	54.40%	54.60%	54.80%	55.00%	55.20%
PUBLIC TOILETS							
Percentage of population using Public Toilets (SFD)	39%	38.6%	37%	35%	33%	31.2%	30%
Population using Public Toilets	1,041,938	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865
Percentage of the public Toilet demand	39.17%	38.87%	38.25%	37.05%	36.28%	36.45%	36.60%
Population demanding public toilets	1,041,938	1,090,632	1,132,323	1,157,162	1,195,310	1,266,934	1,342,211
Public toilet CAPACITY	39%	38.6%	36.6%	34.7%	32.9%	31.2%	29.6%
Maximum amount of People who could use the public toilets		1,083,865	1,083,865	1,083,865	1,083,865	1,083,865	1,083,865
Number of Public Toilets	360	376	376	376	376	376	376
Number of facilities	5792	6052	6052	6052	6052	6052	6052
Users per facilities per day	179	179	179	179	179	179	179
Users per facilities per hour [assuming they open from 4am to 11pm (19 hours)]	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Minutes per person	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Minimum min per person using the toilets						6.4	
Percentage of population relying on onsite sanitation (SFD)	93%	93%	92%	92%	91%	89%	87%
EMPTYING							
number of public toilets	360	376	376	376	376	376	376
number of time emptying the public toilets per week	2	2	2	2	2	2	2
number of times that one public toilets have to be emptied per year	104	104	104	104	104	104	104
number of times that public toilets have to be emptied per year	37,440.00	39,104.00	39,104.00	39,104.00	39,104.00	39,104.00	39,104.00
percentage of private	54.0%	54.6%	55.4%	56.8%	57.8%	57.9%	57.9%
number of people relying in private toilets	1,436,264	1,530,870	1,640,439	1,775,259	1,905,638	2,011,901	2,124,390
number of people per compound	20	20	20	20	20	20	20
number of compounds with toilets	71,813	76,544	82,022	88,763	95,282	100,595	106,220
Percentage of compound empting manually disposed safely or abandoned	11%	10%	10%	9%	8%	8%	7%
Number of compound empting manually disposed safely or not emptied and released into the environment	7,899.45	7,899	7,899	7,899	7,899	7,899	7,899
Number of compound with toilets to be emptied by tankers	63,913.73	68,644.05	74,122.48	80,863.51	87,382.47	92,695.59	98,320.06
Total of installations to be emptied	101,354	107,748	113,226	119,968	126,486	131,800	137,424
Percentage of installation emptied with trucks (Furlong, 2015a)	95%	95%	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	102,361	107,565	113,969	120,162	125,210	130,553
Tanker capacity	113,880	113,880	113,880	113,880	113,880	113,880	113,880
Number of installation that truck can ACTUALLY empty	96,286	102,361	107,565	113,880	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	95%	95%	95%	94.93%	90%	86%	83%
TREATMENT-truck size 7.5, treatment volume capacity 350m3/day							
Truck arriving at the TP per day	51	54	57	60	60	60	60

OFFSITE SANITATION							
Population connected to the sewerage	101,753	101,753	101,753	101,753	101,753	101,753	101,753
Percentage of the population connected to the sewerage	4%	4%	3%	3%	3%	3%	3%
DELIVERY WWTP							
Percentage delivery to treatment	80%	80%	80%	80%	80%	80%	80%
WW TREATED							
Percentage treated	50%	50%	50%	50%	50%	50%	50%
OPEN DEFECATION							
Population OD (if public toilets can meet the demand)	79,792	82,778	85,851	89,011	92,259	95,595	99,019
Percentage OD (if public toilets can meet the demand)	3.0%	2.95%	2.90%	2.85%	2.80%	2.75%	2.70%
Population OD (if public toilets CANNOT meet the demand)	79,792	99,545	85,851	89,011	92,259	95,595	99,019
Percentage OD (if public toilets CANNOT meet the demand)	3%	3.55%	2.90%	2.85%	2.80%	2.8%	2.70%
ONSITE SANITATION							
PRIVATE TOILETS							
Population using PRIVATE TOILETS	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390
Percentage of the population using PRIVATE TOILETS	54.0%	54.20%	54.40%	54.60%	54.80%	55.00%	55.20%
PUBLIC TOILETS							
Percentage of population using Public Toilets (SFD)	39%	38.6%	39%	39%	39%	39.3%	39.33%
Population using Public Toilets	1,041,938	1,083,865	1,470,704	1,470,704	1,470,704	1,470,704	1,470,704
Percentage of the public Toilet demand	39.17%	39.22%	39.26%	39.29%	39.31%	39.32%	39.33%
Population demanding public toilets	1,041,938	1,100,632	1,162,323	1,227,162	1,295,310	1,366,934	1,442,211
Public toilet CAPACITY	39%	38.6%	49.7%	47.1%	44.6%	42.3%	40.1%
Maximum amount of People who could use the public toilets		1,083,865	1,470,704	1,470,704	1,470,704	1,470,704	1,470,704
Number of Public Toilets	360	376	484	484	484	484	484
Number of facilities	5792	6052	8212	8212	8212	8212	8212
Users per facilities per day	179	179	179	179	179	179	179
Users per facilities per hour[assuming they open from 4am to 11pm (19 hours)]	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Minutes per person	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Minimum min per person using the toilets						6.4	
Percentage of population relying on onsite sanitation (SFD)	93%	93%	94%	94%	94%	94%	95%
EMPTYING							
number of public toilets	360	376	484	484	484	484	484
number of time emptying the public toilets per week	2	2	2	2	2	2	2
number of times that one public toilets have to be emptied per year	104	104	104	104	104	104	104
number of times that public toilets have to be emptied per year	37,440.00	39,104.00	50,336.00	50,336.00	50,336.00	50,336.00	50,336.00
percentage of private	54.0%	54.2%	54.4%	54.6%	54.8%	55.0%	55.2%
number of people relying in private toilets	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390
number of people per compound	20	20	20	20	20	20	20
number of compounds with toilets	71,813	76,044	80,522	85,263	90,282	95,595	101,220
Percentage of compound empting manually disposed safely or not emptied and covered in soil (5.11)	11%	10%	10%	9%	9%	8%	8%
Number of compound empting manually disposed safely or not emptied and released into the environment	7,899.45	7,899	7,899	7,899	7,899	7,899	7,899
Number of compound with toilets to be emptied by tankers	63,913.73	68,144.05	72,622.48	77,363.51	82,382.47	87,695.59	93,320.06
Total of installations to be emptied	101,353.73	107,248.05	122,958.48	127,699.51	132,718.47	138,031.59	143,656.06
Percentage of installation emptied with trucks (Furlong, 2015a)	95%	95%	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	101,886	116,811	121,315	126,083	131,130	136,473
Tanker capacity	113,880	113,880	113,880	113,880	113,880	113,880	113,880
Number of installation that truck can ACTUALLY empty	96,286	101,886	113,880	113,880	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	95%	95%	92.6%	89.18%	85.81%	83%	79%
TREATMENT-truck size 7.5, treatment volume capacity 350m3/day							
Truck arriving at the TP per day	51	54	60	60	60	60	60
number of installations emptying by the trucks	96,286	101,886	113,880	113,880	113,880	113,880	113,880
Truck size	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Volume arriving m3/day	382.50	404.74	452.30	452.30	452.30	452.30	452.30

Percentage of the population connected to the sewerage	4%	4%	3%	3%	3%	3%	3%
DELIVERY WWTP							
Percentage delivery to treatment	80%	80%	80%	80%	80%	80%	80%
WW TREATED							
percentage treated	50%	50%	50%	50%	50%	50%	50%
OPEN DEFECATION							
Population OD (if public toilets can meet the demand)	79,792	82,778	85,851	89,011	92,259	95,595	99,019
Percentage OD (if public toilets can meet the demand)	3.0%	2.95%	2.90%	2.85%	2.80%	2.75%	2.70%
Population OD (if public toilets CANNOT meet the demand)	79,792	89,545	85,851	89,011	92,259	95,595	99,019
Percentage OD (if public toilets CANNOT meet the demand)	3.00%	3.19%	2.90%	2.85%	2.80%	2.75%	2.70%
ONSITE SANITATION							
PRIVATE TOILETS							
Population using PRIVATE TOILETS	1,436,264	1,530,870	1,640,439	1,775,259	1,905,638	2,011,901	2,124,390
Percentage of the population using PRIVATE TOILETS	54.0%	54.56%	55.41%	56.84%	57.83%	57.88%	57.93%
Population constructing new facilities in compounds	-	10,000	20,000	40,000	30,000	-	-
Total of population with new facilities in compounds (accumulated)		10,000	30,000	70,000	100,000	100,000	100,000
% population benefited by the project		0.36%	1.01%	2.24%	3.03%	2.88%	2.73%
People living in each compound (at least)		20	20	20	20	20	20
Number of compounds constructing new facilities		500	1,500	3,500	5,000	5,000	5,000
Population trend in construction of public toilets-without project	1,436,264	1,520,870	1,610,439	1,705,259	1,805,638	1,911,901	2,024,390
Trend in construction of public toilets-without project	54.0%	54.20%	54.40%	54.60%	54.80%	55.00%	55.20%
PUBLIC TOILETS							
Percentage of population using Public Toilets (SFD)	39%	38.6%	38%	37%	36%	36.45%	36.60%
Population using Public Toilets	1,041,938	1,083,865	1,132,323	1,157,162	1,195,310	1,266,934	1,342,211
Percentage of the public Toilet demand	39.17%	38.87%	38.25%	37.05%	36.28%	36.45%	36.60%
Population demanding public toilets	1,041,938	1,090,632	1,132,323	1,157,162	1,195,310	1,266,934	1,342,211
Public toilet CAPACITY	39%	38.6%	49.7%	47.1%	44.6%	42.3%	40.1%
Maximum amount of People who could use the public toilets		1,083,865	1,470,704	1,470,704	1,470,704	1,470,704	1,470,704
Number of Public Toilets	360	376	484	484	484	484	484
Number of facilities	5792	6052	8212	8212	8212	8212	8212
Users per facilities per day	179	179	179	179	179	179	179
Users per facilities per hour[assuming they open from 4am to 11pm (19 hours)]	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Minutes per person	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Minimum min per person using the toilets on average						6.4	
Percentage of population relying on onsite sanitation (SFD)	93%	93%	94%	94%	94%	94%	95%
EMPTYING							
number of public toilets	360	376	484	484	484	484	484
number of time emptying the public toilets per week	2	2	2	2	2	2	2
number of times that one public toilets have to be emptied per year	104	104	104	104	104	104	104
number of times that public toilets have to be emptied per year	37,440.00	39,104.00	50,336.00	50,336.00	50,336.00	50,336.00	50,336.00
percentage of private	54.0%	54.6%	55.4%	56.8%	57.8%	57.9%	57.9%
number of people relying in private toilets	1,436,264	1,530,870	1,640,439	1,775,259	1,905,638	2,011,901	2,124,390
number of people per compound	20	20	20	20	20	20	20
number of compounds with toilets	71,813	76,544	82,022	88,763	95,282	100,595	106,220
Percentage of compound empting manually disposed safely or abandoned	11%	10%	10%	9%	8%	8%	7%
Number of compound empting manually disposed safely or not emptied and released into the environment	7,899.45	7,899	7,899	7,899	7,899	7,899	7,899
Number of compound with toilets to be emptied by tankers	63,913.73	68,644.05	74,122.48	80,863.51	87,382.47	92,695.59	98,320.06
Total of installations to be emptied	101,354	107,748	124,458	131,200	137,718	143,032	148,656
Percentage of installation emptied with trucks (Furlong, 2015a)	95%	95%	95%	95%	95%	95%	95%
Number of costumers demanding vacuum trucks services	96,286	102,361	118,236	124,640	130,833	135,880	141,223
Tanker capacity	113,880	113,880	113,880	113,880	113,880	113,880	113,880
Number of installation that truck can ACTUALLY empty	96,286	102,361	113,880	113,880	113,880	113,880	113,880
Percentage of installation emptied with trucks (SFD)	95%	95%	92%	87%	83%	80%	77%
TREATMENT-truck size 7.5, treatment volume capacity 350m3/day							

Appendix 11: Ethical Checklist