

SFD Promotion Initiative

Danang Vietnam

Final Report

This SFD Report was created through desk-based research by Sandec (the Department of Sanitation, Water and Solid Waste for Development) at Eawag (the Swiss Federal Institute of Aquatic Science and Technology) as part of the SFD Promotion Initiative.

Date of production: 13/11/2015

Last update: 16/12/2015

SFD Promotion Initiative

sustainable
sanitation
alliance

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

On behalf of



Federal Ministry
for Economic Cooperation
and Development


UNIVERSITY OF LEEDS

 **WORLD BANK GROUP**
Water

 **wsp**
water and
sanitation program

 **WEDC**  Loughborough
University



eawag
aquatic research

Sandec
Sanitation, Water and
Solid Waste for Development





SFD Report Danang, Vietnam, 2015

Produced by:

Hidenori Harada, Eawag/Sandec

Lars Schoebitz, Eawag/Sandec

Linda Strande, Eawag/Sandec

©Copyright

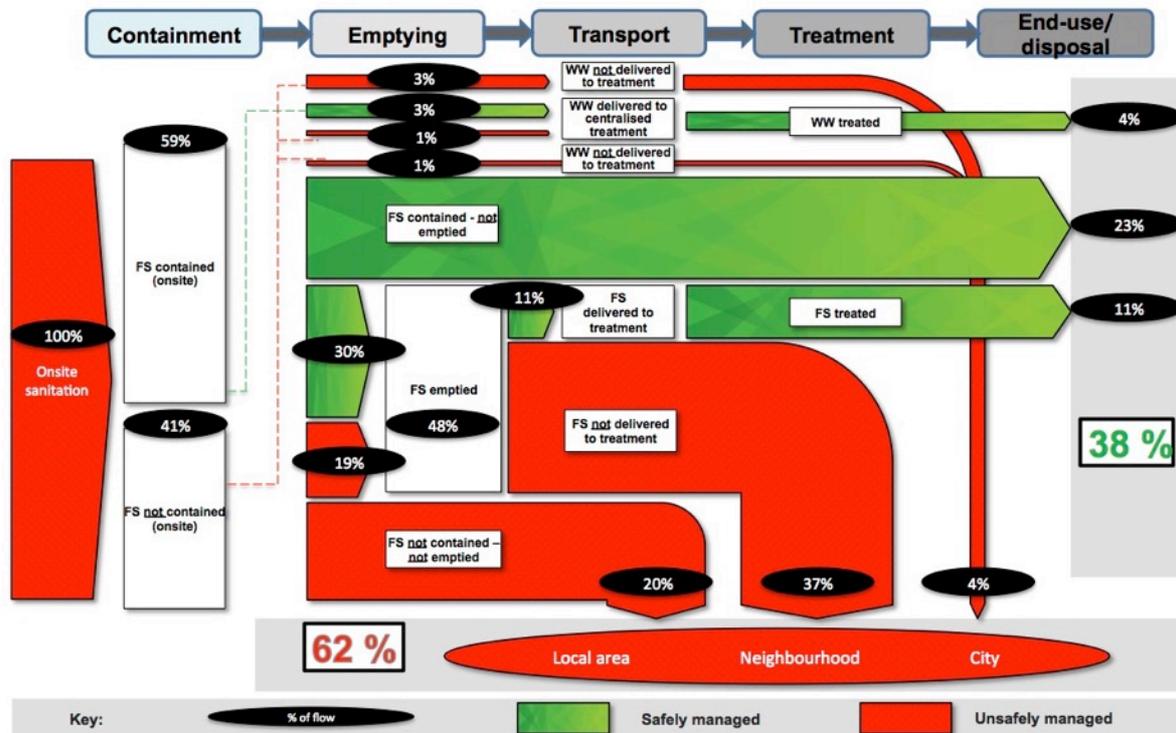
All SFD Promotion Initiative materials are freely available following the open-source concept for capacity development and non-profit use, so long as proper acknowledgement of the source is made when used. Users should always give credit in citations to the original author, source and copyright holder.

This Executive Summary and SFD Report are available from:

www.sfd.susana.org

1. The Diagram

Danang, Vietnam, 13.11.2015
Desk based assessment



Note: Percentages do not add up to 100 due to rounding

2. Diagram information

The Shit Flow Diagram (SFD) was created through desk-based research by Sandec (Sanitation, Water and Solid Waste for Development) of Eawag (the Swiss Federal Institute of Aquatic Science and Technology)

Collaborating partners:

Kyoto University, Japan
The University of Danang, Vietnam
Danang University of Technology, Vietnam

Status:

Final SFD. Not yet reviewed by external committee.

Date of production:

13/11/2015

3. General city information

Danang is located at the South Central Coast of Vietnam. It is the fourth most populated city in the country with approximately 1,007,400 inhabitants in 2014 (GSO 2015), and is a gateway of the East-West Economic Corridor running through Myanmar, Thailand, Laos, and Vietnam.

The total land area of the city is 1,285 km², including 65 km² of residential area (GSO

2015). Danang is divided into two rural districts and six urban districts, and the urban districts accounts for 87.3% of the total city population in 2013 (GSO 2015). Even among the urban districts population densities vary, with some areas being much denser.

The topography of Danang is highly variable, as the north and northwest of the city are located on the south edge of the Truong Son Mountain Range, and the east faces the Pacific Ocean. The city has a tropical monsoon climate with two distinct seasons, the typhoon/rainy season (September - March) and the dry season (April - August). Annual average temperature and rainfall are 26°C and 2,505 mm, respectively (Danang City 2015). Danang experiences flooding every few years. Hydrology issues include the tidal impact of the Pacific, and the Han River, which flows freely through central Danang (Opitz-Stapleton et al. 2009)

4. Service delivery context

Policy

At the national level, the Orientations for Development of Water Drainage in Vietnamese Urban Centers and Industrial Parks up to 2025 and a Vision Towards 2050 (No.1930.QD-TTg, 2009) is the key policy regarding wastewater treatment. However, only 10% of urban wastewater is treated in Vietnam (Pham & Kuyama 2013). The management of faecal sludge from septic tanks is specifically noted in the Decree on Drainage, Sewerage and Wastewater Treatment (No.80/2014/ND-CP): septic tanks shall be periodically emptied; emptying and transportation shall be done by specialized vehicles and equipment; faecal sludge shall be transported to approved sites; and the discharge of faecal sludge emptied from septic tanks into drainage or the environment is strictly prohibited. Notification that detail the decree are expected to be released. The National Strategy for Integrated Management of Solid Waste up to 2025, with a Vision to 2050 (No.2149/2009/QD-TTg) also specify the target of faecal sludge collection and treatment.

The city declared the Wastewater Management Strategy of Da Nang City Towards 2020 and Orientations Towards 2040 (8438/2010/QD-UBND) (GIZ 2014; DOT 2010; CDIA 2012). However, the concrete contents of these regulations could not be found during the research for this study.

Service provision

According to the national orientations above (No.1930/2009/QD-TTg), Danang has a target to achieve 70-80% of household wastewater collection and treatment by 2015. In addition, the city has its own target to up to 2020: 50% of households and 100% of all other wastewater producers are to be connected to treatment plants (No.8438/2010/QD-UBND) (GIZ 2014; DOT 2010). However, only 47% of urban wastewater is collected in Danang (NSC 2012).

According to the national strategy above (No.2149/2009/QD-TTg), the targets for the collection and treatment of faecal sludge up to environmental standards in Danang were set at 30%, 50% and 100% for 2015, 2020 and 2025, respectively. The city's own target from the aspect of solid waste management could not be found during the research for this study.

Service Standards

The Decision on the Issuance of Sector Standard: Sanitation Standard for all Kinds of Toilets (Lavatories) (No.08/2005/QD-BYT)

approved four types of on-site sanitation facilities: double vault toilets, VIP toilets, pour-flush toilets with a pit, and water flush toilets with a septic tank. Also, the Vietnamese Building Code approved by the Decision on Promulgating the Building Code of Vietnam (No. 682/1996/BXD-CSXD) mandates that all urban houses built since 1996 install a septic tank.

The treatment service standards are partly regulated in the National Technical Regulation of Domestic Wastewater (QCVN 14:2008) and in the General Environmental Requirements for Central Domestic Wastewater Treatment Plants (TCVN7222:2002). The service standards for emptying and transport does not exist (KII May 13, 2015; KII July 7, 2015).

5. Service outcomes

Thirty-eight (38%) of the excreta flow is classified as safely managed, and the remaining 62% was classified as unsafely management. The details are discussed along the sanitation service chain below.

Containment

Table 1 shows seven types of containment systems are used in the city (NSC 2010; Harada et al. 2011; Pham et al. 2012; Tran 2012; Pham 2014). There is no user interface which drains toilet wastes directly to combined sewer or open drain.

Of the excreta in the city, 59% (F2) are safely contained by septic tanks connected to soak pits without significant risk from groundwater pollution (47%), and septic tanks connected to combined sewers (13%). On the other hand, 41% (F10) of the excreta was not safely managed at the containment, which is mainly caused by septic tanks connected to soak pits at significant risk from groundwater pollution (31%). Based on the groundwater pollution risk decision matrix of the SFD calculation tool, septic tanks with soak pits in the area with access to the public water supply networks was regarded as safely contained, whereas that without access was regarded as unsafely contained.

Table 1: Sanitation containment systems in Danang

Description of systems (% coverage in the city)
Septic tank connected to a centralised combined sewer (12.6%)
Septic tank connected to a soak pit (46.7%)
Septic tank connected to a soak pit at significant risk from groundwater pollution (31.3%)

Septic tank connected to an open drain (3.1%)
Lined tank with impermeable walls and open bottom at significant risk from groundwater pollution (2.5%)
Lined pit with semi-permeable walls and open bottom at significant risk from groundwater pollution (2.5%)
Unlined pit at significant risk from groundwater pollution (1.3%)

Emptying

There are two types of emptying service providers: a public company, called the Danang Urban Environment Company (URENCO), and private emptying service providers. Both types of providers employ motorized emptying.

In reality, septic tanks are not emptied regularly, but only when a tank malfunctions (Pham et al. 2012). However, according to key informant interviews (KII Jul.7, 2015; KII Aug. 14, 2015), almost no households abandon septic tanks after they malfunction but have them emptied so they can continue using them. Therefore, this study assumed that 100% of the septic tanks are emptied in 9.5 year intervals (Pham et al. 2012). Since information of emptying services for other containment systems exist, this study assumed that 50% of the containment systems that are not septic tanks are emptied.

Forty-seven percent (48%, F3) of the excreta was emptied based on an important assumption: the proportion of faecal sludge in each septic tank (not effluent, supernatant, or infiltrate) is 50%, the default value of SFD calculation tool, and only the 50% was counted to be emptied. On the other hand, 43% of the faecal sludge is not emptied, and is derived from safe containment without emptying (F8: 23%), and unsafe containment without emptying (F15: 20%).

Transport

There are four types of transport systems in the city: combined sewer, open drain, vacuum trucks of URENCO, and vacuum trucks of private emptying service providers. Four percent (4%) of domestic wastewater was transported to wastewater treatment plants (W4a and W4c), whereas 4% (W11a and W11c) reached water bodies without treatment.

Of the faecal sludge, 11% (F4) was transported to a treatment plant, while 37% (F11) was not transported to a treatment plant. These estimations were made based on the following assumptions: average emptying frequency of septic tanks (every 9.5 years) and



Figure 1: A faecal sludge treatment plant of the Khanh Son Landfill (Source: Hidenori Harada/Kyoto Univ. 2009)

the average septic tank volume (3.62 m³) (Pham et al. 2012), transported amount of the Khanh Son Landfill in 2011 (10,687 tons). Of the emptied faecal sludge, 23.8% was transported to the landfill, while the remainder was not.

Treatment

Faecal sludge is treated at a faecal sludge treatment plant of the Khanh Son Landfill (Fig.1). The plant employs a sedimentation process. The sediment is landfilled, whereas supernatant is treated together by a leachate treatment process (DUEC 2006). Wastewater is treated at four centralized treatment plants employing anaerobic lagoons (NSC 2012). This study assumed that the excreta transported to these plants are adequately treated.

The total treated proportion was 15%, composed of 11% for faecal sludge (F5) and 4% for wastewater (W5a). Actually, 37% of the faecal sludge (F11) is not transported to a treatment plant, resulting in no treatment of this faecal sludge. This is the largest flow of unsafe management. Good transportation of the faecal sludge to a treatment plant followed by it being treated is crucial for improving the excreta flow.

In addition, half of the generated wastewater is not treated. Moreover, the treatment performance at the centralized wastewater treatment plants does not meet the effluent standards (WB 2013). If the SFD calculation could take into account the treatment performance, the proportion of wastewater treatment would decrease.

End-use and disposal

End-use of faecal sludge and of wastewater was not identified during the research of this study. Faecal sludge treated at the faecal sludge treatment plant is transported to designated landfill cells, together with sewage sludge (DUEC 2006). There is no available data of the disposal of faecal sludge emptied by private emptying service providers but

transported to the landfill, indicating improper discharge to the environment.

6. Overview of stakeholders

Stakeholders identified during the research of this study are summarized in Table 2. The People’s Committee of Danang is responsible for sanitation services in the city. Its responsibility is partly assigned to public companies/unit, including URENCO. Private emptying service providers also work but no detailed information exist.

Table 2: Stakeholders overview in Danang

Key Stakeholder	Institutions / Organizations
Public Institutions	Ministry of Natural Resources and Environment, Ministry of Construction, Ministry of Health, Danang People’s Committee, Department of Natural Resources and Environment, Department of Construction, URENCO, DDWMC, Danang Water Supply Company, Priority Infrastructure Investment Project Management Unit
Private Sector	Private emptying service providers
Multi/bi-lateral organization	WB, JICA, GIZ, ADB
Others	Academia such as Danang Univ. of Tech., The Univ. of Danang.

7. Credibility of data

Available quantitative data on sanitation services was limited in Danang. There was no quantitative data on the private emptying and transport of faecal sludge, as significant discharge is done illegally. Also, detailed data about sanitation containment systems, especially in rural areas, did not exist. For this reason, the SFD relied on a combination of high to low/middle credibility data sources including internet web sites, unpublished data, key informant interviews and assumptions.

8. Process of SFD development

A first draft SFD was made from secondary data available to desk-based research and through an interview with a sector expert (academia), and then expert comments were obtained. It was revised based on the expert interviews and further secondary data. Lastly,

expert comments were obtained on the revised SFD to create the final SFD.

9. List of data sources

CDIA, 2012. *Pre-feasibility studies in industrial waste water management and drainage systems, Danang: municipal wastewater*. SlideShare.

Danang City, 2015. Danang Portal.

Department of Transport, 2010. "Wastewater management strategy of Da Nang City towards 2020 and orientations towards 2040". News-Da Nang Department of Transport.

DUEC, 2006. *Khanh Son Sanitary Landfill operation manual*.

GSO, 2015. Statistical Handbook of Vietnam 2014.

GIZ, 2014. *Report on research on vacuum sewer collection system for Pilot Project An Hai Bac Ward in Eastern Coastal Area of Da Nang*.

Harada, H. et al., 2011. "Portfolio of toilet and on-site sanitation facility for urban sanitation in Asia". *In Proc. in the 48th Env. Eng. Forum*. 59–67.

Key informant interview, (Aug. 4, 2015).

Key informant interview, (Jul. 7, 2015).

Key informant interview, (May 13, 2015).

NSC, 2012. *Feasibility study of environmental sanitation in Danang, Vietnam*.

NSC, 2010. Report of feasibility study on the improvement of environmental sanitation in Danang.

Opitz-Stapleton, S. et al., 2009. *ACCORN: Responding to the Urban Climate Challenge*.

Pham, N.B. & Kuyama, T., 2013. Urban domestic wastewater management in Vietnam - Challenges and opportunities, WEPA, IGES.

Pham, N.A. et al., 2012. Effects of septic tank management on septage composition: a case study in Da Nang, Vietnam. *J. Sci.&Tech.*, **50**(1C), 138–144.

Pham, N.A., 2014. Study on household wastewater characterization and septic tanks’ function in urban areas of Vietnam. Ph.D dissertation, Kyoto University.

Tran, V.Q., 2012. *Project report on sanitation constraints classification and alternative evaluation for Asian Cities FY2011: Danang*, unpublished.

WB, 2013. *Da Nang priority infrastructure investment project: implementation completion and results report*.

Danang, Vietnam, 2015

Produced by:
Hidenori Harada, Sandec/Eawag
Lars Schoebitz, Sandec/Eawag
Linda Strande, Sandec/Eawag

© Copyright
All SFD Promotion Initiative materials are freely available following the open-source concept for capacity development and non-profit use, so long as proper acknowledgement of the source is made when used. Users should always give credit in citations to the original author, source and copyright holder.

This document is available from:
www.sfd.susana.org

SFD Promotion Initiative

sustainable sanitation alliance



Table of Content

Executive Summary	II
List of tables	VI
List of figures	VII
Abbreviations	VIII
1 City context.....	1
2 Service delivery context description/analysis	2
2.1 Policy, legislation and regulation	2
2.1.1 Policy.....	2
2.1.2 Institutional roles	3
2.1.3 Service provision.....	5
2.1.4 Service Standards.....	6
3 Service Outcomes	6
3.1 Overview.....	6
3.2 SFD Matrix.....	7
3.2.1 Technologies and methods used for different sanitation systems through the sanitation service chain.....	7
3.2.2 Risk of groundwater contamination.....	9
3.2.3 Percentages of population using the systems and services along the sanitation service chain	10
3.2.4 Discussion of certainty/uncertainty levels of associated data used for the SFD Matrix	17
4 Stakeholder Engagement.....	19
4.1 Key Informant Interviews	19
5 Acknowledgements	19
6 References	19
7 Appendix	23
7.1 Appendix 1: Stakeholder identification (Tab 2: Stakeholder Tracking Tool).....	23
7.2 Appendix 2: Tracking of Engagement (Tab 3: Stakeholder Tracking Tool).....	24
7.3 Appendix 3: SFD matrix.....	Error! Bookmark not defined.



List of tables

Table 1: Sanitation containment systems in Danang	II
Table 2: Stakeholders overview in Danang.....	IV
Table 3 Information that was used to assess the risk of groundwater pollution.....	10
Table 4 Percentages of types of sanitation containment systems in Danang.....	12
Table 5 Credibility of data sources.....	17
Table 6 Rubric to evaluate quality of data sources	18



List of figures

Figure 1: A faecal sludge treatment plant of the Khanh Son Landfill (Source: Hidenori Harada/Kyoto Univ. 2009)	III
Figure 2: Map of Danang (Danang City, 2015)	1
Figure 3 Structure of the Government of Danang. Adapted from Ostojic et al. (2007)	5



Abbreviations

DAWACO	Danang Water Supply Company
DDWMC	Danang Drainage and Wastewater Management Company
DOC	Department of Construction, Danang
DOH	Department of Health, Danang
DONRE	Department of Natural Resources and Environment, Danang
DOST	Department of Science and Technology, Danang
DOT	Department of Transport, Danang
MOC	Ministry of Construction
MOH	Ministry of Health
MONRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
PIIP	Priority Infrastructure Investment Project
SFD	Shit Flow Diagram
URENCO	Danang Urban Environment Company

1 City context

Danang is located at the South Central Coast of Vietnam. It is the fourth most populated city in the country with approximately 1,007,400 inhabitants in 2014 (GSO 2015), and is a gateway to the East-West Economic Corridor running through Myanmar, Thailand, Laos, and Vietnam.

The total land area of the city is 1285 km², which is composed of 586 km² forest, 72 km² agricultural land, 65 km² residential area, and 421 km² of specially used land^{1,2} (GSO 2013), meaning residential usage only accounts for 5.6% of the total land area. Danang is divided into two rural districts and six urban districts, and the population in the urban districts accounts for 87.3% of the total city population in 2013 (GSO 2015). Even among the urban districts population densities vary, with some areas being much denser.

The topography of Danang is highly variable, as the north and northwest of the city are located on the south edge of the Truong Son Mountain Range (700-1,500 m), and the east faces the Pacific Ocean. The city has a typical tropical monsoon climate with two distinct seasons, the typhoon/rainy season (September - March), and the dry season (April - August). The annual average temperature and rainfall are 26°C and 2,505 mm, respectively (Danang City 2015). Danang experiences flooding every few years. Hydrology issues include the tidal impact of the Pacific, and the Han River, which flows freely through central Danang without channelization (Opitz-Stapleton et al. 2009).



Figure 2: Map of Danang (Danang City, 2015)

¹ Specially used land is designated as land being used for purposes other than agriculture, forestry or living. It includes land used by offices and non-profit agencies, security and defence land, land for non-agricultural production and businesses and public land.

² The sum of the areas of four types of land uses does not be equal to 285 km² of the total land area. The reason is not written in GSO (2013) but the author guess the total area includes the area of lakes, rivers, etc., which does not included into four types of land uses.

2 Service delivery context description/analysis

2.1 Policy, legislation and regulation

2.1.1 Policy

National Level

There are three laws that relate to sanitation services: the Law on Environmental Protection (Law No.55/2014/QH13) (NAV 2014), the Law on Water Resources (Law No.17/2012/QH13) (NAV 2012), and the Law on Construction (Law No.23/2003/L/CTN) (NAV 2003). Further decrees, decisions, and circulars have been released as a result of these laws in regards to sanitation services. This report summarizes two aspects of Vietnamese policies impacting the sanitation service chain at the national level, which are included under wastewater management, and solid waste management.

In the context of urban wastewater management, sanitation services are mentioned in several legal documents that were produced at the national level. The Orientations for Development of Water Drainage in Vietnamese Urban Centers and Industrial Parks up to 2025 and a Vision Towards 2050 (Decision No.1930.QD-TTg) (GOV 2009a) is one of the key policies. This document outlines wastewater collection and treatment targets up to 2025 for cities depending on city grades³ as follows:

“In big urban centers of grade IV upwards, complete water drainage systems will be constructed to drain rain water, collect and treat wastewater”, and “urban centers of grade IV upwards will have consolidated domestic wastewater-collecting systems and treatment stations; the percentage of daily-life wastewater collected and treated will reach 70-80% and wastewater will be treated up to set standards. In urban centers of grade V, 50% of wastewater will be treated up to set standards.” (Decision No.1930.QD-TTg)

Although the national policy clearly mentions its targets on sanitation services, the targets seem to be challenging. According to Pham & Kuyama (2013), the total capacity nationwide of the 24 existing centralized wastewater treatment plants is about 670,000 m³/day, meaning only 10 percent of urban wastewater is treated in Vietnam.

To implement this, the Decree on Drainage, Sewerage and Wastewater Treatment (Decree No.80/2014/ND-CP) (GOV 2014), which replaced the Decree on Urban and Industrial-Park Water Drainage (Decree No.88/2007/ND-CP) (GOV 2007a), is a key legislation. As the change of the decree title indicates, the new decree (No.80) focuses more on treatment than the previous decree (No.88). It is notable that the management of faecal sludge from septic tanks was mentioned in the new decree for the first time. According to this decree, septic tanks shall be periodically emptied, emptying and transportation shall be done by specialized vehicles and equipment, faecal sludge shall be transported to the sites approved by the competent authorities, and discharge of faecal sludge from septic tanks to the drainage or

³ Urban centres are classified by six grades: special grade, grade I, grade II, grade III, grade IV, and grade V, according to the Decree on the Grading of Urban Centers (Decree No.42/2009/ND-CP) (2009c). Danang is classified as grade I.

the environment is strictly prohibited. Based on the decree, circulars that detail the regulations concerning faecal sludge management are expected to be released.

In the context of waste management, faecal sludge collection and treatment were noted in the National Strategy for Integrated Management of Solid Waste up to 2025, with a Vision to 2050 (No.2149/QD-TTg) (GOV 2009a) that was decided in 2009. In this strategy, specific targets to collect and treat faecal sludge to environmental standards in urban centres of grade II or higher were established for 2015, 2020 and 2025 at 30%, 50% and 100%, respectively, and at 10%, 30% and 50% for the remaining urban centres. However, the Decree on Solid Waste Management (No.59/2007/ND-CP) (GOV 2007c) defined solid waste as follows.

“Solid waste means waste in a solid form, discharged from production, business, service, daily life or other activities. Solid waste includes ordinary solid waste and hazardous solid waste.” (No.59/2007/ND-CP)

Faecal sludge is not specifically mentioned in this decree and is also not noted in the Decree on Environmental Protection Charges for Solid Wastes (No. 174/2007/ND-CP) (2007b). Revisions to these decrees were not found during the research for this study.

City Level

Danang has been a centrally governed city since 1997 and was allocated more political power compared to cities in other provinces. The central government and city government are the bodies that make policies for the city. Since this study could not access original legal documents at the city level, key information about Danang’s policy relating to sanitation services is summarized based on secondary data as follows.

From a general aspect of the environment, the city approved the project “Da Nang City- an Environmental City” in 2008, and the project set the targets to achieve by 2020, which includes the percentage of solid waste collected in coastal areas to be higher than 90%, and the percentage of solid waste recycled to be higher than 70% (APEREC 2015; Ostojic et al. 2007).

More closely related to faecal sludge management, the city declared the targets for 2020: 50% of households with wastewater connection to treatment plants, and 100% for other wastewater, according to the Wastewater Management Strategy of Da Nang City Towards 2020 and Orientations Towards 2040 (8438/QD-UBND, 03/11/2010) (GIZ 2014; DNDT 2010; WB 2013b). It is the first strategy at a city level in Vietnam, covering wastewater collection and treatment, preparation of an implementation plan, and detailed assignation of responsibilities to each agency and department of the city. In addition, the city decided on solid waste management (Decision no. 3903/QD-UB) and environmental protection (Decision 23/2010/QD-UBND), and established regulations on the management, allocation and payment of urban environmental sanitation services (Decision No. 166/2004/QD-UB) (Pham 2012). However, the concrete contents of these regulations could not be found during the research for this study.

2.1.2 Institutional roles

At the ministry level, the responsibilities for sanitation services are divided into several institutional bodies, such as the Ministry of Construction (MOC), the Ministry of Natural

Resources and Environment (MONRE), the Ministry of Health (MOH), and the Ministry of Science and Technologies (MOST) (Pham & Kuyama 2013). For example, MOC is responsible for development planning, MONRE is responsible for environmental water protection and MOH is responsible for the basic design guideline of sanitary toilets. However, these responsibilities have partial overlap.

At the city level, the People's Committee of Danang is responsible for sanitation services in Danang. Under the People's Committee, there are corresponding departments to each ministry, such as the Department of Construction (DOC), the Department of Natural Resources and Environment (DONRE), the Department of Health (DOH), and the Department of Science and Technology (DOST) as shown in Figure 3. The People's Committee has the responsibility, but assigns it to the relevant units. Circular No. 09/2009/TT-BXD (MOC 2009) enacted in 2009 allows the People's Committee of urban centres to assign responsibility to capable specialized units. The management and operation of sanitation services are assigned to four companies/units: the Danang Urban Environment Company (URENCO) for solid waste collection and disposal, the Danang Water Supply Company (DAWACO) for water supply, the Danang Drainage and Wastewater Management Company (DDWMC) for drainage and wastewater collection and treatment, and the Priority Infrastructure Investment Project (PIIP) Management Unit for the World Bank Priority Investment Projects.

Wastewater collection and treatment is the responsibility of DDWMC, and solid waste collection and disposal is the responsibility of URENCO. However, the responsibility of faecal sludge collection and treatment is not clear. At the ministry level, faecal sludge management was mentioned in legal documents in the context of wastewater management (as mainly the responsibility of MOC), as well as solid waste management (as mainly the responsibility of MONRE). This study could not access the legal documents at the city level, and the legal responsibility for these services is not clear. Practically URENCO, oversighted by DONRE, is providing the services for faecal sludge emptying, transportation, and treatment (Pham 2014); it is the only official emptying service provider in the city and is the operator of the public landfill of the city, which includes a faecal sludge treatment plant (DUEC 2006). Moreover, private emptying service providers also work in Danang, which is indicated by advertisements of emptying services on local newspapers.

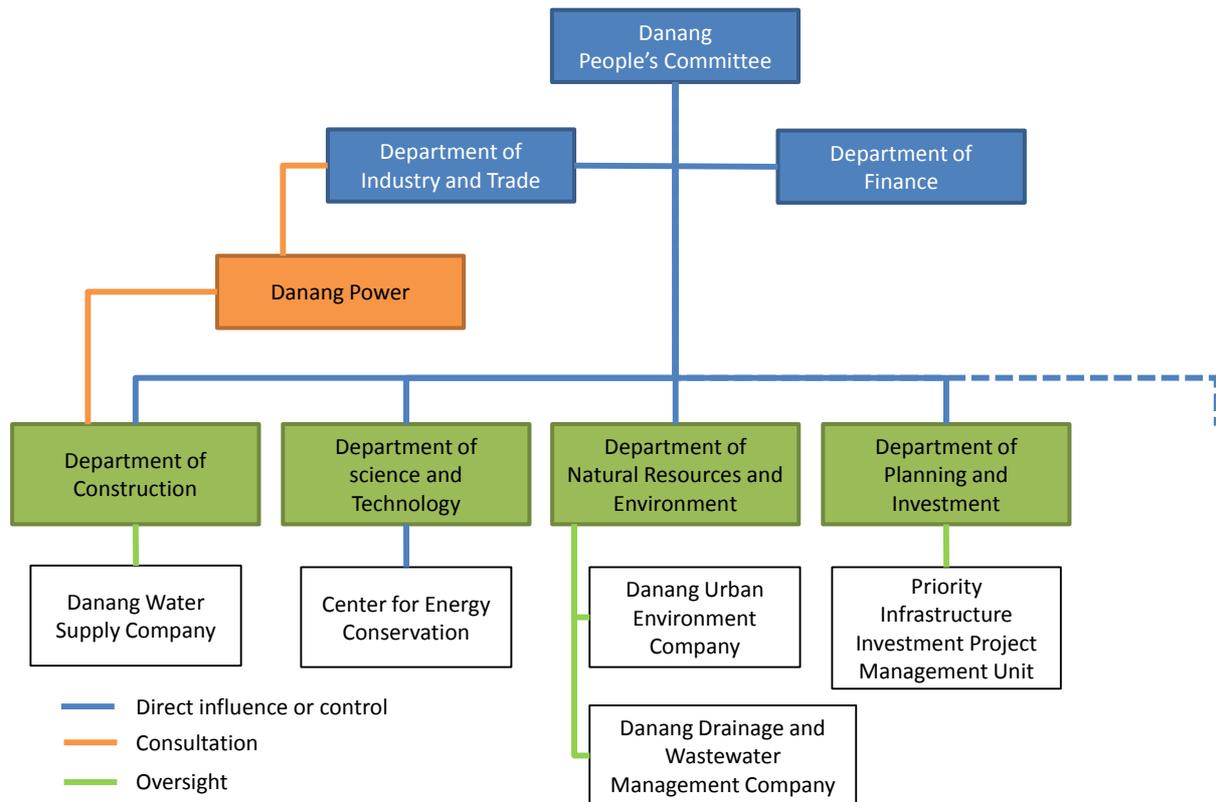


Figure 3 Structure of the Government of Danang. Adapted from Ostojic et al. (2007)

2.1.3 Service provision

Targets related to sanitation services provision in urban centres depending on city grades were declared from the perspective of wastewater management in the Orientations for Development of Water Drainage in Vietnamese Urban Centers and Industrial Parks up to 2025 and a Vision Towards 2050 (Decision No.1930.QD-TTg) (GOV 2009b), as mentioned in 2.1.1. Since Danang is classified as a grade I city, the target percentage of household wastewater to be collected and treated is 70-80%, according to the national orientation. At the city level, the city has its own target up to 2020: 50% of households and 100% of all other wastewater producers are to be connected to treatment plants, according to the Wastewater Management Strategy of Da Nang City towards 2020 and Orientations Towards 2040 (8438/QD-UBND, 03/11/2010) (GIZ 2014; DOT 2010; CDIA 2012).

Concerning solid waste management, faecal sludge emptying and treatment targets were noted in the National Strategy for Integrated Management of Solid Waste up to 2025, with a Vision to 2050 (No.2149/QD-TTg) (GOV 2009a), as mentioned in 2.1.1. Specific target for the collection and treatment of faecal sludge up to environmental standards in urban centres of grade II or higher grades, including Danang, were set at 30%, 50% and 100% for 2015, 2020 and 2025, respectively. At the city-level, this study could not confirm the city's own target in terms of solid waste management.

Separately, since 1996, all newly built houses in urban centres in Vietnam are required to install a septic tank, according to the Vietnamese Building Code approved by the Decision on Promulgating the Building Code of Vietnam (Decision No. 682/BXD-CSXD) (MOC 1996). No

target was confirmed for the provision of septic tanks based on this decision, but this requirement is applied to all housing in urban centres constructed after 1996.

2.1.4 Service Standards

The containment service standards are partly described in some regulations. The Decision on the Issuance of Sector Standard: Sanitation Standard for all Kinds of Toilets (Lavatories) (Decision No. 08/2005/QD-BYT) (MOH 2005) regulates toilets and latrines in Vietnam. It approved four types of on-site sanitation facilities with simple itemized design specifications: double vault toilets, VIP toilets, pour-flush toilets with a lined pit, and water flush toilets with a septic tank. For example, pour-flush toilets should be located at least 10 m away from water resources used for drinking and living, and excreta container tanks should always be lined and not leak. However, pit latrines that were not fully lined are used in Danang (KII July 7, 2015), suggesting that these standards are not fully enforced. Also, the Vietnamese Building Code approved by the Decision on Promulgating the Building Code of Vietnam (Decision No. 682/BXD-CSXD) (MOC 1996) described the installation of septic tanks, but the research for this report could not confirm the details during the research of this study.

The treatment service standards are partly regulated in the National Technical Regulation of Domestic Wastewater (QCVN 14:2008/BTNMT) (GOV 2008) and in the General Environmental Requirements for Central Domestic (municipal) Wastewater Treatment Plants (TCVN7222:2002) (GOV 2002) if the wastewater does not contain industrial wastewater and is not used for agriculture and aquaculture. In the case of wastewater treatment plants in Danang, the effluent water quality standards include 10-30 mg-BOD/L, 10-30 mg-SS/L, 15-30 mg-TN/L, and 5-12 mg-TP/L (NSC 2010). The service standards for emptying, transport and end-use/disposal, and monitoring does not exist in Danang (KII May 13, 2015; KII July 7, 2015).

3 Service Outcomes

3.1 Overview

Regarding onsite containment of excreta, septic tanks are the dominant technology in Danang (NSC 2010; Harada et al. 2011; Tran 2012; Pham 2014). This is because the Vietnamese Building Codes mandate that the urban population use septic tanks. In contrast to Hanoi, the typical receiving environment of septic tank effluent was different. Most septic tanks in Danang are connected to soak pits, and some of them are connected to combined sewers or open drains (Tran 2012). Whereas in Hanoi, most septic tanks discharge to open channels or sewers (Harada et al. 2008). A small portion of the population living far from urban areas use unlined pit latrines; closer to urban areas, lined pit latrines and partially permeable lined pit latrine are in use according to expert interviews (KII July 7, 2015).

Regarding offsite sanitation systems, wastewater is collected through combined sewer or open drain; the city has four domestic wastewater treatment plants with a total capacity of 95,000 m³/day in 2008, with plans to build two more plants by 2040 (Tran 2012; NSC 2010). Currently, around 60% of the population and 16-20% of the land area of Danang is served by these treatment plants (Tran 2012). The treatment process of the existing plants include primary screening, a grit chamber, and an anaerobic lagoon (Tran 2012). According to the

Vietnamese Building Code, in principle, all urban housing needs to have a septic tank. Even if houses are connected to a sewer network, a septic tank still has to be installed under this code. Direct discharge of human waste from a toilet to a sewer is not allowed. Therefore, even in sewered areas, the number of households connected to the sewer without septic tanks is negligible.

Faecal sludge is collected and transported with vacuum trucks by URENCO, and is disposed of at the Khanh Son Landfill, which is owned and operated by URENCO (Pham et al. 2012). At the landfill there is a plant to treat septage (faecal sludge from septic tanks), which is called a septage consolidation unit (DUEC 2006). Faecal sludge collected by URENCO is, transported, discharged and treated at this plant.

A significant amount of faecal sludge are also collected and transported by private emptying service providers. Advertisements for their services can be seen in newspapers. A part of this faecal sludge is discharged at the Khanh Son Landfill (KII 2015b), meaning the remaining part of faecal sludge emptied by private emptying service providers is not transported to the only one faecal sludge treatment plant in the city. Although information of the transport by private emptying service providers does not exist, it seems to be discharged to the environment without proper treatment.

3.2 SFD Matrix

3.2.1 Technologies and methods used for different sanitation systems through the sanitation service chain

- Containment

There are five types of containment systems in Danang (NSC 2010; Harada et al. 2011; Pham et al. 2012; Tran 2012; Pham 2014):

- Septic tank with effluent draining to soak pit
- Septic tank with effluent draining to combined sewer, or open drain
- Lined tank with impermeable walls and open bottom, no outlet or overflow
- Lined pit with semi-permeable walls and open bottom, no outlet or overflow
- Unlined pit, no outlet or overflow

There is basically no user interface, which drains toilet wastes directly to combined sewer or open drain.

Emptying

All containment systems in Danang accumulate faecal sludge and eventually need to be emptied. However, most are emptied only after the system has malfunctioned (Pham et al. 2012), making the emptying of faecal sludge a great challenge.

Emptying service providers in Danang are URENCO or private emptying service providers; they are mechanized and use vacuum trucks (Tran 2012; Pham 2014). There are no records of volumes of faecal sludge emptied in Danang, but the amount transported to the Khanh Son Landfill is recorded with a truck scale at the entrance of the landfill. Emptying by private

emptying service providers is significant as mentioned above, but there is no quantitative information at all concerning the emptying volume by private emptying service providers.

- Transport

There are four types of transport systems in Danang (NSC 2010; Pham et al. 2012; World Bank 2013b; Tran 2012; Pham 2014):

- combined sewer
- open drain
- vacuum trucks of URENCO
- vacuum trucks of private emptying service providers.

Combined sewers and open drains transport effluent from septic tanks and greywater. In Danang, the transport of septic tank effluent is limited since the majority of septic tanks are connected to soak pits (NSC 2010; Tran 2012; World Bank 2013b). Therefore, domestic wastewater discharged from housing to combined sewers and open drains seems to contain mainly greywater while that from a small proportion of the homes also contains septic tank effluent. Forty seven percent (47%) of the domestic wastewater from urban districts is transported to wastewater treatment plants (NSC 2012). The remaining 53% of the urban domestic wastewater and rural domestic wastewater seems to reach water bodies without treatment.

Faecal sludge collected by URENCO is transported to the faecal sludge treatment plant at the Khanh Son Landfill. A part of faecal sludge collected by private emptying service providers are also transported to the landfill. The transported amount is recorded by the truck scale at the site. Although the amounts by UENCO and by private emptying service providers are not separately recorded, according to the interview to a plant manager (KII March 7, 2012), most faecal sludge is transported to the Khanh Son landfill by URENCO. There is no information on the transport which is emptied by private emptying service providers but transported to the landfill.

- Treatment

Danang has four centralized domestic wastewater treatment plants (Hua Cuong, Ngu Hang Son, Phu Loc, and Son Tra), their total capacity was 95,000 m³/day in 2008, and it plans to build two more plants (NSC 2010; Tran 2012). As mentioned above, forty seven percent (47%) of the urban domestic wastewater is transported to the plants and then treated (NSC 2012). However, the treatment performance is not appropriate. The number of days per year of wastewater treatment performance exceeding design capacity in flows and effluent standards for BOD and SS were 360 in 2008 and 292 in 2013 (WB 2013b). The remaining 53% of urban domestic wastewater and rural domestic wastewater are not treated by the centralized treatment plants, indicating it reaches water bodies without further treatment.

Faecal sludge collected and transported by URENCO is treated at the faecal sludge treatment plant at the Khanh Son Landfill. Treatment is gravity thickening. The settled sludge

is pumped to and disposed of at landfill cells. The supernatant is treated together at a leachate treatment process, which consists of an anaerobic lagoon and two facultative lagoons in series (DUEC 2006). There is no available information at all on the treatment of faecal sludge emptied by private emptying service providers but transported to the landfill.

-End-use and disposal

End-use of faecal sludge and wastewater was not identified during the research of this study. Sewage sludge from wastewater treatment plants is transported to the Khanh Son Landfill (NSC 2010). Faecal sludge treated at the plant is transported to designated landfill cells, together with sewage sludge (DUEC 2006). There is no available data of the disposal of faecal sludge emptied by private emptying service providers but transported to the landfill. As mentioned above, a significant proportion of faecal sludge emptied by private emptying service providers does not treated and disposed at the landfill, indicating improper discharge to the environment.

3.2.2 Risk of groundwater contamination

Public water supply networks serve approximately 500,000 inhabitants of Danang, and their source water is obtained from upstream river water (DWSC 2015). Residents drink tap water and/or bottled water in public water supply network areas (Imada et al. 2012), meaning that these 500,000 inhabitants, equivalent to 62.4% of the total population, do not use groundwater for drinking purposes. According to the groundwater pollution risk decision matrix of the SFD calculation tool, if the percentage of drinking water produced from groundwater users is less than 25%, the groundwater pollution risk is regarded as low. Therefore, the risk level from groundwater pollution for this 62.4% of the population was regarded as low.

The remaining 37.6% population without access to the public water supply network use groundwater and/or bottled water for drinking purposes and might face significant risk from groundwater pollution (KII Jul, 15, 2015). Table 3 presents the information that was used for the groundwater pollution risk decision matrix of the SFD calculation tool for urban and rural areas without access to the public water supply network. Due to limited availability of information, the information on rock type in unsaturated zone and on depth to groundwater table was used from neighbouring areas, and the percentage of sanitation facilities that are located less than 10 m from groundwater sources is based on key informant interview (KII Aug. 14, 2015). Based on the decision matrix, the risk was determined for four containment systems employing infiltration of faecal sludge in the area without access to a public water supply network: septic tanks connected to soak pits, lined tank with impermeable walls and open bottom, lined pits with semi-permeable walls, and unlined pits.

Table 3 Information that was used to assess the risk of groundwater pollution

Item	Estimates in the study area	Source of estimates
Rock type in unsaturated zone	Sand	(Thuy et al. 2000)
Depth to groundwater table	>10 m	(WB 2013a)
Percentage of sanitation facilities that are located less than 10 m from groundwater sources	Greater than 25%	(KII Aug. 14, 2015)
Percentage of drinking water produced from groundwater sources	Greater than 25%	(GSO 2012)
Water production technology	Mostly protected wells	(GSO 2012)

3.2.3 Percentages of population using the systems and services along the sanitation service chain

Preparation of data inputted into the SFD calculation tool

Key informant interviews confirmed that there is limitation of available quantitative data about faecal sludge management in Danang (KII May 13, 2015; KII Jul. 7, 2015). Most data obtained through this study was not suitable to be used directly in the production of the Shit Flow Diagram (SFD). It was therefore necessary to make assumptions to convert the data into a usable format for the SFD calculation tool. Following is an explanation of all assumptions.

- Containment

As explained in section 3.2.1, five types of containment systems were identified in Danang. Since housing in urban areas in Vietnam are required to be equipped with septic tanks, according to the Vietnamese Code of Building (MOC 1996), this report assumes that 100% of the urban population in Danang uses septic tanks.

$$ST_{urban} = P_{urban} \tag{Eq. 1}$$

where ST_{urban} = proportion of septic tanks in urban areas, and

P_{urban} = proportion of urban population (87.3%, GSO (2015)).

The receiving environment of the effluent from septic tanks are soak pits, combined sewer, or open drain (3.2.1). According to Tran (2012), the proportion of the population using a septic tank draining effluent to combined sewers or open drains is 15.7%. As there is no available data on each proportion of septic tanks draining effluent to the combined sewer and of those draining to open drain, based on a key informant interview (KII Jul. 7, 2015), this study assumed that 80% of the septic tanks drain effluent to combined sewers and 20% to open drains in urban areas. Each proportion was calculated as follows:

$$ST_{urban+cs} = ST_{urban+cs/od/d} \times 0.8 \quad (\text{Eq. 2})$$

$$ST_{urban+od/d} = ST_{urban+cs/od/d} \times 0.2 \quad (\text{Eq. 3})$$

where $ST_{urban+cs/od}$ = proportion of septic tanks in urban areas draining effluent to combined sewers or open drains (15.7%),

$ST_{urban+cs}$ = proportion of septic tanks in urban areas draining effluent to combined sewers (12.56%), and

$ST_{urban+od}$ = proportion of septic tanks in urban areas draining effluent to open drains (3.14%).

Urban septic tanks not draining to combined sewers or open drains are connected to soak pits. Septic tanks with soak pits without access to public water supply networks are at significant risk from groundwater pollution, as mentioned in 3.2.2. Thus, this study estimated the proportion of septic tanks with and without a significant risk of groundwater pollution as follows:

$$ST_{urban+sp} = ST_{urban} - ST_{urban+cs/od} \quad (\text{Eq. 4})$$

$$ST_{urban+sp-risk} = WS - ST_{urban+} - ST_{urban+od} \quad (WS > ST_{urban+cs/od}) \quad (\text{Eq. 5})$$

$$ST_{urban+sp+risk} = ST_{urban+sp} - ST_{urban+sp-risk} \quad (\text{Eq. 6})$$

Where $ST_{urban+sp}$ = proportion of septic tanks in urban areas draining effluent to soak pits (71.6%).

$ST_{urban+od-risk}$ = proportion of septic tanks in urban areas draining effluent to open drains without a significant risk from groundwater pollution (3.14%),

$ST_{urban+sp-risk}$ = proportion of septic tanks in urban areas draining effluent to soak pits, without significant risk from groundwater pollution (46.7%),

WS = proportion of population with access to public water supply networks (62.4%), and

$ST_{urban+sp+risk}$ = proportion of septic tanks in urban areas draining effluent to soak pits, at significant risk from groundwater pollution (24.9%).

A significant proportion of the rural population also use septic tanks according to key informant interview (KII Jul. 7, 2015), but there is no available statistics on this proportion. An assumption was made that 50% of the rural population use septic tanks. Also, since drainage systems are typically not well established in rural areas, these rural septic tanks were assumed to be connected to soak pits. The public water supply networks are limited in a part of urban areas (DWSC 2015), meaning that people use groundwater. These septic tanks are at significant risk from groundwater pollution:

$$ST_{rural+sp} = P_{rural} \times 0.5 \quad (\text{Eq. 7})$$

$$ST_{rural+sp+risk} = ST_{rural+sp} \quad (\text{Eq. 8})$$

where $ST_{rural+sp}$ = proportion of septic tanks in rural areas with connection to soak pits (6.35%),

P_{rural} = proportion of rural population (12.7%), and

$ST_{rural+sp+risk}$ = proportion of septic tanks in rural areas draining effluent to soak pits, at significant risk from groundwater pollution (6.35%).

It was assumed that the remaining 50% of the rural population uses pit latrines or toilets connected to tanks. No quantitative information exists concerning the proportion of each type of pit latrines or toilets connected to a lined/unlined tank with impermeable/semi-permeable walls. Based on key informant interviews (KII Jul. 7, 2015; KII Jul. 15, 2015), the ratio of a lined tank with impermeable walls and open bottom, a lined pit with semi-permeable walls and open bottom, and an unlined pit were assumed to be 40%, 40%, and 20%, respectively. Each proportion was calculated as follows. Similarly to the septic tanks connected to soak pit in rural areas, these containment systems are at significant risk from groundwater pollution.

$$Tank_{pit} = P_{rural} \times 0.5 \quad (\text{Eq. 9})$$

$$Tank_{lined+per} = Tank_{pit} \times 0.4 \quad (\text{Eq. 10})$$

$$Tank_{lined+semi-per} = Tank_{pit} \times 0.4 \quad (\text{Eq. 11})$$

$$Tank_{unlined} = Tank_{pit} \times 0.2 \quad (\text{Eq. 12})$$

where $Tank_{pit}$ = proportion of pit latrines or toilets connected to a tank (6.35%),

$Tank_{lined+imper}$ = proportion of toilets connected to lined tanks with impermeable walls and open bottom (2.54%),

$Tank_{lined+semi-per}$ = proportion of toilets connected to lined tanks with semi-impermeable walls and open bottom (2.54%), and

$Pit_{unlined}$ = proportion of an unlined pit (1.27%).

All of the estimations for sanitation containment systems in Danang are summarized in Table 4.

Table 4 Percentages of types of sanitation containment systems in Danang

Tab1 ref	Description of sanitation containment system	Estimated proportion
T1A2C1	Septic tank connected to a centralised combined sewer	$ST_{urban+cs}$ (12.56%)
T1A2C5	Septic tank connected to a soak pit	$ST_{urban+sp-risk}$ (46.7%)
T2A2C5	Septic tank connected to a soak pit at significant risk from groundwater pollution	$ST_{urban+sp+risk} + ST_{rural+sp+risk}$ (31.25%)
T1A2C6	Septic tank connected to an open drain	$ST_{urban+od}$ (3.14%)

T2A4C10	Lined tank with impermeable walls and open bottom, no outlet or overflow, at significant risk from groundwater pollution	$Tank_{lined+imper}$ (2.54%)
T2A5C10	Lined pit with semi-permeable walls and open bottom, no outlet or overflow, at significant risk from groundwater pollution	$Tank_{lined+semi-per}$ (2.54%)
T2A6C10	Unlined pit, no outlet or overflow, at significant risk from groundwater pollution	$Pit_{unlined}$ (1.27%)

- Emptying

In reality, septic tanks are not emptied regularly, but only when a tank has malfunctioned (Pham et al. 2012). However, according to key informant interviews (KII Jul.7, 2015; KII Aug. 14, 2015), almost no households abandon septic tanks after they malfunction but have them emptied so they can continue using them. Therefore, this study assumed that 100% of the septic tanks (T1A2C1, T1A2C5, T2A2C5, and T1A2C6 in Table 4) are emptied in 9.5 year intervals (Pham et al. 2012). Since the proportion of the content of each septic tank / lined tank / unlined tank which is faecal sludge could not be determined, this report used the default value of 50% for this proportion. The SFD calculation tool calculated that 50% of the faecal sludge from each septic tank is emptied, whereas the remaining 50% is not.

The other sanitation containment systems (T2A4C10, T2A5C10, T2A6C10) are located in rural areas, where URENCO generally does not provide any services. These could be emptied by private emptying service providers. However, as quantitative information of private emptying services is not available (3.2.1), there is no available information of emptying in rural areas. This report assumed that 50% of the containment systems that are not septic tanks are emptied.

- Transport

Faecal sludge emptied by URENCO is transported to the septage consolidation unit of the Khanh Son Landfill as mentioned above, also some of the faecal sludge emptied by private emptying service providers is transported to this site according to key informant interview (KII May 13, 2015). Records from the truck scale at the landfill are the only available data of collected faecal sludge. However, it does not distinguish between faecal sludge collected by URENCO and that by private emptying service providers.

In 2011, 10,687 tons of faecal sludge from septic tanks was transported to the landfill based on the truck scale records (Anonymous 2012). The amount of the sludge transported to a treatment plant and the amount not transported to a treatment plant was estimated as follows.

Firstly, the volume of faecal sludge accumulated in septic tanks in Danang was estimated by the following equations:

$$Po_{st} = Po \times (ST_{urban+cs} + ST_{urban+sp-risk} + ST_{urban+sp+risk} + ST_{rural+sp+risk})$$

$$+ST_{urban+od})/100 \quad (\text{Eq. 13})$$

$$N_{st} = PO_{st}/N_{user,per-st} \quad (\text{Eq. 14})$$

$$V_{fs,st} = V_{st} \times N_{st} \times P_{fs-st} \quad (\text{Eq. 15})$$

where PO_{st} = Population using septic tanks (943,000 persons),
 PO_{urban} = Population in Danang (1,007,400 persons),
 N_{st} = Number of septic tanks (236,000 tanks),
 $N_{user,per-st}$ = Number of users per a septic tank (4 persons, Pham et al. (2012)),
 $V_{fs,st}$ = Volume of faecal sludge in septic tanks (427,000 m³),
 V_{st} = Volume of a septic tank in Danang (3.62 m³, Pham et al. (2012)),
 P_{fs-st} = Proportion of each septic tank which is faecal sludge (i.e. not effluent, supernatant or infiltrate) (0.5, default value of *SFD calculation tool*).

Secondly, the average frequency of emptying from septic tanks was reported to be 9.5 years (Pham et al. 2012) and given this, the total amount of sludge emptied in a year was calculated as follows:

$$V_{fs,st,emp-annual} = V_{fs,st}/F_{emp}$$

where F_{emp} = Frequency of emptying (9.5 years, Pham et al. (2012)), and
 $V_{fs,emp/year}$ = Volume of faecal sludge from septic tanks emptied per year (44,900 m³/year).

Thus, since the amount of faecal sludge transported to the Khanh Son Landfill was known, the amount of faecal sludge transported and not transported to the treatment plant, and the proportion of each of them were estimated as follows:

$$V_{fs,emp/year,to-plant} = V_{fs,KS\ record/year}$$

$$V_{fs,emp/year,not-to-plant} = V_{fs,emp/year} - V_{fs,emp/year,to-plant}$$

$$P_{fs,emp,to-plant} = V_{fs,emp/year,to-plant}/V_{fs,emp/year}$$

$$P_{fs,emp,not-to-plant} = V_{fs,emp/year,not-to-plant}/V_{fs,emp/year}$$

where $V_{fs,st,emp-annual,to-plant}$ = Volume of faecal sludge emptied and transported to a treatment plant per year (10,687 m³/year),
 $V_{fs,KS\ record/year}$ = Volume of faecal sludge transported to the Khanh Son Landfill per year based on the record of a track scale (10,687 m³/year, Anonymous (2012)),
 $V_{fs,emp/year,not-to-plant}$ = Volume of faecal sludge emptied but not transported to a treatment plant per year (34,213 m³/year),

$P_{fs,emp,to-plant}$ = Proportion of faecal sludge which transported to a treatment plant (23.8%), and

$P_{fs,emp,not-to-plant}$ = Proportion of faecal sludge which not transported to a treatment plant (76.2%).

For the transport of wastewater, 47% of wastewater, regardless of whether it is contained or not contained, is delivered to wastewater treatment plants (variable $W4a$ and $W4c$), according to NSC (2012).

- Treatment

This study assumed that 100% of faecal sludge transported to the Khanh Son Landfill is treated, as the sludge is disposed of safely and the settling effluent is treated together with the landfill leachate. This could not be confirmed, as treatment is not clearly monitored at the faecal sludge treatment plant. Although centralized wastewater treatment plants in Danang did not meet the effluent quality standards (WB 2013b), as the treatment plant capacity is larger than the dry weather influent flow of the target population (Tran 2012) and therefore all dry weather influent could pass through the anaerobic lagoon processes at the plants, the treatment was also assumed to be 100%.

Results and Discussion of the SFD for Danang

The calculated SFD of Danang is shown in executive summary. Thirty-nine percent (38%) of the excreta flow was classified as safe management, and the remaining 62% was classified as unsafe management. The details are discussed along the sanitation service chain below.

At the containment, 59% (F2) of the excreta was safely managed, i.e., contained by septic tanks connected to soak pits without significant risk from groundwater pollution (47%), and septic tanks connected to combined sewers (13%). On the other hand, 41% (F10) of the excreta was not safely managed at the containment, which is caused by septic tanks connected to soak pits at significant risk from groundwater pollution (31%), septic tanks connected to open drains or drainages (3%), lined tanks with impermeable walls and open bottoms (3%), lined tanks with semi-permeable walls and open bottoms (3%), and unlined pit (1%). Septic tanks connected to soak pits accounted for the major proportion of both the safe containment in the area with connections to the public water supply networks and the unsafe containment in areas without connection to the public water supply network. Septic tanks with soak pits in the area with access to the public water supply networks were regarded as a safe containment system, whereas that without access was regarded as an unsafe containment system, as mentioned in 3.2.2. The area covered by the public water supply networks has been expanding year by year; therefore, the proportion of safe excreta containment will increase accordingly.

Concerning emptying, 48% of the excreta in Danang was emptied (F3); this is composed of safe containment with emptying (30%: F3a), and unsafe containment with emptying (19%: F3b). The difference of safe and unsafe is derived from the area with and the area without

access to the public water supply networks, respectively. This study assumed that the proportion of each septic tank which is faecal sludge (not effluent, supernatant, or infiltrate) is 50% and that 100% of the septic tanks are eventually emptied. Therefore, 30% (F3a) is equivalent to 50% of the septic tanks without significant risk from groundwater pollution (T1A2C1 and T1A2C5 in Table 3), and 19% (F3b) is equivalent to 50% of the containment systems with significant risk from groundwater pollution (T2A2C5, T2A4C10, T2A5C10 and T2A6C10). However, only a small proportion is emptied on an annual base in reality; most containment systems are not regularly emptied. Some of the septic tanks have not been desludged for more than 10 years (Pham et al. 2012). This has to be considered in order to understand the SFD appropriately.

On the other hand, 43% of the faecal sludge is not emptied, and is derived from safe containment without emptying (F8: 23%), and unsafe containment without emptying (F15: 20%). The former is derived from the remaining 50% of the septic tanks connected to soak pits without significant risk from groundwater pollution (T1A2C5). The latter (F15) is derived from the remaining 50% of the faecal sludge in septic tanks at significant risk from groundwater pollution (T2A2C5), and 50% of pit latrines and the lined tanks (T2A4C10, T2A5C10, and T2A6C10).

Concerning transport, the wastewater transported to centralized treatment plants in a contained manner and in an uncontained manner is 4%; this is composed of transport by a combined sewer (3%: W4a) or by open drains (1%: W4c). Wastewater not transported to centralized treatment plants is 4%, composed of transport of combined sewers (3%: W11a) and that of open drains (1%: W11c). Half of the produced wastewater is not delivered to treatment plants. On the other hand, 11% of the faecal sludge was transported to a treatment plant, while 37% was not transported to a treatment plant. The amount of faecal sludge not being transported for treatment is the largest proportion of the total unsafe management of excreta.

Concerning treatment, all the wastewater and faecal sludge transported to treatment plants are treated. The total treated proportion was 15%, composed of 11% of faecal sludge treatment at a public faecal sludge treatment plant, and 4% of wastewater treatment at centralized wastewater treatment plants. Actually, a large part of the faecal sludge is not transported to a treatment plant, resulting in no treatment of this faecal sludge. Good transportation of the faecal sludge to a treatment plant followed by it being treated is crucial for improving the excreta flow in Danang. In addition, half of the generated wastewater is not treated. Moreover, the treatment performance at the centralized wastewater treatment plants does not meet the effluent standards although the SFD assumed that 100% of wastewater transported to the treatment plants is treated. If the SFD calculation could take into account the treatment performance, the proportion of wastewater treatment potentially decreases. However, since the city has a plan to improve wastewater collection and to develop new centralized wastewater treatment plants, the proportion of wastewater treatment will increase.

3.2.4 Discussion of certainty/uncertainty levels of associated data used for the SFD Matrix

Available quantitative data on sanitation services was limited in Danang. Especially, no quantitative data exist on the private emptying and transport of faecal sludge since it seems to be illegal. Also, the detailed data about sanitation containment systems, especially in rural areas, did not exist. For this reason, the SFD relied on assumptions and key informant interviews explained in section 3.2.3.

Six key informant interviews were conducted at three times during the development of the SFD: one early on, one in the middle, and three at the end. These validated the assumptions for the SFD development. The most uncertain part of the SFD report is the emptying of faecal and transport of the faecal sludge not delivered for treatment. One expert mentioned the possibility that the estimated proportion of faecal sludge not delivered for treatment was too large compared to the actual proportion. Further investigations of emptying and transport of faecal sludge are required to increase the accuracy of the SFD.

Table 5 Credibility of data sources

References used at each sanitation service chain (the reference number is equal to the order for each reference to appear in the reference list):						
CONTAINMENT: 6, 10, 21, 22, 23, 25, 26, 29, 31, 32, 33, 34, 43, 44, 45						
EMPTYING: 2, 12, 16, 17, 24, 26, 32, 33, 34, 39, 40, 42						
TRANSPORT: 1, 2, 3, 5, 7, 11, 12, 13, 14, 16, 17, 18, 28, 30, 32, 33, 34, 35, 36, 39, 42, 44, 45						
TREATMENT: 5, 11, 12, 13, 14, 16, 17, 18, 19, 20, 30, 32, 33, 34, 36, 38, 39, 41, 42, 44, 45						
END-USE / DISPOSAL: 1, 5, 12, 26, 28, 30, 32, 33, 34, 36, 38, 42, 44						
Credibility of data source by sanitation service chains:						
	Containment	Emptying	Transport	Treatment	End-use / Disposal	
Types of data sources used	x		x	x	X	Municipal, utility or private local service provider records
						Interviews with city authorities and local government departments
	x	x	x	x	X	Documented studies
	x	x	x	x	X	Community representatives (interview / FGDs)
						Service Providers (interview / FGDs)
						Observation
Further availability of data sources:	x	x	x			This is a one-off exercise; no further data expected.
				x	X	Limited amount of new data expected, SFD to be revised.
						Substantial amount of new data expected, SFD to be revised.
Final SFD						SFD has not been shared with local stakeholders.

X	SFD has been shared with local stakeholders but no follow up action agreed.
	SFD has been shared and follow up actions have been agreed.
	SFD has been shared and follow up actions have been agreed and initiated.

Table 6 Rubric to evaluate quality of data sources

	Containment	Emptying	Transport	Treatment	End-use / Disposal	
Wastewater direct to sewer (decentralized)			M	M	M	Municipal, utility or private local service provider records
						Interviews with city authorities and local government departments
	M		M	M	M	Documented studies
	M	M	M	M	M	Community representatives (local expert)
						Service Providers
						Observation
Onsite (contained or not)				M	M	Municipal, utility or private local service provider records
						Interviews with city authorities and local government departments
	L	L	L	M	M	Documented studies
	M	M	M	M	M	Community representatives (local expert)
						Service Providers
						Observation

4 Stakeholder Engagement

4.1 Key Informant Interviews

The stakeholders identified in this study are summarized in Appendix 1, and the tracking records of when they were contacted are summarized in Appendix 2. This report conducted key informant interviews with three Vietnamese researchers: two are working in the city as environmental scientists and the other, although not currently working in Vietnam, has published academic papers on the city's septage management. An interview was conducted early on, another one was after developing the initial draft of the SFD, two interviews were after the second draft, and another two interviews were after the third draft. Then, the final SFD was created. The interviews emphasized the limitations of the data about faecal sludge management in Danang, provided expert opinions on the lacking information, validated the assumptions in the study. The draft SFDs were revised based on the experts' comments, especially for faecal sludge transport and containment systems in rural areas.

5 Acknowledgements

The authors are grateful for the expert opinions of Professor Tran Van Quang of the Danang University of Technology, to Dr. Hoang Hai of the University of Danang, and to Dr. Pham Nguyet Anh of the Kyoto University which were used to generate this report.

6 References

1. Anonymous, 2012. "Quantity of input waste to Khanh Son Landfill", unpublished.
2. Asia Pacific Energy Research Centre, 2015. "Summary Table (Da Nang, Viet Nam)". *APEC Low Carbon Model Towns (LCMT)*. Available at: http://aperc.iecej.or.jp/publications/reports/lcmt/vietnam_da-nang_detail.html [Accessed July 29, 2015].
3. Cities Development Initiative for Asia, 2012. "Pre-feasibility studies in industrial waste water management and drainage systems, Danang: municipal wastewater". *SlideShare*. Available at: <http://www.slideshare.net/RuurdKuiper/120530-da-nang-municipal-wastewateren> [Accessed July 25, 2015].
4. Danang City, 2015. "Danang Portal". Available at: <http://www.danang.gov.vn/portal/page/portal/danang/english/> [Accessed June 17, 2015].
5. Danang Urban Environment Company, 2006. *Khanh Son Sanitary Landfill operation manual*, Danang.
6. Danang Water Supply Company, 2015. "Water supply in Danang". Available at: <http://www.dawaco.com.vn/> [Accessed July 31, 2015].
7. Department of Transport, 2010. "Wastewater management strategy of Da Nang City towards 2020 and orientations towards 2040 (in Vietnamese)". *News-Da Nang Department of Transport*. Available at: <http://www.sgtvt.danang.gov.vn/> [Accessed August 5, 2015].
8. General Statistics Office, 2015. *Statistical Handbook of Vietnam 2014*, Hanoi: Statistical Publishing House.

9. General Statistics Office, 2013. *Statistical Yearbook of Vietnam 2013*, Hanoi: Statistical Publishing House.
10. General Statistics Office, 2012. *Viet Nam Household Living Standards Survey 2012*, Statistical Publishing House. Available at: <http://www.gso.gov.vn/>.
11. GIZ, 2014. *Report on research on vacuum sewer collection system for Pilot Project An Hai Bac Ward in Eastern Coastal Area of Da Nang, Vietnam*,
12. Government of Vietnam, 2009a. *Approving the National Strategy for Integrated Management of Solid Waste up to 2025, with a Vision to 2050*, Socialist Republic of Vietnam. Available at: <http://www.moc.gov.vn/en/>.
13. Government of Vietnam, 2009b. *Decision on Approving Orientations for Development of Water Drainage in Vietnamese Urban Centers and Industrial Parks up to 2025 and a Vision Towards 2050 (No.1930/QD-TTg)*, Socialist Republic of Vietnam.
14. Government of Vietnam, 2007a. *Decree on Drainage and Sewerage for Urban Areas and Industrial Zones (No. 88/2007/ND-CP)*, Socialist Republic of Vietnam.
15. Government of Vietnam, 2014. *Decree on Drainage, Sewerage and Wastewater Treatment (No.80/2014/ND-CP)*, Socialist Republic of Vietnam.
16. Government of Vietnam, 2007b. *Decree on Environmental Protection Charges for Solid wastes (No.174/2007/ND-CP)*, Socialist Republic of Vietnam.
17. Government of Vietnam, 2007c. *Decree on Solid Waste Management (No.59/2007/ND-CP)*, Socialist Republic of Vietnam.
18. Government of Vietnam, 2009c. *Decree on the Grading of Urban Center (No. 42/2009/ND-CP)*, Socialist Republic of Vietnam.
19. Government of Vietnam, 2002. *General Environmental Requirements for Central Domestic (municipal) Wastewater Treatment Plants*, Socialist Republic of Vietnam.
20. Government of Vietnam, 2008. *National Technical Regulation on Domestic Wastewater*, Socialist Republic of Vietnam.
21. Harada, H., Dong, N.T. & Matsui, S., 2008. "A measure for provisional-and-urgent sanitary improvement in developing countries: septic-tank performance improvement". *Water science and technology*, **58**(6): 1305–1311, DOI:10.2166/wst.2008.715. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18845871> [Accessed April 24, 2012].
22. Harada, H., Fujii, S., Nguyen, P.H.L., Kimoto, Y., Pham, H.G., Komai, T., Pasakhara, B., Kunacheva, C. & Tanaka, S., 2011. "Portfolio of toilet and on-site sanitation facility for urban sanitation in Asia". In *Proc. in the 48th Environmental Engineering Forum*. pp. 59–67.
23. Imada, K., Tanaka, S., Fujii, S., Harada, H., Tran, V.Q., Hoang, H. & Vo Diep, N.K., 2012. "Investigation of water use structure of household sector for water demand forecast in Danang, Vietnam ". In *Proc. in the 49th Environmental Engineering Forum*. pp. 196–198.
24. Key informant interview, 2015a. "Key informant interview (Aug. 14, 2015)".
25. Key informant interview, 2015b. "Key informant interview (Jul. 15, 2015)".
26. Key informant interview, 2015c. "Key informant interview (Jul. 7, 2015)".
27. Key informant interview, 2015d. "Key informant interview (March 7, 2012)".
28. Key informant interview, 2015e. "Key informant interview (May 13, 2015)".
29. Ministry of Health, 2005. *Decision on the issuance of Sector Standard: Sanitation Standard for all kinds of Toilets (Lavatories) (No.08/2005/QD-BYT)*, Socialist Republic of

Vietnam.

30. Ministry of Construction, 2009. *Circular on detailing some provisions of Decree No. 88/2007/ND-CP on urban and industrial-park water drainage (No. 09/2009/TT-BXD)*, Socialist Republic of Vietnam.
31. Ministry of Construction, 1996. *Decision on Promulgating the Building Code of Vietnam (No.682/BXD-CSXD)*, Socialist Republic of Vietnam.
32. National Assembly of Vietnam, 2003. *Law on Construction (No.16/2003/QH11)*, Socialist Republic of Vietnam.
33. National Assembly of Vietnam, 2014. *Law on Environmental Protection (No.55/2014/QH13)*, Socialist Republic of Vietnam.
34. National Assembly of Vietnam, 2012. *Law on Water Resources (No. 17/2012/QH13)*, Socialist Republic of Vietnam. Available at: <http://www.wepa-db.net/policies/law/vietnam/lwr.htm>.
35. Nihon Suido Consultants, 2012. *Feasibility study of environmental sanitation in Danang, Vietnam* (in Japanese), Tokyo.
36. Nihon Suido Consultants, 2010. *Report of feasibility study on the improvement of environmental sanitation in Danang* (in Japanese).
37. Opitz-Stapleton, S., Seraydarian, L., MacClune, K., Guibert, G. & Reed, S., 2009. *Asian Cities Climate Resilience Network (ACCCRN): Responding to the Urban Climate Challenge* ISET, ed., Boulder: ISET.
38. Ostojic, R.D., Bose, K.R., Krambeck, H., Lim, J. & Zhang, Y., 2007. *Energizing Green Cities in Southeast Asia: Applying Sustainable Urban Energy and Emissions Planning*, Washington DC: World Bank. Available at: <http://www.worldbank.org/content/dam/Worldbank/document/EAP/region/sueep/energizing-green-cities-da-nang-vietnam.pdf>.
39. Pham, N.A., 2014. *Study on household wastewater characterization and septic tanks' function in urban areas of Vietnam*. Kyoto University.
40. Pham, N.A., Harada, H., Fujii, S., Tran, V.Q., Hoang, H., Tanaka, S. & Kunacheva, C., 2012. "Effects of septic tank management on septage composition: a case study in Da Nang, Vietnam". *Journal of Science and Technology*, **50**(1C): 138–144.
41. Pham, N.B. & Kuyama, T., 2013. *Urban domestic wastewater management in Vietnam - Challenges and opportunities*, WEPA, IGES.
42. Pham, T.N.N., 2012. "Solid waste management system in Da Nang city". In *Asia Pacific Workshop on Integrated Solid Waste Management, 19-20 April 2012, Osaka, Japan*. Osaka.
43. Thuy, H.T.T., Tobschall, H.J. & An, P. V., 2000. "Distribution of heavy metals in urban soils - a case study of Danang-Hoian Area (Vietnam)". *Environmental Geology*, **39**(6): 603–610, DOI:10.1007/s002540050472.
44. Tran, V.Q., 2012. *Project report on sanitation constraints classification and alternative evaluation for Asian Cities FY2011: Danang*, Danang.
45. World Bank, 2013a. *Da Nang - Quang Ngai Expressway Project: final update of environmental impact assessment*, Washington DC. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/02/16/000333037_20150216134825/Rendered/PDF/E26290V10REVIS00Box385438B00PUBLIC0.pdf.



46. World Bank, 2013b. *Da Nang priority infrastructure investment project: implementation completion and results report*, Washington DC.

7 Appendix

7.1 Appendix 1: Stakeholder identification (Tab 2: Stakeholder Tracking Tool)

	Stakeholder Group*	Name of organisation	Name of contact person	Contact No.	Email Address	Position	Source of contact	Influence (high/medium/low)	Interest (high/medium/low)	Additional comments
Stakeholder 1	1	Danang People's Committee	-	-	-	-	-	-	-	-
Stakeholder 2	1	Department of Natural Resources and Environment	-	-	-	-	-	-	-	-
Stakeholder 3	1	Department of Construction	-	-	-	-	-	-	-	-
Stakeholder 4	6, 9	Danang Urban Environment Company	-	-	-	-	-	-	-	-
Stakeholder 5	6	Unknown private emptying service providers	-	-	-	-	-	-	-	-
Stakeholder 6	7	Danang Drainage and Wastewater Treatment Company	-	-	-	-	-	-	-	-
Stakeholder 7	7	Danang Water Supply Company	-	-	-	-	-	-	-	-
Stakeholder 8	1, 2, 4	Ministry of Natural Resources and Environment	-	-	-	-	-	-	-	-
Stakeholder 9	2, 3	Ministry of Construction	-	-	-	-	-	-	-	-
Stakeholder 10	4	Ministry of Health	-	-	-	-	-	-	-	-
Stakeholder 11	10	Danang University of Technology	-	-	-	-	-	-	-	-
Stakeholder 12	10	The University of Danang	-	-	-	-	-	-	-	-

* No. of stakeholder group are followings: 1 City council / Municipal authority / Utility; 2 Ministry in charge of urban sanitation and sewerage; 3 Ministry in charge of urban solid waste; 4 Ministries in charge of urban planning, environmental protection/ health, finance and economic development, agriculture; 5 Service provider for construction of onsite sanitation technologies; 6 Service provider for emptying and transport of faecal sludge; 7 Service provider for operation and maintenance of treatment infrastructure; 8 Market participants practising end-use of faecal sludge end products; 9 Service provider for disposal of faecal sludge (sanitary landfill management); 10 External agencies associated with FSM services: e.g. NGOs, academic institutions, donors, private investors, consultants

7.2 Appendix 2: Tracking of Engagement (Tab 3: Stakeholder Tracking Tool)

Informant	Date of Engagement	Purpose of Engagement	Summary of outcomes
Academia 1	13-May-15	To know available secondary data	No local policy and regulation on FSM were confirmed; there is little secondary data on FSM in Danang. Data on septage collection was obtained, but it is unofficial and not reliable.
Academia 2	7-Jul-15	To know available secondary data and to have expert opinion on first draft of SFD and lacking data	No local regulation on FSM was confirmed. Initial SFD was shown and obtained positive feedback. He mentioned the initial SFD is in a same magnitude of the reality in the city. Expert opinion (Key informant interview 2015a) was obtained for the sanitation systems in rural areas.
Academia 2	15-Jul-15	To get the review on the second draft of SFD report.	The academia reviewed the draft SFD. Validity of the major assumptions for the SFD development was agreed. Comments was that under the limited data, the report nicely described excreta flow; there is not available data on faecal sludge emptying, transportation and treatment by private emptying service providers, and this is the most challenging part of this report.
Academia 1	14-Aug-15	To get the review on the second draft of the SFD.	The academia reviewed the draft SFD. Validity of the major assumptions for the SFD development was agreed. Main comments are followings: this is a very useful report to understand faecal sludge management in Vietnam and current flow in Danang; the proportion of faecal sludge not delivered to treatment might be too high; significant amount of sludge emptied by private emptying service providers were transported at the treatment plant.
Academia 2	16-Aug-15	To get the review on the third draft of the SFD.	The academia reviewed the draft SFD. Minor modifications were suggested.
Academia 3	4-Oct-15	To get the review on the third draft of the SFD.	The academia reviewed the draft SFD. Validity of major assumptions for the SFD development was agreed. Main comments are followings: actual treatment performance of centralized treatment plants are poor, and



			treatment proportion at the plants would be lower in considering the performance in the SFD calculation.
--	--	--	--