Papua New Guinea: Faecal Sludge Management in Port Moresby

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FAECAL SLUDGE MANAGEMENT IN PORT MORESBY

Half of the population in Port Moresby dispose of their faecal waste via networked wastewater systems (sewerage or storm water drains) of which only 10% is safely transported and treated. The networked wastewater system failures are caused by the congestion of the sewers with foreign objects and overloading with water. Almost all the other half of the population reside in non-networked or informal settlements using on-site sanitation systems with only 4% safely transported and treated. The on-site sanitation system failures are primarily caused by the failure to manage the effluent (liquid) rather than the sludge (solids). For dry pit toilets, excessive moisture in the pits destroys the aerobic digestion process rendering the pit contents unsafe. Limiting the intrusion of water, improving air flow and reducing their use for just urination will greatly improve the efficiency of dry pit toilets. For the water borne toilets, the high density of the soil in Port Moresby means that all the effluent cannot be absorbed by the leach drains leading to either the discharge of effluent to the storm water or the premature filling of septic tanks with effluent (not sludge). Separating the grey water from the black water will improve the efficiency of leach pits dramatically increasing the time between empties for septic tanks. Separating the grey water from the black water appears to be practical given that most households already appear to have separate grey and black water plumbing. Separating the grey water from black water also appears to be prudent, given that the efficiency of the water borne sanitation systems is compromised by excessive volumes of water and the effectiveness plagued by foreign objects (i.e. fats, oil, grease, soap, detergent) that often enter via the grey water.

A Technical, Social & political Economy Assessment of the Status of Faecal Sludge Management in Port Moresby

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Executive Summary

The MDTP III (2018-2022) goal 7.4 seeks to improve access to Safe (drinking) Water, Reliable and Affordable Sanitation and Hygiene Facilities through the implementation of the WASH Policy. Achieving 100% sanitation has been targeted in the WASH Policy (2015-2030) as the first of the priorities under Strategy 4 and the MDTP III has prioritised investments to upgrade the Port Moresby Sewerage System (as well as establish the National Water Sanitation and Hygiene Authority).

While most households in Port Moresby access 'basic' sanitation facilities via networked sewers, the transport and the treatment fail to meet the 'safely managed' sanitation standard defined by the SDGs. For the remaining households that access on-site sanitation systems, the containment of their faecal waste also fails to meet the 'safely managed' sanitation standard. Achieving the 'safely managed' sanitation standard in Port Moresby is challenged by several factors:

- *The on-site management of dry faecal sludge:* is undermined by the sub-optimal design and operation of dry pit toilets which is primarily rooted in a lack of awareness of the need to limit the level of moisture within the dry pits.
- *The on-site management of wet faecal sludge:* from water borne systems is complicated by the density of the soil that limits leaching, exacerbated by the large volumes of water supplied to households (with large household sizes increasing the leaching challenge) and compounded by the entry of non-biodegradable products (i.e. fats, detergents, pads). The inability of the soil to absorb all the septic tank effluent, results in either the effluent being discharged into the storm water drains or the premature filling of septic tanks with liquid. As a result, septic sludge tankers often empty & transport faecal effluent rather than faecal sludge.
- *The networked water borne sewerage systems:* are stifled by silt, fat and solids, hampered by collapsed / bypassed sections and overloaded by large volumes of wastewater that results in the transfer of faecal waste into the stormwater system. This worsens in the wet season when rainwater enters the sewerage system displacing sewage back into the stormwater system.

Given the high access to piped water, the sloping terrain and the low absorption capacity of the soil in Port Moresby, the household preference for networked sewerage is likely to remain, however:

- as sewer blockages can prevent toilets from functioning, households often find it more convenient to discharge their wastewater to the stormwater drains. When the sewers block, or the pump stations fail, sewerage operations staff can also find it more convenient (or even necessary) to bypass sewage into the storm water drains.
- In the areas not covered by sewerage networks, where the absorption capacity of the soil is low, households often connect their septic tank outlets to the storm water drains. This results in effluent with high pathogen counts being discharged to the drain. Over time, when septic tanks are not emptied, this results in faecal sludge also being discharged into the storm water drains.

The convenience associated with the use of stormwater drains to transfer faecal effluent and sludge is something that needs to be recognised and regulated. In the short term, this potentially requires greater attention to the safe transport, containment and treatment of high-risk stormwater flows. In the longer term, this will require either an expansion of the sewerage system capacity or operational modifications to reduce the spurious wastewater loading on the existing sewerage system.

While networked gravity sewerage systems will continue to form the backbone of the water borne faecal waste management systems in Port Moresby, the effectiveness of both on-site and networked water borne systems could be improved by:

- **Reducing fats, oil & grease (FOG) in wastewater discharges** (i.e. introduce oil recycling to collect, transport & treat food industry oils; require commercial & recommend domestic grease trap installation on wastewater lines; educate households to dispose of cooking oil with their solid waste).

- **Reducing biodegradable kitchen, laundry and bathroom residues within the wastewater discharges** (i.e. reducing the discharge of food residue and detergent down the sink or separating grey water from black water can significantly increase the fill time of septic tanks).
- **Preventing non-biodegradable sand and plastics from entering wastewater systems** (i.e. by educating households what NOT to flush; training plumbers to cover pipes during installation; stopping sweepers from pushing dirt into sewers, installing sand traps on sewer junctions).
- **Reducing the percentage of water that enters septic tanks and sewers**: improves the efficiency of the wastewater transfer and biological treatment systems (i.e. reduce wastewater volume by reducing household water use including increasing water tariffs; by preventing rainwater ingress into the wastewater system; by separating black water from grey water).
- **Improving the isolation of septic tanks and sewerage from the stormwater drains** (i.e. by removing sewer overflows and septic tank outlets that discharge into the open drains; by undertaking soil percolation tests to design functional leach drains; by repairing collapsed sewerage pipe sections that are discharging sewage into the storm water).
- **Improving the effectiveness of wastewater treatment facilities** (i.e. remove the silt from the settling ponds at Waigini, Morata & Geremu; add waste stabilization ponds to treat the stormwater outfalls at Tareko Lagoon; introduce septage treatment facilities proximate to the suburbs with septic tanks, explore the potential sale or re-use of safely digested sludge).
- **Improving wastewater / faecal sludge transport systems** (i.e. clean the silted & blocked sewer networks; upgrade the sewer sections that are overloaded; require property developers to sewer new sub-divisions; license/register septic sludge tanker operators with NCDC, reverse the money flow to incentivise septic tanker disposal at the treatment plants).

As dry pit toilets will continue to be the dominant faecal sludge management system for informal settlements in Port Moresby (and rural settings throughout PNG) the design and operation of dry pit systems could be improved by:

- **Reducing moisture levels in dry pit latrines** (i.e. design the toilet slab to slope away from the hole to prevent rainwater running into the hole; educate users not to use water for anal cleansing or to wash the toilet slab; promote separate urinals that discharge to the grey water).
- **Improving air flow within the pit** (i.e. promote the installation of vent pipes to improve airflow in the pit; use fly screens to cover the hole and vent allowing air flow but preventing flies).
- **Reducing odour generation** (i.e. encourage the use of biodegradable materials for anal cleansing, promote the addition of leaves, ash, sawdust, worms or kitchen compost to the pit, promote materials for toilet slabs that do not react with urine … unlike concrete does).
- **Ensuring that full toilet pits are covered** (i.e. encourage the practice of digging a new pit, moving the superstructure and covering the old pit when it is full; reinforce the understanding that exposure to wet faecal sludge is not safe).

The responsibilities for the safe management of faecal waste are reasonably well defined in legislation. However, the complex nature of these responsibilities and lack of their delineation has contributed to a situation where the responsibility to ensure that faecal sludge is safely managed is poorly understood and even more poorly executed. In the absence of any deliberate attempts to regulate the systems that collect, contain, empty, transport & treat faecal waste, the faecal sludge management systems in Port Moresby are driven by private incentives to reduce time and cost.

An institutional response to this faecal sludge management challenge requires the clarifying and strengthening of the regulatory system. Given the weakness of regulatory systems in PNG, it is suggested that **separating (a) the regulation of failure** (by the national government) **from (b) the licensing of compliance** (by local governments) **from (c) the management of services** (by providers) may improve the incentives for compliance.

Introduction

Due to a lack of information on the status of faecal sludge management in Port Moresby, this report has drawn on secondary data from national surveys summarized in the JMP (https://washdata.org/), utility benchmarking data from IBNet (https://www.ib-net.org/). Data from the Household Income and Expenditure Survey (HIES) and sample surveys of informal settlements has been used to estimate access levels in Port Moresby. This has been combined with primary data collected from surveys of septic sludge tanker operators, interviews with sector stakeholders and three consultative workshops. As the institutional incentives at the national affect the local (and vice versa), this report has estimated the faecal sludge management status in the urban sector and informal settlements in general before deriving the faecal sludge management status for Port Moresby specifically.

Background

Millennium Development Goals (MDGs)

Against a 1990 baseline of 46% coverage with improved sanitation in PNG, the MDG target of halving the percentage of those without access to sanitation was set at 72% for PNG. According to the WHO & UNICEF Joint Monitoring Programme, access to improved sanitation facilities declined in PNG over the last 15 years leaving 65% of the population still accessing unimproved sanitation facilities. This contrasts with the rest of the World where access to improved sanitation facilities increased by 9 percentage points over the last 15 years. Accounting for population growth this means that another 1.4 billion people were reached globally with access to improved sanitation over the past 15 years, while in PNG the additional 0.4 million that gained access to improved sanitation facilities were overshadowed by the 1.5 million additional people accessing unimproved sanitation facilities [1]. ***The growth in the use of unimproved sanitation facilities presenting a major challenge for PNG.***

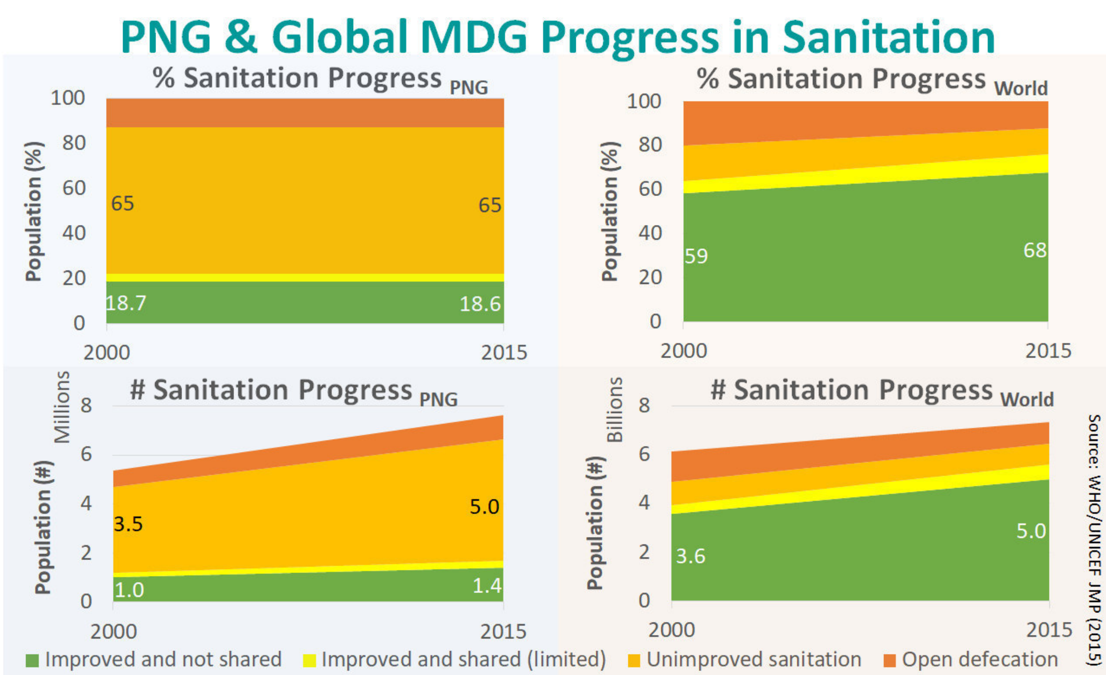


Figure 1: PNG & Global MDG Progress in Sanitation

The lack of progress in urban sanitation in PNG over the last 15 years is not significantly different from the slow progress in urban sanitation globally. What is different globally, is that rapid global urban population growth means that another billion urban dwellers have received access to improved sanitation over the last 15 years. By contrast, the modest levels of urbanization in PNG mean that only an additional 100,000 urban dwellers received access to urban sanitation over the last 15 years.

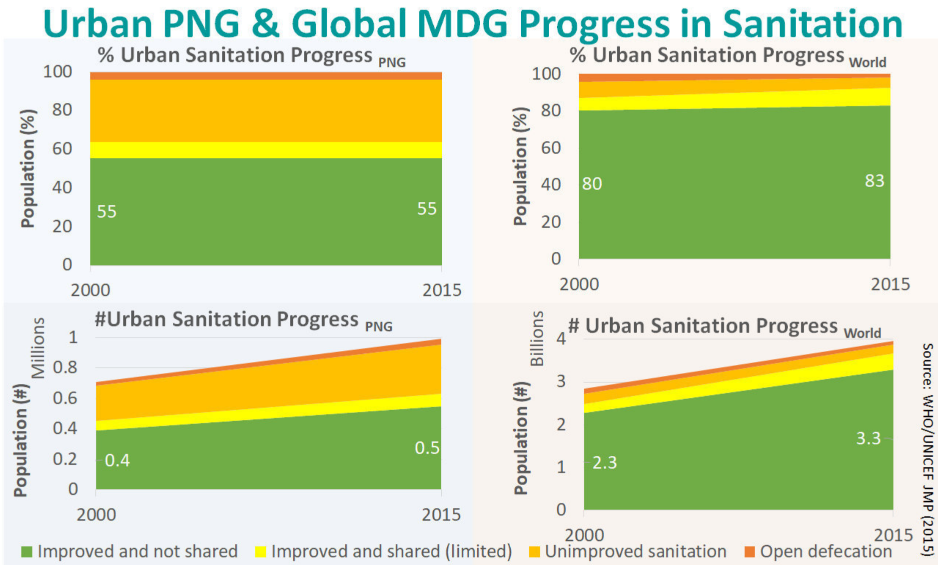


Figure 2: Urban PNG & Global MDG Progress in Sanitation

Sustainable Development Goals (SDGs)

There have been three significant shifts from MDGs to the SDGs within the sanitation sub-sector.

- Firstly, acknowledging the public health priority and personal wellbeing associated with ending open defecation which was not even conceptualized in the MDGs … the SDGs have targeted the elimination of open defecation as the first sanitation target.
- Secondly, recognizing that the halving of those without access has an implicit bias against the hardest to reach (i.e. the poor and the disabled are most likely to be in the half left behind) … the SDGs have targeted universal access and the elimination of inequalities.
- Thirdly, understanding that access to improved facilities does not necessarily mean the provision of a safe sanitation service … the SDG's have introduced a safely managed sanitation category to measure the safe containment, emptying, transport and treatment of excreta.

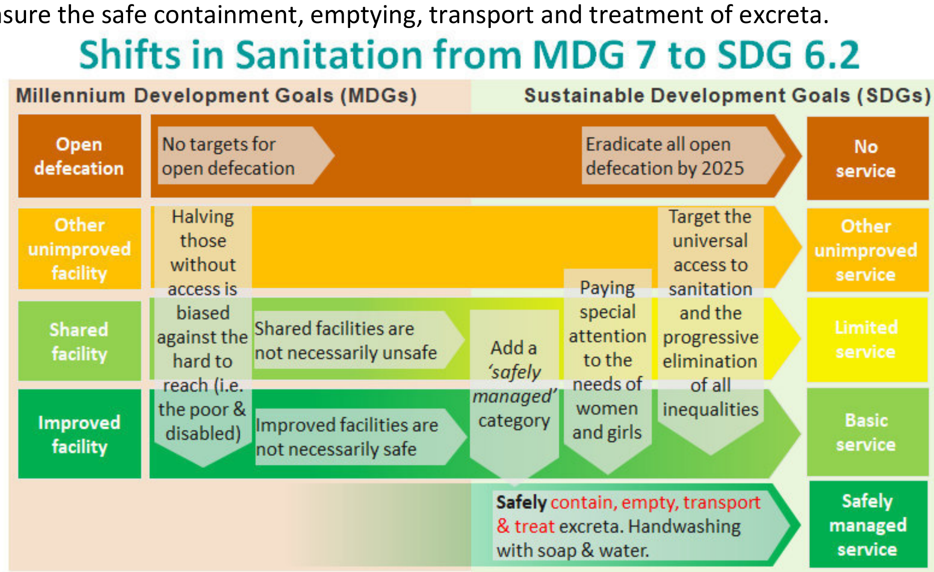


Figure 3: Shifts in Sanitation: from MDG 7 to SDG 6.2

According to these SDG sanitation service standards, the challenge for PNG still lies in addressing the significant percentage of the population accessing unimproved sanitation facilities. While this challenge lies predominantly in the rural areas (where there is a heavy reliance on pit toilets which tends to be associated with households that do not have water piped onto the premises) there is still a significant percentage of the urban population that accesses unimproved sanitation.

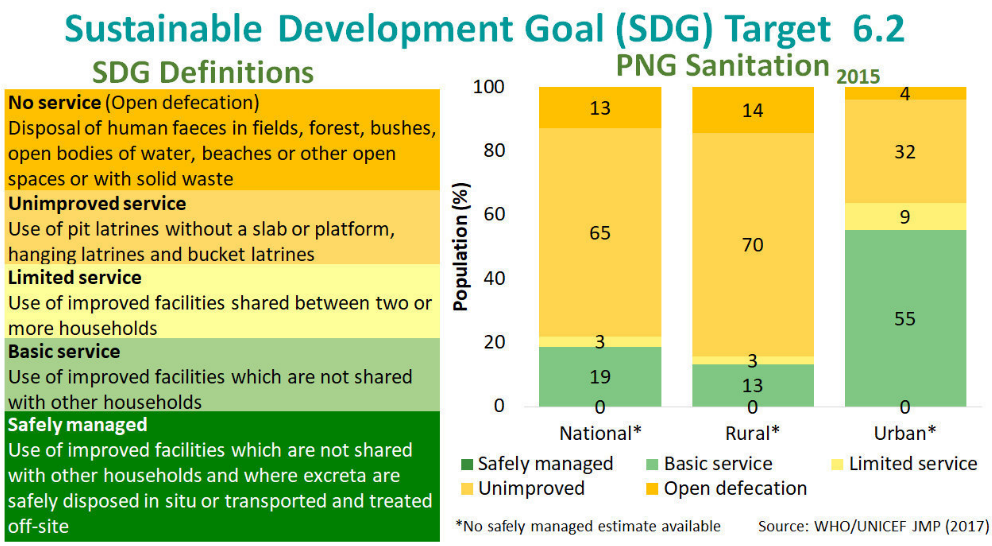


Figure 4: Papua New Guinea SDG Sanitation Status

The Safely Managed Sanitation Target

The SDGs define a 'safely managed' sanitation service as the use of an improved facility that is not shared with the:

- *wastewater treated offsite, or*
- *excreta transported and treated offsite, or*
- *excreta treated and disposed of in-situ.*

Wastewater treated offsite: implies the containment & transport in separate or combined sewerage systems and treatment in wastewater treatment plants.
Excreta transported and treated offsite: reflects the containment within septic tanks and leach pits where the sludge is safely pumped out and transported to treatment plants.
Excreta treated and disposed of in-situ: captures the extent to which new pits are dug when pit latrines fill up. The old pit being covered over or dug out when the contents are dry and safe.

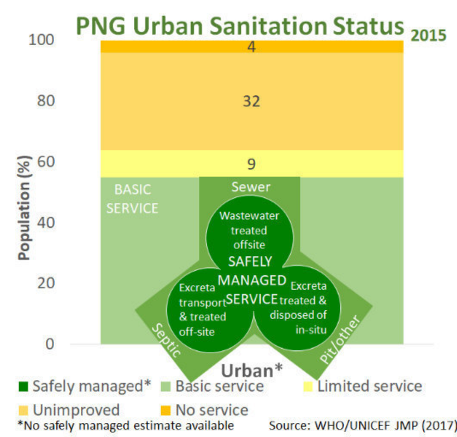


Figure 5: PNG Urban Sanitation Status

The WHO / UNICEF Joint Monitoring Programme (JMP) utilizes national household survey data to generate estimates on the levels of access to sanitation facilities for the collection and containment of excreta. The JMP also utilizes water utility operational performance data from the World Bank International Benchmarking Network (IBNet) to estimate the extent to which sewerage is safely contained, transported and treated. This is insufficient however to estimate the safe management of the faecal waste contained in septic tanks and pits across the faecal sludge management chain.

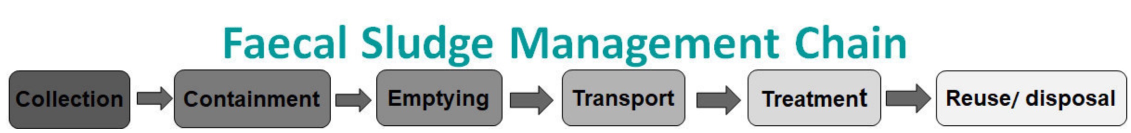


Figure 6: Faecal Sludge Management Chain

Using sample survey data to estimate the extent to which the contents of septic tanks are safely emptied, transported and treated off-site or pit latrines are safely contained and treated on-site enables the generation of a Shit Flow Diagram. The Shit Flow Diagram represents the extent to which sanitation is safely managed across the whole faecal sludge management chain also enabling the identification of the locus of the major faecal exposure risks.

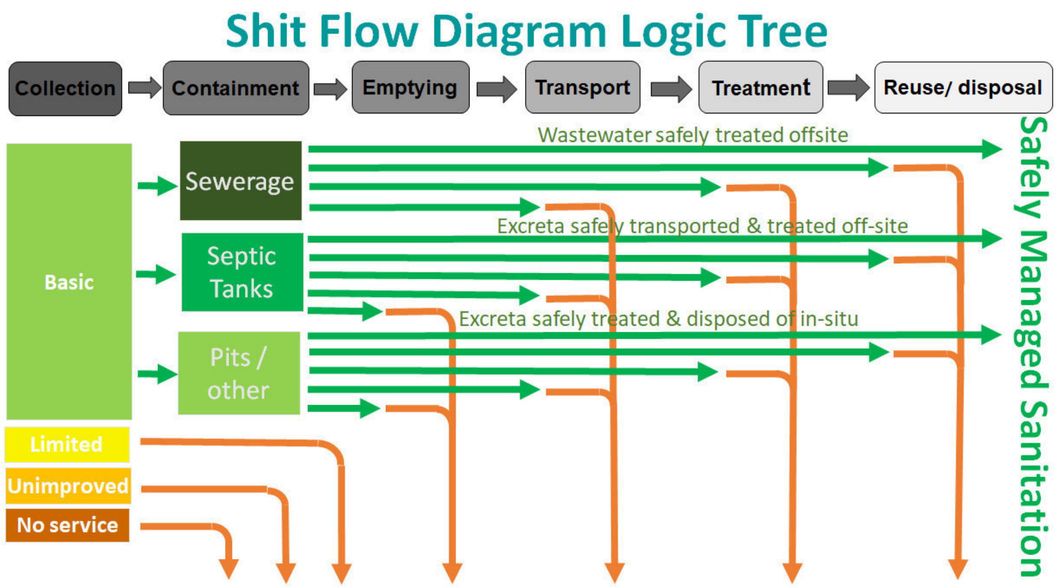


Figure 7: Shit Flow Diagram Logic Tree

Urban PNG - Safely Managed Sanitation Status

The 2017 JMP report has estimated the levels of access to sanitation facilities in urban settings in PNG in 2015 based on household survey data from the DHS 1996, DHS 2006 and HIES 2010.

Collection: According to these estimates, an estimated 4% of the urban population have no access to a sanitation service (i.e. practice open defecation), 32% have access to an unimproved sanitation service (i.e. utilise unimproved facilities), 9% have access to a limited sanitation service (i.e. utilise an improved sanitation facility but shared by two or more households) and 55% have access to a basic service (i.e. household has access to their own improved sanitation facility) in 2015 [1].

Containment: These household survey instruments also record the form of containment of faecal waste (i.e. sewer, septic tank or pit toilet) applying these estimates to the percentage of the population accessing a basic sanitation service. Of the 55% of the urban population accessing basic sanitation facilities, an estimated 20% of the faecal waste is contained within sewers, 21% within septic tanks and 14% within pits or another form of containment (i.e. 0.4% bucket latrines) [1].

- **Excreta treated and disposed of in-situ:** Optimal digestion of excreta within dry pit latrines occurs under aerobic conditions. The ingress of excessive moisture into a dry pit will create an anerobic environment within the pit that will destroy the aerobic bacteria. This results in the release of a foul odour and a reduction in the effectiveness of the digestion of pathogens (bacteria & viruses). If the operation of one third of dry pit latrines are affected by water, an estimated 9% of dry pits can be assumed to safely contain excreta. The covering of full pit latrines and the digging of new pits is a safe means of excreta disposal. Given the widespread aversion to the emptying of pit latrines, it is estimated that the 9% of the contents of the 14% of households with dry pit latrines are 'safely managed'.
- **Excreta transported and treated offsite:** The safe containment of faecal sludge within a septic tank (anaerobic) also requires the faecal effluent to be safely contained and treated (generally within an aerobic leach drain or soak pit). The release of effluent from a septic tank without undergoing some form of aerobic treatment will discharge pathogens into the environment. If half of the septic tanks do not have a soak pit (i.e. release effluent to storm water drains), then 11% of septic tanks can be assumed to safely contain faecal sludge & treat faecal effluent. If 90% of these septic tanks are safely emptied by sludge tanker trucks, half of which is safely

transported to a treatment plant then 5% of urban faecal waste will reach a treatment plant. Given the poor maintenance of treatment plants it is estimated that 20% of faecal waste is treated, leaving just 1% of the faecal waste contained in the 21% of septic tanks as 'safely managed'.

- **Wastewater treated offsite:** While 20% of urban households are connected to gravity sewer systems they have received minimal maintenance or upgrading over the last 50 years. The collapsing of sewers in some places has resulted in sewage being diverted to the stormwater drains, while the silting of sewers has led households to install overflow pipes that divert their sewage into the stormwater when the sewer blocks. Due to the overloading and blocking of sewers, one quarter of sewerage is estimated to be transported through the stormwater drainage system. Almost all urban wastewater treatment systems are settling ponds that require minimal maintenance however they do not appear to have received any maintenance since they were installed over 50 years ago. Due to associated silting of the ponds it is estimated that they are effectively treating only 20% of the wastewater that they receive. In the end, this means that only 3% of the faecal waste collected from the 20% of households connected to sewers as 'safely managed'.

This indicates that only 12% of the urban population can be assumed to have access to a 'safely managed' sanitation service. The major risks occur to the 50% of urban dwellers that rely on toilets that fail to safely contain faecal waste (predominantly dry pit). The secondary risk occurs to urban dwellers that are exposed to the unsafe transportation of the wastewater of 21% of the population with access to sewers and septic tanks. The tertiary risk occurs in the environmental exposure to the unsafely treated wastewater of 16% of the urban population with access to sewers and septic tanks.

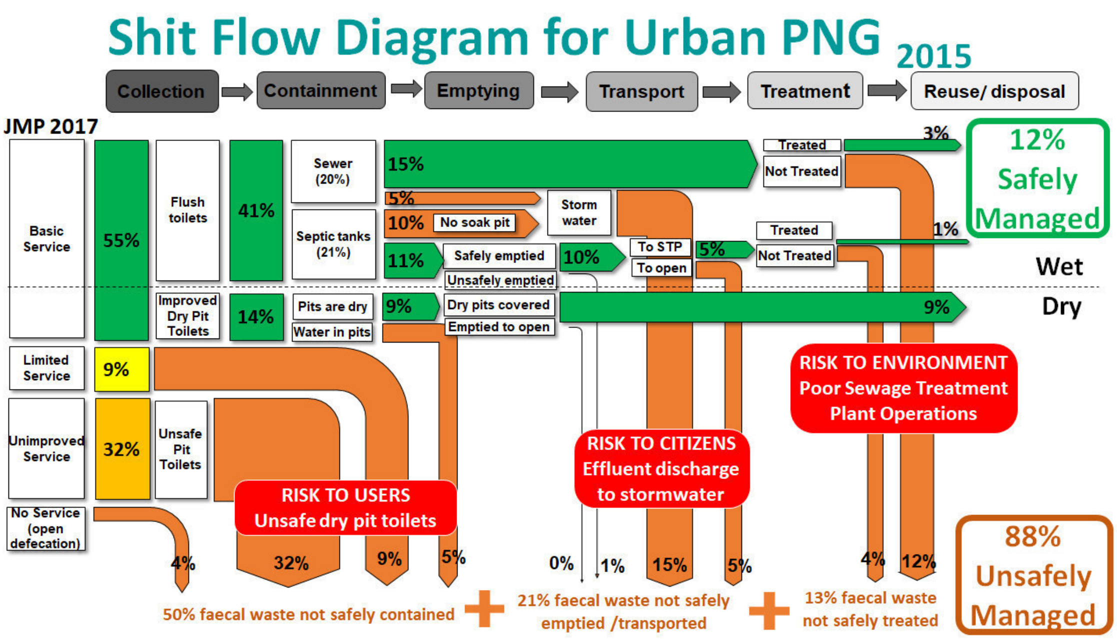


Figure 8: Shit Flow Diagram for Urban PNG (utilising 2015 JMP data)

Informal Settlements - Safely Managed Sanitation Status

World Bank (with WaterAid) conducted a survey of the WASH status of 200 households in eight informal settlements in the urban areas of Port Moresby and Wewak in 2014. ADB (with the WASH PMU) also undertook an assessment of the WASH status and 'willingness to pay' for improved services of 152 households in the Tete settlement in Port Moresby in 2018. These two assessments form the basis for estimating the 'safely managed' sanitation status of informal urban settlements.

Collection: According to the World Bank assessment, an estimated 8% of informal settlements have no access to a sanitation service (i.e. defecate in the open, in a bag or a drain), 72% have access to an unimproved sanitation service, 5% have access to a limited sanitation service (i.e. an improved but shared facility), and 15% have access to a basic sanitation service (i.e. an improved facility). Most of the population prefer the use of paper for anal cleansing, with 75% reliant on newspaper, 55% on toilet paper, 8% on leaves and 5% on water [2].

Containment: The survey results recorded high levels of usage of low-quality toilets with 85% of the population reliant on dry pit latrines and 7% reliant on flush latrines.

- **Excreta treated and disposed of in-situ:** Of the 8% improved toilets that discharge to dry pits, an estimated half of these pits have enough water to destroy the aerobic bacteria (releasing a foul odour and reducing the efficiency of digestion of pathogens) which leaves only 4% of pits safely containing excreta. When the pits are full, 90% of households will dig a new pit & cover the old pit, while 5% of households empty their pits (into open drains) and 3% continue to use even when full. The covering of full pits and digging of new pits is a safe means of excreta disposal, meaning that 3.8% of the contents of the 8% of households with dry pit latrines are 'safely managed'.
- **Excreta transported and treated offsite:** Of the 7% of the population that were reliant on flush latrines, 1% were connected to septic tanks, 4% were connected to pits and 2% connected to anywhere. If the 3% connected to septic tanks & anywhere lack a leaching facility, then effluent will be discharged to the stormwater. Then if the 4% contained within the pits safely contains the sludge & leaches the effluent, the sludge will need to be either covered or safely transported & emptied. If 1% of the pits are unsafely emptied to open, then 3% of the contents of the pits are safely treated.

This indicates that only 6.8% of the urban population residing within informal settlements can be considered to have access to a 'safely managed' sanitation service. The major faecal exposure risk occurs to the 89% of informal settlements that rely on pit toilets which fail to safely contain faecal waste. The secondary risk occurs to the citizens exposed to the unsafe emptying and transportation of the wastewater of the 4.2% of the informal settlements with access to flush toilets.

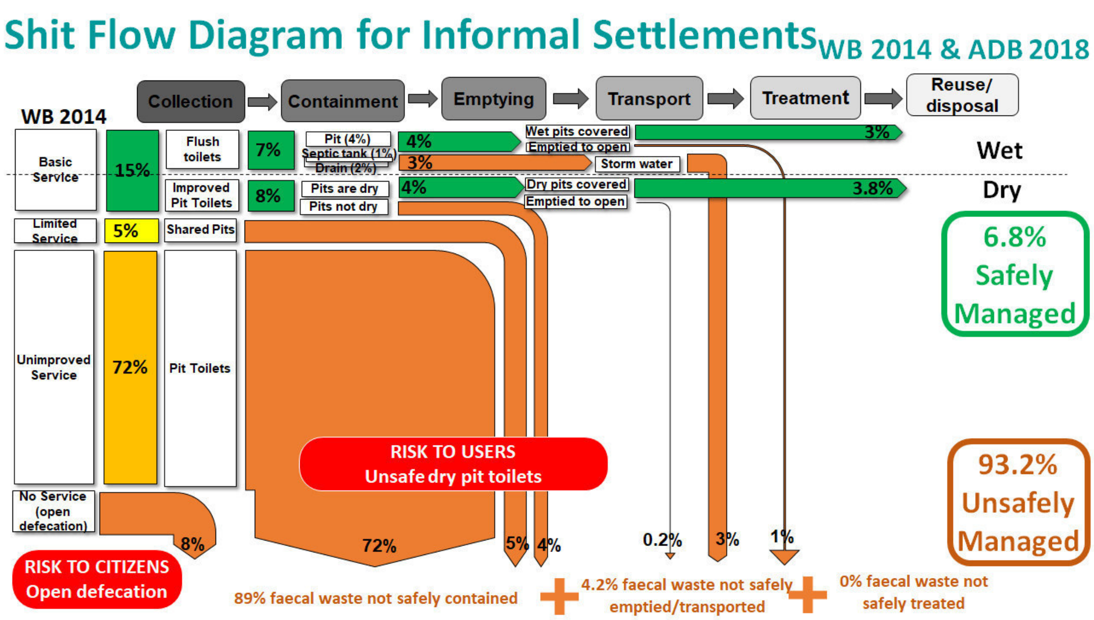


Figure 9: Shit Flow Diagram for Informal Settlements

Port Moresby

Geography

Port Moresby is the administrative and economic hub for Papua New Guinea and one of the major cities in the Pacific. Port Moresby lies in the catchment areas of the Vanapa and Brown Rivers but the only water body within NCDC is the Boroko Creek that drains into the Waigani Lagoon. Several ridges (roughly 200 metres above sea level) run northeast-southwest separated by broad flat valleys (roughly 50 metres above sea level) leading to a widely dispersed settlement pattern.

Demography

The population of Port Moresby has been growing steadily since independence at around 3% per annum. With a Census 2011 population of 364,125, the population in 2018 is estimated at half a million. Census figures indicate that most of the population growth occurred in the inland suburbs of Gerehu, Morata, Gordens and Tokara prior to 2001 and more recently on the peninsula where the port is located [3].

There are 20 planned settlements, 79 informal settlements and seven urban villages in Port Moresby with an estimated 45% of the population residing within informal settlements.

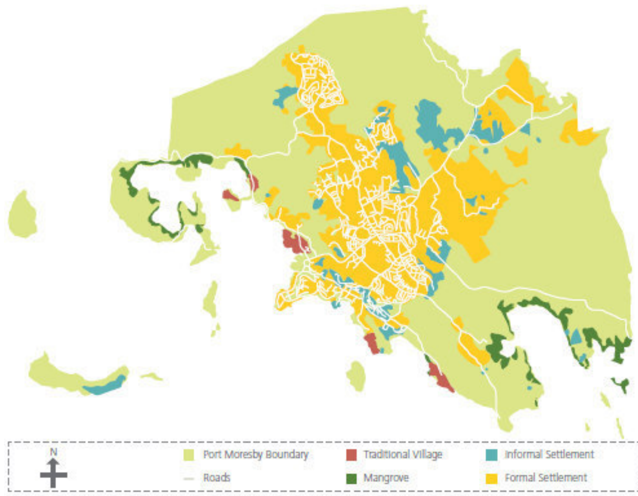


Figure 10: Formal & informal settlements in Port Moresby

Governance

The National Capital District Commission (NCDC) is the administrative unit that encompasses the city of Port Moresby. NCDC is divided into three electorates (North East, North West and South East) and twelve wards. The Motu Koitabu Council represents the traditional land owners and is the only recognised locally elected government in Port Moresby. While NCDC is classified as an Urban Local-Level Government, from an electoral perspective it is the equivalent of a province with MPs from the three Wards and MKC Chair represented on the NCDC Board where a Member is elected Governor and chair of the National Capital District Commission. [4]

Land Use

The National Capital District covers a total land area of approximately 267.6 km², 60% of which is state owned and 40% customary. Of the total land area, approximately 25% (or 67.5 km^2) was comprised of built up areas in 2003. Of the 79 informal settlements, 44 are on state land and 37 are on customary land [5].

NCDC is responsible for planning administration but the acquisition and allocation of land is the responsibility of the Department of Lands and Physical Planning.

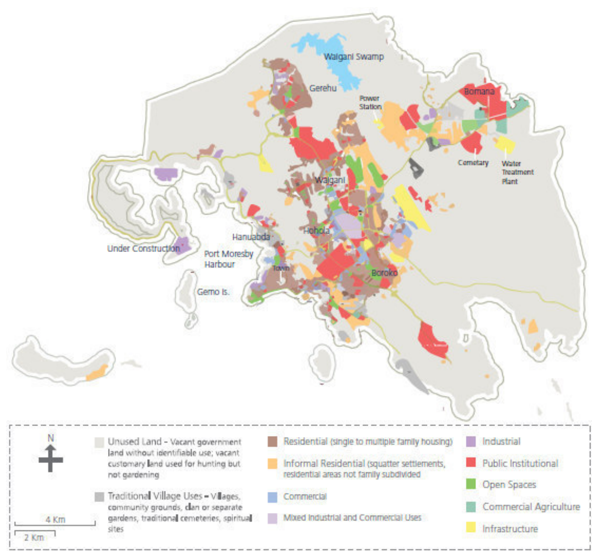


Figure 11: Land Use patterns in Port Moresby

Infrastructure Services

The construction and maintenance of roads, stormwater drains, and sea-walls is the responsibility of NCDC. The collection, transport & treatment of solid waste is also the responsibility of NCDC. The generation, transmission, distribution and retailing of electricity throughout PNG is the responsibility of PNG Power Limited (PPL). The provision of water and sewerage services in urban centres throughout PNG is the responsibility of Water PNG and within Port Moresby this is delegated to Eda Ranu.[1] PPL, Water PNG and Eda Ranu are Independent Public Corporations owned by Kumul Consolidated Holdings Limited (KCHL) on behalf of the Government.

Institutional Responsibility for FSM in Port Moresby

National Government

__Department of National Planning:__ De jure is responsible through the WASH PMU for advising the government on water, sanitation and hygiene policies and laws. The 2015 National WASH Policy [6] proposes the establishment of a successor National Water Sanitation and Hygiene Authority (NWSHA) with the powers necessary to generate the information and identify the challenges, to ensure that WASH sector agencies fulfil their roles in the delivery of water and sanitation services. The draft NWSHA Bill has been placed before the Minister and is expected to be passed into legislation by 2019.

- *De facto* there has been no recognition of WASH as a sector within PNG prior to the establishment of the PMU. As a result, the fulfillment of essential roles related to faecal sludge management has been completely neglected by responsible sector agencies. It will therefore take some time for the WASH PMU (or the NWSHA) to leverage significant reforms in the sector.

__Department of Health:__ De jure is responsible for advising the government on environmental health standards and policies related to the exposure to sanitary risks [7]. This includes the issuing of Public Health Regulations (1973) detailing the asset creation & management standards for Sanitation pertaining to dry toilet closets and cesspits; Septic Tanks pertaining to water borne septic tank and drain pipes, and Sewerage pertaining to wastewater sewers and drains [8] [9] [10].

- *De facto* the Department of Health has not upskilled its workforce to update or implement the Public Health Regulations related to sanitation. As a result, the assignment of responsibilities for sanitation under these regulations to the Local Medical Authorities (incl. Health Inspectors and Sewerage Engineers) have been poorly understood and even more poorly undertaken.

__Department of Works:__ De jure is responsible for advising the government on national building and infrastructure standards. This includes standards related to the construction of sanitation facilities as well as the training of builders and plumbers [11] [12].

- *De facto* while the Department of Works has engaged with builders on building standards, they have not engaged with the certification standards or training needs of the plumbing trade.

__Department of Lands & Physical Planning:__ De jure is responsible for advising the government on policies relating to urbanization, land use and land development. The Physical Planning Act (1989) and the Physical Planning Regulation (2007) delegates the responsibility for the preparation of spatial zoning plans and infrastructure master plans in Physical Planning Areas to Provincial Planning Boards and coordinated by the National Planning Board [13] [14].

- *De facto* the Department of Lands and Physical Planning primarily focuses on the mandatory acquisition of custom land for the state in urban areas. This limits the ability of Provincial Planning Boards to acquire or allocate state land for specific purposes.

__Department of Environment and Conservation:__ De jure is responsible for advising the government on the development of environmental policies, laws and regulations associated with disposal of faecal

[1] A proposed merger of Eda Ranu and Water PNG was announced in 2018.

waste. The Conservation and Environment Protection Authority (CEPA) Act 2014 has delegated the responsibility for environmental protection to CEPA [15]. On the submission of environmental impact assessments CEPA issues clearances for projects and licenses for wastewater discharge [16].

- *De facto* the CEPA is enforcing the compliance of the submission of plans (i.e. environmental no objection certificate for all major infrastructure projects) however CEPA is unable to monitor construction and post-construction compliance with clearance certificates and licenses. This is largely a result of the lack of resources (manpower, mobility, technical ability) arising from the centralized environmental management model.

Department of Provincial and Local-level Government Affairs: *De jure* is responsible for advising the government on the execution of the functions assigned to the provincial and local governments. With the assignment of law-making powers for water supply, sanitation and hygiene to the Local-level Governments under the Organic Law (1995) this means ensuring that Local-level governments have the freedom, functionaries and finances to fulfil this responsibility [17].

- *De facto* local level government finances are miniscule (1.6% of total government expenditure in 2016) and the management authority over functionaries is meagre (local level staff are engaged centrally). Local-level governments have therefore been unable to fulfil their assigned role of ensuring safely managed sanitation services for all.

Department of Agriculture & Livestock: *De jure* is responsible for the development of organic fertilizer standards and the administration of the approval processes to ensure that faecal waste is safe for commercial use as a fertilizer.

- *De facto* the organic agriculture sector in PNG is miniscule. There is currently no market for organic produce, no demand for organic fertilizer and no regulations on the potential re-use of faecal waste or effluent in the agriculture industry.

Local Level Government

National Capital District Committee: *De jure* is responsible through the Health Division to ensure that environmental health standards are met by city residents and tenants; through the Waste Management Division for solid waste collection, transportation and disposal, street and storm water cleaning and maintenance; through the Engineering Department for the design and construction of all public roads and bridges, drains and buildings; through the Regulatory Services Department for physical planning and development control as well as the issuance of trade licenses.

- *De facto* the NCDC manages solid waste and storm water but is not aware of their responsibility to oversee the whole of the faecal sludge management chain. NCDC manages planning approval and building permit processes but does not regulate the construction of septic tanks and leach pits. NCDC environmental health staff respond to all sewage failures by notifying Eda Ranu but NCDC has no authority to 'follow-up' on the response time by Eda Ranu.

Service Providers

Eda Ranu: *De jure* the responsibility for planning, design, construction, management and levy of charges of water supply and sewerage is assigned to Eda Ranu under the National Capital District Water Supply and Sewerage Act (1996) [18]. Eda Ranu does not have any relationship with NCDC, let-alone a 'quality of service' agreement through which it might be held accountable by the responsible city government & its citizens. In 2018, a proposed merger of Eda Ranu and Water PNG (the national water and sewerage provider [19]) was announced, to reduce the overheads and improve the management of knowledge amongst these two wholly owned subsidiaries of Kumul Consolidated Holdings Limited (KCHL).

- *De facto* while Eda Ranu does not necessarily have a mandate it does have the capacity to treat faecal sludge delivered to its treatment plants by tankers. Billing for sewerage services is incurred by households if they are within 25m of a sewer line irrespective of whether they connect, receive or bypass the sewer. This means that the level of follow-up by Eda Ranu on residential or commercial wastewater consumers behaviour is limited.

Property Developers: *De jure* are required to meet all the costs to ensure that new releases of land comply with quality standards for water supply & sewerage, vehicular access and drainage.

- *De facto* the easiest option for developers is to propose that every household will be responsible for their own septic tank and leach drain even in areas where the density of the soil means that leach drains don't be capable of diffusing the effluent.

Builders: *De jure* are required to comply with public health regulations regarding the design of septic tanks however the installation of a leach drain is considered optional and the provisions for the design of leach drains are wholly inadequate to their significance in faecal sludge management.

- *De facto:* the low effectiveness of leach drain systems in the dense soil in Port Moresby leads builders to install septic tanks that discharge to the stormwater drains. Reducing the volume of water discharged to septic tanks by separating the grey water is rarely undertaken by builders.

Plumbers: *De jure* are required by the Public Health Regulations to hold a licence under the Trade Licensing Act as a sanitary plumber.

- *De facto:* plumbers are often not sufficiently trained or aware of the national standards or best practice required for the installation of either on-site or networked sanitation systems.

Septic Sludge Tanker Operators: *De jure* are required to be provided by, or authorized by, the Local Medical Authority to empty septic tanks and discharge into treatment facilities.

- *De facto:* are operating privately without any regulatory oversight by the NCDC Environmental Health Department or any formal relationship with the treatment facilities operated by Eda Ranu. This means that there is no means by which septic sludge tanker operators, NCDC and Eda Ranu can collaborate to ensure that the best interests of Port Moresby citizens are being met.

Households: *De jure* tenants and owners are required to safely operate and maintain household sewer connections, septic tanks and pit toilets.

- *De facto:* in the non-sewered areas where the leach drains can't absorb the effluent, households may discharge their effluent from the septic tank into the storm water drain. In those areas where the sewerage network blocks regularly, there is evidence that households may install an overflow pipe designed to divert their sewage into the stormwater drains, although this practice is not permitted by Eda Ranu, NCDC or CEPA.

External Agents

World Bank: has supported the government in the preparation of the WASH Policy and undertaking an assessment of WASH services in informal settlements. The World Bank currently provides support to WaterPNG in the development and implementation of plans to install networked water facilities in district towns. The World Bank also supports the WASH PMU in the implementation of the national WASH Policy including the development and implementation of District WASH plans through NGOs and establishment of the National Water, sanitation and Hygiene Authority (NWSHA) in particular.

Asian Development Bank: is managing several streams of technical assistance to the WASH PMU, Eda Ranu and WaterPNG to improve WASH services in informal settlements and urban centres. This includes the management of a grant to improve access to piped water supply in Tete Settlement. ADB is also supporting the preparation of an urban water supply and sanitation project in Vanimo, Kerema and potentially Mendi.

JICA: is funding 55% of the Port Moresby Sewerage System Upgrading Project (POMSSUP) jointly with the Government of Papua New Guinea. The POMSSUP is composed of construction of a Sewage

Treatment Plant (STP) at Kila Kila in Joyce Bay to treat 18,400 cubic meter of water per day plus 13 km of trunk sewers, 15 km of feeder sewers and the construction/rehabilitation of 13 pumping stations.

International Organizations: World Vision has been supporting waste management services in Hanoubada village. Oxfam has been supporting improved sanitation management in Goroka. WaterAid has been the District of Wewak to improve rural and urban water supply and sanitation. UNICEF has been supporting WASH in schools. UNICEF has been supporting the implementation of a WASH in Schools programme with the support of the European Union.

Civil Society Organizations (CSOs): Most of the CSOs in PNG are faith based with limited engagement in the sanitation sub-sector. There are very few local CSOs with a focus on the environment or informal settlements in urban areas.

Summary of Responsibilities

The responsibilities for faecal sludge management in Port Moresby can be summarised as follows:

- **At the national Level:** the Department of Works is responsible for regulation of the building code and plumbing standards; the Department of Lands & Physical Planning is responsible for spatial planning standards; the Department of Health is responsible for the Public Health Regulations; the Department of Environment & Conservation is responsible for wastewater emission standards; the Department of Agriculture is responsible to establish standards for the use of faecal sludge or effluent as fertilizer, the Department of Provincial and Local Government Affairs is responsible to ensure NCDC and Local Governments have the capacity to comply with all of these regulations including the issuing of trade licenses to all service providers.
- **At the local government level:** the National Capital District Council (NCDC) is responsible to ensure the compliance of all homeowners & tenants, property developers & builders, plumbers & septage tanker operators, Edu Ranu and waste management staff to ensure that faecal waste is safely managed for all.
- **At the service provision level:** all public and private providers who collect, contain, empty, transport, treat or re-use faecal sludge are obliged to comply with all regulations regarding the planning, design, construction, operation and maintenance of facilities that affect the management of faecal sludge.
- **At the arbitration level:** the draft National Water, Sanitation and Hygiene Authority (NWSHA) bill proposes the establishment of a regulatory authority with the powers to adjudicate on the price associated with a level of service. In effect, this gives NWSHA the powers to identify quality of service shortfalls and to pursue the responsible agencies to address these deficiencies.

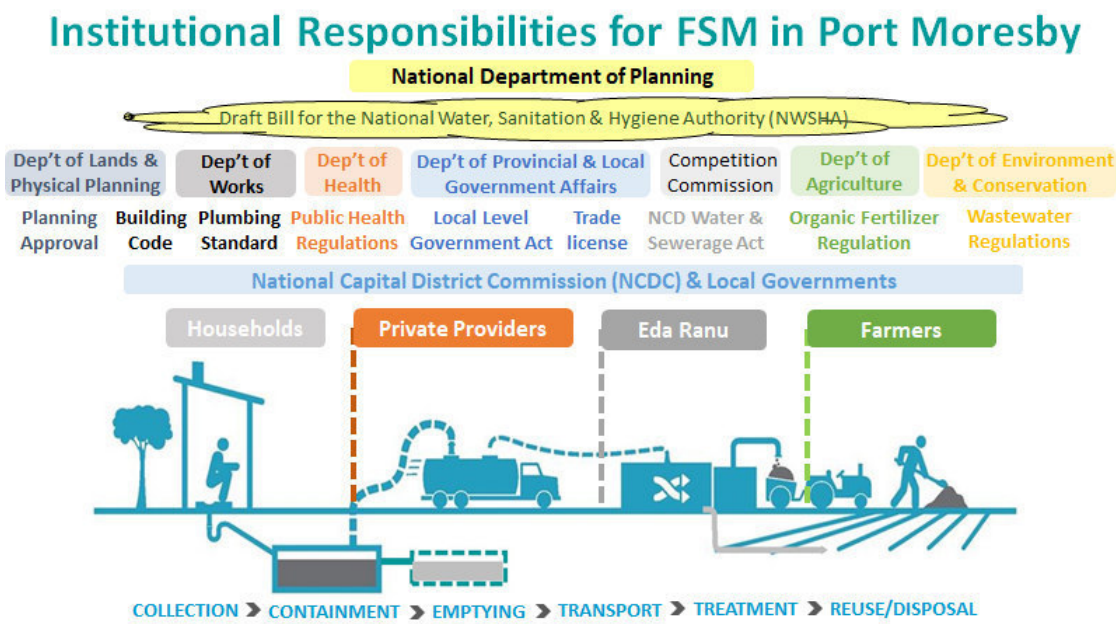


Figure 12: Summary of the Assignment of Responsibilities for FSM in PNG

Safely Managed Sanitation Status in Port Moresby

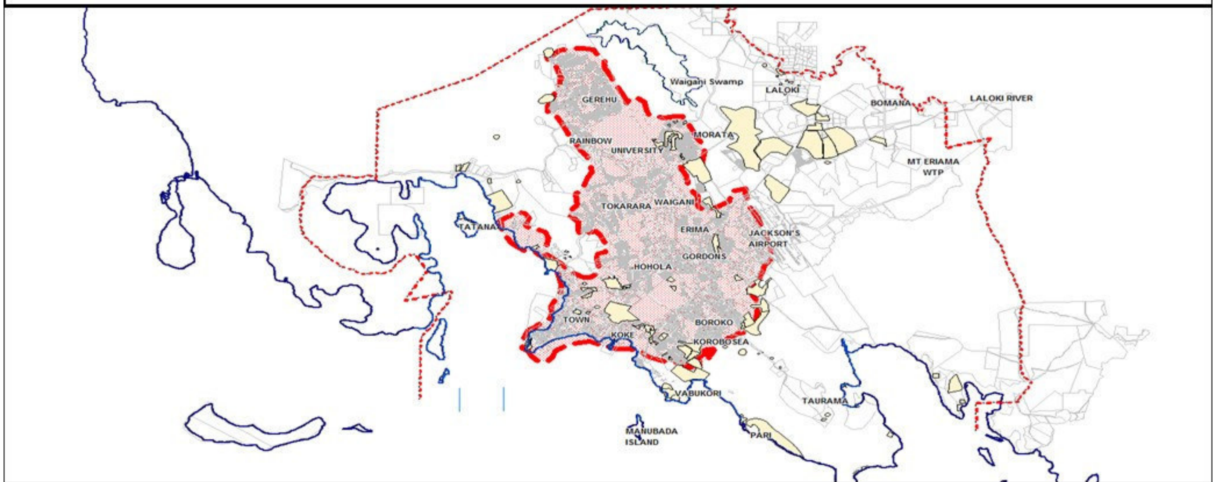
The 2009-2010 Household Income and Expenditure Survey (HIES) conducted by the National Statistical Office (NSO) of PNG identified sanitation and housing characteristics for larger metropolitan areas (i.e. within the metropolitan areas of Port Moresby and Lae). This survey, along with Edu Ranu data on the delivery of water and sanitation services, forms the basis for estimating the 'safely managed' sanitation status of Port Moresby.

According to the HIES, 65% of the population of the larger metropolitan areas use flush toilets, 1.2% VIP latrines, 11% pit latrines with a slab, 16.7% pit latrine w/out slab, 3.3% hanging toilet, 0.2% bucket latrine and 2.7% with no toilet. Again, the HIES indicates that 96.6% of the urban population access piped water (75.3% piped into the household and 21.3% piped into the community) with 1.4% relying on rainwater, 0.3% bottled water and 1.4% other [20].

Eda Ranu delivers on average 175-178 MLD to Port Moresby. With a Census 2011 population of 364,125 and assuming 3.3% population growth rate, the current population of Port Moresby is 503,795. With a total of 54% non-revenue-water (NRW), and an assumed 29% unaccounted-for-water (UFW), the average water consumption in Port Moresby is 246 litres per capita per day (lpcd). Assuming 73% of the water supplied is released as wastewater[2] [21], then the wastewater system needs to manage at least 180 lpcd. Given an average household size of 7.7 persons (as per Census 2011), the wastewater system needs to be capable of handling an average of 1.4m3/household/day (greywater + blackwater).

[2] Municipal water demand corresponds to 11% of global water withdrawal (AQUASTAT) of which 3% is consumed and 8% is discharged as wastewater.

SEWERAGE COVERAGE



- **Total Number of properties in NCD - 19,484** (inclusive of vacant land – 2062 & bulk metered communities – 2642)
- **Total number of sewerage accounts - 15,926**
- **Total number of water accounts - 17,794**

Summary of Accounts by classifications as at 30/09/2017

Classfication	Total number of accounts	Un-Metered	Metered supply		Non-disconnected meters		Unread meters in "no go areas"
			Disconnected	Not Disconnected	Read	Unread	
Non-Domestic - Residential	2,200	20	252	1,928	1,892	36	5
Non-Domestic - Commercial	1,949	1	276	1,672	1,627	45	2
Low Covenant	6,984	25	1,875	5,084	4,739	345	170
High Covenant	5,360	9	845	4,506	4,448	58	2
Schools	63	-	2	61	57	4	3
Government	1,028	-	140	888	867	21	2
Stand Pipe(Flow Control)	4	-	1	3	3	-	-
Exemption	27	-	-	27	4	23	6
Bulk metered supply	179	-	35	144	105	39	8
	17,794	55	3,426	14,313	13,742	571	198
					14,313		

Source: Bills & Collections department (CSA)

Figure 13: Eda Ranu Water & Sewerage Accounts (as at 30/09/2017)

Assuming a 3.3% growth rate in households from the 47,559 recorded in the 2011 Census, in 2018 the National Capital District area should contain roughly 65,800 households. As of the 30th September 2017, NCD had a total of 19,484 registered properties of which 2,062 were vacant land. This suggests a total of 17,422 inhabited properties, of which a total of 2,642 properties housed community settlements, which suggests 14,780 individual properties.

The primary source of drinking water for 97% of the population is piped water (HIES 2010) and Edu Ranu provides water to 14,313 registered connections (of the estimated 14,780 individual properties registered with NCD). If 45% of the population reside within informal settlements, then the 144 bulk metered connections provide water to an average of 211 households each. The remaining 14,169 registered water connections must therefore deliver water to an average of 2.5 households each.

Wastewater Treated Offsite (i.e. sewers)

The water service coverage area of Eda Ranu is 311 km^2 while the sewerage network only covers 70 km^2. According to IBNet data (https://www.ib-net.org/) less than 1% of the annual operating costs in 2017 were spent on electricity because the water and sewage transfer and treatment primarily relies on gravity. The sewerage is divided into two networks, with an inland network serving an estimated 45% of NCDC households and a coastal network serving an estimated 5% of NCDC households.

Coastal System: The average 'paid' water consumption in the catchment area of the Joyce Bay STP is 15.4 MLD (i.e. 14% of daily total water consumption) from the 1,721 water connections (i.e. 14% of the total # Eda Ranu operational water connections) which equates to 8.9 m^3/connection/day. Assuming 2.5 HH per connection and 7.7 persons per HH this gives an average consumption of 464 litres per capita per day. If 73% of the water supplied is released as wastewater then the loading on the sewerage system will be 340 lpcd from the 1,247 registered sewerage connections (or an equivalent of 3,117 households or 5% of the estimated 65,800 households in NCDC) in the Joyce Bay catchment area (i.e. 10% of total Eda Ranu registered sewerage connections) [22].

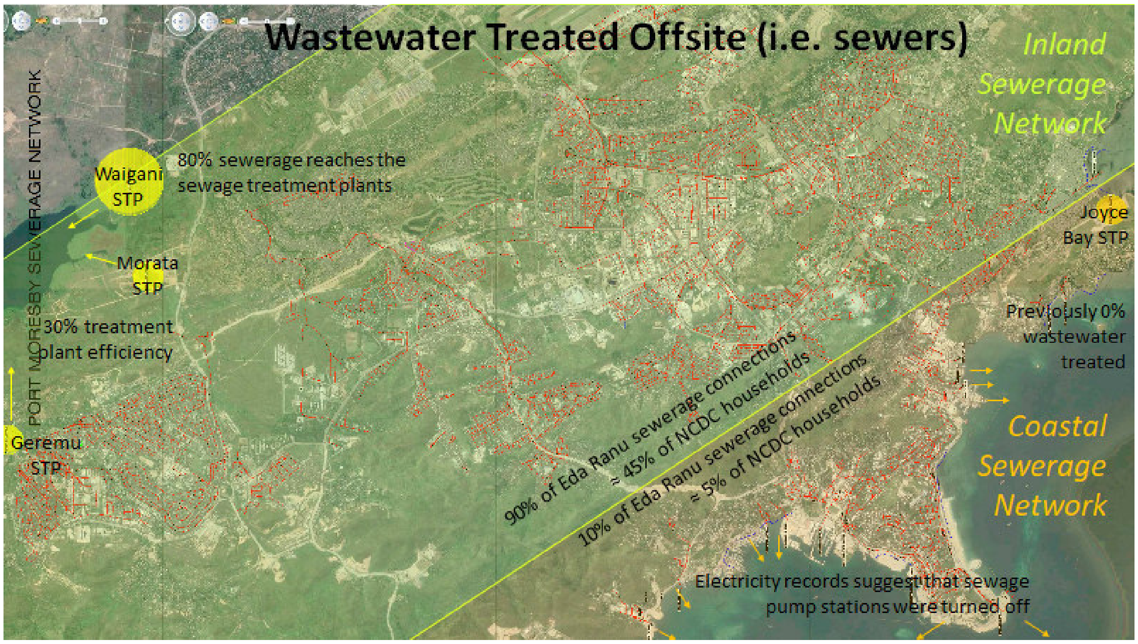


Figure 14: Port Moresby Sewerage Networks (Source: Eda Ranu)

The pre-existing coastal system comprises of 10 sewage pumping stations (Konedobu, Yacht Club, Stanley, Paga, Davara, Lawes Rd, Koki, Badili, Kaugere and Morata) with 8 coastal outfalls. However financial data from Eda Ranu shows that the electricity costs were only 1% of the total operational costs. This suggests that these pump stations have been bypassed by a gravity feed to the ocean outfall. To address this problem, the Government of PNG with the support of JICA has allocated 100 million Kina under the MDTP III to the Port Moresby Sewerage Upgrade Project (POMSSUP) linking the pump stations to a treatment facility [23]. The Joyce Bay Sewage Treatment Plant is designed with a capacity of 18,400 m^3/day to serve a catchment population of 70,384 (i.e. 53,400 in 2011 with a 2.8% population growth rate) or an average wastewater generation of 261 lpcd. Given the legacy of sub-optimal management of the previous system, it remains to be seen how the refurbished coastal pump stations and the Joyce Bay Treatment Plant will be operated and maintained.

Inland System: The inland system therefore serves the estimated 90% of the remaining households with registered sewerage connections (i.e. approximately 11,600 connections or 29,000 households which is approximately 45% of the estimated 65,800 households in NCDC). The inland system discharges to three waste stabilization pond systems at Waigani, Morata and Gerehu with design capacities of 57 MLD, 5.4 MLD and 7.3 MLD respectively. These Inland STP's have capacity to treat all the sewage from NCDC households but not all the wastewater reaches the treatment plants. As these plants are almost 50 years old and as they do not appear to have received any major maintenance since they were installed (except Morata), the effective capacity is well below the design capacity. [24]

STP (MLD)	Date Installed	Pond Type	Depth (m)	Volume (m3)	Capacity (m^3/day)
Waigani (57)	1970's	Anaerobic	2.2	207,600	103,800
	1982	Facultative	1.8	228,700	57,175
Morata (5.4)	1970's	Anaerobic	2.1	10,800	5,400
		Facultative	1.5	21,900	5,475
Gerehu (7.3)	1960's	Anaerobic	2.1	19,500	9,750
		Facultative	1.5	29,300	7,325

Figure 15: Data on STP Capacity (Source: Eda Ranu)

Operation & Maintenance: The regular blocking of sewers with silt, fat, detergent and plastic has resulted in some households installing overflow pipes to discharge their sewage into the stormwater drains. The collapsing of certain sections of the sewer main has also resulted in sewage being diverted into the storm water drains. As a result, the stormwater drainage system (managed by NCDC) ends up carrying a significant proportion of sewage diverted by either households or Eda Ranu. The discharge of sewage into stormwater poses a significant risk to citizens as the systems are not sealed. The accumulation of solid waste and silt compounds the risks for NCDC staff in the cleaning of the stormwater drains to ensure that they can accommodate the peak flows during the monsoon.

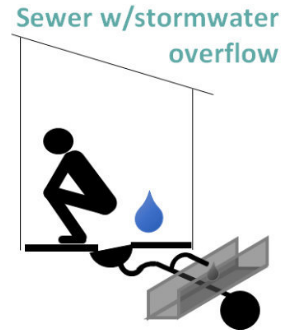


Figure 16: Stormwater o/flow

This is a consequence of the discharge of fats, oil and grease (FOGs) from households and the food industry into the sewers and exacerbated by the discharge of detergent and other wastes from laundries, showers and kitchens. This flushing of plastics and other sanitary products down toilets and the washing/sweeping of dirt into drains that connect to the sewers compounds the problem while the failure of plumbers to protect sand and rocks from entering newly installed pipes that connect to the sewers is also an issue. In the absence of a Trade Waste licensing regime for industrial wastewater discharges it is extremely difficult to regulate FOGs within the sewerage networks.

This is also a consequence of the excessive volume of wastewater discharged into the sewer network that increases the likelihood of overflows from an old and overloaded sewerage system. This will occur due to both the excessive wastage of water by households and a failure to prevent rainwater from entering the sewerage system by households. The entry of excess rainwater into the sewerage system can also occur at points within the network when manholes are not properly sealed or when sewer pipes are broken. The rush of stormwater into an unsealed sewerage system forcing sewage out into the open stormwater system.

Excreta Transported and Treated Offsite (i.e. septic tanks)

Given the high access of households to sewers in Port Moresby (i.e. 50%) relative to the urban sector in PNG (i.e. 20%), the percentage of households relying on septic tanks in Port Moresby (i.e. 10%) is significantly lower than the urban sector for PNG in general (i.e. 21%).

Containment: The recommended design for an on-site water borne system entails a sealed anaerobic tank for separating out and digesting the solids which is connected to leach drain enabling aerobic bacteria within the soil to digest the pathogens and remove the nutrients from the effluent. While anaerobic processes are more efficient in reducing the solids within faecal waste (often measured in terms of reduction in BoD & CoD), aerobic processes are more efficient in reducing the pathogens (i.e. faecal bacteria, parasites & viruses). However, it is important to note that the efficiency of the aerobic processes in neutralizing the pathogens is often a function of the effectiveness of the anaerobic process in removing the solids from the liquids and the liquids from the solids.

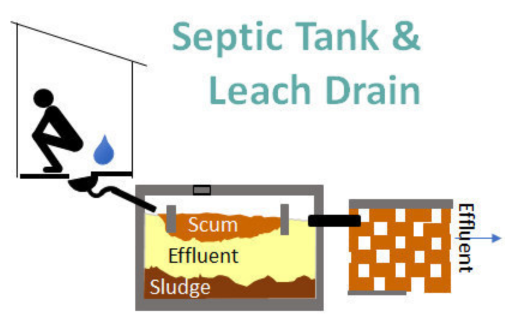


Figure 17: Sanitary Septic Tank Design

This means that a septic tank without a leach pit is not a sanitary system. However, the *Public Health (Septic Tanks) Regulation 1973 (Chapter 226H)* enables the discharge of effluent from septic tanks into storm water drains [9]. While the faecal waste has been subject to anaerobic processes to remove (and reduce) the solids from the effluent, the faecal effluent has not been subject to any aerobic process to remove the pathogens. Faecal effluent that has only been subject to anaerobic processes will not have removed faecal nutrients (i.e. nitrogen and phosphorous). This means that effluent discharged from septic tanks into storm water drains will still carry a significant nutrient and pathogen loading. [25] [26]

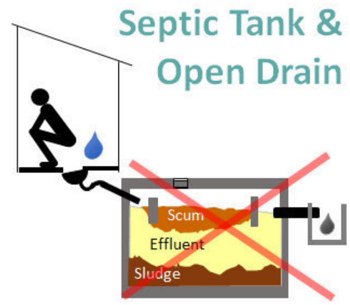


Figure 18: Unsanitary Septic Tank Design

One challenge with the sanitary design of septic tanks in Port Moresby is the low effluent absorption capacity of the soil. Soil percolation tests are necessary to calculate the size of the leach drain required. The Environmental Health Officers indicated that soil percolation tests used to be undertaken when NCDC handled both sewerage and on-site sanitation, but this is no longer the case.

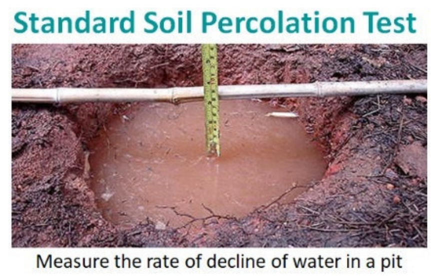


Figure 19: Soil percolation test procedure

According to the graph, the calculated effluent absorption capacity of fine sand with a percolation rate of 60 min/inch is 26 litres/m^2/day. This means that a leach drain that is 3 metres long * 1 metre deep * 1 metre wide will have the capacity to absorb 211 litres of effluent per day. Assuming an average of 8 persons per household this equates to an absorptive capacity of 26 litres per person per day. However previous estimates indicate that the daily discharge of wastewater in Port Moresby is closer to 200 litres per person per day.

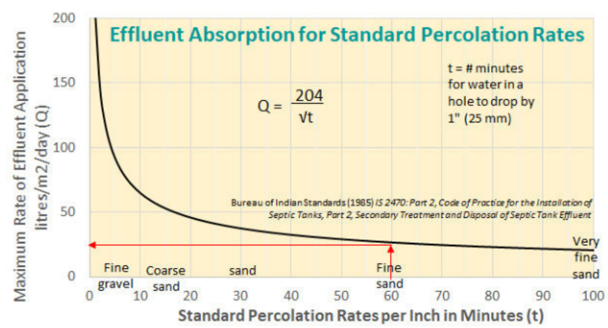


Figure 20: Effluent absorption for standard percolation rates

This means that a normal size leach drain (3m*1m*1 m) will not be capable of dispersing both the grey and black wastewater from a family of eight users. This may lead households to devise other methods of removing the excess effluent. This may include the installation of a pipe exiting the leach drain into the stormwater drains. The implication of this is that the leach drain will start of function as a second anaerobic tank denying the effluent access to any aerobic process. As a result, the effluent will carry unacceptably high levels of nutrients and pathogens.

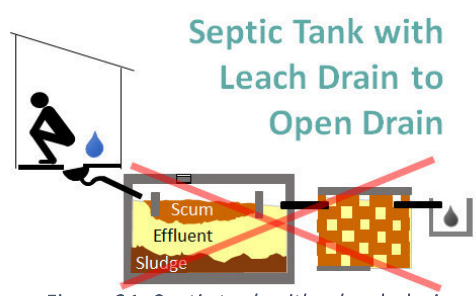


Figure 21: Septic tank with a leach drain discharging to the open drain

Emptying: The emptying of septic tanks should occur before the accumulation of sludge reaches the baffles, as this will force the scum to the roof of the septic tank forcing the effluent over the baffles. Faecal sludge accumulation rates within septic tanks are dependent on many factors, the most important being the number of users, the size of the tank and what is being discharged to the septic tank. As the volume of faecal sludge digested increases over

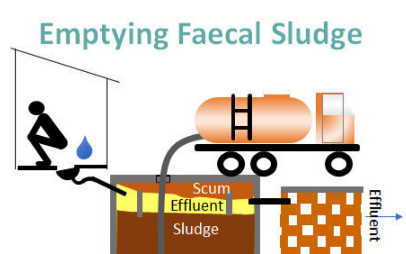


Figure 22: Faecal sludge emptying

time, a higher number of users equates to both more faecal sludge as well as a faster accumulation rate.

Wet septic sludge accumulation rates are estimated at 25-40 litres per capita per year, with the solids associated with grey water accounting for an estimated 15 litres per capita per year. For a septic tank of dimensions 2.5 m long * 1.m wide * 1.3 m deep the working volume will be 2.5 m^3. Assuming 8 users per household with a sludge accumulation rate of 40 litres per capita per year (i.e. the solids from both grey and back water) the septic tank will take roughly 8 years to fill with sludge. If only black water is discharged into the septic tank, then it will take twelve and a half years to fill with sludge. Septic tank fill rates of less than 2 years are most likely due to the accumulation of effluent in the septic tank.

The discharge of fat, oil and grease (FOG), as well as soaps and detergents, constitutes a scum layer that decreases the effective working volume of the septic tank. The washing of sand and other non-biodegradable items into the septic tank will also reduce the capacity of the septic tank decreasing the time between empties.

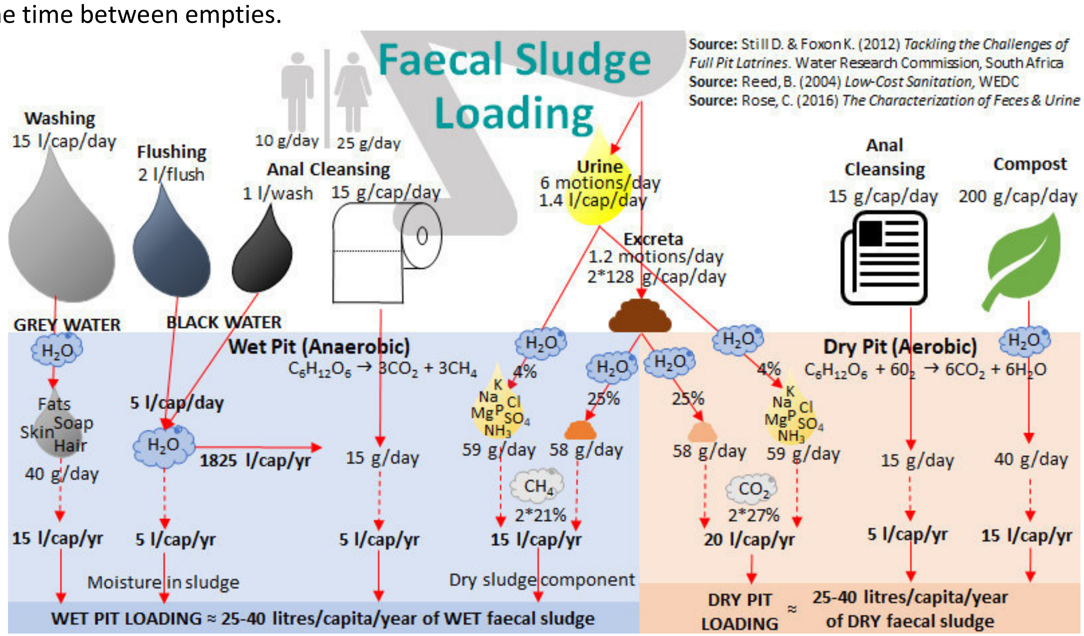


Figure 23: Faecal Sludge Loading Rates

A survey of septic sludge tanker operators in Port Moresby revealed:

- A surprisingly small number of operators (i.e. only 5 private companies could be identified managing a total of approximately 8 tanker trucks of 2,700 – 3,800 litre capacity).
- A surprisingly small number of customers (i.e. these 5 private companies empty a small number of septic tanks of which a significant number appeared to be industrial / commercial clients).
    - The larger operators (with several trucks) reported emptying between 20-40 septic tanks per week in the dry season and 40-60 septic tanks per week in the wet season.
    - The smaller operators (with a single truck) reported emptying between 3-5 septic tanks per week in the dry season and 6-10 septic tanks per week in the wet season.
- The time between pump outs for a septic tank tend to vary from between 6-9 months in the dry season to between 3-6 months in the wet season. This suggests that most of the septic tanks served by the septic sludge tanker operators are emptied twice a year … which means that the operators are primarily emptying effluent from these septic tanks not sludge.

Collectively, this means that a maximum of 75 septic tanks are emptied every week in Port Moresby in the dry season and 150 septic tanks in the wet season. This will enable 2,925 (or less than half) of the estimated 6,500 households with septic tanks in Port Moresby to be emptied twice a year.

The suggests that:

- over half of the septic tanks are not ever emptied, because they are not filling-up, because the effluent is being discharged into the stormwater drains. Over time, as the tank fills with sludge, then the sludge is also discharged into the stormwater drains.
- less than half of the septic tanks are being emptied too regularly because they are filling with effluent (rather than sludge) because the soil is not leaching satisfactorily.

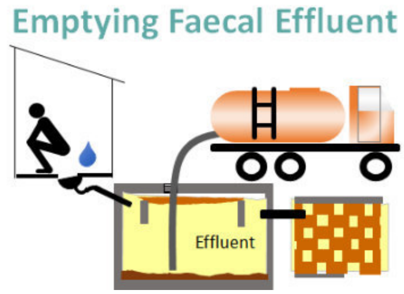


Figure 24: Emptying faecal effluent

Transport: Interviews with Septic Sludge Tanker operators indicated that the most frequently emptied residential septic tanks are 9 mile, Pari, Tokarara, Taurama and the villages along Magi Highway. The areas with the most frequently emptied commercial septic tanks are Rouna, Vitis, LNG Site, Dai Nippon and Clough Niugini.

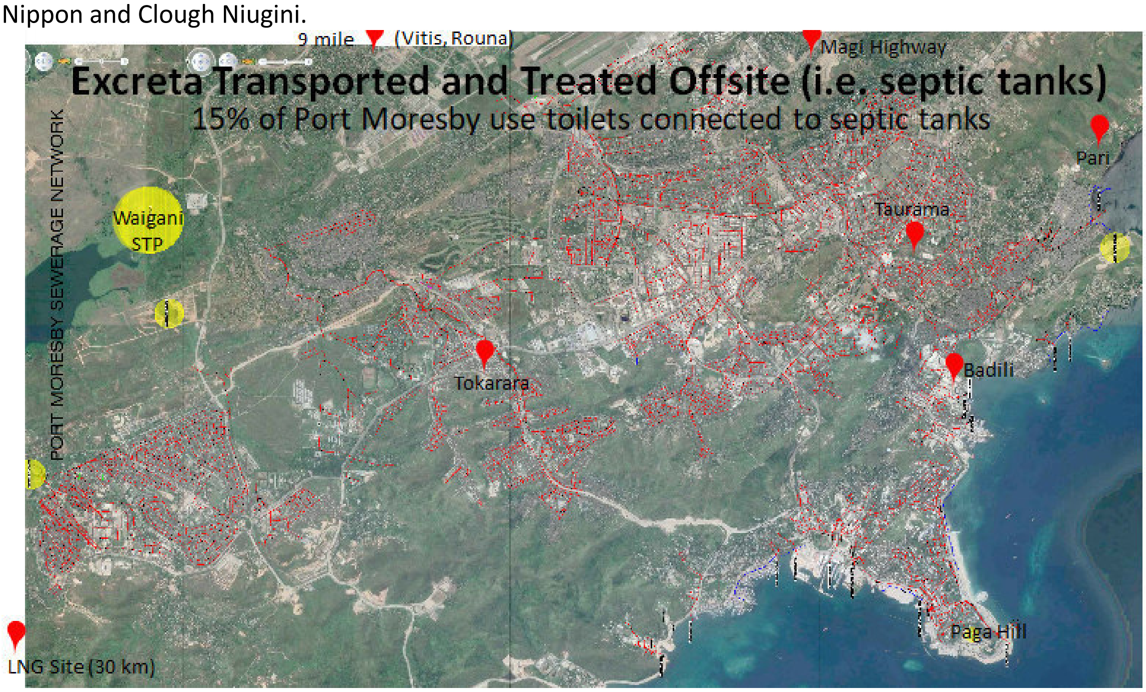


Figure 25: Major areas reported by tanker operators for the emptying of septic tanks

All the sludge tanker operators reported transporting and dumping their faecal waste at Waigani which implies between 20-40 tanker disposals per day. The frequency of tankers disposing sludge at the Waigani site seems wholly inadequate to justify this claim. This implies that most faecal sludge tanker loads are being dumped in more convenient locations.

The main variable in the cost of the emptying of septic tanks lies in the distance to an appropriate treatment facility. While the Waigani Sewage Treatment Plant at 8 mile is convenient for the Tokarara and 9 mile settlements, it is not convenient for most of the other locations. The sludge tanker operators indicated that the price for emptying and transporting could be reduced if septage sludge treatment facilities were closer to the major septic tank locations.

Treatment: Sludge tanker operators are required to discharge their septic sludge at the existing sewage treatment plants operated by Eda Ranu. However, as there is no system for the registration of septage tanker operators or each load of sludge from the septic tanks, there is no way of tracking whether they discharge to the treatment plants or not.

Even if they do discharge to the treatment plants, the low efficiency of the existing sewage treatment plants associated with the lack of maintenance means that any septic sludge discharged at these plants will not necessarily be treated. Both improving the maintenance on the existing sewage treatment plants, as well as installing septage treatment plants proximate to the suburbs with septic tanks, is necessary to ensure that septic sludge is adequately treated.

The absence of any treatment (or recycling) facility for fats, oil & grease (FOGs) means that even when they are properly extracted from the wastewater transfer system, they are not treated. Introducing a commercial system for the collection, recycling and sale of FOGs will create the financial incentives necessary to remove FOGs from clogging up the wastewater treatment systems.

Excreta Treated and Disposed of In-situ (i.e. pits / other)

An estimated 45% of the population of Port Moresby reside in informal settlements. Though most informal settlements are served by piped water, very few households have individual water connections. The lack of a proximate water supply means that most households rely on pit latrines, while a few households depend on public toilets connected to septic tanks or storm water drains.

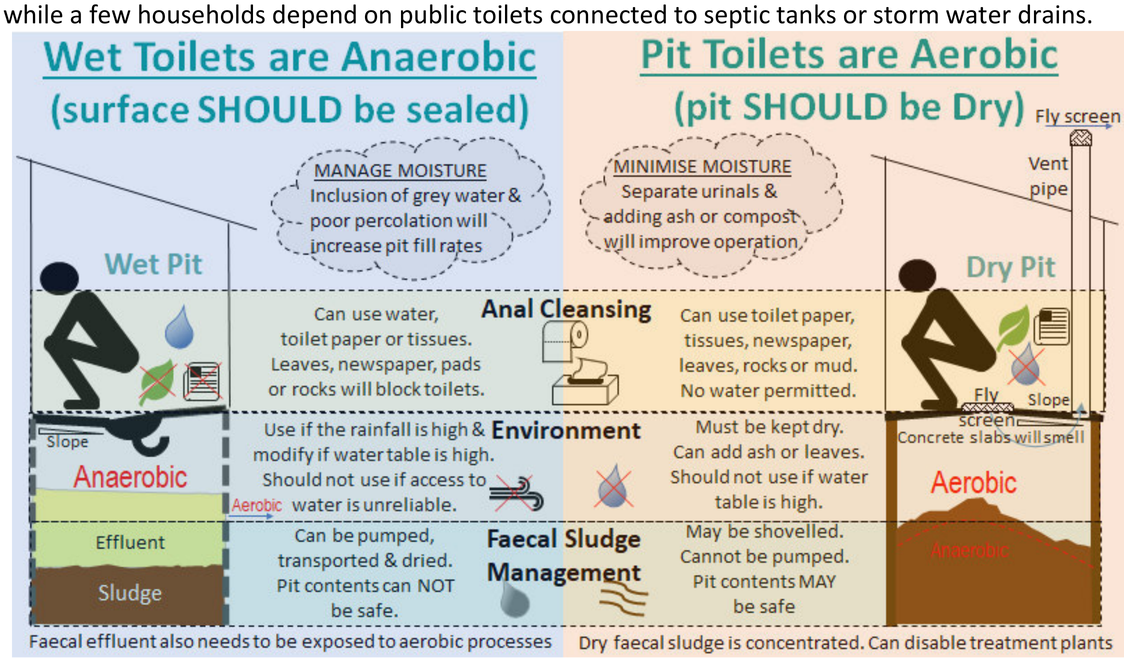


Figure 26: Aerobic versus anaerobic technology options

Containment: By and large the quality of faecal containment within dry pit toilets is extremely poor. This is primarily a function of a lack of understanding of the principles underpinning the design of dry pit toilets, especially the contradistinction in the operational principles that underpin wet pit toilets.

Dry pit toilets function effectively when the pit is maintained in an aerobic condition. The biggest threat to the functioning of dry pits is excess moisture which kills the aerobic bacteria, forcing the pit into an anaerobic state reducing the inactivation of pathogens accompanied by a foul odour.

The aerobic composting of faecal sludge is optimized at a moisture content of 30-60% but raw faecal waste typically contains between 63-86% moisture. This means that dry pits will operate most effectively when the evaporation of moisture is fostered through the circulation of air. In practice, this means that optimizing the operation of dry pit toilets can be achieved by:

- Preventing the use of water for anal cleansing or cleaning of the toilet slab
- Promoting the use of toilet paper, newspaper, leaves, corn cobs or rocks for anal cleansing
- Preventing the entry of rainwater into the pit and sloping the slab away from the hole
- Promoting the addition of ash or compost to facilitate the aerobic digestion process

- Limiting the risk of any groundwater or stormwater entering the pit
- Promoting vent pipes and fly screen covers over the hole to draw air through the pit
- Prioritizing the use of urinals (when not defecating) that deal with the urine separately
- Limiting the use of concrete for slabs (due to the smell when cement reacts with urine)

Emptying & Treatment: The emptying of dry pit latrines in PNG is extremely rare. In almost all cases, new pits are dug, and the old pits are covered. On those occasions when dry pits are emptied, the contents cannot be pumped-out due to the lack of moisture and the presence of foreign objects in the pit. The faecal sludge must therefore be left until it is dry and can be safely removed with a shovel. However, the septic sludge is so concentrated that it can disable conventional wastewater treatment plants. This means that the septic sludge from dry pit latrines must either be treated in a specifically designed septic sludge drying facility or buried [27] [28].

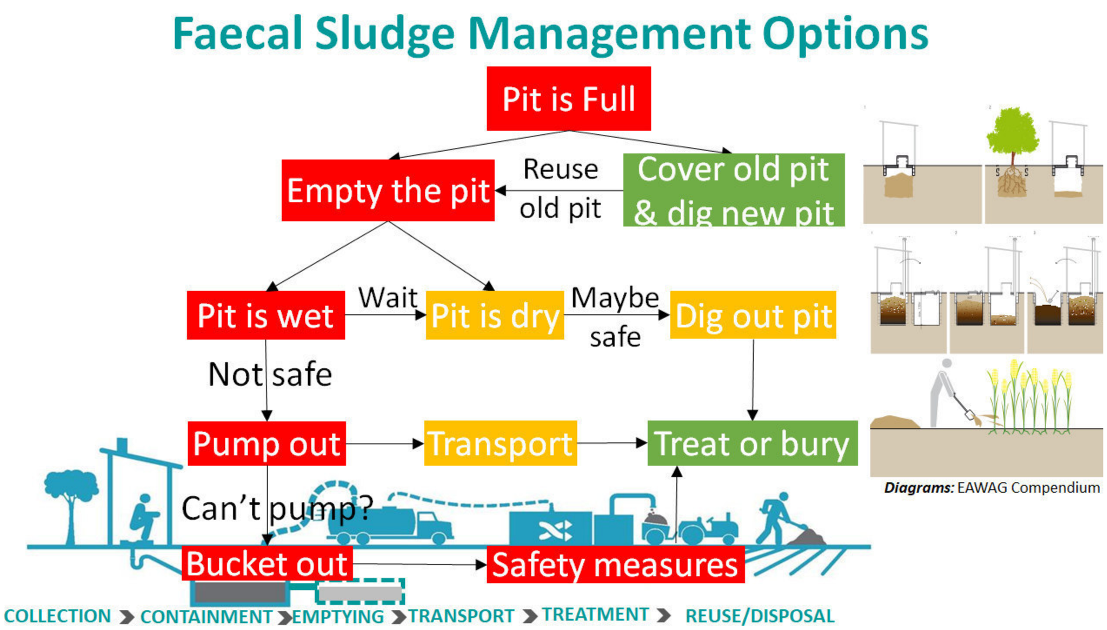


Figure 27: Faecal Sludge Management Options

The time taken for dry pit latrines to fill-up will depend on the size of the pit relative to the number of users, the choice of anal cleansing materials and the use of the pit for disposing of other biodegradable and non-biodegradable material. Aerobic digestion processes are not as efficient as anaerobic processes in digesting faecal sludge, accumulating at an estimated 25-40 litres per capita per year of dry faecal sludge, rather than wet faecal sludge. In low-income countries, the volume of excreta per person (256 g/cap/day) is double that of high-income countries (128 g/cap/day) of which 75% is water. The volume of dry solids in excreta in low income countries (58 g/cap/day) is roughly equal to the volume of dry solids in urine (59 g/cap/day) that is being digested at half the maximum digestion efficiency of 27%. This leaves the solids within excreta and urine accounting for an estimated 20 litres per capita per year accumulation within a dry pit [29].

The addition of bulky anal cleansing materials or compost will improve the effectiveness of the aerobic digestion process in reducing foul odours, but it also increases the solids accumulation rate within dry pits. The use of biodegradable anal cleansing materials is estimated to account for an additional 5 litres per capita per year of accumulated solids. The use of the pits for the composting of biodegradable materials and disposal of non-biodegradable materials is estimated to account for an additional 15 litres per capita per year of accumulated solids. This leaves dry pits with an estimated solids accumulation rate of 40 litres per capita per year [30].

A dry pit of 1 metre diameter and 1.5 m depth will have a working volume of 1.2 m^3. Assuming 8 users per household and a sludge accumulation rate of 40 litres per capita per year (i.e. excreta + biodegradable anal cleansing materials + compost) the pit will fill with sludge within four years. If the pit is not used for the disposal of kitchen waste, then the pit will take six years to fill.

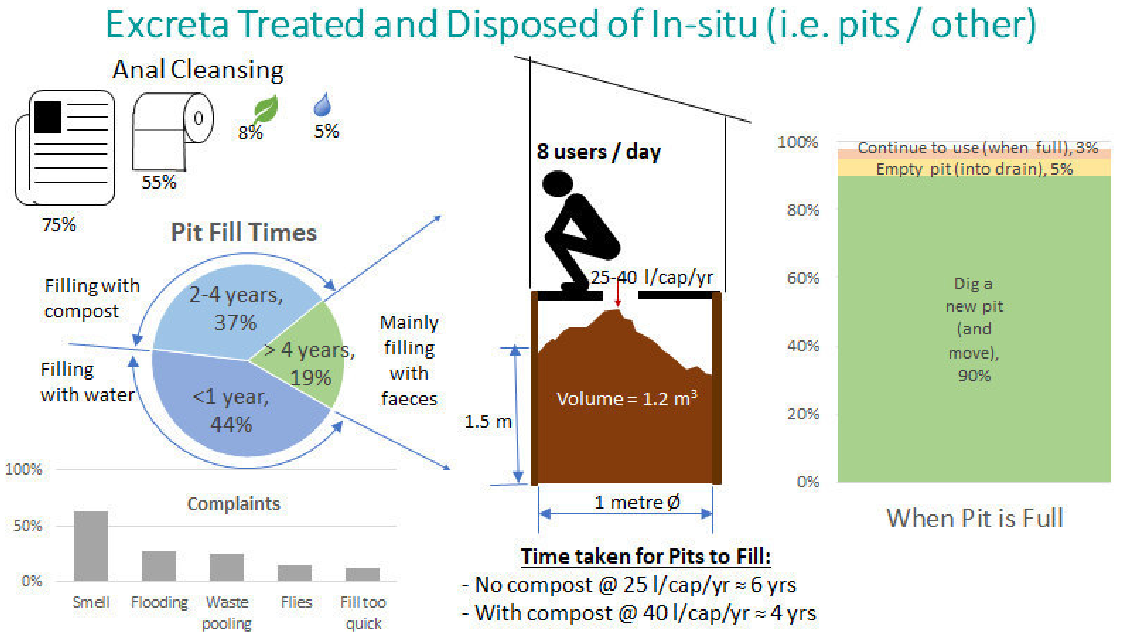


Figure 28: Excreta treated and disposed of in-situ (i.e. pits / other)

Reducing the number of times that the pit is used for urination will increase the time for the pit to fill, as well as improve the efficiency of the aerobic digestion process. Placing bins within dry pit toilets for the disposal of non-biodegradable materials (i.e. menstrual pads & nappies) will also increase the life of dry pit latrines. Advising against the use of water for anal cleansing will improve the aerobic efficiency of pit latrines, increasing the life of dry pits by reducing the likelihood that used plastic water bottles will be discarded into the pit.

Port Moresby - Shit Flow Diagram

Collection: According to the HIES 2010 estimates, an estimated 3% of the urban population have no access to a sanitation service (i.e. practice open defecation), 20% have access to an unimproved sanitation service (i.e. utilise unimproved facilities), 12% have access to a limited sanitation service (i.e. utilise an improved sanitation facility but shared by two or more households) and 65% have access to a basic service (i.e. household accessing their own improved sanitation facility). Of the 65% of the population within Port Moresby accessing a basic sanitation service, an estimated 60% utilise improved flush latrines while the other 5% utilise improved pit latrines.

Containment: Of the 65% of the population accessing a basic sanitation service, 50% is estimated to contained within sewers, 10% contained within septic tanks and 5% contained within pits. The logic applied by the JMP for estimating the status of safely managed sanitation has then been applied to the emptying, transport & treatment in situ and offsite.

Emptying, Transport and Treatment: The choices for safely managing sanitation beyond the point of containment are largely dependent on whether the faecal waste has been contained within pits, septic tanks or sewers. This is represented by the three following management options:

- **Excreta treated and disposed of in-situ (primarily from pits):** An estimated one third of the 5% of improved pit latrines are assumed to affected by water, leaving 3% of dry pits safely containing excreta. All these latrines are assumed to be covered when full (and replaced by an improved superstructure over a new pit), which will leave an estimated 3% of the faecal waste contained within the 5% of improved dry pit toilets as 'safely managed'.
- **Excreta transported and treated offsite (primarily from septic tanks):** Half of the 10% of households which discharge to a septic tank are assumed to have been installed with a functional soak pit, meaning that 5% of septic tanks safely contain faecal sludge & treat faecal effluent. If all these septic tanks are safely emptied by sludge tanker trucks where just over half is discharged at a treatment plant that effectively treats one third of the wastewater, this will leave just 1% of the faecal waste contained within the 10% of septic tanks as 'safely managed'.
- **Wastewater treated offsite (primarily from sewers):** One third of the discharge of the 50% of households connected to sewers is assumed to enter the stormwater drain due to the diversion of household connections or diversion of sewers. Of the 35% of wastewater that reaches a treatment plant or outfall, less than one third is adequately treated, which leaves only 10% of the wastewater collected from the 50% of households connected to sewers as 'safely managed'.

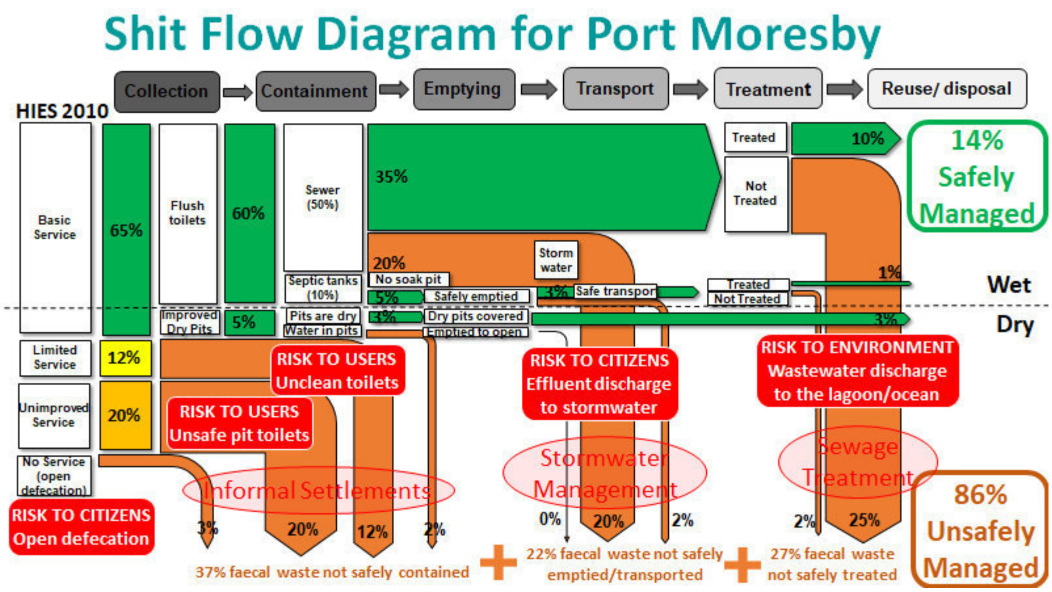


Figure 29: Shit Flow Diagram for Port Moresby (2010)

This indicates that only 14% of the faecal waste generated by the population of Port Moresby can be considered 'safely managed'. Of the 86% of the faecal waste that is unsafely managed, the primary faecal exposure risk occurs to the 37% of the urban population that do not have access to toilets that safely contain excreta, the majority of whom reside in informal settlements accessing dry pit toilets. The secondary faecal exposure risk is the environmental risk associated with the failure of the treatment plants to adequately treat 27% of the sewage or septage from Port Moresby. The tertiary faecal exposure risk occurs to citizens exposed to the unsafe transportation of an estimated 22% of the wastewater primarily through the open storm water drains in Port Moresby.

Recommendations

Given the high access to piped water, the sloping terrain and the low absorption capacity of the soil, networked sewage systems are likely to remain the preferred sanitation solution for Port Moresby. However, the relative convenience associated with the use of stormwater drains to transfer faecal waste by both households and Eda Ranu is something that needs to be recognised and regulated. In the short term, this potentially requires the safety of the transport, containment and treatment of high-risk stormwater flows to be addressed. In the longer term, this will require operational modifications to reduce the spurious wastewater loading on the existing sewerage system or a significant expansion of the capacity of the sewage transport & treatment system. Taking the grey water off the sewerage and septic tank systems will increase the ability of the existing systems to safely manage the current loading rates.

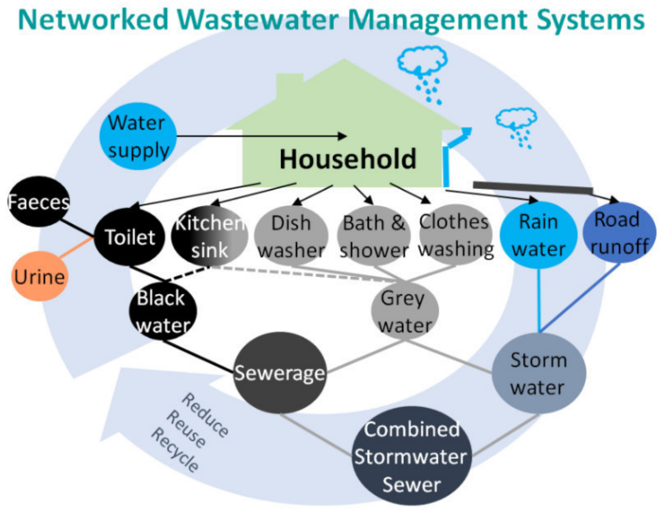


Figure 30: Relations of networked wastewater management systems

While networked gravity sewerage systems will continue to form the backbone of the water borne faecal waste management systems in Port Moresby, the effectiveness of both on-site and networked water borne systems could be greatly improved by:

- Reducing the entry of non-biodegradable solids into sewerage and septic tank systems would increase the fill times and decrease the occurrence of blockages. This could be achieved by:
  - Requiring grease traps in buildings to prevent fats entering septic tanks and/or sewers.
    - For the retail food industry, this will require a commercial business that collects and recycles cooking fat. It should also require the installation of industrial grease arrestors prior to the approval to connect to the sewerage system. This will require the introduction of a Trade Waste licensing regime.
    - For households, this will include education on the benefits of not pouring cooking fat down the sink (but rather collecting & disposing with solid waste). This should include the promotion of household grease traps.
  - Reducing the volume of detergent, soap & kitchen waste routinely discharged into the septic tanks (and/or sewers).
    - Almost half of the solids accumulation within septic tanks is attributable to washing powder from the laundry, dishwashing detergent & scraps from the kitchen, soap and bodily oils from the bathroom. Reducing the discharge of these products into septic tanks will prolong the life of septic tanks.
    - Diverting grey water from the bath, kitchen and washing machine into a soak pit or drain will at least double the time between the emptying of the septic tank.
  - Preventing the entry of foreign objects that can block septic tanks and sewers.
    - Public education to not flush wet wipes, cotton buds, condoms, nappies, menstrual pads, tampons, rags, plastic wrappers & bottles into the toilets will reduce the frequency of blockages of sewers and septic tank systems.
    - Silt and rocks swept or washed into sewers (or septic tanks) during heavy rains, or that enter during construction and the fitting of new connections reduces system capacity. Training plumbers, sealing sewers, preventing municipal workers from sweeping sand into sewers and installing sand traps at sewer

junctions will reduce the blockages. Improving the management of solid waste also reduces the likelihood of blockages in sewerage and storm water systems.

- Reducing the volume of water discharged as waste into the sewerage and septic tank systems will increase the capacity of the sewer to handle the wastewater flow as well as improve the efficiency of the settling ponds and the septic tank & leach drains to treat the wastewater. As both sewers and leach pits are overloaded relative to their absorptive capacity and as the treatment processes rely on bacteriological processes, the efficiency of transfer and treatment will increase at higher ratios of faecal waste to water.
    - Strengthening the demand management of water consumption will reduce the volume of water that is discharged as waste (0.45 US cents per m^3 for water is amongst the cheapest water in the world). There are many strategies for households to reduce their water consumption as a means of decreasing their generation of wastewater.
    - Separating black water from grey water (i.e. managing grey water with the storm water) will improve the efficiency of septic tank systems both reducing the effluent loading on the leach drains and reducing the volume of solids accumulating in the septic tanks.
    - Preventing the ingress of rainwater and groundwater into the wastewater systems is important in both the design of household systems as well as eliminating the presence of cracks, breaks and manholes in the pipes that enable the ingress of stormwater.

- Improving the safety of the management of faecal flows within the stormwater networks in the short term, while preventing overflows of the sewerage and septic tank systems into the stormwater networks in the long term. This could be achieved by:
    - Removing sewer overflow connections that discharge into the storm water drains
    - Preventing effluent from septic tanks discharging into the storm water drains
    - Repairing the collapsed sections of pipe where sewage is diverted into the storm water
    - Covering polluted stormwater drains where they pose a significant human exposure risk

- Monitoring the quality of stormwater discharge and installing some treatment on stormwater outfalls in the short term, while increasing sewage treatment capacity and regulating the quality of effluent discharge in the long term. This could be achieved by:
    - Removing the silt from the settling ponds at Waigani, Morata & Geremu
    - Installing settling ponds on the stormwater outfalls at the Tareko Lagoon
    - Monitoring the quality of all outfalls and reporting on all overflows
    - Installing septage treatment facilities proximate to the areas covered by septic tanks

- Improving the maintenance of the gravity sewerage mains in the short term, while replacing and upgrading the sewerage networks in the long term. This could be achieved by:
    - Systematically cleaning the heavily silted & blocked sewer networks
    - Upgrading the sewer sections that are overloaded
    - Extending the sewer network into unsewered areas
    - Require property developers to sewer all new sub-divisions
    - Impose headworks fees on property developers for the upgrade of treatment plants

As dry pit toilets will continue to be the dominant faecal sludge management system for informal settlements in Port Moresby (and rural settings), the design and operation of dry pit toilets in PNG needs to be improved. This could be achieved by:

- Reducing the levels of moisture within dry pit latrines by:
    - Educating users not to use water for anal cleansing or for washing of the toilet slab
    - Designing the toilet slab to slope away from the hole to stop water draining that way
    - Always installing a roof over the toilet to stop rainwater entering the pit

    - Promoting the use of urinals (when not defecating) that discharge to the grey water
- Improving the flow of air into and within the dry pit by:
    - Prioritizing the installation of vent pipes (with fly screens) that draw air through the pit
    - Promoting hole covers made of fly screen allowing air flow but preventing flies
- Reducing odour generation within dry pit latrines by:
    - Encouraging the use of paper and other biodegradable materials for anal cleansing
    - Promoting the addition of ash or kitchen compost to the pit if it is smelly
    - Testing materials for toilet slabs other than concrete that do not react with urine
- Ensuring that safe handling of faecal sludge within dry pits by:
    - Promoting the practice of digging a new pit, moving the superstructure and covering the old pit when it is full
    - Reinforcing the idea that any exposure to wet faecal sludge is dangerous

Action Points to Improve FSM in PoM

The major faecal sludge management failures in Port Moresby primarily relate to a failure of national government department to enforce compliance to existing standards manifest in the functioning of Eda Ranu and NCDC and the interface between these two agencies. It is proposed that **separating (a) the regulation of failure** (by the national government) **from (b) the licensing of compliance** (by local governments) **from (c) the management of services** (by providers) may improve the incentives for compliance. The proposed National Water, Sanitation and Hygiene Authority (NWSHA) appears to have the mandate necessary to enable and enforce all these actors to play their designated roles.

Working with the NWSHA. a concerted effort to improve faecal sludge management in Port Moresby could be undertaken at three levels.

- At the policy making level, national stakeholders should increase the focus on the identification of failures to meet sanitation related standards. This should include the imposition of penalties by CEPA for sewage or septage overflows, by the Department of Works for unsanitary building works or plumbing, by the Department of Health for unsanitary practices, by the Department of Local Government for unlicensed service providers. Updating the Public Health Regulations Public (1973) for Sanitation (226G), Septic Tanks (226H) and Sewerage (226J) appears to be a necessary first step.
- At the local government level, NCDC should increase the focus on the licensing of compliance of all providers of sanitation related services (i.e. households, builders, plumbers, sludge tanker operators) with national standards. This should include a quality of service agreement with Eda Ranu that includes standard operating procedures to deal with areas of overlap or ambiguity.
- At the service provision level, the capacity of all service providers (including Eda Ranu) to comply with sanitation related standards will need to be built. This should include ensuring that households, builders, plumbers, sludge tanker operators and Eda Ranu have access to the technical and financial resources necessary for compliance. This will potentially require Eda Ranu to develop a Trade Waste licensing regime (in collaboration with NCDC Health Inspectors) to ensure that the quality of industrial waste released to the sewers is regulated.

Following several consultations with stakeholders, the following priority activities were identified.

Behaviour Change (by NCDC)	Institutional (by NCDC)	Learning (via NWSHA)	Institutional (via NWSHA)	O&M (by Eda Ranu)
Households to adopt best practices in black & grey water management	Define clear roles and responsibilities for NCDC w.r.t. Eda Ranu, DoH, CEPA & DoW.	Initiate a national *'Bildim Gutpla Haus Pekpek'* competition	Include members from NCDC and DoW on the WASH Task Force	Desilting of the settling ponds at Waigani
Restaurants and households to reduce FOG discharges	Develop a Citywide Inclusive Sanitation (CWIS) plan for PoM	Undertake soil percolation tests to inform appropriate toilet designs	Establish a technical working group on FSM to drive forward recommendations	Update sewer asset management system Prioritise collapsed sewers for repair
Increase awareness of NCDC hotline to report sanitation problems	Identify problematic septic tanks that require redesigned leach drains	Update Public Health Regulations (1973) for Sanitation (226G), Septic Tanks (226H) and Sewerage (226J)	Review Building Board approval processes for plumbing, septic tanks & leach pits	Initiate a customer call centre & complaint escalation system for sewage faults
Implement new leach pit standards of DoW & process of Building Board	Give rebates/rewards to households that separate their grey and black water	Investigate crossflow between the Eda Ranu sewage and the NCDC storm water systems	Withhold Eda Ranu water connections pending NCDC septic tank clearance	Reduce, reuse and recycle water to improve faecal waste management

Figure 31: Action points to improve faecal sludge management in Port Moresby

The priority action points that appear to offer the biggest returns at the least cost are:

- the separation of grey and black water because it will dramatically reduce the excessive liquid and the problematic solids that compromise the performance of on-site and networked systems
- the redesign of dry pit toilet systems to reduce the moisture content in the pit because this will remain the major form of access for informal settlements (as well as the rural population).
- the clearing of blocked sewers, replacing of collapsed pipes and grading of settling ponds at Waigani because this gravity system serves almost half of the population of Port Moresby.

Annex 1: Review of FSM in PNG and the Pacific

Access to sanitation in PNG and the Pacific in urban areas is considerably higher than that in rural areas with Kiribati, PNG and Vanua having the lowest levels of access to a basic sanitation service.

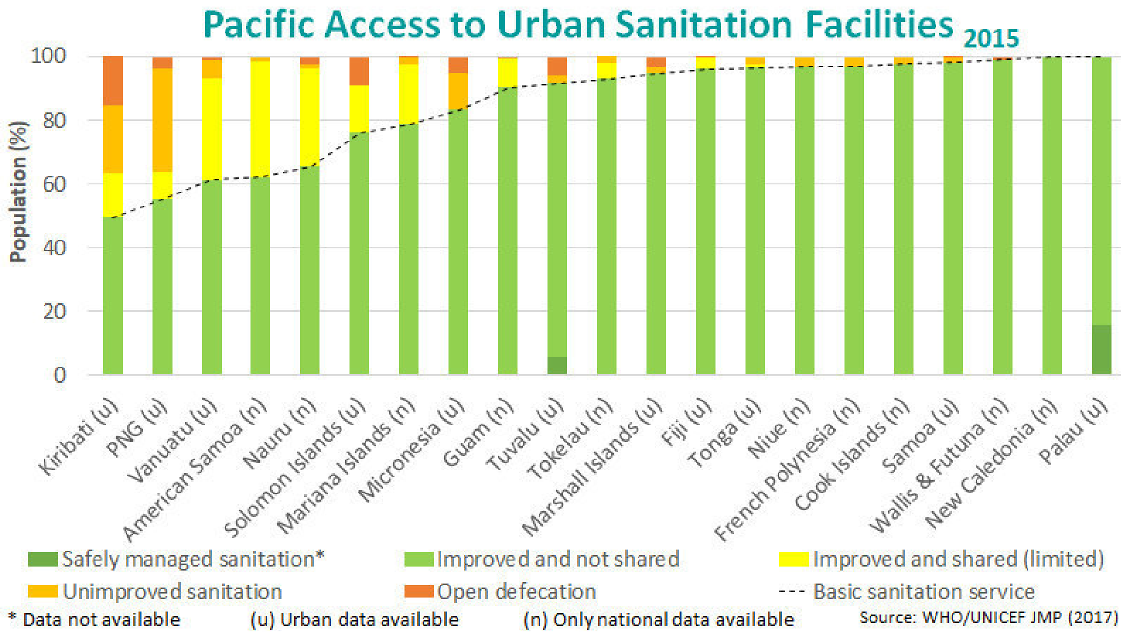


Figure 32: Access to basic urban sanitation services in the Pacific countries in 2015

Subtracting the access to sewers from the access to a basic sanitation service, enables the potential demand for faecal sludge management services to be identified. This can be further broken down into the potential demand for off-site treatment services (from septic tanks) and on-site treatment services (from dry pits). This reveals a significant theoretical demand for the emptying / transport / treatment of wet faecal sludge from septic tanks in the Pacific countries. However, demand in PNG is the third lowest in the region with only20% of the urban population with access to a basic sanitation service potentially requiring wet septic sludge emptying, transport and treatment services.

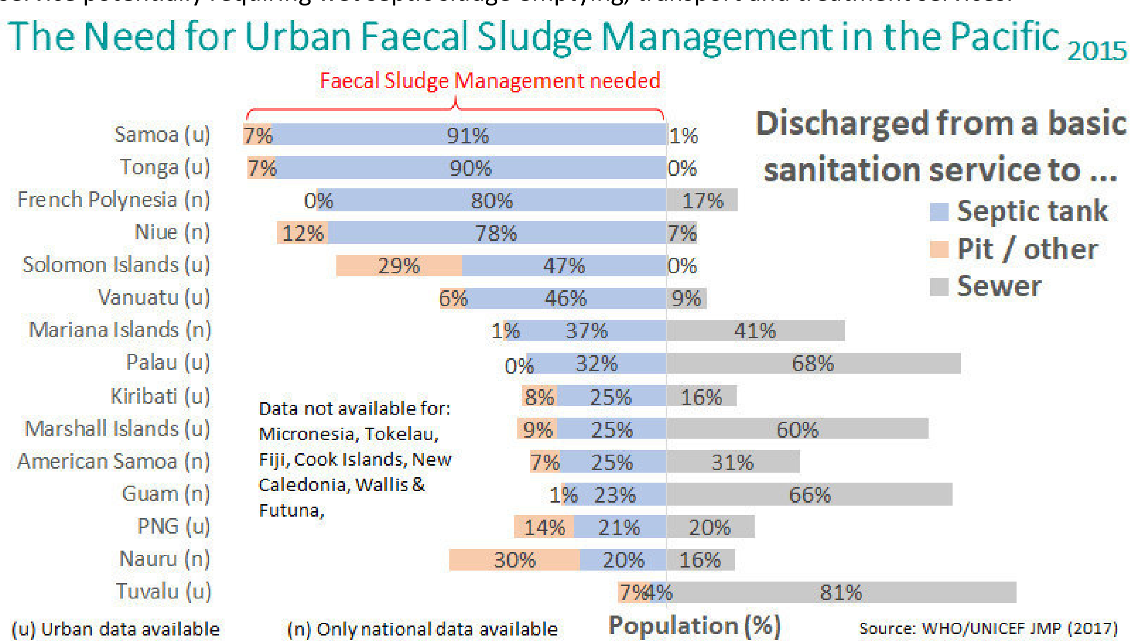


Figure 33: Projected demand for faecal sludge management services in the Pacific region

Surprisingly there is very little literature on the management of faceal sludge in PNG or the Pacific.

- The 2008 WHO & SOPAC report *"Sanitation, hygiene and drinking-water in the Pacific island countries"* highlighted the challenge in just reaching the MDG target levels of access to sanitation facilities in some Pacific countries. For the Pacific countries that had achieved almost 100% access to sanitation facilities it did not mention the challenge of safely managing that faecal waste. [31]
- The 2013 World Bank service delivery assessment *"Water Supply and Sanitation in Papua New Guinea"* highlights the lack of information on the access to and performance of urban sanitation systems. The report emphasizes the need to generate information in order to clearly allocate responsibilities for the collection, treatment and monitoring of urban septage. [32]
- The 2014 World Bank publication *"Sanitation, Water Supply and Hygiene in Urban Informal Settlements"* highlighted the heavy reliance on dry pit toilets by 85% of the population in Wewak and Port Moresby. The report emphasized the self-built and innovative nature of these dry pit latrines but a lack of technical knowledge on latrine design was manifest in premature fill rates, foul odours and poor-quality containment of faecal waste. [2]
- The 2015 World Bank publication *"Unsettled: Water and Sanitation in Urban Settlement Communities of the Pacific"* highlights the significant proportion of the population that rely on unsanitary shared or private dry pit latrines. Even where residents construct improved toilets, virtually none of the waste appears to be safely removed, transported, and treated or reused however the absence of data makes this very difficult to estimate. [33]
- The 2015 *"Water, Sanitation and Hygiene (WaSH) Policy (2015-2030)"* sets out the means to achieve the government of PNG's access to sanitation targets, but it does not specifically address any aspects of faecal sludge management. The WaSH Policy proposes the establishment of a National Water and Sanitation Authority to provide leadership and coordination in the implementation of the WaSH Policy. [6]
- The 2015 WHO, SOPAC, UNICEF, UN-Habitat report *"Sanitation, drinking-water and health in Pacific island countries"* highlighted the limited progress towards the MDG of halving those without access to sanitation. Over the period from 1990 to 2015, improved sanitation coverage increased by only 2% and open defecation decreased by only 1%. PNG had both the lowest levels of progress and access representing the greatest number of unserved people in the region. While highlighting that access to improved sanitation facilities in urban areas is three times higher than rural areas, the report did not address the management of faecal sludge from those facilities. [34]
- The 2017 WHO, SOPAC, UNICEF report *"A Snapshot of Water and Sanitation in the Pacific"* also highlighted the inequities in access to sanitation between countries and rural / urban inequities within countries, with PNG having the greatest challenge on both counts. The report highlighted the lower rungs of the access to sanitation within the Pacific region with the 17% access to sewers being less than a third of the 53% average for the world. [35]
- The 2017 UN Water report *"Wastewater the Untapped Resource"* highlighted the extremely low levels of treatment of wastewater in many of the Pacific countries where 10 countries recording 0% treatment. Referencing the public health risks caused by sewage effluent mixing with contaminated stormwater during floods, the report recommends innovative city planning that includes appropriately decentralized climate resilient water and wastewater systems. [21]
- The 2018 ADB funded report *"Voice, Choice and Babies' Poop"* highlighted the low levels of reliance on flush toilets (5%) relative to the reliance on pit toilets (92.5%) in Tete settlement. The poor hygiene status of pit toilets generating an almost universal belief in the superiority of flush toilets tempered however by the lack of access to individual piped water connections. [36]

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