

**DEVELOPMENT CONTROL AND STANDARDS IN DECENTRALIZED
SANITATION SYSTEMS IN KARENGATA AND ONGATA RONGAI,
KENYA**

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DEDICATION

To my lovely parents, James and Margaret and siblings, Moreen and Lorna, thank you for your support.

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ABSTRACT

Sanitation and hygiene promotion is an integral part of national development strategy. Everyone is entitled to adequate, safe, accessible, and non-discriminatory sanitation as enhanced in the 2010 Kenyan Constitution. The research employed the use of general system theory in sanitation services delivery chain, which requires the participation of various stakeholders or players in a framework for wastewater management. This is achieved through sanitation systems that are compliant to sanitation standards contained in development controls. This research was conducted in Karengata and Ongata Rongai, which are peri-urban areas that have undergone rapid urbanisation and population growth. The main objective of the research was to establish the existence of sanitation standards in development control mechanisms and their relationship to installation and management of decentralised sanitation systems and their compliance. The specific objectives were to: assess sanitation standards governing decentralised sanitation systems, examine the types of decentralised sanitation systems in use, evaluate compliance of decentralised sanitation systems to sanitation standards, and effects of compliance on the environment in Karengata and Ongata Rongai areas. The research used a descriptive survey research design with a sample size of 400 households. Eight zones were sampled using spatial stratified systematic random sampling. The tools used for collection of data include household questionnaire, global positioning systems, digital distance measuring instrument, Olfactometer, observation, and desktop research. Statistical Packages for Social Science software was used to run descriptive statistics and produce frequency distribution, and percentages. Data from observational methods were in the study results as graphs and photographs. Inferential statistics such as t-test and analysis of variance were used to determine associations between variable and its significance. Sanitation systems in Karengata and Ongata Rongai were septic tanks at 75% and 50% respectively and pit latrines at 24% and 50% respectively. The most preferred type of pit latrine was with slab at 20% in Karengata and 34% in Ongata Rongai. On the other hand, for septic tank systems, those without Soakaway facilities were dominant with 57% in Karengata and 72% in Ongata Rongai. Compliance to sanitation standards showed variance between Karengata and Ongata Rongai. The sanitation standards in both areas were not compliant ($p=0.0019<1.96$), which confirm the null hypothesis. Standards on separation distance of sanitation facility from boundary showed significance in pit latrine ($p=0.003<0.05$) and no significance in septic tank ($p=0.180>0.05$). Based on the research findings, the study recommends establishment of a central institution governing sanitation at National and County levels, which will be responsible for coordination, regulation, monitoring and enforcement of sanitation development control policies and regulations. In addition, the public should be sensitized on sanitation standards to enhance compliance and adoption of safe sanitation systems.

ACRONYMS AND ABBREVIATIONS

AAK	Architectural Association of Kenya
AMCOW	African Ministers' Council on Water
CAB	Community Ablution Block
CBD	Central Business District
CBO	Community Based Organization
COHRE	Centre On Housing Rights and Evictions
DEH	Division of Environmental Health
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Coordination Act
FBO	Faith Based Organizations
GoK	Government of Kenya
ISO	International Organization for Standardization
JMP	Joint Monitoring Program
KLDA	Karen Langata District Association
KNBS	Kenya National Bureau of Statistics
LPDP	Local Physical Development Plan
MDG	Millennium Development Goals
MoL	Ministry of Lands, Housing and Urban Development
NACOSTI	National Council for Science and Technology and Innovation
NCA	National Construction Authority
NCWSC	Nairobi City Water and Sewerage Company
NEMA	National Environment Management Authority
NEPA	Network of the heads of Environment Protection Agencies
NETWAS	Network for Water and Sanitation
NGOs	Non-Governmental Organizations
OECD	Organization for Economic Co-operation and Development
SDG	Sustainable Development Goals
SSISP	Small Scale Independent Service Providers
STP	Sewage Treatment Plant
UNICEF	United Nations Children's Fund
USEPA	United States Environmental Protection Agency
VTO	Vacuum Tank Operator
WASH	Water Sanitation and Hygiene
WASREB	Water Services Regulatory Board
WHO	World Health Organization
WSB	Water Services Board
WSP	Water Stabilisation Ponds

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Globally, one of the most pressing confronting concerns is access to well-managed sanitation systems (Bishoge, 2021). Sanitation systems, together with clean drinking water and proper hygiene, are critical to good health and economic and social growth (WHO, 2020).

International sanitation standards emerge from organizations that contribute considerably to the sanitation sector and many countries have implemented standards according to country-specific elements for forming their own local legislation and policies (WHO, 2020). In the Kenyan context, development controls and sanitation standards for decentralized sanitation systems are contained in various statutes and legislative sources, which contain standards on design and specifications for decentralized sanitation systems (World Bank, 2022).

Over 4.2 billion people globally still lack access to safely managed sanitation, with 2 billion people lacking basic sanitation and the majority of these individuals live in poor countries (United Nations, 2020; WHO, 2021). Independence is less important than sanitation if human sanitary provision standards are ineffective (Mara *et al.*, 2010; Weststrate *et al.*, 2019).

Safely managed sanitation involves management of human waste before disposal into the environment in order to prevent environmental hazards that impacts human health (Nanda and Berruti, 2021). The function of safe management of human waste is carried out through sanitation systems and services that meet sanitation standards

Proper management of waste calls for sanitation systems to be designed, sited, constructed and maintained according to standards to undertake their functions on treatment of human waste (Marayan *et al.*, 2021). Sanitation systems manage human excreta across the sanitation service chain i.e. from the toilet through containment (Pit Latrine), to storage and treatment (Septic tank with soakaway and Waste Stabilisation Pond) or conveyance (Emptying, Transport and Sewer) before safe disposal to the environment (WHO, 2018).

Sanitation standards are quantifiable criteria that must be met in order for sanitation systems to achieve an acceptable level of quality (WHO, 2018). They are consensus-based specifications, regulations, guidelines, or requirements that have been authorized by a recognized authority or government. If sanitation systems follow these sanitation standards, they will meet the quality, safety, and efficiency requirements for human waste treatment before it is released into the environment. When these sanitation systems are not adequately planned, developed, operated, and maintained, they deteriorate and fail to perform their role of safely treating human excreta, resulting in environmental pollution, namely air pollution, water pollution, land pollution, and aesthetic pollution. These standards should incorporate all the components of wastewater management across the sanitation service chain as well as ensure equitable access to safely managed sanitation for the entire population (AMCOW, 2021).

Governments are required to develop standards for safe sanitation systems that specify minimum requirements that ensure public health and environmental protection (COHRE and Water Aid, 2008; Pickford, 2017). These sanitation standards should be included in county, state, and national legislation

(WHO/UNICEF, 2015, WHO, 2018). In Kenya, the Government enforces sanitation standards compliance by developing and enforcing rules or directives (regulations) to ensure behaviour that yields to or corresponds with sanitation standards (Onjala, 2002). According to an assessment conducted on sanitation policies in African states, Kenya included, sanitation policy was identified to be inadequate in terms of institutional capacities, personnel, financial resources, legal frameworks and coordination mechanisms (AMCOW, 2021).

Decentralised sanitation systems should meet all sanitation standards that protect public health and the environment (Mezzacapo, 2019; Sharma *et al.*, 2021). These sanitation standards are in the national legislation and county government laws and by-laws, which include Physical and Land Use Planning Act 2019, Environmental Management Coordination Act 2015, Water Act 2016 and Public Health Act 2012. The Public Health Act 2012 calls for systems to be designed, sited, constructed and maintained to meet public health standards (GoK, 2012c). International Standards Organisation has also developed sanitation standards, which can be adopted locally such as ISO 24511, ISO 24516, ISO 24521 and ISO 30500. These standards provide guidelines on management of assets relating to wastewater services including wastewater utilities, non-sewered sanitation systems and prefabricated integrated treatment units (toilet facilities and treatment facilities).

Decentralized, on-site sanitation system is an alternative or complement to the centralized wastewater treatment paradigm. Excrement is processed and disposed of locally with a type of facility and technology that is appropriate for the given setting (Nanda and Berruti, 2021). In Kenya, decentralized sanitation can offer a viable alternative to conventional systems for dispersed rural populations and informal

urban/periurban settlements due to its low cost and limited use of technology (AMCOW, 2021). Decentralization often reshapes the institutional arrangements in a country, with implications for individual sectors including sanitation. Theoretically, decentralization can assist service delivery through improved understanding of local needs and conditions, localization of decision-making powers, improved resourcing for implementation, and enhanced administrative performance (VanVliet *et.al.*, 2021). In Kenya, sanitation systems have been devolved to intermediate level and their operations being delimited to County governments. The functions and powers of county government include sanitation and water services (GoK, 2012a). Counties may further delegate functions to cities boards and town committees, or other service provision entities such as water services providers (GoK, 2011a). In Kenya developmental control in decentralized systems are centered towards wastewater treatment and sanitation (GoK, 2019). Despite clear intuitive linkages, there is limited empirical data on how and why decentralization matters for institutional performance in sanitation sector in Kenya (AAK, 2011a).

Diseases associated with poor sanitation account for approximately 10% of the worldwide illness burden (UNICEF, 2022). At any given time, about half of the urban population in Africa, Asia, and Latin America suffers from a disease associated with poor hygiene, sanitation, and water (United Nations, 2020). It is apparent that a lack of information on how to minimize the issues associated with filthy settings, as well as a lack of sanitation facilities, leads to health concerns (Jenkins *et al.*, 2007; Tilley *et al.*, 2008; Mconville, 2014). Most of these regions, particularly in poor informal neighbourhoods, have congested toilets, clogged

sewers, indiscriminate wastewater disposal, and an overall sense of unkempt environment (Genser *et al.*, 2008; French *et al.*, 2021). Poor socioeconomic status raises the risk of diarrhoea, which is mostly caused by a lack of sanitation, bad infrastructure, and poor living circumstances.

Rapid urbanization has put a strain on the developing countries' capacity to provide basic amenities, including sanitation (VanVliet *et.al.*, 2021). Furthermore, a lot of cities in developing nations cannot afford the expensive costs of physical infrastructure and maintenance required by centralized sanitation. Investing in low-cost decentralized sanitation systems instead of centralized systems can help meet the population's sanitation demands more efficiently and sustainably (Obermann & Sattler, 2013). Various sanitation technologies have been modified to make installation, use, and maintenance easier, and to eliminate or reduce the handling of fresh human excreta (Sharma *et.al.*, 2021). Decentralized sanitation systems are critical in developing nations where centralized wastewater collection and treatment facilities are inadequate. The public health and environmental implications of poorly performing latrines, septic tanks, and soakaway systems (surface and ground water pollution, aesthetic pollution, air pollution) are now being examined to highlight the challenges arising from not properly designing, building or servicing of these decentralised systems (Sarker *et.al.*, 2021).

The Kenyan Constitution 2010 states that all Kenyans have a right to adequate water and sanitation and entrusts both private and public institutions including government ministries with this mandate. They include the county governments through their own Water and Sanitation Companies, Non Governmental Organizations, Multi-national Bodies, Ministries of; Water and Sanitation, Health, Environment and

Forestry, and Lands and Physical Planning and Devolution and ASALs. Environmental concerns are integrated into the design and implementation of development projects through Environmental Impact Assessment (EIA), which is coordinated by the National Environment Management Authority (NEMA). It also sets water and effluent quality standards and regulates effluent discharge into the environment. County governments are in charge of providing water and sanitation services and enacting legislation (GoK 2012a). These institutions exist to preserve public health and the environment in cities through City Councils, where fast urbanization, rural-to-urban migration, and natural population expansion necessitate equitable sanitation management.

Development control manages and regulates physical development in order to ensure that all development in human settlements are provided with the basic services and facilities necessary to support the needs of those who live in these settlements (Venables, 2015). In Kenya, development control is provided in GoK 2019, which governs all physical developments. Non-enforcement of development control measures results in settlements, which feature low-quality developments with inadequate sanitation, endangering both human and environmental health.

The current development control measures are referred to as being too prescriptive and non-adaptive to changes in urban character and setting (Sindarwaithe *et al.*, 2021). The systems prescribed are too conventional, are more suited to traditional urban layout, and are incompatible to changing peri urban local conditions and settings. Therefore, the research sought to assess sanitation standards in development controls, examine sanitation systems in peri urban areas, and establish factors contributing to the safe treatment of wastewater by the systems prior to

discharge into the environment. Further, the research then evaluated compliance of the sanitation systems to sanitation standards and the implications arising from non-compliance on the physical and human environment in peri urban areas.

1.2 Statement of the problem

Residential developments in peri urban areas have increased the need for sanitation and water supply systems (Adeyeye *et al.*, 2020). More than half of wastewater in African cities is not safely managed. Many peri-urban areas are currently relying on decentralised sanitation for safe management of human waste, however as peri-urban areas continue to grow in population and development; the decentralised sanitation systems have not evolved in compatibleness for this growth (Peale *et.al.*, 2020).

In the large majority of peri-urban areas, these systems are largely non performing and this has resulted in widespread wastewater disposal problems (Parkinson and Tayler, 2003). Problems in excreta disposal and management are evident where contents of pits and tanks that are not emptied are overflowing, leaking, or discharging in open drains and into the surrounding environment; or are emptied by vacuum tankers but are not delivered to licensed treatment sites which results in hazards to public health (Peale *et.al.*, 2020).

Ongata Rongai Sub County, Kajiado County, has widespread wastewater disposal issues. The estimated volume of wastewater flow in Ongata Rongai is 22800m³/day with majority of the population relying on pit latrines and septic tanks for disposal (GoK, 2017c). According to District Public Health reports, residents of Ongata Rongai have reported untreated wastewater flowing into abandoned quarries, open drainage, access roads and nearby rivers (District Public Health Report, 2014).

Considering that all this untreated wastewater is being discharged into the terrestrial environment (subsurface, riverine, and abandoned excavations), it calls for an investigation into development control measures applicable to decentralised wastewater systems i.e. the regulatory framework involved in wastewater and septage management of urban settlements (Snyder *et al.*, 2020).

This is further compounded by uncontrolled and unregulated land subdivisions (mutilations) which have emerged in Ongata Rongai, (GoK, 2017c.). As evidenced by the Kajiado Survey Report the majority of this growth is in areas poorly served by sanitation infrastructure (GoK, 2017). This increase in residential density puts more pressure on existing sanitation amenities and results in the overloading and failure of the wastewater management infrastructure. Residents complain of flooding of residential and business premises making them inaccessible to both tenants and clients increase of sanitation related illnesses, damage to infrastructure and in some areas impassable roads arising from flow of unregulated discharge of wastewater.

Karengata, a suburb of Nairobi County, shares a common boundary with Ongata Rongai and experiences common wastewater management challenges. Karengata and Ongata Rongai both peri-urban areas, have experienced fast urbanisation and population increase (GoK, 2011b). Karengata and Ongata Rongai are not served by trunk sewer infrastructure. Residents of these locations have adopted decentralised sanitation systems like septic tanks and pit latrines to treat or dispose of wastewater (Chikozho *et al.*, 2019). The two areas use Vacuum tank operators (VTOs) to empty wastewater, which they disposed of in unlicensed disposal sites such as abandoned quarries, open channels and rivers Kandisi and Mbagathi in Ongata Rongai. Media articles and court proceedings show that wastewater challenges arising from failing

treatment systems in Ongata Rongai have affected residents as well as the natural resources including Mbagathi River and Nairobi National Park.

This research therefore aimed at investigating the reasons for presence of untreated wastewater in the environment and discharge of wastewater into undesignated treatment sites. The research also aimed at determining whether the wastewater pollution is as a result of the failure of existing wastewater treatment systems or the standards on installation and management of these sanitation systems and treatment facilities.

1.3 Research objectives

1.3.1 Main objective

The main objective that directed the research was “to establish the existence of sanitation standards and development control in decentralized sanitation systems and to evaluate the compliance of sanitation systems to the sanitation standards”.

1.3.2 Specific objectives

The following specific objectives guided the study:

1. To assess sanitation standards governing decentralised sanitation systems in use in Karengata and Ongata Rongai areas.
2. To examine the types of decentralised sanitation systems in use in Karengata and Ongata Rongai areas.
3. To evaluate compliance of decentralised sanitation systems to sanitation standards in Karengata and Ongata Rongai areas.

4. To determine the effects of (non)compliance of sanitation systems to sanitation standards on the physical and human environment in Karengata and Ongata Rongai areas.
5. To establish the factors influencing adoption of sanitation standards and sanitation systems in Karengata and Ongata Rongai areas.

1.4 Research questions

The following research questions guided the research:

1. What are the sanitation standards governing sanitation systems in Karengata and Ongata Rongai?
2. What type of sanitation systems are in use in Karengata and Ongata Rongai?
3. How compliant are sanitation systems to sanitation standards in Karengata and Ongata Rongai areas?
4. What are the implications of compliance or non-compliance of sanitation systems to sanitation standards on the physical and human environment in Karengata and Ongata Rongai areas?
5. What are the factors influencing adoption of sanitation standards in Karengata and Ongata Rongai areas?
6. What measures can be proposed to address the problem of wastewater pollution in Karengata and Ongata Rongai?

1.5 Research Hypotheses

The following hypotheses guided the research:

H₁: Sanitation systems in Karengata and Ongata Rongai are compliant to existing sanitation standards.

H₀: Sanitation systems in Karengata and Ongata Rongai are not compliant to existing sanitation standards.

1.6 Justification of the study

According to the Constitution of Kenya (GoK, 2010), access to a clean and safe environment is a right to every Kenyan. Adequate sanitation contributes to social development, improves the quality of life and contributes to reduction of communicable diseases (Joshi and Amadi, 2013; Salman, 2018). Sanitation involves safe treatment of wastewater through sanitation systems i.e. centralised and decentralised sanitation systems. Development control ensures provision of sanitation services in all physical development in human settlements through regulation of sanitation systems (Venables, 2015). Clear policy, legislation and minimum standards are an important foundation for securing potential health gains from safe and adequate sanitation. However, ministries of health and sanitation play a minimal role in sanitation policy setting and programming and are generally approached from engineering perspective, which does not recognise the public health implications of sanitation (Water Aid, 2011). In many developing countries, contractors in construction of residential and institutional buildings have not followed development control regulations and bylaws closely; thereby facilities fall into disrepair and malfunction leading to health challenges (AMCOW, 2021).

In the last 10 years, Karengata and Ongata Rongai, which function as residential areas to the urban population of Nairobi City, have had rapid population increase (GoK, 2010). The two areas rely on decentralised sanitation. However, the increase

in population density calls for commensurate transition in sanitation systems from existing decentralized sanitation systems to semi-centralized or centralized systems, failure of which environmental sanitation problems are bound to occur (Kumwenda, 2019). Numerous media articles (such as, Kamau R, 2022), documentaries and court cases (e.g. Transcentury Ltd vs. NEMA, 2013) give attention to sanitation issues adversely affecting residents and environmental conditions in Karengata and Ongata Rongai areas (Kazungu *et al.*, 2011).

Presence of untreated wastewater in the environment is therefore evidence of an underlying failure of wastewater treatment systems being used in the area. To identify the cause of the untreated waste water, there was need to examine the types of sanitation systems adopted by residents in Karengata and Ongata Rongai, establish the development controls and standards applicable while constructing and maintaining these sanitation systems, thereby identifying whether their failure is as a result of non-compliance to the sanitation standards governing sanitation infrastructure in these areas or whether there are other factors contributing to the presence of untreated waste water in the environment.

1.7 Significance of the study

The study of development control in decentralized sanitation systems will increase the awareness by the public on the importance of adopting the measures directed by development controls when constructing and maintaining their sanitation systems in their dwelling or premises. These systems built and maintained according to sanitation standards encompassed in development control measures will therefore safely treat wastewater before it is discharged into the environment.

The outcome of the study will contribute to the development of a clear strategy to ensure and support mutual participation of all stakeholders, in particular residents, sanitation service providers, institutions and policy makers, in the conceptualization, planning and development control of sanitation interventions. The study will also promote harmonization, coordination of implementation and enforcement of sanitation standards in order to realize safe management of wastewater in Kenya.

The research will provide a case study that will inform future studies by upcoming researchers in the fields of environmental planning, urban infrastructure, sanitation engineering and will allow for improvement of sanitation planning strategies and interventions.

1.8 Scope of the study

Though the research sought to investigate development control of decentralized sanitation systems in Karengata Sub County in Nairobi County and Ongata Rongai Sub County in Kajiado County, it narrowed its focus on sanitation standards, an aspect of development control.

The focus of sanitation standards zeroed in on mainly septic tanks and pit latrines. As the main systems, it largely aimed at investigating the following: construction (siting), maintenance (water quantity requirement) and operation (density of sanitation systems per unit area and population sewage load per unit area), as tools for wastewater treatment before disposal into the environment.

The research also sought to investigate the compliance of sanitation systems to the sanitation standards relating to decentralized sanitation systems found in the area of study and the implications thereof on the environment and public. Factors

influencing adoption of sanitation standards by the public were also identified including intervening variables.

1.9 Limitations of the study

This study was limited due to the following

Sanitation related standards and guidelines were fragmented and scattered across various ministries and institutions. Therefore, the researcher faced challenges in collating and consolidating them to establish the sanitation standards relevant to decentralized sanitation systems. This also presented a problem to developers and property owners in adopting and implementing the standards while constructing and maintaining sanitation systems for their development situation.

The researcher along with carrying out interviews with government officials adopted desktop research and consultation of sanitation sector experts to acquire relevant information.

Lack of available and/or reliable data. Due to the sensitive nature of the wastewater disposal in the area of study, there was limited data on the existing disposal methods adopted by residents and VTOs. Ground water being the major source of drinking water in the study area, the data was important, as it would highlight the health risk of consumption of drinking water abstracted from the local aquifers that are likely contaminated with untreated wastewater. The researcher therefore applied covert methods of observation to collect the information and avert the security risk.

Misconceptions in reported data. While determining the decentralized sanitation systems, there was a chance of misconception of the terms such as holding tank and

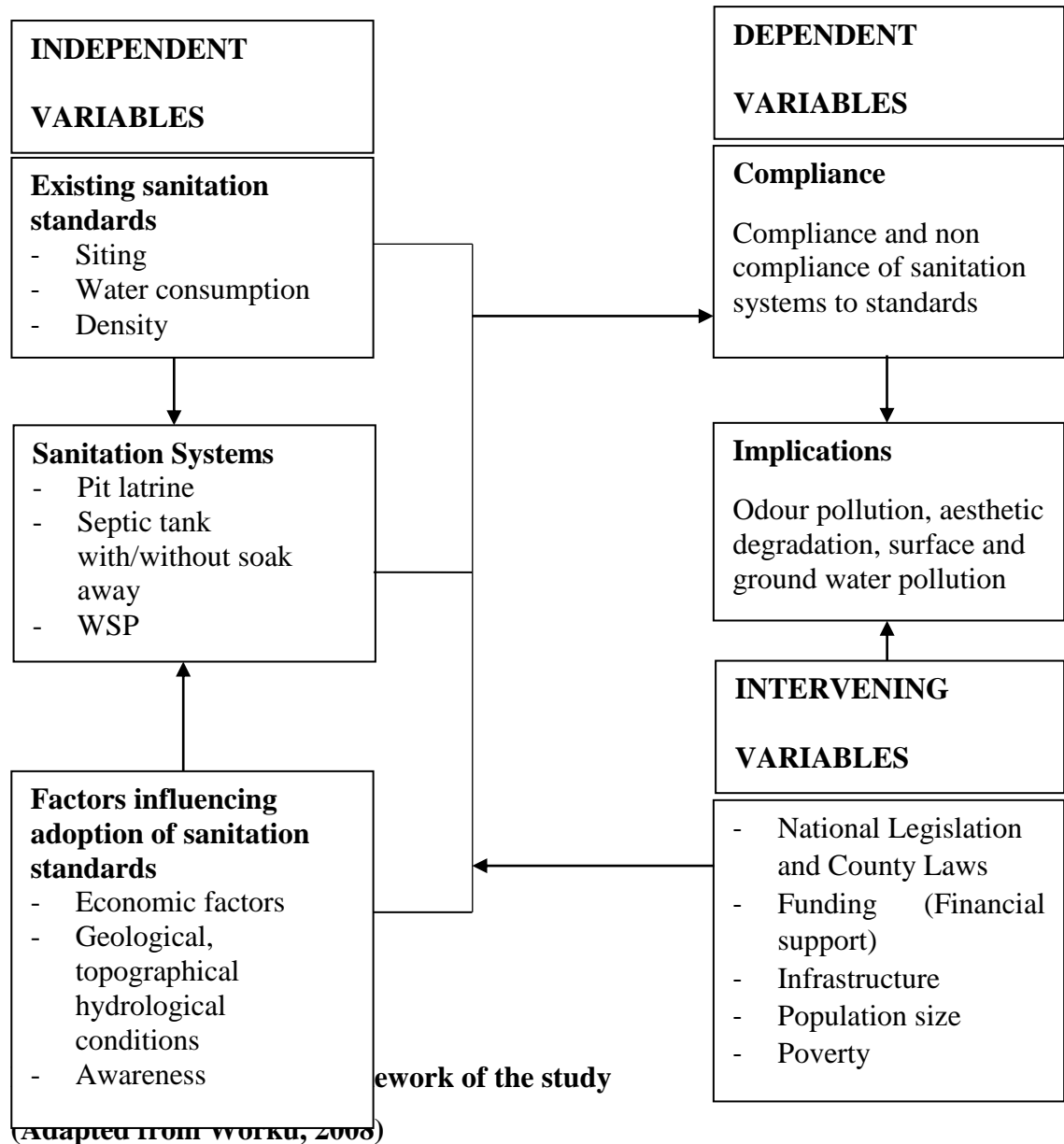
septic tank by the respondents. This was mitigated through indirect observation by the enumerator to confirm the information given was correct.

Lack of specific measuring equipment to collect the data. While determining the implications of systems not complying with standards on the environment and public, the expensive equipment was beyond the financial capacity of the researcher and as such services of accredited laboratories had to be used and secondary data sourced from relevant government institutions such as NEMA, water service providers and meteorological department were acquired.

1.10 Conceptual Framework

In this research, the independent variables were determined to be sanitation standards because they control the construction, operation and maintenance of decentralized sanitation systems. Compliance or non-compliance of sanitation systems to standards is based on existing sanitation standards (siting, water consumption, and density). The standards are derived from the national legislation and County laws and are geared towards better sanitation provisions in use within the areas inhabited by the residents. The lack of awareness, economic factors, and topographical and hydrological conditions influences the provision of better sanitation systems. Sanitation systems were also considered as independent variables because they use predesigned technology and the standards in this research apply only to installation and maintenance of these systems. The resulting outcome is either compliance or non-compliance resulting in implications thereof on the environment and public health and these therefore become the dependent variables. The conceptual framework also highlights the relationship of intervening variables with the independent and dependent variables. Finally, the adoption of sanitation

standards in Karengata and Ongata Rongai depends on the economic, hydrogeological, topographical and awareness factors which determine the compliance of sanitation systems to the standards in place. Figure 1.1 depicts the relationship between the study variables.



Basic Sanitation - This refers to access to, and the use of, excreta and wastewater facilities to ensure a clean and healthy environment within the household level and any other living environment.

Cess Pool/Cess Pits – an underground chamber for the temporary storage of liquid waste and sewage

County laws – Refers to laws made by the county governments to control public under their jurisdiction and are uniform and not in conflict with national laws.

Density Standards - is a quantitative measure of the intensity with which land is occupied by either development or population.

Development control process - development control is the process of ensuring development applications comply with policy guidelines, planning regulations, standards, approved physical development plans, Local Authority by-laws as well as other relevant statutes. This also involves enforcing compliance with these requirements in implementing the approved development proposals to ensure sustainable development.

Environmental Sanitation - Actions taken to prevent disease exposure by ensuring a clean environment; measures or requirements taken to break the disease cycle. Control of vector-borne diseases, sanitary management and/or disposal of human and animal waste, excreta, and wastewater, and household hygiene encompassing home sanitation and occupational sanitation. Sanitation involves appropriate behaviour and acceptable facilities, which together constitute a hygienic environment.

Improved sanitation facility- a sanitation facility where excreta are processed and disposed of on-site or transported and treated off-site. Toilets connected to sewer systems, septic tanks or pit latrines, upgraded pit latrines and composting toilets.

Improved Sanitation and Hygiene – It includes activities and abilities that promote a healthy and clean environment for individuals, families, and communities. The practice focuses on clean drinking water and effective excreta disposal. It also stresses responsible waste management and protecting houses from rodents and vectors, especially those of public health concern.

On-site sanitation – This refers to sanitation systems where the human excreta and wastewater are collected and treated and disposed on-site it is generated, for example, in septic tank with soak away systems, ventilated and improved (VIP) latrines are some of the technologies that are used for the purpose.

Peri-urban Area – This refers to an area immediately adjacent to a city or urban area. It relates to the processes of scattered and dispersive urban growth that create hybrid landscapes of fragmented and mixed urban and rural characteristics.

Regulations - It is the deliberate action by the government authorities to enforce compliance by individuals to; for example, sanitation standards by making and maintaining rules or directives to ensure behaviour that yields or complies with sanitation standards.

Sanitation - Refers to the provision of facilities and services for the safe management of human excreta and wastewater from containment, storage and treatment; conveyance, semi centralised treatment and eventual safe end use or disposal.

Sanitation Standards - Sanitation standards are quantifiable criteria needed to achieve acceptable level of quality for sanitation systems.

Sanitation Provisions - Offering of technologies, services for safe disposal of human excreta and wastewater.

Wastewater – Liquid wastes generated by households, industry and commercial sources as a result of daily usage, production and consumption activities.

Wastewater Treatment - When used in reference to waste management, it means, any method, technique or process designed to change the biological character or composition of wastewater to reduce or eliminate its potential for causing harm.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section gives a broad literature review on sanitation standards in development controls applicable to decentralized sanitation systems as a means of wastewater treatment before disposal into the environment at the global scale and the Kenyan set up. It also revealed the theory that informed the study. In addition, in the literature, review it was discussed the types and processes involved in decentralized sanitation systems and the implications of non-compliance of these sanitation systems on the environment and the public.

2.2 Importance of Development Controls in Decentralized Wastewater Treatment Systems in Human Settlements

Access to adequate wastewater treatment systems in global south countries in urban informal settlements remain a challenge (Faldi *et al.*, 2019). Access to sanitation is as low as 20% in urban poor settlements where half the urban population lives. It is currently estimated that about 50% of Kenya's urban population live in unplanned settlements lacking in basic infrastructure provision and services (UNICEF, 2022). In Nairobi, three out of every five, or 60%, of the population live in the informal settlements, occupying only 5% of residential land (GoK, 2016b).

Inadequate sanitation services results in sewage disposal that is not according to accepted standards which in turn leads to water pollution, water borne diseases, poverty and environmental degradation (UN, 2020). Water pollution carries environmental and health risks to communities living in unplanned settlements (UNICEF, 2022).

Nearly 2.5 billion people in developing nations do not have access to adequate sanitation (Akpakli *et al.*, 2018). As a result, people living in poor areas confront some of the most severe environmental and health concerns, such as water pollution and disease transmission. For instance, 115 persons in Africa die each hour of diseases due to inadequate sanitation resulting from water contamination and poor hygiene (Gebremichael *et al.*, 2017).

According to Van-Vliet (2021), around 52% of municipal wastewater is treated globally. In terms of wastewater treatment rates, there are significant disparities between global south and global north countries. While wealthy countries handle over 74% of municipal wastewater, developing countries treat only 4.2% on average (Van-Vliet *et al.*, 2021). The remaining 95% of untreated wastewater in these countries is discharged into the environment thereby polluting it and thus poses consequential threats to clean water sources.

According to the African Ministers' Council on Water (Ombella, 2020), mutually reliant sanitation services which include; collection, transportation, treatment and disposal of excreta are mandatory in order to safely manage wastewater. Thus, sanitation services must be regulated by non-textually complicated and easy to understand and accept standards and policies. These rules and norms should be explicit, consistent, unfragmented, standardized and open to access.

2.3 Theoretical Framework

This study adopted the General System Theory by Ludwig von Bertalanffy in the 1940s (Griffiths and Tabery, 2013). Systems theory is a theory of process interaction and how they influence each other across time, allowing the continuity of a greater whole. Bertalanffy saw General System Theory as a solution to the world's growing

complexity of concerns. Bertalanffy identified the need to develop a general theory that can be applied to any system, regardless of the properties or elements of the system (Cordon, 2013).

In the context of sanitation, the health, social and environmental benefits of improved sanitation are maximised when decentralised sanitation systems incorporate; health and hygiene aspects, environment and natural resources, technology and operation, financial and economic issues and sociocultural and institutional/governance arrangements (Obermann and Sattler, 2013). Governance arrangements are activities that ensure functionality of the system and formal and informal institutional arrangements that enable effective delivery of the required activities. This concept involves first and second order governance as conceptualized by Kooiman, 2012.

Systems theory therefore suggests that, the handling of complex issues, which transcend several domains, such as safe waste management through decentralized sanitation systems, requires the participation of various stakeholders or players in various functions in order to sustain a healthy and safe environment in urban habitation to protect environmental and population health (Liu *et al.*, 2021). Safe wastewater management demands the implementation of sanitation system standards for the installation, operation, maintenance of wastewater systems to avoid their degradation processes, and eventual failure that leads to the release of untreated wastewater causing pollution of water sources.

2.4 Decentralized Sanitation System

Decentralized sanitation is defined as the collection, treatment, disposal/reuse of sewage from individual homes; cluster of homes, communal scale facilities and institutional facilities and from portions of communities at or near the point of generation. (Ross *et.al.*, 2014). These sanitation systems include; pit latrine, septic tanks, holding tanks/vaults, biodigesters and waste stabilization ponds.

Conventional centralized wastewater systems for urban municipal services have been common practice for over 100 years (Cookey *et.al.*, 2020). However, in this century, rising difficulties such as climatic unpredictability, population increase, aging infrastructure, urbanization, and resource limits are exposing the flaws and limitations of these wastewater treatment systems (Chirisa *et. al.*, 2016). Developing countries lack both the financial resources and technical expertise to build and operate centralized facilities (Massoud *et.al.*, 2009). Alternatively, the decentralized wastewater treatment solution, which combines onsite and/or cluster systems, is gaining popularity (Capodaglio *et.al.*, 2017). This strategy allows for management flexibility, and both simple and complex technologies are offered. Decentralized sanitation systems are not just a long-term answer for small communities, but they are also more dependable and cost-effective (Sarker *et.al.*, 2021).

If properly designed, built, used, and serviced, decentralized sanitation systems can be effective in delivering safe sanitation. In 2017, it was estimated that decentralized sanitation systems accounted for over 90% of all sanitation systems in Sub-Saharan Africa (AMCOW, 2021). Decentralized sanitation systems meet the requirements for sanitation that is safely maintained.

To guarantee that decentralized sanitation systems achieve the essential health and socioeconomic advantages, laws should allow for decentralized systems to be reinforced by sanitation standards. Most settlement types (e.g., urban, peri-urban, rural, and small towns) and contexts, including humanitarian crises, can benefit from decentralized sanitation systems. They are, nevertheless, reliant on numerous important aspects to perform efficiently in higher density environments, including skilled labour, effective and properly controlled emptying, transportation, treatment, and disposal services (Chirisa et al., 2016). They also require ground conditions that allow for the proper absorption of septic tank effluent or pit latrine leachate without damaging groundwater if it is used for potable water (Obermann and Sattler, 2013).

Where decentralized systems are implemented, government policies should specify that these characteristics must be accommodated. However, in the majority of countries, there is a lack of suitable institutional arrangements for managing decentralised systems and a lack of a suitable policy framework that encourages a decentralised approach (Massoud *et.al.*, 2009). Without technical assistance and other capacity-building measures, problems of institutional capacity that existed under a centralised operation are simply passed on to the new structures (Bernal *et.al.*, 2021). Similarly, there is limited information on how sustainability applies to the general field of wastewater infrastructure, including both centralised and decentralised treatment approaches (Cookey *et.al.*, 2008).

The decentralisation for wastewater management encompass different levels ranging from individual solutions, clusters and individual buildings to semi-centralised or satellite treatment systems that could be also integrated within the existing centralised system. Libralato *et.al.*, (2012) assert that a semi-centralised scheme can

be a viable option for introducing decentralisation in a developing country's urban area, given that the planning policies and regulatory framework do not have many components that facilitate a different kind of management than long - established "end-of-the-pipe" solutions and the use of conventional technology.

2.5 Sanitation Standards

Sanitation standards are criteria that reflect understanding of the appropriate levels of service required to develop and maintain healthy ecosystems (Massarutto *et al.*, 2020). The standards concentrate on individual components of sanitation service chains, but they also apply to entire sanitation systems or parts of them, as in sanitation by-laws commonly referred to as planning legislation (WHO, 2018). Sanitation requirements applicable to sanitation systems in the context of planning legislation and development control include siting criteria, density standards, and water consumption standards. The sanitation standards that apply to the design, construction, operation, and maintenance of these onsite systems are referred to as siting standards, which as defined in the study include situating and building a sanitation system in regard to other plot features. Water consumption standards are the water quantity and quality standards for domestic purposes and for operation and maintenance of sanitation systems. Finally, density standards are defined as quantitative measures of the intensity a unit of land is occupied by developments, population or sanitation systems (Hong Kong Government Planning Department, 2016). These standards therefore, are important in the selection of sustainable sanitation systems, which are compatible to the land use context.

International sanitation standards emerge from organizations that contribute considerably to the sanitation sector and many countries have implemented

standards according to country-specific elements for forming their own local legislation and policies (WHO, 2020). Some of these international organizations include World Bank (WB), World Health Organization (WHO) and International Standard Organization (ISO). These organizations set separation distances from the onsite systems to the building, water sources and property boundary. Water consumption requirements are stated in World Bank 2012 standards for all onsite facilities including septic tanks, pit latrines and bio digesters. Density standards are specified in WHO 2012 which include minimum plot size and population per facility. In addition, the WHO 2018, specifies standards that cover the whole sanitation service chain from the toilet or containment stage to the end use or disposal stage. Thus, most countries worldwide have adopted these sanitation standards with reference to WHO, WB and ISO (Narayan *et al.*, 2021).

Locally, sanitation standards are from various sources including NEMA Wastewater Quality Standards in Environmental Management and Coordination Act (GoK, 2015), Physical Planning Handbook and Building Code both under the Physical and Land use Planning Act (GoK, 2019), Sanitation and Sewerage Manual in the Water Act GoK (2016) and the Public Health Act GoK (2012). The KEBS (Standards Act 496) DKS 2768-1 2021/06 has provided standards to civil engineering on design and specifications for decentralized wastewater systems.

The overall legal structure for sanitation is enacted by the Kenyan Constitution 2010, which outlines the need for access to a clean and healthy environment, adequate housing and sanitation rights for all. The Constitution states, “That every person has the right to institute court proceedings when his or her rights to sanitation have been denied, violated, infringed or threatened” (GoK, 2010). Alongside the

constitution, the Kenya Environmental Sanitation and Health Policy and the Kenya Vision 2030 developed the framework for sanitation.

According to general system theory, all components of a system must work in concert for the desired outcome to be realised. This also applies to development and implementation of sanitation standards and if the individual components consisting of financial, policy, regulatory, technical and organisational aspects are not performing their functions as required this will result in problems, such as multiplicity of roles, conflict of roles, bureaucracy and delays in service provision.

In the Kenyan context, at statutory level, the existing legal environment for sanitation remains fragmented with sanitation-related laws scattered across various legal instruments including, local government, public health, environmental and water resources legislation, local by-laws, building and planning codes or standards, public utility regulation among others. Specifically in the sanitation sector, there are various ministries, which have a stake in sanitation services. The ministries mandated to govern sanitation are; ministry of water and sanitation, ministry of health, ministry of devolution, ministry of lands and physical planning, ministry of environment and forestry among others. This is bound to create a challenge for enforcement of sanitation standards due to multiplicity of roles and a ‘wait and see’ situation.

To mention, in the Water Act 2016 and Nairobi City County laws, there are regulatory overlaps regarding urban sanitation infrastructure between the Nairobi Water and Sewerage Company, the Athi Water Services Board and the Nairobi City County Government (GoK 2016). There is also significant institutional duplication and overlap between the Ministry of Health and the Ministry of Water and

Sanitation. The Ministry of Health manages the sanitation portfolio wholly, but has the main duty of coordinating rural sanitation. The Ministry of Water and Sanitation is the primary institution responsible for the formulation of policies and strategies relating to urban water and sewerage. Therefore, both institutions formulate and enact Water and Sanitation Policies, Legislations and Regulations. Additionally, the National Environment and Management Authority is the institution responsible for regulation of effluent disposal and environment protection (GoK, 2015), while, KEBS also provides standards for effluent and water quality and building and installation of onsite facilities.

2.6 Sanitation Systems

Sanitation systems are processes and services in the sanitation chain that ensure the safe disposal of human waste (Cookey *et al.*, 2021). These processes and services should incorporate sanitation standards in the entire sanitation service chain derived from legislative laws (WHO, 2018). The treatment and disposal of wastewater is performed by suitable and sustainable sanitation systems under specific local conditions. There are three categories of systems for sanitation, which are namely, centralised sanitation systems, semi-centralised and decentralised sanitation systems.

A sanitation system is typically defined as a series of technologies that allow for material flows in a sanitation chain. A sanitation chain begins with faeces and urine, as well as its organic mineral components, wastewater, or flush water from various sources, such as sinks and washing machines and showers (Tilley, *et.al.*, 2011).

A sanitation system is made up of five interfaces, each of which has technologies that perform different roles depending on the context: collection, storage, transit, transformation, use, or disposal. The first phase is the user interface (UI), which

describes how the user interacts with the pedestal, toilet, urinary system, or pot. The final component of wastewater is also specified by the UI because it is where water enters the system (Cirolia *et al.*, 2021). The second interface in treating wastewater is collection and storage, describing the way the wastewater is collected and stored from the UI, and the storage often takes place at certain levels of treatment. Examples of technology performing this purpose include pit latrines, septic tanks and organic processing plants (Therrien *et al.*, 2020). Following this is the transport interface describing how wastewater is transferred from one process to another. While wastewater can need to be transported in different ways in order to reach the required process, the longest and largest gap lies in between the user interface or storage and collection interface and the semi-centralized treatment interface. Due to this gap there is exposure to mishandling of the wastewater by motorized transport services by vacuum tankers operators (VTOs) and may be not delivered to the semi centralized treatment interface (Tilley *et al.*, 2011).

The fourth interface is the semi-centralized treatment phase, which refers to installations that transform untreated wastewater from previous interfaces into useful resources or risk-reduced products. These systems are larger in scale, require greater inflows (such as a neighbourhood or municipal wastewater stream), and often more qualified operations than treatments on site during collection and storage (Kerstens *et al.*, 2016). Finally, the disposal interface refers to the process in which treated wastewater is subsequently returned to the land or water as harmless chemicals or beneficial resources (WWAP, 2017). In addition, treated wastewater can potentially be recycled as new products into the system. A common example is the usage of

partially treated grey water used for washing the toilet (Drechsel *et al.*, 2008; Shaikh and Ahammed, 2020). Wastewater also is a valuable fertilizer that rich in nutrients.

The four steps covered by the sanitation value chain for decentralized sanitation systems include the user interface, collecting and storage and or processing, emptying and conveying, processing and disposal and every interface has a variety of different challenges and requires regulation and monitoring of the interfaces by enforcement agencies (WHO, 2018). The interfaces technologies, which are involved in processing of wastewater in the sanitation service chain, include; dry toilets, flush toilets, septic tanks with or without soakaways, bio-digesters and sewage systems (Tilley *et al.*, 2011). The interface technologies are briefly described in the proceeding section:

2.6.1 Collection/User Interface Technologies

The user interface relates to the stage of the sanitary system where excretion is gathered and any kind of toilet seat or latrine plate, pedestal or urinal can be incorporated. There are various types of toilets, including dry toilet, pour flush and cistern toilets (Ebrahimzadeh, 2020). A dry toilet is the system that the user interacts with to enter the sanitation chain, complete with the subsequent treatment and disposal processes. In both cases, faeces fall through a hole. If two pits are being used, the base or slab should be built to be transferred from one pit to the other. The slab or pedestal foundation should be properly connected to the pit to ensure user safety and prevent storm water infiltration. To keep insects and rodents out, the hole should be with a lid. Local concrete squatting and pedestal slabs can be manufactured.

The pour flush toilet eliminates human excreta by flushing it into a drainpipe to be disposed of elsewhere. In the sanitation value chain, this toilet collects human urine and faecal waste (Harper, 2020). Pour-flush toilets are intended to be squatted in the case of Eastern toilets or sat in the case of Western toilets. This toilet is linked to a septic tank, bio digester, waste stabilising pond, or sewer.

2.6.2 Containment and Treatment Technologies

This phase comprises systems that collect, store and process material created by the user interface entirely (Velkushanova *et al.*, 2021). Technologies for this role are pit latrines, septic tanks, vaults and organic digesters. Products partially processed by these processes often require further treatment before being used or disposed.

2.6.2.1 Pit Latrine

The most popular type of latrine in the global south is a simple pit latrine in its basic form due to its simplicity and the use of cheap building materials. It is easy to use and maintenance is low (Mubats *et al.*, 2021). It comprises a hole carved in the ground, a plate housing the hole made of wood or concrete, an entrance hole in the slab to insert the excreta and a structure surrounding the pit. Depending on user interface, the system can be utilized even without flush water. The latrine might be a dry toilet or pour flush, the first being the more frequently utilized (Libby *et al.*, 2020). The user interface consists of dry toilet, flush toilet and is directly connected to a single pit or ventilated enhanced pit or to dual pits for collection and recycling. A solitary pit latrine ought to have a slab that can be 2m or more in depth, below the slab. The plate should be supported and raised above the ground on all sides, to ensure that water cannot enter the pit (Gokçekuş *et al.*, 2020). The pit walls must

also be lined in order to support the earth. A little drop hole leads into the pit for excrement or urine.

2.6.2.2 Single Ventilated Improved Pit Latrine

The single VIP latrine is a system, which can collect, store and treat wastewater (Obeng, 2020). The method generates a continuous airflow across the ventilation tube vents and provides a path for catching flies as they flee in the vicinity of the light. Despite its complexity, well-designed pits may be odourless and more enjoyable than other water-based methods. The venting pipe also permits odour to discharge and lowers the fly attraction.

The vent pipe must be created with an inner diameter of 110 mm and 150 mm above the top of the toilet structure and not surpass more than 300 mm. The efficiency of the ventilation is boosted by painting the pipe black, since the heat difference in between cool pit and the heated vent creates an attraction that pulls the stench up or out of the pit (Libby *et al.*, 2020). Furthermore, the ventilation is thought to operate best in windy environments. The mesh size of the fly-screen must be big enough to prevent dust blocking and unimpeded passage of air (Trepanier *et al.*, 2021). Aluminium screens have proved to be the most efficient with a hole size of 1.2 to 1.5 mm. The pits must be dug at minimum 3m depth and the top portion of the pits must be between 1 and 1.5m in diameter (Ferreira, 2019).

2.6.2.3 Twin Pits for Pour Flush

This system has two alternating pits and a pour-flush toilet. The wastewater is collected in pits and slowly absorbed into the earth (Bhadaran *et al.*, 2017). After a while, the solids are sufficiently dewatered to be shovelled out. The superstructure, toilet, and pits can be arranged in several ways: the toilet can be placed near or over

the pits. The superstructure can be built completely over both pits or moved from side to side depending on which one is in use. This is because only one pit should be used at a time. The sanitation system can thus be utilized endlessly by alternating pits. For example, as one pit fills with cleansing materials, excreta, and flush water, the other stays idle. The pits ought to be large enough to hold the waste created over a year or two. This allows the pit's contents to decompose into safe, non-toxic compost that may be physically excavated, as most faecal waste is too dense to be vacuum pumped. Faecal organisms are removed as wastewater trickles from the pit through a soil matrix. A minimum of 30m should be maintained between the pit and a water source to avoid biological and chemical contaminants (Omarova *et al.*, 2018). The twin pits should be built 1m apart to prevent cross-contamination between the maturing and usage pits. The pits should be built 1m away from any structural foundations because leachate can damage the structural supports. Water in the pit can affect its structural stability. To avoid collapse, all walls should be built to the pit's maximum depth, with the top 30cm entirely pummelled to minimize unnecessary infiltration and protect the superstructure's support.

2.6.2.4 Septic Tank System

A septic tank or a multi-chamber tank is a waste tank that drains partially treated wastewater into soaking systems (Fitriani and Muchtar, 2018). The chambers give an avenue for reserving wastewater long enough to separate solid particles and absorb accumulated materials partially. It separates the settling solids and floating solids and clarified liquid in between. It helps in the growth of anaerobic bacteria that are crucial for the breakdown of solids and stores the sludge and scum that follow (Adhikari and Lohani, 2019). According to Sarker *et al.* (2021), there are

many regularly utilized wastewater and treatment systems onsite, the most important being septic tanks without a soak away system. The soak away is a technique for soil remediation, which gathers partly treated septic tank water. The type of soil on a location in which the facility is sited shall be suited for a soakaway. It is confirmed that the effluent from a septic tank is by no means suitable for disposal into a waterway or into an environment where animals and humans could access (Lahmouri *et al.*, 2019). Not all sites are suitable for developing septic tanks and soakaways. The porosity and soil type at the site are of fundamental concern. Too coarse aggregate soils can hamper the effectiveness of the treatment unit or soakaway.

2.6.2.5 Sewage Holding Tanks or Vaults

An option to a standard onsite wastewater treatment method wherein septic tanks is not viable is a sewage-holding tank or vault. The holding tanks collect sewage to a single compartment, keep waste temporarily from an installation before evacuation, and transfer to an authorized processing and disposal site (Murat-Błażejewska and Błażejewski, 2020). Therefore, no wastewater from a holding tank should be discharged into the environment because wastewater is only partially treated. Although, where septic tanks contain an outlet pipe leading to the soakaway mechanism, retaining tanks do not have such a feature and act as wastewater store-tanks before emptying. These holding tanks are erroneously described as septic tanks due to the similarities in function.

2.6.2.6 Biodigesters

Biodigesters are compatible with two user interface technologies: a Pour Flush Toilet and a Urine-Diverting Flush Toilet, where bio-slurry is used in agriculture

(Ouhammou *et al.*, 2019). This closed system comprised of a rectangular or circular container constructed of plastic, steel, or concrete. It uses an anaerobic microbial inoculum consortium of bacteria to transform human waste into biogas and pathogen-free fertilizer. To save space, it is usually connected to existing toilets or stored beneath the toilet pan. The material of a bio digester varies depending on where it is to be built. This sanitation system has been carefully designed to ensure that wastewater is effectively treated. The anaerobic procedure ensures that disease-causing microorganisms are deactivated 99% of the time (Diamantis *et al.*, 2021). Furthermore, this facility decreases greenhouse gas emissions and regulates water and air pollution. According to Oibileke *et al.* (2021), the first biogas sanitation facility was created in Mumbai in 1859, and since then, numerous stakeholders in India have utilised and pushed this sanitation strategy.

Globally, Bio digesters have been used in Chinese communities and families since the 1960s (Lam *et al.*, 2020). The main disadvantage of using bio digesters is the need for maintenance. The majority of the 35 million devices deployed in China remain abandoned. This is because its upkeep and maintenance are labour-intensive investments. Anaerobic digestion occurs in four stages: hydrolysis, acidogenesis, acetogenesis, and lastly methanogenesis, which produces methane and carbon dioxide gas (Wang *et al.*, 2020). Catabolism involving hydrolytic bacteria, fermentative bacteria, acetones, and methanogens is essential and different in each of these stages. Biogas and slurry are produced as by-products of this process and are channelled out of the bio digester for use and disposal. Because untreated wastewater is dangerous to humans, considerable distance is essential to isolate the

effluent from human touch. As a result, a separation distance of 7m from the bio digester to the property and 10m from the discharge point is necessary.

2.6.2.7 Community Ablution Blocks

Community ablution blocks (CAB) are communal sanitation and water facilities featuring female and male blocks, toilets, showers, hand washing stations, and laundry basins. CABs can be owned and administered by the community or by private individuals (Parikh *et al.*, 2020). Privately owned ablution blocks provide these services for a nominal cost, making them profitable enough to entice private investment, particularly in sites where residential use is complemented by temporary use, such as near a market or bus station. However, there are significant dangers associated with pay-per-use ablution blocks, such as the block being too far away from houses or the tariff being too high to enable consistent use. CABs operated by the community provide free water and sanitation services to the community. However, because these facilities are likely to have large construction costs per capita, they will necessitate a strong community commitment to manage and maintain them (Visagie *et al.*, 2020).

The toilet block is connected to a sewer system in highly populated regions that are adjacent to a sewer line. When there is no local connection to the sewerage system, the toilet block should be connected to a storage tank or VIP pits. Because only urine and faeces can reach the pit, washing operations can take place around the standpipe rather than draining into the pits. The municipality pipes the wastewater into a storage tank (or individual pits) and empties it at regular intervals. A truck must have enough space and road access to pump the effluent out of the tank.

2.6.3 Transportation or Conveyance Technologies

This interface includes a sewer pipe, which transports faeces directly from the toilet to a wastewater treatment plant via sewer (Delaire *et al.*, 2020). The faecal sludge that was stored and partially treated in the previous interface will need to be emptied and transported from one location to another. For example, exhauster trucks or bores can transport waste from a storage tank to a treatment plant. When the collection, storage or treatment component reaches its capacity, this becomes necessary.

2.6.3.1 Sewerage

The two user interface technologies that can be employed for this system are the Pour Flush Toilet and the Cistern Flush Toilet (Shamna Abdulla and Ullas, 2020). This sanitation facility, according to WHO (2018), is an offsite sanitation technology. This technique carries wastewater from the user's residence to semi-centralized treatment or discharge stations. There are two types of sewerage: conventional and unconventional. The unorthodox, also known as low-cost sewerage technology is divided into two types: settled sewerage and simplified sewerage. This facility is best suited for low-income communities with adequate water supply. Traditional sewerage has been associated with expensive costs because to rigorous design criteria, which limit its growth to poorer and middle-income regions.

2.6.4 Semi-centralized Treatment Technologies

Wastewater treatment is the process of removing pollutants from wastewater using sanitation systems that decrease the destructive potential of wastewater before it is discharged into the environment (Ho and Goethals, 2020). This analysis takes into account wastewater stabilisation ponds, manmade wetlands, and sand filters.

2.6.4.1 Waste Stabilization Ponds

This procedure converts the organic content of the wastewater into more stable and less irritating forms for a set retention time, after which it is discharged into the environment as well-treated effluent. Waste stabilisation ponds (WSP) have become the most important form of sewage treatment in hot regions, where temperatures are most favourable and adequate area is usually available for their operation (Capodaglio *et al.*, 2017). WSPs are utilized for wastewater treatment in areas with enough acreage and a tropical or temperate environment. WSPs are holding basins used for primary wastewater (sewage effluent) treatment in which organic matter breakdown is treated naturally, i.e., biologically. The WSP process is a complicated symbiosis of bacteria and algae that eliminates infections and stabilizes waste (Gruchlik *et al.*, 2018).

2.6.4.2 Constructed Wetlands

Natural wetlands can be found to varying degrees along all bodies of water. In certain cases, the saturated hydrosols that are distinctive of wetlands may only stretch a few feet. In some circumstances, marshes might extend for several acres beyond the reservoir or watercourse limit. Because natural wetlands absorb certain nutrients, the extent of terrestrial buffers around natural wetlands may be reduced. The hydrology of natural wetlands can be channelized at times, which can overwhelm and impair the efficient pollutant sequestration observed at low flows. As a result, it is critical that terrestrial buffers be retained as close to wetlands as possible, and that the water body boundary be delineated at the up-gradient boundary of wetlands (Golden *et al.*, 2017). Wetland buffer management should be no different.

2.6.4.3 Sand Filters

Sand filters are onsite wastewater treatment systems, which consist of beds of granular material, usually sand, that are drained from below. This system removes components from wastewater mostly by a physical process of sieving out particles from the water using sand and other media filters (de Deus *et al.*, 2020). The type of medium used and the distribution of grain size determine how small a particle is filtered out. Coarser sands contain greater pore spaces and higher flow rates, but they pass larger suspended particles. Very fine sand, on the other hand, has narrow pore spaces with sluggish flow-through rates and filters out smaller total suspended solids (TSS) particles. Some media, such as a peat-sand mix, may also provide ionic adhesion or exchange for some dissolved elements, improving effluent quality even further.

According to Wang *et al.* (2020), a typical sand filter is a waterproof box coated with plastic or concrete and filled with a specific sand material. The bed is constructed on a foundation of graded gravel and collecting tile. Wastewater is applied to the bed's surface at regular intervals via distribution pipes. The re-circulating intermittent sand-filter sieves wastewater by mixing filtrate with incoming wastewater effluent and re-circulating it through the filter media numerous times before discharge to a final land application system. The components of this filter are similar to those of an intermittent sand filter.

2.7 Compliance Requirements for Performing Sanitation Systems

In order for sanitation systems to perform their wastewater treatment tasks, they must meet certain performance requirements set forth in laws and rules (Synder *et al.*, 2020). Safely managed sanitation systems must take into account siting,

population density, accessible water supply, and appropriate soil conditions during their installation, operation and maintenance. The role of governance in decentralised sanitation is to create an enabling environment to promote compliance of sanitation systems to sanitation standards (Ross *et al.*, 2014). It create conditions that foster innovation in both technology and funding systems, allocating financial resources for training and monitoring, defining cooperation among essential stakeholders, and implementing and maintaining sanitation standards (Ross *et al.*, 2014). Governance should establish procedures for monitoring and enforcing standards. In addition, it should direct actors to monitor certain elements and include penalties for rule violators (Krajewski *et al.*, 2021). Sanitation and hygiene regulations apply to all persons, educational institutions and commercial establishments.

International Standards Organization (ISO 24521: 2016) outlines the objectives and considerations of basic on-site wastewater systems to be adopted by member countries including Kenya. The four main objectives of basic on-site domestic wastewater services include public health and safety; occupational health and safety; environmental protection and sustainable development. Basic on-site domestic wastewater system solutions should adapt to local conditions, respond to actual needs and be adaptable to a changing environment. Besides constituting these main objectives, basic on-site sanitation solutions should consider effective disease barrier and prevention of environmental pollution. They should also optimize the use of resources in terms of water and energy; simplicity of construction, operation, maintenance and repair; adherence to hygienic safety standards; affordability and willingness to pay. For the systems to be effective, it is important to consider

existing institutional support; existing best practice, experience and infrastructure; development of ownership, involving property owners, users of all kinds, public water utilities and the private sector in design and planning.

2.7.1 Siting standards for Decentralized Sanitation Systems

The purpose of siting standards is to protect groundwater used as drinking water from contamination by sewage (Graham and Polizzotto, 2013). Setbacks for onsite systems prevent environment pollution such as water pollution, air pollution and degradation of aesthetic beauty. This is achieved by setting setbacks for septic tanks, soakaways, pit latrines, lagoons and sewers from wells, rivers, lakes and impoundments. Setbacks are also provided for roads, water pipes, plot boundaries, and from buildings to prevent structural failures (Figure 2.1).

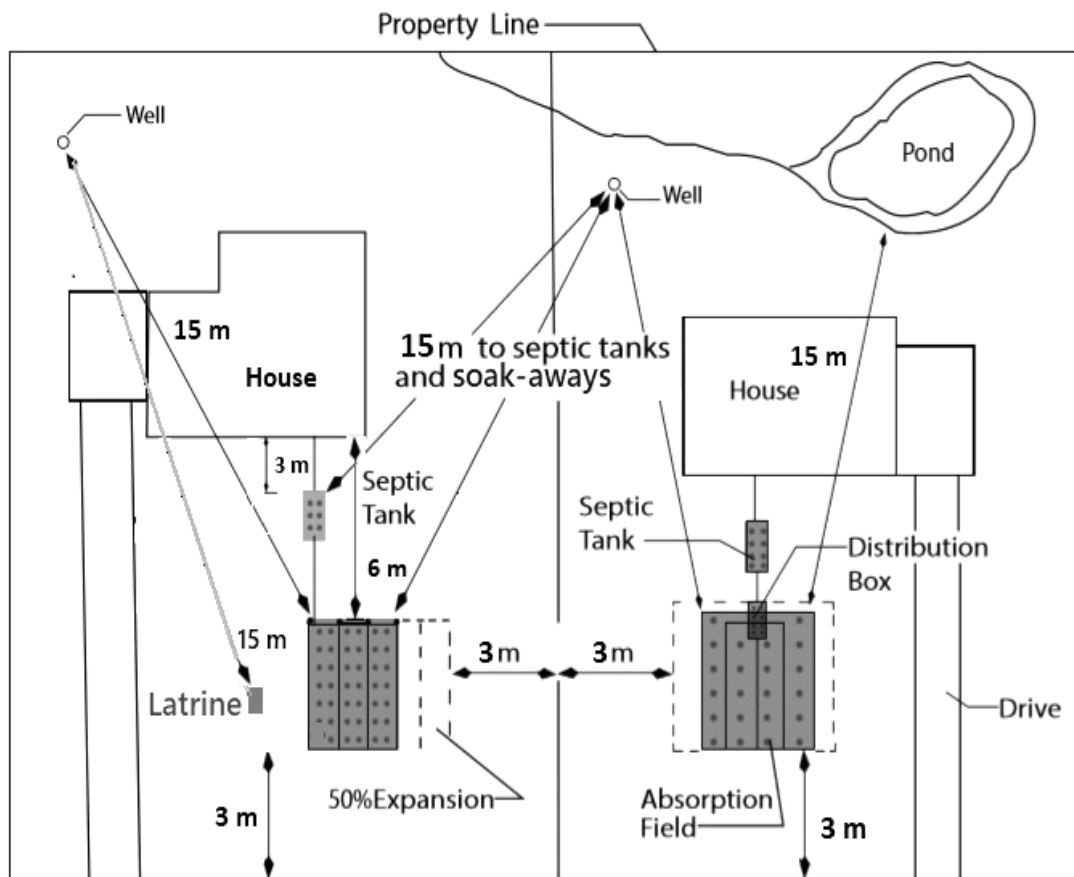


Figure 2.1 Siting requirements for Onsite Sanitation Facilities (adopted from USEPA 2001)

2.7.1.1 Septic Tank Siting Standards

The septic tank is a passive system as there is nothing electrical or mechanical involved (Hashemi and Boudaghpour, 2020). Septic tank siting standards have been researched and developed by various international organisations, individual researchers such as Bradley, 1992; Franceys *et al.*, 1992; Kolsky, 1993; Davis and Lambert 1995; Brandberg 1997; WHO/UNICEF 2005; GoK 2009; Fry *et al.*, 2008; WHO/UNICEF 2008 and Mihelcic *et al.*, 2009.

These siting standards are shown in the Table 2.1 and include; Septic tank 15m from surface water, Septic tank 15m from all wells, septic tank 1.5m from foundation, Septic tank and drain field to be 2m apart, avoid low lying areas, and avoid areas where roots may grow towards the septic tank causing structural failure and hence groundwater pollution. The Manual for Sewerage and Sanitation Services in Kenya (GoK, 2008) asserts that emptying should be done when the sludge level reaches 200 mm from the bottom of the outlet tee, or after the design desludging interval of 3 years. Therefore, the septic tanks should be accessible for manual emptying or vacuum emptying to take place if drain fields are not applicable.

Table 2.1 Siting standards for septic tank

Sanitation Provision	Siting
Septic tank	<ul style="list-style-type: none"> • 15m from surface water (NWSC, 2008) • 15m from wells (GoK, 2008) • 1.5m from building foundation (GoK, 2007) • 1.5m set back from plot boundary (GoK, 2008) • 3m setback from plot boundary (GoK, 2009) • 5m setback from road/ driveway (NWSC, 2008) • 1.5m setback from any building (GoK, 2007) • 7.5m setback from streams (NWSC, 2008)

2.7.1.2 Soak-away siting standards

The size of a soakaway is determined by the size of the dwelling as well as the size of the septic tank. There are other siting considerations (shown in Table 2.2) including; Soak-away pits to be sited 15m from all temporary surface water (ditches and canals), Soak-away to be 30m from surface water (stream, lakes, or rivers), they should be 30m from all wells and all this should depend on soil type. Soak-away to be 6m from building foundation. Soak-away should be away from areas where vehicles may compact such as driveways, parking and roads. When building soakaways one should avoid - steep slopes less than 20% gradient, areas where tree

may grow towards and affect the soak-away, low-lying areas where there are runoffs or storm water drains or where water may pond temporarily, and areas with high water tables (GoK, 2008).

Table 2.2 Siting Standards for Soakaway Facilities

Sanitation Provision	Siting
Soakaways	<ul style="list-style-type: none"> • 30m from wells (GoK, 2008) • 15m from groundwater source (GoK 2009) • 1.5m to property line (GoK, 2009) • 30m from streams/embankments (NWSC, 2008) • 6m setback to building (GoK, 2009) • Depth to ground water table is 1.5m (GoK, 2008)

2.7.1.3 Pit Latrines Siting Standards

A latrine should ideally be located in the backyard of the house, away from a village alley. As further highlighted in Table 2.3, it should not be more than 50m or less than 6m away from the house. The wind should be blowing away from the main residence. If the compound has a well, the toilet should be 30m distant and on the downhill side to avoid possible seeping and contamination of groundwater. A minimum distance of 30–50m is recommended, with a minimum of 10m being the absolute minimum.

Typically, the depth of the pit should be at least 3m for a family of five with a design period of three to five years. The pit should be at least 1m to 1.2m in diameter, which will make it easier to dig. However, if it exceeds 1.5m there is an increased risk of collapse, especially in sandy soils.

Table 2.3 Siting Standards for Pit Latrine Facilities

Sanitation Provision	Siting
Pit Latrine	<ul style="list-style-type: none">• 15m to a well or groundwater source (GoK, 2009)• 50m from groundwater source (GoK, 2008)• 1.5m above water table (Water Aid, 2011)• 10m to a dwelling house (GoK, 2009)• 3m to plot boundary (GoK, 2008)• 4m from any building (WHO, 1992)

2.7.1.4 Community Ablution Block Standards

A block should serve 100 housing units; in reality, however, a single block may serve up to 200 dwellings (each composed of an average of 5.5 people). The dwellings should be within a radius of 150 to 200 m from the toilet block. GoK (2009) ensure adequate sanitation by inhibiting use of shared sanitation facilities for households, which WHO and UNICEF 2015 excludes from the improved sanitation category, requires for each family or group not exceeding six persons, to be provided one latrine and one abluion, or one combined water closet and abluion.

In those Community Ablution Blocks (CABs) connected to the sewerage systems, water is reticulated to the facility. Typically, blocks are supplied with water meters and water consumption per person is estimated to be around 35-40 litres per day. In the Ventilated Improved Pit (VIP) latrine block, water is supplied through standpipes located at a reasonable distance from the abluion block and drained to a soak away.

2.7.1.5 Sewer Siting Standards

Sewer siting standards state that setback from any residential development is 15m on either side of the sewer. Furthermore, the land requirement for a buffer zone for sewer areas is seventy-five square meters (see Table 2.4).

Table 2.4 Siting Standard for sSewers

Sanitation provision	Siting
Sewers	<ul style="list-style-type: none">• 15m sewer line reserve on either side of the sewer (GoK, 2007c)• 60m from municipal sewer line (GoK, 2008)

2.7.1.6 Waste Stabilization Pond Standards

The waste stabilization pond (lagoons) standards require separation distance of 200m downwind from the dwelling (GoK, 2016). This is due to odour, which is released from the anaerobic ponds and has negative effects on public health. Lagoons should also be situated in clay soils or soils with a coefficient of permeability less than 10^{-7} m/s (see table 2.5).

Table 2.5 Siting standards for wastewater stabilization pond

Sanitation provision	Siting
Waste Stabilization Pond	<ul style="list-style-type: none">• 200m setback from dwelling (GoK, 2016)• Should be situated in clay soils or soils with permeability of less than 10^{-7} m/s

2.7.2 Density Standards for Sanitation Provision

Density is a quantitative measure of the intensity with which land is occupied by either development or population. Control of density is a fundamental component of effective planning for sanitation provision, as the relative distribution of population

has major implications for the provision of sanitation facilities and infrastructure (Hong Kong Government Planning Department, 2016). There are two types of density considered in this study, which are plot density and population density.

Plot density is controlled by plot ratio and minimum plot size density standards. Plot ratio is described as the ratio of gross permissible, erected area to the plot of land gross area (Wong *et al.*, 2020). Planning authorities designate zones within which every plot that lies within these areas is assigned a plot coverage and ratio. The (GoK, 2007c) requires the plot coverage to be 25% of the area of the plot and a ratio of 1:4 in low-density areas. For high-density areas, the required plot coverage is 70% with a plot ratio of 1:2. The minimum plot size specified by GoK 2014 is 0.25 of an acre. This is derived from considering the availability of water, proximity and capacity of surface water drainage infrastructure, availability of sewers, availability of electricity mains, availability of telephone lines, proximity and extensiveness of fire fighting services, closeness of schools, and shops. A sufficient area for wastewater disposal in decentralised systems is determined by the expected population of users who generate a specified volume of wastewater that will be treated by the soil absorption area of the decentralised wastewater treatment system. The larger the population the higher the volume of wastewater generated that is loaded into the system thus a larger area is required to cater for them (USEPA, 2001). Groundwater contamination is avoided when the plot size is in the range of 0.4 to 1 ha. Rivett *et al.* (2008) noted that the maximum nitrate absorptions in groundwater (20-30 mg/l) were linked with high population and pit latrines in a settlement.

Second type of density is the population density, which determines the sewage load per unit of area of land occupied and hence the absorption of contaminants in ground water. The population density standards in Kenya (as highlighted in Table 2.6) require a density of less than 120 people/ha for areas using onsite systems, while in Kampala Uganda, the population density is 200 people/ha (Norman, 2011) and Brazil 160 people/ha (Sinnatamby, 1983). The standard also requires the number of users per sanitation facility to be 1 toilet per 12 persons. This standard therefore promotes the use of improved sanitation systems, which treat the wastewater effectively therefore reduces sanitation related diseases such as diarrhoea related morbidity in young children and accelerates economic and social development (WHO/UNICEF, 2010).

Table 2.6 Density standards requirements for sanitation provisions

Sanitation provision	Density standards
Septic tank	<ul style="list-style-type: none"> • <120-300 ppl/ha (WHO, 1992; GoK, 2008) • <250ppl/ha (NWSC, 2008), • <160 ppl/ha (GoK, 2008, WHO,1992) • At least 0.25acre plot size (GoK, 2014)
Soakaways	<ul style="list-style-type: none"> • Plot size 0.2 Ha (GoK, 2007) • 120ppl/ha (GoK, 2008)
Pit Latrine	<ul style="list-style-type: none"> • 1 latrine/12 persons (GoK, 2008) • <200ppl/ha (GoK, 2009)
Sewers	<ul style="list-style-type: none"> • >200 ppl/ha (GoK, 2007) • >120 ppl/ha (GoK, 2009) • Settlements >3000 people (GoK, 2007c) • Urban layout of >10,000 people (GoK, 2009)
Wastewater Stabilization Pond	<ul style="list-style-type: none"> • Settlements >3000 people per WSP (GoK, 2007c)
Bio digesters	<ul style="list-style-type: none"> • 177-530 ppl/ha (BSI, 2002)

2.7.3 Water Consumption Standards

Access to adequate water supply is a vital part of ensuring a safe sanitation service chain operation (Nzimakwe, 2020). This includes; flushing, sewerage, maintenance and cleaning of facilities and various parts of the sanitation service chain. In some cultures, or religions, water is necessary for anal cleansing after defecation, so its absence may encourage open defecation near surface water bodies (Adeoti *et al.*, 2021). Piped water to the household can incentivize all householders in a community to build and use toilets, and must be available year-round to enable this outcome. The water supply for sanitation purposes depends upon the context and includes aspects such as water availability, type of facilities, number of users, cleansing requirements and other local factors. All these require consideration when designing and implementing a comprehensive sanitation programme.

Table 2.7 Water consumption standards for sanitation provisions

Sanitation Provision	Water consumption standards
Septic tank	<ul style="list-style-type: none"> • Piped water supply of 100 l/cap/day (GoK, 2008; NWSC, 2008; WHO, 2008) • 70 l/cap/day for ablution with yard tap (splash area) (GoK, 2009)
Soakaways	<ul style="list-style-type: none"> • 100 l/cap/day (WHO, 1992, GoK, 2008) • Low density housing, 200 l/cap/day (GoK, 2009) • Medium density housing, 150 l/cap/day (GoK, 2009) • High density housing, 70 l/cap/day (GoK, 2009)
Pit Latrine	<ul style="list-style-type: none"> • Communal 40-60 l/cap/day (GoK, 1987) • 20-30 l/cap/day (GoK, 2008) • 40-80 l/cap/day (GoK, 2009)
Sewers	<ul style="list-style-type: none"> • 100 l/cap/day (GoK, 2008) • Low density 150-250 l/cap/day (GoK, 2009) • Medium density 110-160 l/cap/day (GoK, 2009) • High density 55-70/cap/day (GoK, 2009)
Stabilization ponds	<ul style="list-style-type: none"> • 100 l/cap/day (GoK, 2008)
Bio digesters	<ul style="list-style-type: none"> • 70 l/cap/day (GoK, 2008)

Piped water required for water consumption and hygienic needs is 100 l/cap/day (GoK 2008). The government of Kenya states that water consumption requirements vary according to the area and type of housing. That is, urban areas with low-density housing to receive 250 l/cap/day, medium density 150 l/cap/day and high-density housing to receive 70 l/cap/day (Table 2.7).

2.7.4 Effluent quality standards

Effluent is regarded as sewage, water, or other liquid that has been partially or totally treated or is in its natural condition and flows out of a septic tank, supplemental treatment unit, dispersal system, or other component of an Onsite Wastewater Treatment System (Chuka-ogwude *et al.*, 2020). Effluent rules govern the discharge of effluent from a sanitation system into any receiving water body or groundwater. Regulation of such discharges will protect receiving waters and aquatic habitats, as well as human health from the damaging impacts of untreated sewage. The fact that sewage discharges contribute a large amount of biodegradable organic matter, suspended particles, and ammoniacal nitrogen to the nation's waterways has influenced the necessity for these requirements. In Kenya, NEMA has developed a set of rules to regulate wastewater emissions from home and industrial sources in compliance with the EMCA 2015. The summary of the standards on effluents in Kenya is as shown in Table 2.8.

Table 2.8 Effluent discharge Standards used in Kenya (Source: GoK 2006)

Parameter	Unit	Maximum permissible limit	
		Land/Underground	Surface water courses
Total coliforms	MPN per 100 ml	-	<400
E. Coli	MPN per 100 ml	<1000	<1000
Free Chlorine	mg/l	-	0.5
Total Suspended Solids (TSS)	mg/l	45	35
Reactive Phosphorus	mg/l	10	1
Colour	-	Not objectionable	
Temperature	0C	40	
pH	-	5 – 9	
Chemical Oxygen Demand	mg/l	50	
Biochemical Oxygen Demand	mg/l	40	
Chloride	mg/l	750	
Sulphate	mg/l	750	
Sulphide	mg/l	0.002	
Ammoniacal Nitrogen	mg/l	1	
Nitrate as N	mg/l	10	
Total Kjeldahl Nitrogen	mg/l	25	
Nitrite as N	mg/l	1	
Aluminium	mg/l	5	
Arsenic	mg/l	0.1	
Beryllium	mg/l	0.1	
Boron	mg/l	0.75	
Cadmium	mg/l	0.01	
Cobalt	mg/l	0.05	
Copper	mg/l	0.5	
Iron	mg/l	2.0	
Lead	mg/l	0.05	
Lithium	mg/l	2.5	
Manganese	mg/l	0.2	
Mercury	mg/l	0.005	
Molybdenum	mg/l	0.01	
Nickel	mg/l	0.1	
Selenium	mg/l	0.02	
Sodium	mg/l	200	
Total Chromium	mg/l	0.05	
Vanadium	mg/l	0.1	
Zinc	mg/l	2	
Oil & Grease	mg/l	10	
Total Pesticides	mg/l	0.025	
Total organic halides	mg/l	1	
Cyanide (as CN -)	mg/l	0.1	
Phenols	mg/l	0.5	
Detergents (as LAS*)	mg/l	15	

2.7.5 Odour as an Implication of Effluent Quality

Odour is a special scope of air pollution arising from an unpleasant smell in the ambient air and water (Bokowa *et al.*, 2021). Odour can be defined as the perception of smell or in scientific terms as a sensation resulting from the reception of stimulus by the olfactory sensory system. Odorous gases emitted from a source are carried and spread by wind movement in the atmosphere. In the last 30 years, odours have become a significant environmental concern, and the discussion about the possible negative effects of odours on human health is still a widely studied and debated issue. Some studies prove that the exposure to odours may result in different effects on human beings, ranging from emotional stresses such as states of anxiety, unease, headache or depression to physical symptoms. Odour problems are particularly worrying when more activities that are industrial exist near residential areas (Wojnarowska *et al.*, 2021).

Wastewater treatment plants (WWTPs) are one of the main sources of odour in urbanized areas (Zarra *et al.*, 2021). To regulate and control odour, innovative methods of odour measurements are essential (Bax, 2020). The key parameter that is quantified with odour measurement is the concentration. The concentration of an ambient odour is generally determined through two steps a sampling phase and a subsequent analysis phase.

In recent years, international regulations about odour emissions tend to consider the employment of human assessors as a valuable method to assess the odour impact of an industrial plant on the territory (Hawko *et al.*, 2021). For example, German VDI 3940 standardizes a method of field inspection by using trained assessors, applied by several researchers in order to get quantitative indexes of annoyance (Nicell, 2009).

The term Enhanced Field Inspection is used to describe the combination of VDI 3940 Impact Frequency method with SM100 odour concentration measurements for a complete odour impact assessment. The method provides a more complete idea of the odour impact by combining all aspects of FIDOL (Frequency, Intensity, Duration, Offensiveness and Location) principle.

Residential sewage primarily contains the gases that produce offensive odour. Often, methane is the gas of next highest concentration, as well as other gases such as Ammonia and Hydrogen sulphide (Billiau and Mcewan, 2020).). Exposure to low levels of these compounds can irritate the eyes, cause a cough or sore throat, shortness of breath, and fluid accumulation in the lungs. Prolonged low-level exposure may cause fatigue, pneumonia, and loss of appetite, headaches, irritability, poor memory, and dizziness.

2.8 Factors Affecting Compliance of Sanitation Systems to Sanitation Standards

Decision-makers, sanitation providers, and homeowners are all significant players in the execution of sanitation standards (Gabrielsson *et al.*, 2020). This ensures their compliance towards sanitation systems and their impact on public health and the environment. Banerjee and Morella (2011) outlined elements that influence people's motivation to adopt and adhere to sanitation standards when building and running sanitation systems in Africa (Kithia and Majambo, 2020). Economic factors (such as income, poverty, and government funding or support), level of awareness or exposure to standards (such as sanitation education level, accessibility, and complexity of standards), topographical, geological, and hydrological factors, and

Central and County Government policies are among them (which include sanitation policies, government institutions).

2.8.1 Economic Factors Influencing Adoption of Sanitation Standards

Income level of the population should be considered, since all the costs of installing sanitation systems, which comply with standards, is borne by them (Tidwell, 2020). The costs vary according to the sanitation system. Surveys need to be carried out to determine the household incomes in order to determine the ability to pay of the target population (Garbarino, 2011). Monthly income per household, size of the household, and credit facilities are factors having a significant impact on the extent of compliance to sanitation standards.

The ability to pay for sanitation products and services by individuals is a major deciding factor for compliance to standards on sanitation provisions. The influence of land prices, infrastructure (water supply and sewerage) and population density are significant to the final decision to adopt a sanitation system, which meets the sanitation standards. Urban poverty coupled with rural urban migration is one of the causes of the increase in housing that lack adequate sanitation systems in African cities (Poku-Boansi *et al.*, 2020).

According to Ogetii (2019), the absence of a city wide inclusive sanitation contributes to non-compliance to building regulations since it does not consider the needs of the people and their socioeconomic conditions. A large proportion of urban population is in poverty struggling to make a living, compliance to urban development regulations is not among their key priorities and a significant percentage (35%) of the population lack access to improved sanitation facilities (Sinharoy *et al.*, 2019; WHO, 2017).

2.8.2 Lack of Public Awareness on Sanitation Standards

To provide safe sanitation systems that adhere to standards, set rules, guidelines, or any specifications, developers and homeowners must be aware of their contents and existence (Cookey *et al.*, 2020). Individuals will be unable to meet the established standards if they do not understand what is expected of them. According to UN Habitat (2012), there is a lack of public awareness, particularly among urban dwellers, about the development control standards and regulations set by urban authorities, which leads to violations of all or some of the development control regulations. Guidelines that give direction on standards on sanitation systems have not been satisfactorily shared with the public (Rohilla *et al.*, 2019). For instance, residential developers lack education and training concerning standards for sanitation systems and only get to know of them during the submission process of the development proposals (Ogundele *et al.*, 2011). As noted by AAK (2011a) low level of awareness of the sanitation requirements in development control regulations leads to construction of buildings without safe and adequate sanitation systems.

2.8.3 Geological Factors Affecting Compliance to Sanitation Standards

Environmental factors are key determinants for which sanitation systems are suited for a specific area (Giné-Garriga *et al.*, 2018). Soil permeability is a key factor in adopting infiltration disposal for either excreta alone or a mixture of excreta and sullage. The soil type affects the rate at which liquid infiltrates from pits and drainage trenches (Ebrahimian *et al.*, 2021). Clays that expand when wet may become impermeable. Other soils such as silts and fine sands may be permeable to clean water but become blocked when transmitting effluent containing suspended and dissolved solids and are not suitable for onsite sewage treatment.

The rate of infiltration depends on the level of groundwater table relative to the pit or trench. Infiltration is likely to be severely limited in saturated conditions resulting from a high-water table (De Carlo *et al.*, 2020). In the saturated zone, all pores are filled with water and drainage is slow depending on the size of the pores and the differences in the soil water potential. Soil porosity also affects infiltration of wastewater. Soils with large pores, such as sand and gravel, and rocks such as some sandstones and those containing fissures, drain easily (Joly, 2021).

The rate of groundwater flow in unsaturated soils is a complex function of size, shape and distribution of the pores and fissures, the soil chemistry and the presence of air (Lu *et al.*, 2020). The speed of flow is normally less than 0.3m per day except in fissured rocks and coarse gravels, where the speed may be more than 5.0m per day, with increased likelihood of groundwater pollution from effluent (Sphere Association, 2018).

2.9 Research Gap

The following research gaps on sanitation standards contained in development controls of decentralised sanitation systems and the compliance of these systems to the development controls has been drawn from the existing literature

From this research, it can be concluded that there is regulatory legislation for sanitation provision yet sanitation related laws are fragmented and scattered across various legal instruments. In addition, due to multiple enforcement institutions being mandated to manage and implement sanitation standards they are unable to perform their functions due to this multiplicity of roles, conflict of roles and bureaucratic delays, which further compound the problem. This creates a challenge for developers and households to access and implement the sanitation standards when

building. Thus in un-accessible, fragmented standards, the low level of knowledge of sanitation standards by developers and households results in buildings without safe and suitable sanitation systems. This therefore results in release of raw wastewater into streams and rivers and abandoned quarries (Ddiba *et al.*, 2020).

There is diffusion of responsibility among sanitation actors i.e. lack of literature on structured framework on implementation and enforcement of policies that define roles of the actors involved in intervening or mitigating the wastewater mismanagement before it become a health disaster.

Wastewater management remains a major challenge in the city of Nairobi where Karengata lays and its environs, as illegal wastewater discharge into undesignated sites such as open quarries, fields and local rivers damage the environment and public health. Many stakeholders associate ineffective wastewater handling in Nairobi City and peri-urban areas such as Ongata Rongai with the inefficient implementation and enforcement of policies due to lack of a structured framework for roles of the actors.

There is lack of existing literature available on the procedure on the transitioning of decentralized sanitation systems to semi-centralized or centralized systems to match the changes in local setting and land use type through urbanisation. Rapidly increasing urban population results in changes in the nature of the setting i.e. the growth in density of peri-urban areas, increased land subdivision resulting in lack of land availability for minimum setback for siting decentralized systems and expansion of demand in water services required for operation and maintenance of the systems (UN-Habitat, 2012).

With these changes, decentralised sanitation systems are no longer suitable to local conditions which makes the sanitation systems unable to treat wastewater prior to discharge into the environment leading to water contamination as well as air pollution and aesthetic degradation (Obermann & Sattler, 2013). Therefore, malfunctioning sanitation systems and wastewater management problems will become evident due to ineffective transition of the sanitation solutions.

There is lack of literature on strategy to tackle the challenge of viable wastewater management in the city of Nairobi and its environs effectively when engagement of stakeholders is required. The approach should employ a mixture of strategies across multiple segments relevant to sanitation, together with a forum for stakeholders, NGOs and communities and relevant government institutions to deliberate and come up with viable solutions. This will enhance policy implementation, capacity, stewardship and management of sanitation in these areas (Ogut *et al.*, 2021).

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents the description of the research design, the area of the study, study population, sampling strategy and sample size, data collection, reliability and validity of data instruments, data analysis and ethical considerations at the conclusion of this chapter.

3.2 Research design

This research investigated the presence of untreated wastewater in the environment of Karengata in Nairobi County and Ongata Rongai, a peri-urban area in Kajiado County and hence determines the cause of the problem. To establish the underlying cause of this problem the study investigated the existing sanitation standards applicable to sanitation systems pertaining to their construction, operation and maintenance as outlined in the identified sanitation standards as defined in development controls. Secondly, the study sought to determine the existing sanitation systems in the study area. Thirdly, to evaluate the compliance or non-compliance of the existing sanitation systems to sanitation standards. Fourthly, the study sought to establish whether non-compliance results in implications of untreated wastewater release into the environment. Lastly, to propose recommendations that would ameliorate the implications highlighted from research findings.

The research adopted a descriptive survey research design, which involves collecting data on a particular subject in order to determine ‘what’ rather than ‘why’ without manipulating or influencing it in any way (Siedlecki, 2020). Descriptive

survey research design was used since it serves as a logical proof model and allows inferences to be made about relationships between the variables under inquiry. It also serves as the foundation for generalizing about circumstances (Bowden, 2015). The study adopted desktop research to identify the sanitation standards that are applicable while developing, adopting and constructing sanitation systems in peri-urban areas and these were obtained from literature review of various authors, legislative laws and interviewing sanitation sector experts. It also sought to identify the sanitation systems adopted in the peri-urban areas through questionnaire survey, key informant interviews, observation methods and desktop review and the factors influencing the adoption of the sanitation systems were established using these methods. Finally, compliance of the sanitation systems with the laid down sanitation standards was measured using various measuring instruments including; GPS readers, digital distance measuring instrument. The implications of compliance or non-compliance of sanitation systems was determined through engaging professional laboratory testing services. Through desktop research, the study also identified trends in sanitation use in the study area over the 10-year period between 2010 and 2020 to determine the improvement of sanitation provision as a sign of social development goal achievement.

This research design allowed the researcher to observe and measure statistics to assess the relationship between and among variables without manipulation of the independent variables (correlational research). The independent variables assessed in the study were existing sanitation standards, sanitation systems and factors influencing adoption of sanitation standards while the dependent variable in the study was implications of compliancy of sanitation systems to sanitation standards.

The study also identified the intervening variables influencing the existing sanitation standards and systems.

3.3 Study Area Location

The study was localized in Karengata and Ongata Rongai areas, located in counties of Nairobi and Kajiado respectively (Figure 3.1). Karengata is an area found southwest of Nairobi city between the city and the peri-urban areas of Ngong, Kiserian and Ongata Rongai. Karengata is located southwest of Nairobi central business district at latitude -1.32° and longitude 36.72° and is adjacent to Ongata Rongai peri-urban area. Karengata occupies an area of 56 square kilometres (GoK, 2006). Ongata Rongai is located in Kajiado County and spans over an area of 16.5km^2 . It is amongst the fast-developing urban residential areas and lies at latitude $0^{\circ} 53' 60 \text{ S}$ and longitude $36^{\circ} 25' 60\text{E}$ (GoK, 2013).

Karengata and Ongata Rongai are cross border areas with Mbagathi River and Nairobi National Park forming the physical boundary. They also share infrastructural elements such as Magadi road and Ushirika road. Both areas are not connected to the trunk sewer network for Nairobi and have opted for decentralised wastewater systems. It is clear that any change in the built environment or in human behaviour on one side of the subject border has immediate spill over effect on the other side (GoK, 2014). For example, VTOs that provide wastewater emptying services for septic/conservancy tanks in Karengata have been discharging their wastewater into illegal sites in Ongata Rongai (GoK, 2014).

3.3.1 Topography, Geology and Climate

The study area was divided into two broad geographical areas namely Karengata and Ongata Rongai (Figure 3.2). The broad areas were further clustered into eight zones,

four on each area based on key development typologies and specific structuring elements like the existing and proposed road networks, rivers, forests and national park (GoK, 2013). Karengata is divided into four zones namely: Bogani, Miotoni, Mbagathi and Karen plains. Ongata Rongai spatially consists of four zones namely Maasai Lodge, Gataka, Laiser and Kware (Figure 3.2).

The mean annual temperature of Karengata is 18°C and annual rainfall is 869 mm (GoK, 2006). The area is characterised by deep well-formed red soils in the North West and relatively shallow sodic alkaline soils in the southeast and predominantly loamy and black cotton soils in the remaining locations of Karengata (GoK, 2013). Karengata is not connected to Nairobi trunk sewer system. Population density is predominantly low density in Karengata area. The land use is mainly low-density residential with majority of the housing occupying a minimum land area of 0.2 ha. The types of housing include mansions, bungalows and maisonettes averaging 10 units per hectare (GoK, 2013).

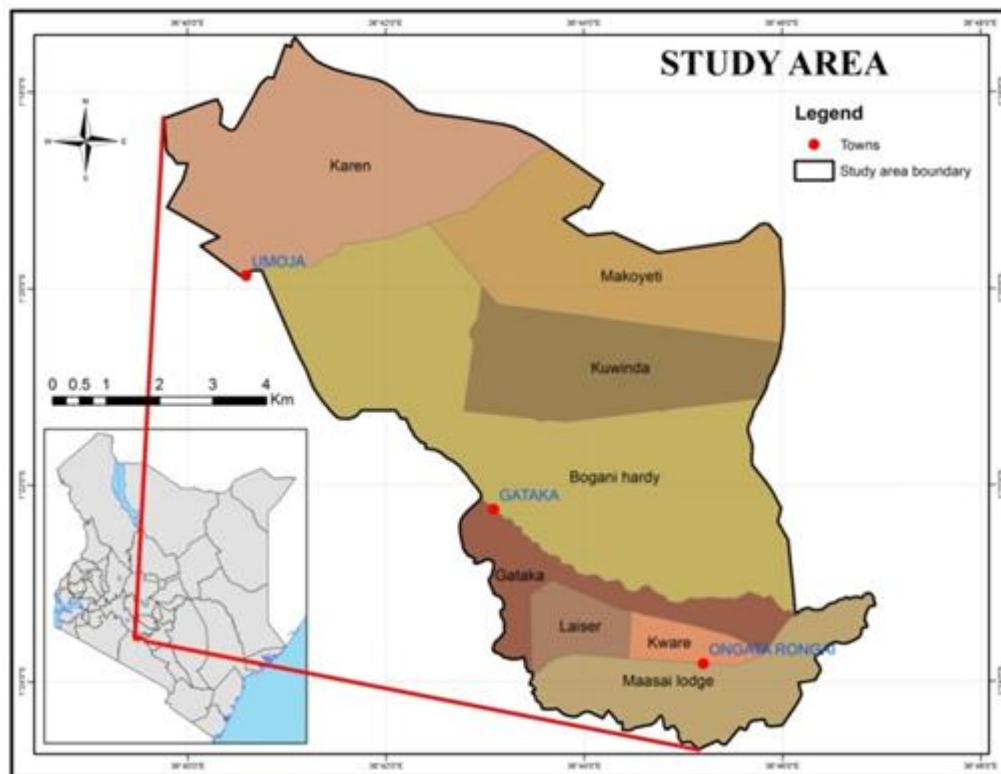


Figure 3.1 Map of study area (source: Ministry of Lands and Physical Planning, GoK, 2013)

Ongata Rongai sub county of Kajiado has a warm and temperate climate with mean annual rainfall of 844mm and mean annual temperature of 18.3°C. Geologically, the area consists of volcanic layers of tuffs, basalts, phonolites and trachytes, which overlay thick layers of clay soil (GoK, 2013).

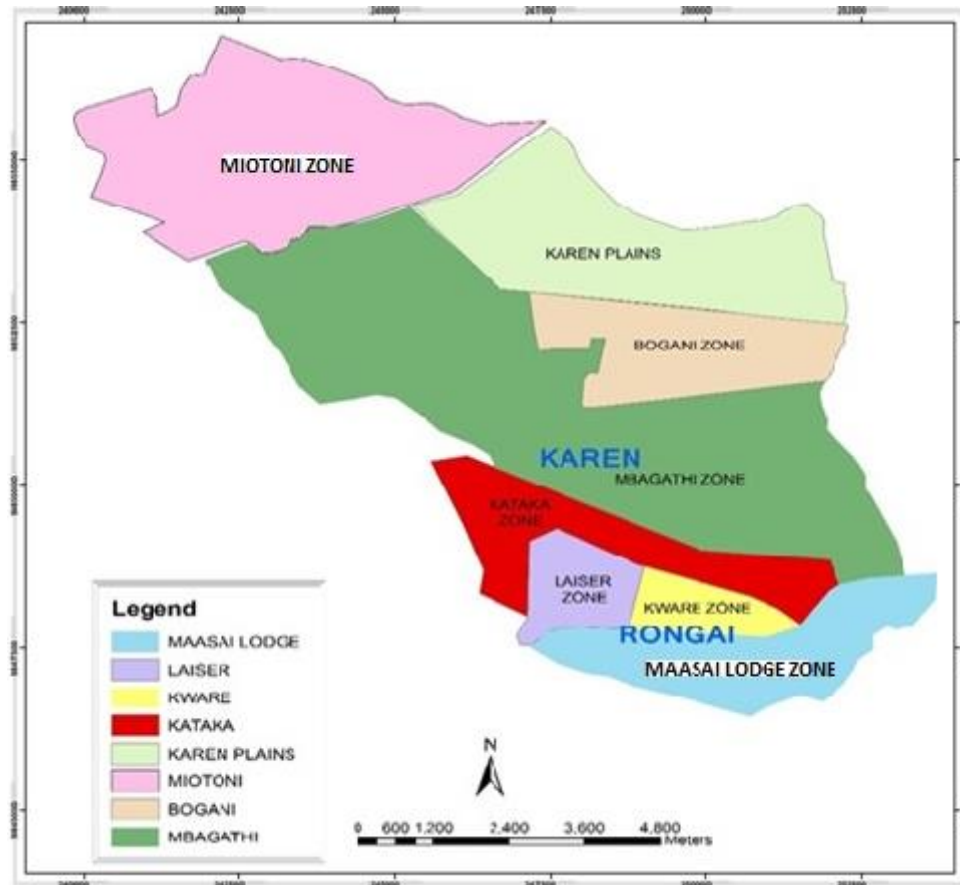


Figure 3.2 Karengata and Ongata Rongai areas (source: Ministry of Lands and Physical Planning GoK, 2013)

3.3.2 Urbanization Trend of Karengata and Ongata Rongai

The urban grain of the two areas differs where Ongata Rongai is fine grained with more social integration and Karengata is coarser grained with weaker social integration (GoK, 2007). Ongata Rongai is a town that has grown in a linear form along Magadi road. The town has both commercial and residential land use with retail and wholesale units at its centre and residential units forming the periphery. Zones located at the centre are densely populated with a fine-grained pattern and a more dispersed pattern as progress is made towards the hinterland. The housing is characterized by low-rise dwellings with 75-100% plot coverage for medium to high residential densities (GoK, 2014). The zones found to be adjacent to the centre are

Kware and Gataka while the ones found away are Laiser and Maasai Lodge (GoK, 2013). The outer zones exhibit mixed use with residential use being dominant. Maasai Lodge and Laiser are medium density with a dispersed layout. The residential units in these two areas are a combination of single-family dwelling and multi dwelling units (GoK, 2017).

Karengata is a suburban area that consists of neighbourhoods that are monofunctional predominantly residential, characterized by bungalows and masionettes. The area is low-density residential, single use with plot coverage of mostly 50%. Some areas, however, are high-density residential due to informal settlements such as Kuwinda and Kambi Kisii found in Karen Plains Zone (GoK, 2013).

The evidence of wastewater pollution in Karengata and Ongata Rongai and outcry of the residents in both of the areas compelled the research to be based in this study area (Mbira, 2013; Kamau, 2022).

Karengata and Ongata areas are in close proximity to the capital city, and intense development has been taking place since the 1990s due to the huge demand for housing by people working in the city (GoK, 2006; GoK, 2017). The two towns were also used as a case to inform studies on wastewater pollution issues facing similar towns in Kenya (GoK, 2014).

3.3.3 Total Population of Karengata and Ongata Rongai

The study targeted the residents of Karengata and Ongata Rongai areas with a total population of 85151 persons. According to the Kenya National Bureau of Statistics (KNBS) 2009 Population Census, Ongata Rongai recorded 44,678 persons however,

this rose to 56,294 persons (KNBS, 2015). In Karengata, the total population was 22902 persons (KNBS 2009) this population increased to 27857 persons at the time of the study. Table 3.1 and 3.2 highlight the total population for the study areas from the projected population (KNBS 2015).

Table 3.1 Population of Karengata

Area		Male	Female	Population
Miotoni	} Karen	9387	7986	17373
Kuwinda				
Karen plains				
Bogani/Hardy	} Hardy	6109	5375	11484

Source: (KNBS, 2015)

Table 3.2 Population of Ongata Rongai

Area		Male	Female	Population
Maasai	} Olekasasi	3026	2644	5670
Lodge				
Rongai				
Township	} Ongata Rongai	24281	26343	50624
Kware				
Laiser				
Gataka				

Source: (KNBS, 2015)

3.4 Research Methodology

3.4.1 Sampling Techniques

This study used two sampling techniques; stratified random sampling and systematic random sampling. All households in the areas of study were divided into strata where all households were systematically randomly sampled to meet the threshold on sanitation systems and compliance that were under study. According to Fisher and Bloomfield (2019), sampling is a method whereby the researcher divides the entire population into strata or different subgroups, then randomly picks the subjects proportionally from the different strata. The population was subdivided into subgroups based on building densities, which were high, medium, medium/low, and low densities and guided by information from maps and surveys obtained from Kenya population and housing census and Ministry of Lands and Physical Planning GIS Department (GoK, 2013). Through proportionate sampling, the study sampled approximately 40% of the sample population for Karengata and 60% for Ongata Rongai. The subgroups included; Gataka and Kware zones which represented the high-density subgroup (27% of sample); the medium density group was Maasai Lodge zone (20% of the sample); the medium low subgroup was Laiser and Karen plains zones (17% of the sample) and Bogani Miotoni and Mbagathi zones (36% of the sample) showed the low-density stratum. Therefore, the distribution of the samples maintained the proportion of 60% from Ongata Rongai and 40% from Karengata population. This technique ensured that the number of respondents in the sample groups was proportional to the number of residents in each subgroup of the population of Karengata and Ongata Rongai (Tables 3.1 and 3.2).

3.4.2 Sample Size

The sample size was determined using Slovin's formula (Equation 3.1) (Slovin, 1960), where n is the number of samples, N represents the total population (table 3.1 and 3.2) and e is the error tolerance.

$$n = \frac{N}{1 + N(e)^2} \dots\dots\dots(3.1)$$

Where;

n: Sample Size

N= Total population

e= Confidence index interval @ 5%

$$n = \frac{85151}{1 + 85151(0.05)^2} \dots\dots\dots n= 399 \sim 400$$

A total of 400 respondents were sampled at a 95 % confidence level and an accuracy level of ±5.

3.4.3 Spatial Distribution

The spatial extent of the study area was two broad geographical areas namely Karengata and Ongata Rongai adopted from the cadastral maps developed by the Ministry of Lands and Physical planning (GoK, 2013). The maps further divided these two broad areas into 8 zones, four (4) for each area based on key development typologies and specific structuring elements like the existing and proposed road networks, rivers, forests and national park (GoK, 2013).

Spatial sampling was used to map out the study area for the survey and was generated from a network of grids overlaid on the map of the zones. The study zones

in Karengata were; Bogani, Karen Plains, Mbagathi, Miotoni, while those of Ongata Rongai were, Gataka, Kware, Laiser and Maasai Lodge. The eight study zones are shown in (Table 3.3). Each of the grids measured 250 m by 250 m, which served as the primary sampling units for the selection of households. All the grids were assigned consecutive numbers and depending on the desired sample size, the “nth” grid was selected. Then the plot falling on the centre of the identified grid was also selected from which one household will be surveyed. Afterwards, four other neighbouring plots were selected randomly within the grid. An illustration of how this technique was applied, is shown in Figure 3.3 representing Kware zone. The sampling procedure was repeated for each of the eight zones until 400 households were identified. Zone sampling grid illustrations are contained in Appendix IV of the document.

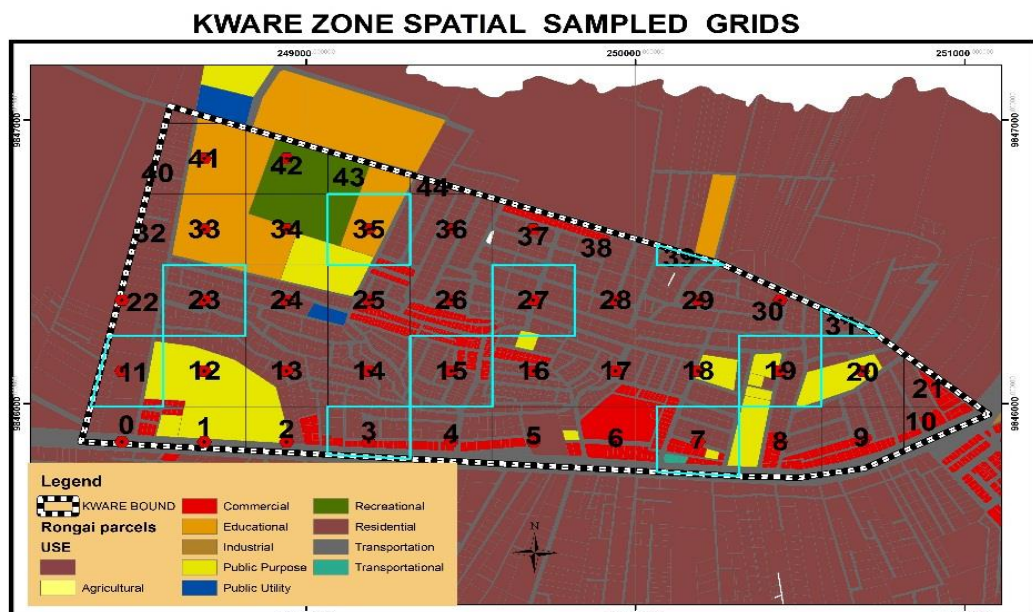


Figure 3.3: Kware sampling and sampled plot grid

Through randomization, this sampling technique guaranteed that every plot in the Zones had an equal opportunity for selection. In addition, it assured no biases on samples for the entire population.

The sample size of each zone in the study area was obtained using the proportional method of sample size distribution as seen in Equation 3.2.

$$zone = \frac{\text{plots...in...zone}}{\text{total...plots}} \times \text{sample...frame} \dots\dots\dots(3.2)$$

Table 3.3 shows a summary of the grids generated for each zone or cluster and the nth grid for each selected clusters or zones.

Table 3.3 Systematic sampling of grids from strata or zones

Study Zones	Total grids	Grid sample size	Sample nth grid
Karengata			
Bogani	32	10	3
Miotoni	62	10	6
Karen Plains	37	10	3
Mbagathi	103	10	10
Ongata Rongai			
Gataka	100	10	10
Kware	44	10	4
Laiser	46	10	4
Maasai Lodge	112	10	11

3.4.4 Data Collection Methods

The research targeted both primary and secondary data from the two-target locations. Primary data was collected through the questionnaires, interview schedules, GPS receivers, Digital Distance Measuring instruments (Digital wheel), Odour measuring instrument (olfactometer) and both direct and covert observations. Secondary data was collected through desktop research of sources, which included; legislation documents, policies, journals, NGO reports, government publications and media reports.

3.4.4.1 Key Informant Interviewing

Interviews on key informant are used commonly in data collection practices for rapid assessments (Lavrakas, 2008). A key informant interview is one where a person with vast knowledge of the community affected is interrogated to gather key information on a phenomenon and its impact on a community (Lavrakas, 2008). The key informants in the study were officials from the Kajiado and Nairobi Counties in particular the Public Health Inspectorate, Development Control Department, and NEMA office. Other Key informants were from Government Ministries including, Ministry of Lands, Housing and Urban Development, Ministry of Health and Ministry of Environment, Water and Natural Resources.

3.4.4.2 Questionnaire Survey

This method was used to collect demographic data, data on sanitation system types, siting distances, water consumption quantities, population densities, views relating to issues on the use of sanitation systems and environmental and public health concerns affecting residents in the study area. The questionnaire was administered to

household heads and institution officials in Karengata and Ongata Rongai. It was also used to quantify the sanitation systems and assess usage patterns.

3.4.4.3 Global Positioning System-Tracking

GPS devices were used to provide the geographical coordinates for sanitation systems and the plot features in Karengata and Ongata Rongai. In order to identify the sample plots, satellite imagery obtained using Google Earth software was used. Points of easily identifiable features on the aerial map were georeferenced to actual x and y coordinates using Arc GIS software. The satellite image was then laid over a base map of the study area, which assisted in locating the targeted sample plot on the ground in each of the selected grids/blocks. Once the targeted plots were identified, GPS receivers were used to provide geographical coordinates of the plot features at these locations.

3.4.4.4 Distance Measurement using Digital Measuring Wheel

Measurement of siting distances was conducted using a digital measuring wheel (STANLEY DMW 30™). In particular, the instrument was used to measure the distance between the sanitation system and the plot features such as plot boundary, building or dwelling, borehole or well, and the sampling intervals for odour impact assessment.

3.4.4.5 Odour Measuring Instrument using Olfactometer

The study used Scentroid SM100 field olfactometer which is compliant with EN 13725 European standard to determine the compliance limits for odour impact levels, in Karen Brooks Estate within Karen plains zone. This standard was used instead of the NEMA air quality regulations to determine accurate in-field odour measurement of ambient air and stack emissions. Odour perception analysis using

the KEBS certified SM 100 field olfactometer was found to be more appropriate due to its ease of use, practicality for field measurement of odour concentration with high accuracy levels. This tool was used to capture odour intensity in the atmosphere. It uses compressed air from a high-pressure carbon-fibre tank to dilute sample air prior to presenting it to the panellist (Kulig *et al.*, 2021). The sample was drawn using vacuum generated by the flow of compressed diluting air through a venturi pump. The dilution ratio of clean air to sample air is controlled via Scentroid's patented flow regulator valve. The panellist can select 15 discrete dilution ratios. The overall range of the unit is selectable via changeable restrictor plates. Minimum dilution is two and maximum dilution is 30000 ouE/m³.

3.5 Reliability and Validity of Data Instruments

3.5.1 Reliability

Reliability is a degree to which a research instrument produces constant results or data after repeated trials (Shao *et al.*, 2021). The researcher used test and retest techniques, where the same data collection tools were administered twice to the same respondents during the pilot study over six month period (Appendix xiii) in Ongata Rongai and Karengata areas, to determine the suitability of the instruments to be used and the procedures for data collection to ascertain their reliability and validity. After the research instrument had yielded the same results, the researcher went ahead and administered an improved questionnaire (appendix xii) to the selected samples in Ongata Rongai and Karengata areas.

3.5.2 Validity

Validity is the correctness and meaningfulness of interpretations, which are, centred on the research results (Kharasch *et al.*, 2021). A tool is valid if it measures what it

claims to measure. Validity must do with how much accuracy the data acquired in the study epitomizes the variables of the study. It is essentially obtained by the presence or non-appearance of systematic error in data. Content validity is a measure of amount to which data collected using an instrument represents a specific domain of indicator or content of a particular concept. The concept in this study was that wastewater discharge was evident in the study area and the possible underlying cause was failure or malfunctioning of the sanitation systems, which are the treatment instruments of wastewater before its release into the environment. This research used content validity to ascertain whether the tools measured what were stated in the objectives which were sanitation standards (desktop research), sanitation systems (survey using questionnaires and observation), compliancy of sanitation systems to the sanitation standards (using GPS, Olfactometer and digital distance measuring instruments) and implications of noncompliance on the environment (using professional laboratory testing services).

3.6 Data Analysis

Both quantitative and qualitative approaches were used in the analysis of the data. Quantitative data from the questionnaires was coded and keyed into a computer for computation of descriptive statistics. The Statistical package for social sciences (SPSS) version 23 was used to run descriptive statistics to produce frequency distribution, and percentages. The data collected on compliance to sanitation standards included, minimum building line, water quantity for domestic use and maintenance of sanitation facilities, minimum setbacks, minimum plot sizes, plot coverage, and wastewater disposal mechanisms. Data collected on sanitation systems included sanitation systems types, water sources, frequency of desludging,

disposal mechanisms and implications which included odour concentration, effluent quality and water quality.

Inferential statistics such as t-test and ANOVA were used to determine associations between variables and its significance. The hypothesis of the study (H_{01}) was “Sanitation systems in Karengata and Ongata Rongai areas are not compliant to existing sanitation standards”. The independent variable in this hypothesis is sanitation standards and the dependent variable is compliance of existing sanitation systems to sanitation standards. Results were summarized, interpreted, reported and presented using percentages, frequency tables, and narrative description of the tables. The summary of data variables and approaches is given in table 3.4.

Table 3.4: Summary of Data Variables and Approaches

Objective	Research Tools	Analysis Method
To assess sanitation standards governing decentralised sanitation systems in use in Karengata and Ongata Rongai areas	Questionnaires Interviews Observations Desktop research	Descriptive(mean, frequency, standard deviation) Document analysis
To examine the types of decentralised sanitation systems in use in Karengata and Ongata Rongai areas	Questionnaires Interviews Observations	Descriptive(mean, frequency, standard deviation)
To evaluate compliance of decentralised sanitation systems to sanitation standards in Karengata and Ongata Rongai areas.	Questionnaires Interviews Measuring instruments Observations	Descriptive(mean, frequency, standard deviation) Inferential analysis (ANOVA, t-test)
To determine the effects of compliance or non-compliance of sanitation systems to sanitation standards on the physical and human environment in Karengata and Ongata Rongai areas.	Questionnaires Interviews Measuring instruments, Observations	Descriptive(mean, standard deviation) Inferential analysis (ANOVA, t-test), Lab analysis
To establish the factors influencing adoption of sanitation standards in Karengata and Ongata Rongai areas.	Questionnaires Interviews Observations	Descriptive(mean, standard deviation)
To propose recommendations from the findings.	Questionnaires Interviews Observations Desktop research	Content and Document analysis

3.7 Ethical Consideration

The researcher obtained a research permit from National commission for science, technology and innovation (NACOSTI), with the recommendation of Kenyatta University. The Nairobi and Kajiado County Commissioners gave consent for the

research to be conducted in Karengata and Ongata Rongai respectively. Consent was obtained from all the respondents to ensure that they participated willingly and the researcher assured the respondents of the privacy and confidentiality of the information provided. The respondents were informed the purpose of the study was for academic purpose. Lastly, the identity of individuals was protected by using unique codes that kept them anonymous.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the research based on the research objectives. The objectives were, firstly, to assess sanitation standards domiciled in development controls in both local and international laws and policies and their applicability to decentralized sanitation systems in use in Karengata and Ongata Rongai areas. Secondly, to examine the types of sanitation systems currently in use in Karengata and Ongata Rongai areas. Thirdly, to evaluate compliance of sanitation systems to sanitation standards and determine the implications of compliance or non-compliance of sanitation systems to sanitation standards on the physical and human environment in Karengata and Ongata Rongai areas. Finally, the research sought to establish the factors influencing adoption of sanitation standards and sanitation systems in Karengata and Ongata Rongai areas.

4.2 Sanitation Standards Governing Sanitation Systems in Karengata and Ongata Rongai Areas

The first specific objective of the research was to assess existing sanitation standards in Karengata and Ongata Rongai in order to evaluate their suitability for sanitation systems to treat wastewater in Karengata and Ongata Rongai areas. The sanitation standards ascertained through desktop review were drawn from local and international laws and policies in order to determine their applicability to decentralised sanitation systems in the two study areas. The sanitation standards were identified in local legislation and policies and were found to be comparable to International sanitation standards from organizations that include World Bank (WB,

2012), World Health Organization (WHO, 2018), International Standard Organization (ISO, 2016) and Water Aid (Water Aid, 2011).

The sanitation standards found in development controls pertaining to decentralized sanitation systems were established to be siting standards, water consumption standards and density standards and are highlighted in Appendix I. The sanitation standards relating to siting of the sanitation systems were established as follows

Water Act (GoK, 2016) and Landuse and Planning Act (GoK, 2019) set separation distances from the sanitation systems to the building, water sources and property boundary. The standards, which are listed in tables 2.1 - 2.8, can be summarized to be:- The septic tank system to be separated from property boundary by at least 1.5m (GoK 2016), from building or dwelling by 3m (GoK 2019) and from well/groundwater source by 30m (GoK 2016). In addition, for pit latrine systems the separation distance from property boundary should be 3m, (GoK 2019), from the building or dwelling to be at least 10m (GoK 2019) and from well/groundwater source by 50m (GoK 2016). Finally, for wastewater stabilisation ponds the minimum separation distance from building or dwelling is 200m (GoK 2019).

Water consumption requirements were stated in GoK 2016 and considered water quantities required for domestic needs and operation of sanitation systems. Water consumption standards specify 100 lpcd to be sufficient for domestic use including flushing and treating human waste across the sanitation service chain (GoK, 2016). Water is required as a treatment and transport medium of human waste up to disposal into the environment. Effluent which is the liquid waste generated from treatment process in the sanitation service chain is the final end product and NEMA

effluent quality standards specify the acceptable limits of effluent as BOD-40mg/l, COD-35mg/l, TSS-35mg/l and TDS-1200mg/l, (GoK 2015).

Density standards as used in this study include the population density (people per unit area) which will be supported by the opted sanitation systems and the number of sanitation systems per unit area (GoK, 2012c). Further density standards are specified in the Land Use and Physical Planning Act as 0.25 of an acre (GoK, 2019) as the minimum plot size, which allows for setbacks for sanitary facilities and other amenities for the design capacity population to be served by wastewater disposal mechanisms.

4.3 Sanitation Systems in Use in Karengata and Ongata Rongai

Results based on the second specific objective from the study show that the sanitation systems in use in Karengata and Ongata Rongai are decentralised systems, specifically pit latrines, septic tanks, and bio digesters (Table 4.1). It was evident from the study that neither location is serviced by the County Governments' sewer system. The residents opted for decentralised sanitation systems as shown in Table 4.1. Karengata residents opted for septic tanks at 75% as compared to 50% of residents in Ongata Rongai opting for same. Regarding the pit latrine systems, out of the 50% preference in Ongata Rongai, Gataka zone, a very high-density zone, had 19% and Kware zone, a high-density zone, had 15%. In addition, Table 4.1 shows that bio-digesters were responsible for only 1% of

the four sanitation systems evaluated in Karengata, while none were found in the Ongata Rongai area.

Table 4.1: Household sanitation systems in Karengata and Ongata Rongai

Sanitation options	Sanitation systems (%) in Karengata				
	Miotoni (%)	Bogani (%)	Mbagathi (%)	Karen plains (%)	Total (%)
Septic tanks	20	22	20	13	75
Sewerage	0	0	0	0	0
Pit latrines	5	3	3	13	24
Bio digester	0	0.5	0.5	0	1
Total					100%
Sanitation options	Sanitation systems (%) in Ongata Rongai				
	Laiser (%)	Kware (%)	Maasai lodge (%)	Gataka (%)	Total (%)
Septic tanks	16	10	17	7	50
Sewerage	0	0	0	0	0
Pit latrines	9	15	7	19	50
Bio digester	0	0	0	0	0
Total					100%

Upon further analysis, the sanitation systems in the study area (Table 4.2 and 4.3) results indicate that the septic tank systems in Karengata and Ongata Rongai were mainly septic tanks without soakaway. In Table 4.2, in Karengata, 75% of households responded septic tank usage. On analyzing septic tanks usage in Karengata, those using Septic tanks with Soakaways were 43% while without Soakaways were 57%. In Ongata Rongai out of the 50 percent of households using septic tanks, those using septic tanks with soakaways were 28% and without Soakaways were 72% (Table 4.2 and 4.3). Therefore, these septic tank systems function as conservancy/holding tanks that partially stabilise effluent and require emptying and conveyance to an offsite treatment plant for further treatment and disposal. A septic tank is a watertight chamber consisting of an inlet and an outlet into a leaching or soak away field while a conservancy tank is a temporary storage chamber for sewage that requires frequent emptying (Murat-Błażejewska & Błażejewski, 2020).

Upon examining, the pit latrine systems in Karengata and Ongata Rongai it was noted they included Ventilated Improved Pit (VIP) latrine, simple pit without slab and simple pit with slab (Table 4.2 and 4.3). In Karengata out of the 24% of households who use pit latrines, those with slab were 83%, and without slab were 17%. In Ongata Rongai out of 50% of households using pit latrines, those using pit latrines with slab were 70%, while those using latrines without slab were 30%. Pit latrines without slab are categorised as unimproved sanitation. Pit latrines with or without slab directly load human excreta into the soil and therefore when pit latrines density is high, the capacity of the soil to treat is overwhelmed and effluent remains untreated as it is leached into the aquifer (Rivett *et al.*, 2018).

Table 4.2: Percentage of sanitation systems options in Karengata area

Sanitation options	Sanitation options in Karengata				
	Miotoni (%)	Bogani (%)	Mbagathi (%)	Karen plains (%)	Total (%)
Septic tanks	20	22	20	13	75
Sewerage	0	0	0	0	0
Pit latrines	5	3	3	13	24
Biodigester	0	0.5	0.5	0	1
Total					100%
Pit latrines type					
VIP Latrine	0	0	0	0	0
Pit latrine with slab	3	2	2	12	20
Pit latrine without slab	2	1	1	1	4
Biodigester	0	0.5	0.5	0	1
Septic tanks type					
Septic tank with soakaway	16	6	2	8	32
Septic tank without soakaway	4	16	18	5	43
Total					100%

Table 4.3: Percentage of sanitation systems in Ongata Rongai

Sanitation options	Sanitation options in Ongata Rongai				
	Laiser (%)	Kware (%)	Maasai lodge (%)	Gataka (%)	Total (%)
Septic tanks	16	10	18	6	50
Sewerage	0	0	0	0	0
Pit latrines	8	16	8	18	50
Biodigester	0	0	0	0	0
Total					100%
Pit latrines type					
VIP Latrine	0	1	0	0	1
Pit latrine with slab	4	10	4	16	34
Pit latrine without slab	3	4	4	4	15
Septic tanks type					
Septic tank with soakaway	6	2	4	2	14
Septic tank without soakaway	10	8	14	4	36
Total					100%

Septic tank systems operate with piped water supply to individual compounds (Mckeown and Bugyi, 2016). This is because flush cistern systems do not operate efficiently under conditions where water is not piped directly to the toilet located in the house (Kalbermatten *et al.*, 1980). The study established increased usage of septic tanks in both study areas, which leads to increased demand for piped water from the water service providers operating in the area. Where service providers are unable to meet this demand the residents opt to supplement their water supply with borehole water drawn from numerous existing boreholes in the study area.

Further analysis of the sanitation systems in the study area showed the least used facilities within the study area were pit latrines without slab and ventilated improved pit latrines (Table 4.2 and 4.3). In Karen plains zone, an exception to the norm

occurred with respondents indicating greater use of pit latrines with slabs as compared to the rest of Karengata. This was because the respondents living in Kuwinda and Kambi Kisii settlements were using these systems in the zone. In Ongata Rongai, respondents from Gataka indicated a high usage of pit latrines with slabs followed by pit latrines without slabs. Gataka mainly comprises of a very high density of rental houses and because of maximising profits by individual owners, they offer pit latrines with slabs that require less frequent emptying therefore they save on maintenance costs such as desludging costs. A similar pattern was observed in Kware where densely populated plots are also common and the property owners provide pit latrines with slabs to reduce emptying costs. However, this status quo is changing with the roads being improved and new upcoming residential flats necessitating owners to provide flushing toilets to attract clientele. Laiser area is largely middle and upper class thus the occurrence of flushing toilets is high. However, some landowners provide high-rise flats and provide pit latrines to reduce on operation and maintenance costs. In Maasai lodge zone most plots were for rental use and property owners provide pit latrines because of intermittent water supply thus accounting for the occurrence of high pit latrine use (Table 4.4).

Table 4.4: Sanitation systems in Ongata Rongai and Karengata

Sub- Location	Small Sewer (%)	Septic Tank (%)	VIP Latrine (%)	Pit Latrine (%)	Total (%)
Kware Laiser Gataka } Ongata Rongai	2.8	40.7	2.4	54.1	100
Maasai Lodge } Olekasasi	0.5	10.8	6.3	82.4	100
Karen Plains Bogani Mbagathi } Karen	14.3	50.9	6.5	28.3	100
Miotoni } Lenana	9.9	55.7	4.8	29.6	100

Adopted from Population and Housing Census (KNBS, 2009)

4.3.1 Shared Facilities in Karengata and Ongata Rongai

Kware has the highest number of households sharing facilities with 71% of the households (Table 4.5). In Gataka, 59% of the households share a facility. Kware and Gataka are areas with low-income populations and minimal space available to provide adequate sanitation facilities. On the other hand, non sharing in Laiser and Maasai Lodge zones was 72% and 68% respectively. Laiser and Maasai lodge are medium density areas and therefore more land is available to provide adequate sanitation. In Karengata where there were larger plot sizes available, the facility sharing was minimal. In Bogani zone, 87% did not share, in Karen plains it was 71%, in Mbagathi, it was 90% and Miotoni 76% did not share (Table 4.5). Social developmental goals state that shared facilities are limited sanitation services.

Table 4.5: Shared facility in Karengata and Ongata Rongai households

Study Area	Zone	Non compliant		Compliant		Zone Total (%)
		Frequency	%	Frequency	%	
Karengata	Bogani	5	13	33	87	100
	Karen Plains	13	29	32	71	100
	Mbagathi	3	10	27	90	100
	Miotoni	9	24	28	76	100
Ongata Rongai	Gataka	24	59	17	41	100
	Kware	29	71	12	29	100
	Laiser	11	28	28	72	100
	Maasai Lodge	12	32	26	68	100

4.3.2 Ablution Blocks in Karengata and Ongata Rongai

Ablution blocks are buildings containing facilities for washing and with one or more toilets (Georgi *et al.*, 2021). In formal areas, ablution blocks were found in institutions. In informal settlements such as Kware, Kuwinda, and Kambi Kisii ablution blocks were situated at a greater distance than the required 100m (GoK, 2007c) from the dwelling units. In some cases, such as in Kambi Kisii the ablution blocks were located as far as 500m away from the dwelling units (Research, 2019). According to sphere standards (Sphere Association, 2018) greater distances increases crime and insecurity risk and as well as reduces the accessibility for the elderly, the disabled and children. As shown in Table 4.6, the majority of respondents replied that the distance of the ablution blocks was too far (76% in formal and 53.2% in informal).

Accessibility to the ablution blocks was limited due to inadequate numbers of toilets and distance of the ablution blocks from the dwelling units. In Kuwinda, results from causal observation methods identified one ablution block was serving 2000

people, which results in the dilapidation of the facility leading to possible spread of sanitation related diseases (Research, 2019). Godana and Mengisties (2017) also alluded that, inadequate sanitation facilities proliferate the spread of diseases.

Table 4.6 Residents views on accessibility and safety for ablution blocks

Ablution blocks in the vicinity	Type of Settlement		Study area		
	Formal	Informal	Total	Ongata Rongai	Karengata
Yes	17.2%	31.4%	23.9%	15.1%	35.6%
No	82.8%	68.6%	76.1%	84.9%	64.4%
Is it greater than 100m from the dwelling units					
Yes	76.0%	53.2%	61.1%	56.3%	62.5%
No	24.0%	46.8%	38.9%	43.8%	37.5%

Source: (Research, 2019)

4.3.3 Desludging and Septage Disposal of Decentralized Sanitation Systems

In Karengata and Ongata Rongai, decentralised sanitation systems were the main wastewater treatment method through containment systems such as septic tanks, conservancy tanks/vaults and pit latrines (Table 4.1). These systems require emptying services from small-scale operators to handle sludge removal from conservancy tanks and latrines in the study area. In Karengata and Ongata Rongai areas, 98 % of the respondents indicate that the most common service providers in disposing of wastewater were private companies.

From the study area, the main sanitation systems were septic tanks without soakaway (conservancy tanks) i.e. 43% in Karengata and 36 % in Ongata Rongai (Table 4.2and 4.3). The conservancy tanks require frequent emptying because filling occurs rapidly as no outlet to soakaway is available; therefore, partial treatment of faecal sludge does not occur. This means, the quality of faecal sludge being emptied

is one to two times higher in COD and TSS magnitude and variability than partially treated wastewater (Gold *et.al.*, 2017). Furthermore, variability could also be due to the differences in onsite containment technologies, retention times, household usage patterns, quality of construction and collection practices and soil type (Strande *et.al.*, 2018). The complicated biochemical processes associated to methanogenic fermentation become efficient after 2 years of operation, with sludge accumulation reduction being ideal after 2.5–3 years (Mahon *et.al.*, 2021; Strande *et.al.*, 2018; Philip *et.al.*, 1993). The research findings show that the frequency of desludging of conservancy tanks was below the minimum requirement of 2 years with the average desludging interval of less than 1 year being 55% in Ongata Rongai and 29% in Karengata (see Table 4.7). From the study 71% of Karengata residents indicated they desludge their septic tanks every two years and above while in Ongata Rongai 45% of residents indicated the same. It was noted that where the respondents indicated two years interval in Ongata Rongai, the researcher observed through covert direct observation the pumping of the contents of conservancy tanks into open drainage and open cess pools (Plate 4.1). This practice could explain the survey findings where respondents indicated the engagement of emptying services for their conservancy tanks after 2 years and above. Nonetheless, short desludging intervals signify that the effluent quality of the wastewater discharged into open drainage, quarries and rivers has higher concentrations of faecal sludge than is permissible in NEMA effluent quality standards.

The frequency of disposing of waste from sanitation facilities show that 36 % of the respondents indicate that the septage removal duration was every two years. Twenty percent indicate they dispose of twice a year, 14 % indicate less than once a year, 10

% indicate more than 2 years and 7 % indicate once a month or less as seen in Table 4.7.

Table 4.7 Desludging interval of sanitation systems in Karengata and Ongata Rongai

Duration	Kware (%)	Laiser (%)	Kataka (%)	Maasai Lodge (%)	Bogani (%)	Mbagathi (%)	Karen Plains (%)	Miotoni (%)
Once a month or less`1	3.7	8.0	10.0	8.7	16.7	4.8	3.7	
Every 3 months					3.3			
Twice per year	33.3	12.0	20.0	43.5	13.3	9.5	7.4	18.2
Less than once a year	29.6	12.0	15.0	21.7	20.0	14.3		
Annual		4.0					3.7	
Every two years	29.6	32.0	50.0	21.7	20.0	33.3	48.1	54.5
More than 2 years	3.7	20.0	5.0		13.3	9.5	22.2	4.5
Other					3.3	14.3	7.4	22.7
Never		12.0		4.3	10.0	14.3	7.4	

4.3.3.1 Wastewater Discharge into Illegal Sites

The research faced challenges in the collection of empirical data on the existence of illegal disposal practices of wastewater by vacuum tankers operators (VTOs). This was because none of the VTOs would admit to disposal of wastewater to illegal sites and thus it was not safe to interview the operators. It was then decided that covert

observation methods had to be utilized. The findings from the exercise confirmed privately owned vacuum tankers were dumping raw sewage into unauthorised disposal sites near Kandisi river in Gataka zone (Plate 4.1).

Kandisi River discharges its waters into Mbagathi River, which flows in Nairobi National Park. Considering that, the main sanitation systems in the area were holding or conservancy tanks and latrines, the wastewater being discharged into the open quarries and the rivers were untreated wastewater.



Plate 4.1 Discharge of raw sewage into open illegal cesspools in Gataka zone

The discharge of wastewater by private VTOs into unauthorized sites is violation of the EMCA 2015, which prohibits discharge or disposal of any wastes in such a manner as to cause pollution or ill health to any person. The findings also agree with that of Kanuku et al. (2020), on effective management of waste in urban areas is critical not only to the environment but to human public health in general.

It was also found that wastewater from septic or conservancy tanks from storey buildings in Rongai was discharged into open channels draining into Kandisi and

Mbagathi rivers that pour their waters into Nairobi National Park. The researcher through covert observation witnessed wastewater being pumped from buildings into the open channels between 10 pm and midnight. Due to security concerns, the exercise was carried out under guard of un-uniformed administration police with a lot of discretion. The discharge of wastewater was via open channels along Church Road, Soronik road and Mayor Road in Rongai. Other open channels discharges were found in Gataka and Maasai Lodge areas draining into Mbagathi River. This therefore shows poor effluent management because of inadequate sewerage and wastewater treatment systems compounded with poor enforcement and will result in environmental and public health hazards.

4.4. Compliance of Decentralized Sanitation Systems to Sanitation Standards in Karengata and Ongata Rongai

The third objective of the research was to evaluate compliance of decentralized sanitation systems to sanitation standards. For sanitation systems to treat sewage emanating from blackwater (human excreta) and greywater (sullage) before it is released into the environment they must meet standards pertaining to construction, operation and maintenance. They must also meet certain level of performance capacity as prescribed in the standards, laws and policies (Snyder *et al.*, 2020).

The standards for decentralized sanitation systems found in the study area are contained in laws and policies, which govern urban development and housing. The sanitation standards for development of decentralized sanitation systems considered in this study include; siting standards, density standards and water consumption standards. All onsite waste disposal options require adequate space within the plot for their installation. Such space becomes available by applying the following siting

standards, separation of the building from property boundary, separation of sanitation facility from plot boundary and separation of sanitation facility from building. Furthermore, the density standards considered are plot density and population density. Plot density standards recommend sufficient area be available for wastewater disposal by decentralised systems through plot coverage and ratio requirements. Density standards consider the volume of wastewater loading on the decentralized sanitation system based on the population of users. They also consider the number of decentralized systems loading per unit area. The water consumption standard indicates a nominal figure of 100l/c/d for domestic and hygienic purposes. All these sanitation standards are required to be complied with when constructing, operating and maintaining decentralized sanitation systems to prevent implications that may arise from non-compliant systems.

The summary of the compliance of the decentralized sanitation systems to sanitation standards in Karengata and Ongata Rongai is discussed in the subsequent sections.

4.4.1 Separation of the Building from the Property Boundary

Setbacks are building constraints imposed by the government on property owners by law and building rules. They ensure privacy, safety, infrastructure and service access, and environmental preservation. Property border setbacks keep landowners from crowding each other's properties, allow for the safe installation of pipelines, and aid in the preservation of wetlands. Setbacks define boundaries by specifying the exact distance from a fixed point, such as a property line or an adjacent structure, within which construction is banned. In Kenya, the Building code specifies the setback distance from the property boundary for any building to be 3m. In the study, measurement of separation distances of building from property boundary was

carried out in order to ascertain the compliance by property owners to building line setback standards.

Karengata was more compliant at 97% than Ongata Rongai was at 31% (Table 4.8). Spatially, Karengata being a low-density area had a greater minimum plot size of 0.5 acre thus plot developers are able to avail more space for siting sanitation systems. Ongata Rongai area is predominantly high density with minimum plot sizes of between 1/8 and 1/16 acre therefore application of setback distances is impractical for installation of decentralized systems (Table 4.8). The plot sizes restrict the sanitation options for plot owners to provide wastewater disposal to conservancy tanks built under the dwelling or to pit latrines which do not conform separation distance of 10m. As a result emptying of and disposal of untreated wastewater into illegal sites is the existing practice.

Table 4.8 Compliance of 3m on building separation from property boundaries

Study area	Zone	Non-compliant		Compliant		Zone total
		Frequency	%	Frequency	%	(%)
Karengata	Bogani	1	5	20	95	100
	Karen Plains	4	9	40	91	100
	Mbagathi	0	0	36	100	100
	Miotoni	0	0	31	100	100
Ongata Rongai	Gataka	7	44	9	56	100
	Kware	33	94	2	6	100
	Laiser	5	50	5	50	100
	Maasai Lodge	29	90	3	10	100

4.4.2 Separation of Septic tank from Building

The septic tank was identified as a major sanitation provision in both study areas. The separation distance of septic tank from dwelling should be 3m. Non-compliance is evident in both Ongata Rongai and Karengata. Karengata showed a compliance level of 69% while Ongata Rongai had a non-compliance of 55% (see table 4.9). Compliancy of Karengata is as a result of higher land availability with larger plot sizes of 0.5 acre. In Ongata Rongai, the non-compliancy can be attributed to high residential density with smaller plot sizes averaging at 1/16 to 1/8 acre.

Table 4.9: Septic tank separation distance of 3m from dwelling areas

Study area	Zone	Non-Compliant		Compliant		Zone total
		Frequency	%	Frequency	%	(%)
Karengata	Bogani	4	21	15	79	100
	Karen Plains	8	30	19	70	100
	Mbagathi	9	31	20	69	100
	Miotoni	11	44	14	56	100
Ongata Rongai	Gataka	9	56	7	44	100
	Kware	24	69	11	31	100
	Laiser	5	50	5	50	100
	Maasai Lodge	11	46	13	54	100

4.4.3 Separation of Pit latrine from building

Pit latrines were one of the major sanitation systems identified in the study area. The siting of a pit latrine must take into consideration the surrounding features and be adequately separated from them to protect the water sources such as wells, watercourses, groundwater; and building or habitable dwellings, to prevent odour and flies and other disease vectors from affecting households. To separate latrine from a dwelling one requires a distance of 10 meters.

Karengata area shows compliance with 10m siting of pit latrines from dwelling at 100%. This was attributed to the fact that Karengata is a low-density area and therefore has enough space to site a pit latrine. In Ongata Rongai however, the compliance was 53%, meaning that the area was more of a high-density area with plot sizes ranging from 1/8 to 1/16 of an acre (Table 4.10).

Table 4.10: Pit latrine separation distance of 10m from dwelling areas

Study area	Zone	Non-Compliant		Compliant		Zone total (%)
		Frequency	%	Frequency	%	
Karengata	Bogani	0	0	2	100	100
	Karen Plains	0	0	17	100	100
	Mbagathi	0	0	7	100	100
	Miotoni	0	0	6	100	100
Ongata Rongai	Gataka	2	22	7	78	100
	Kware	14	78	4	22	100
	Laiser	3	60	2	40	100
	Maasai Lodge	4	50	4	50	100

4.4.4 Separation Distance of the Main Building to Plot Features

Separation distance from the main building to plot features are key considerations in construction, as they indicate compliance to local and international siting standards (O'Brien *et al.*, 2020). Karengata being a low-density zone with sizeable plots of land is compliant to the siting requirement (Table 4.14). In Karengata for example, results show the separation distance from building to property line is as high as 52m in Miotoni (Table 4.11).

In Ongata Rongai , 70% of the plots surveyed in the study were in high density and very high density settlements of between 1/16 and 1/8 of an acre (Table 4.14) and do not have enough space for the owners to allocate any gap between the building and the other plot features such as; property lines, easements and boreholes. In Ongata Rongai, the maximum separation distance from building line in some plots is 10m,

found in Kware and Laiser while the minimum distances left for setbacks is none (zero meters) in all four zones.

Table 4.11 Building main plot feature separation of 3m

Study area	Zone	Building line (m)	
		Minimum	Maximum
Karengata	Bogani	2.5	30.5
	Karen Plains	1.5	50
	Mbagathi	3	46
	Miotoni	3.2	52.2
Ongata Rongai	Gataka	0	9
	Kware	0	10
	Laiser	0	10
	Maasai Lodge	0	5

On comparison of the means using the box plot, Ongata Rongai areas (Kware, Laiser and Maasai Lodge) are found to be non-compliant with reference to sanitation facilities distance from the plot boundary (Figure 4.1).

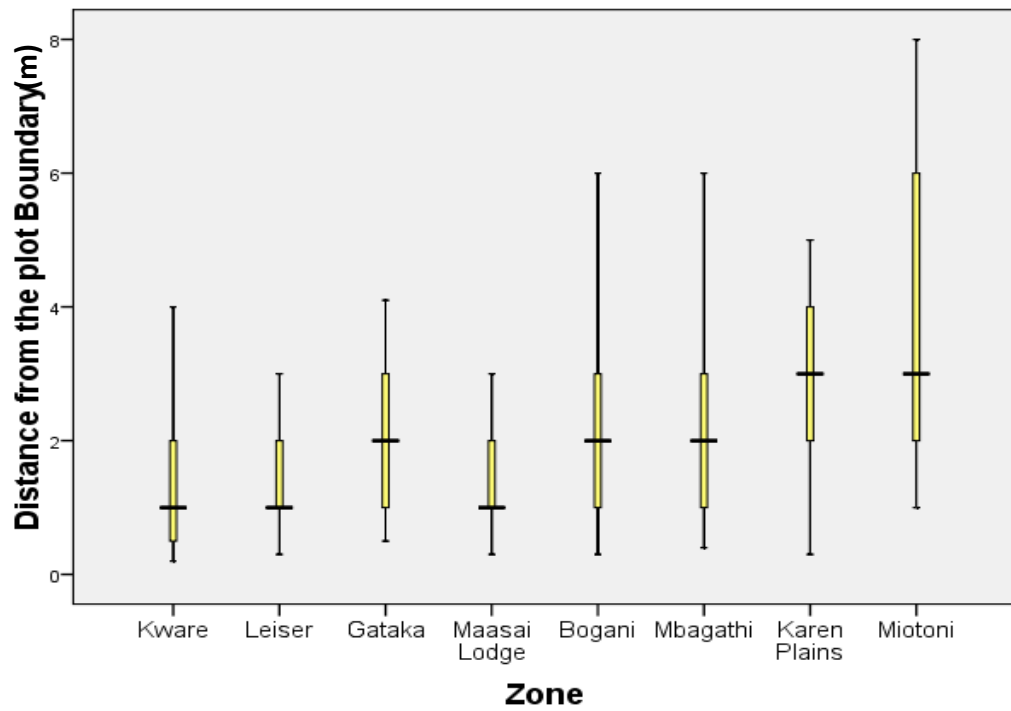


Figure 4.1: Distance of the sanitation system from plot boundaries

With reference to separation of the dwellings from the sanitation facilities, Kware and Leiser zones had the least means in comparison to the other zones, and hence non-compliant to standards (Figure 4.2).

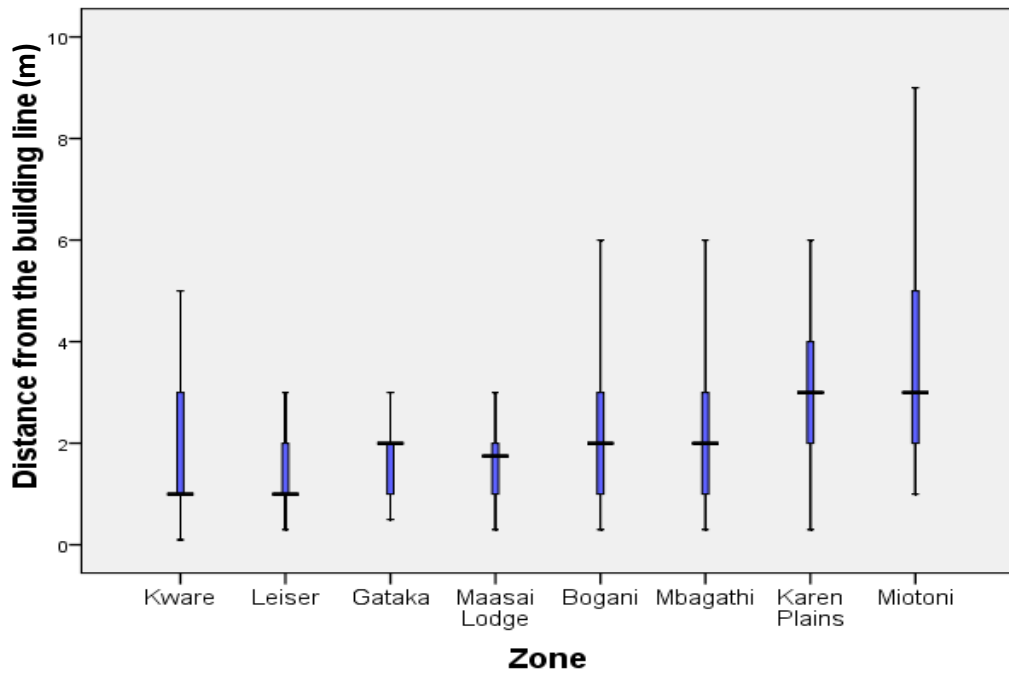


Figure 4.2: Distance of the sanitation system from buildings

The higher mean compliance to sanitation standards in Karengata is attributed to more space available for the various sanitation systems due to bigger plot sizes. For instance, 69% of residences in Ongata Rongai do not comply with the separation distance 3m of property boundary to building while 97% of residences from Karengata were compliant. Karengata shows compliance with septic tank separation distance, while in Ongata Rongai incidences of non-compliance are high, particularly evident in Kware and Maasai lodge (Table 4.9). Karengata area show compliance with siting of pit latrines, while Ongata Rongai has challenges with compliance, especially in Gataka, Kware and Maasai lodge (Table 4.10). This shows that most of the individuals in Ongata Rongai do not adhere to building a sanitation facility 3m away from the property boundary. The requirements set by standards indicate that the separation distance for septic tank from dwelling should be 3m. Non-compliance is evident in Ongata Rongai resulting in limited land area needed

for construction of the septic tank and provision of adequate absorption area for treatment of wastewater on site. Furthermore, the lack of adequate space made available by complying with the requirements will not allow for easements, which are necessary for the septic tank system to function.

4.4.5 Separation Distance of 200m from Wastewater Stabilization Ponds

Four wastewater stabilisation ponds were identified in the study area while undertaking the study. While conducting the survey, residents identified odour as a problem, with those of Karen Plains' zone being the most notable with 47% responses (Table 4.40). The 0.7-acre pond is situated within Karen Brooks estate on Langata road and serves the Karen commercial centre. The effluent from the pond empties into North Mokoyeti River that drains into Nairobi National Park. Further investigation using a field olfactometer that measured ambient air surrounding Karen brooks pond, revealed that there was odour emanating from this WSP, which affected residents in this estate. A separation distance of 200m is required from residential developments to a WSP to prevent odour nuisance from affecting nearby residents (GoK, 2008). The study revealed out of 69 dwellings, twenty-seven dwellings were sited less than 200m from the pond, while 42 houses were sited greater than 200m from the WSP. Six houses nearest to the pond, (Appendix viii) have not been occupied due to high odour concentration, which has caused economic losses to developers. The summary of the compliance to separation distance of the dwellings from the pond is as shown in Table 4.12.

Table 4.12: Stabilization pond separation distance of 200m from dwelling in Karen Brooks of Karen Plains Zone

Compliance	Residence no. of houses (X)	Mean Distance (m)	F	P
Compliant	42	275.91m	2.712	0.003
Non-compliant	27	152.23m		
Total (N)	69			

A detailed study on the implications of non-compliance to the separation distance standard of 200m has been carried out on the Karen Brooks stabilization pond in later section (section 4.5) of this study. Wagura 2014 also showed the odour emanating from the pond negatively affects land values, house prices, rental values and environmental amenities.

4.4.6 Density Standards

In the study area, the findings show the prevalent decentralized sanitation systems were septic tanks and pit latrines. The plot density standards recommended 0.25 acres as the minimum plot size (GoK, 2008) for installation of a decentralised sanitation system. The study findings show that Karengata residences are compliant whilst Ongata Rongai are non-compliant (Table 4.14). Plot utilisation within the two areas is diverse. In Kware, Laiser and Maasai lodge, the building line is a minimum of zero, indicating the households within the areas occupy the entire plot and no distance is left for setbacks. The plot coverage pertaining to sanitation planning is significant. In Karengata, majority of the plots visited were larger than 0.25 acre and plots in all zones had plot coverage of 0-50%. Bogani had 92%, Karen Plains had 58%, Mbagathi had 91% and Miotoni had 75%. This indicates that Karengata is a

low-density zone and plots in the four Karengata zones had sufficient space available for the siting of decentralised sanitation systems.

In Ongata Rongai, Gataka, Kware and Maasai Lodge zones had plot sizes of <0.25 acre and plot utilisation was significantly higher with majority of the plots surveyed had plot coverages of >75%. In Gataka 58% of the plots surveyed occupied greater than 75%, while in Kware they were 86%, Laiser 58% and Maasai lodge 81%. Therefore, with majority of plots indicating greater than 75% plot coverage it signifies there is inadequate space available for siting decentralised sanitation systems in Ongata Rongai (see Table 4.13).

It can therefore be surmised that in Ongata Rongai, due to the insufficiency of land available for construction of septic tanks (conservancy/holding tanks), the constructed capacity of the systems cannot be adequate to cater for the sewage load generated by the high population density in the area. Therefore, the residents will have to resort to the illegal practice of emptying by pumps of untreated wastewater into open drainage at night. This means faecal sludge will be unacceptable for discharge into surface waters, as digestion processes will not have completed to reduce the pollutant compounds in it.

Table 4.13 Density standards compliance (Plot size and Plot coverage) in Karengata and Ongata Rongai areas

Study area	Zone	Minimum plot size (0.25 acre)		Plot coverage (%)				Zone Total %
		Min (acre)	Max (acre)	Low Density (25%)	Medium density (50%)	High Density (75%)	Vey High density (80%)	
Karengata	Bogani	0.5	77	54	38	5	3	100
	Karen Plains	0.4	12	28	30	15	10	100
	Mbagathi	0.9	45	69	22	9	0	100
	Miotoni	0.4	66	42	33	25	0	100
Ongata Rongai	Gataka	0.2	22	20	26	28	26	100
	Kware	0.07	25	2	12	38	48	100
	Laiser	0.3	25	21	21	40	18	100
	Maasai Lodge	0.06	2.9	8	11	46	35	100

Table 4.14: Compliance on plot size (0.25 acre) in Karengata and Ongata Rongai

Study area	Zone	Non-Compliant		Compliant		Zone Total
		Frequency	%	Frequency	%	%
Karengata	Bogani	0	0	38	100	100
	Karen Plains	0	0	40	100	100
	Mbagathi	0	0	36	100	100
	Miotoni	0	0	37	100	100
Ongata Rongai	Gataka	2	13	14	87	100
	Kware	27	77	8	23	100
	Laiser	0	0.0	10	100	100
	Maasai Lodge	13	41	19	59	100

4.4.7 Water Consumption Standards

Access to adequate water supplies is a vital part of ensuring a safe sanitation service chain by making operation, use, and maintenance of the systems easier and prevents contact with pathogens found in fresh human excreta (WHO, 2018). Therefore, water availability alongside other factors requires consideration when designing and implementing a comprehensive sanitation system. Piped water to the household can incentivize all householders to adopt safe sanitation systems and is an important strategy in meeting of the SDG on sanitation.

According the GoK 2008 100 l/c/d is sufficient to meet all sanitation needs of an individual including; drinking, bathing, washing and toilet operation. Compliance on the 100 litres per person per day was different in the two study areas (Table 4.15). Findings show Miotoni and Karen plains had the highest average water consumption of 89.49 litres per day, while Kware (77.10 litres per day) had the least. Appendix

VII shows a summary of daily water consumption within the study area. Table 4.15 shows that there is low water consumption rate in sample zones in Ongata Rongai compared to high water consumption rate in Karengata area. Although both zones are non compliant to the 100 l/c/day nominal requirement, Karengata's higher consumption is attributed to the high prevalence of septic tanks and flush toilets that need high volumes of water compared to other sanitation facilities such as pit latrines. Compliance to the 100 litres per person per day standard was tested in the two study areas. Non-compliance was observed in both Karengata and Ongata Rongai with high compliance levels in Karengata (Table 4.15). This can be attributed to the high density of boreholes observed in the area. In addition, there was consistency in water supply to home for sanitation and other household uses. Non-compliance in Ongata Rongai is attributed to low prevalence of boreholes and piped water to plots and homes for sanitation purposes yet this study area has a high population density.

Table 4.15 Compliance on water consumption by respondents 100 l/p/day

Study area	Zone	Non-compliant		Compliant		Zone Total (%)
		Frequency	(%)	Frequency	(%)	
Karengata	Bogani	23	61	15	39	100
	Karen					
	Plains	28	70	12	30	100
	Mbagathi	18	50	18	50	100
	Miotoni	14	52	13	48	100
Ongata Rongai	Gataka	17	63	10	37	100
	Kware	26	63	15	37	100
	Laiser	29	74	10	26	100
	Maasai					
	Lodge	24	65	13	35	100

In Karengata, the projected total water demand is 31,850 m³/d (GoK, 2011). The NCWSC, which is the water provider for Nairobi, supplies 20% to 25% of the

current demand (GoK, 2011). The installed capacity of public water supply infrastructure in Karengata has been designed to supply 31850 m³/d; however, this has yet to be realized. Due to the shortfall in water supply for consumption, residents have supplemented their water supply through boreholes. There are between 400 and 440 boreholes in Karengata area (GoK, 2006) giving a concentration of greater than seven boreholes per km². This density is the highest borehole density in the country (GoK, 2006). According to GoK (2010b), boreholes are the highest source of water supply for residents of Karen in Karen plains zone (41%) and Hardy in Bogani zone (42%). Other sources include piped water into dwelling (21% and 23%) piped (19% and 24%) and water vendors (12% and 7%) respectively (Table 4.16).

Septic tanks require piped water to flush all the wastes through the drainpipes into the tanks (Capone *et al.*, 2020). Flush toilets require 6 litres (assuming that one person uses a toilet three times daily with 2 litres per use (GoK, 2007b). Access to adequate water supplies is a vital part of ensuring a safe sanitation service chain for operation, (flushing, sewerage) maintenance and cleaning of facilities and various parts of the sanitation service chain (containers, personal protective equipment, and others), as well as for personal and domestic hygiene purposes. GoK (2008) specify that a nominal water supply of 100 l/cap/day is required while Lyonnaise Des Eaux (1980) stated at least 250 l/cap/day is required. Generally, septic tanks are suited for areas with piped water into dwelling (GoK, 2010b).

Table 4.16 Household access to water in Karengata and Ongata Rongai

Water sources	Sampled study zones in Karengata and Ongata Rongai			
	Hardy%	Karen%	Ongata Rongai%	Olekasasi%
Pond/dam	0	0	0	1
Spring/well/borehole	42	41	34	59
Stream	2	5	0	0
Piped into house	23	21	17	13
Piped yard	24	19	22	14
Rain water	1	1	0	1
Water vendor	7	12	25	11
Other	1	1	2	1

In Ongata Rongai, there are two water service providers; Oloolaiser Water Company and Olkejuado Water and Sewerage Company (GoK, 2016). Per the WASREB performance review of water service sector, Oloolaiser serves a total population of 71,896 people, with total production of 1,982m³. The company has a production per capita of 76 l/cap/day and consumption per capita of 38 l/cap/day with 5318 active connections. Olkejuado serves a total population of 12,871 people, with a total production of 234m³. The production per capita is low at 50 l/cap/day while the consumption per capita is 33 l/cap/day. Olkejuado water service provider has 637 active water connections. Besides Oloolaiser Water Company, there are three community owned and several privately owned boreholes operating in Ongata Rongai. Thus, borehole water supply is the major source of water for residents of Ongata Rongai town of Gataka (34%) and Olekasasi area of Laiser (59%) (Table 4.16). In Olekasasi sub location in Laiser zone, Olekasasi Primary School and Olekasasi Secondary School are the largest borehole operators supplying water to at least 100 households and 50 households respectively (GoK, 2017).

4.4.7.1 Ground Water Contamination by Decentralized Sanitation Systems

To conduct a full bore hole water analysis is very expensive and prohibitive, the parameters considered for this study included conductivity, total dissolved solids, turbidity, colour and temperature. Services of a professional laboratory (Analabs Ltd) were secured. A test on water from selected boreholes in the study area (one borehole per zone) was conducted for determining whether there is presence of contamination in drinking water from the sources of drinking water. The results from boreholes sampled indicated higher turbidity values than the WHO (2008) guidelines. In the wet season the turbidity results were between 1.18 ± 0.44 NTU and 24.44 ± 4.18 NTU while in the dry season the values were between 3.10 ± 0.1 NTU to 21.47 ± 0.55 NTU as indicated in tables 4.17 and 4.18. One of the sample boreholes in Karengata area had the highest turbidity values. It was noted that the turbidity levels were greater during the wet season than during the dry season due to more suspended particles being introduced into the aquifer after the rainy season. For the boreholes sampled, the water was used as a source of drinking water and for other household uses.

Table 4.17: Sample results of groundwater quality during the wet season

Study area	Borehole Zone	Turbidity (NTU)	TDS (mg/L)	Conductivity ($\mu\text{S/cm}$)	Colour (TCU)	Temp ($^{\circ}\text{C}$)
Karen-gata	Bogani	3.78 \pm 0.11	314.67 \pm 6.11	0.7 \pm 0.02	<5	28.67 \pm 0.12
	Karen Plains	1.18 \pm 0.44	382.67 \pm 4.16	0.58 \pm 0.00	<5	24.1 \pm 0.66
	Mbagathi	24.44 \pm 4.18	617.00 \pm 10.82	0.93 \pm 0.02	<5	28.43 \pm 0.49
	Miotoni	20.97 \pm 4.79	318.67 \pm 6.64	0.49 \pm 0.37	<5	28.67 \pm 0.12
Ongata Rongai	Gataka	15.70 \pm 0.78	203.67 \pm 3.51	0.32 \pm 0.00	15.00	26.17 \pm 0.06
	Kware	15.56 \pm 2.27	298.67 \pm 9.45	0.46 \pm 0.23	15.00	20.8 \pm 0.17
	Laiser	13.43 \pm 0.47	215.33 \pm 5.69	0.33 \pm 0.03	10.00	27.97 \pm 0.67
	Maasai Lodge	16.23 \pm 0.06	210.67 \pm 6.64	0.32 \pm 0.02	15.00	21.87 \pm 2.06
WHO Guideline		5.00	1200.00	1500	15.00	Cool
NEMA Standard		5.00	1200.00	1500	15.00	-
KEBS Limit		5.00	1500.00	-	15.00	-

High turbidity adds extra cost during water treatment process since it can quickly block filters. Where chlorination of water is practised, even quite low turbidity will prevent chlorine from killing the microbes in the water efficiently. High turbidity values could be attributed to particles originating from organic matter into the ground water through a porous soil media.

Table 4.18: Sample results of groundwater quality during the dry season

Area	Borehole Zone	Turbidity (NTU)	TDS mg/l	Conductivity ($\mu\text{S}/\text{cm}$)	Colour (TCU)	Temp ($^{\circ}\text{C}$)
Karen-gata	Bogani	3.10 \pm 0.1	170.30 \pm 2.31	0.28 \pm 0.03	<5	24.6 \pm 0.23
	Karen Plains	2.87 \pm 0.58	175.60 \pm 1.53	0.25 \pm 0.01	<5	25.2 \pm 0.00
	Mbagathi	21.47 \pm 0.55	877.67 \pm 8.62	1.32 \pm 0.01	<5	24.5 \pm 0.00
	Miotoni	20.23 \pm 1.21	532.33 \pm 11.85	0.80 \pm 0.01	<5	24.1 \pm 0.06
Ongata Rongai	Gataka	6.27 \pm 0.12	581.33 \pm 16.07	0.97 \pm 0.17	10.00	23.5 \pm 0.75
	Kware	9.83 \pm 0.25	225.00 \pm 4.36	0.35 \pm 0.03	50.00	25.8 \pm 0.21
	Laiser	11.03 \pm 0.97	193.67 \pm 5.13	0.33 \pm 0.03	5.00	20.8 \pm 0.58
	Maasai Lodge	9.70 \pm 0.46	189.67 \pm 4.93	0.29 \pm 0.01	<5	27.1 \pm 0.31
WHO Guideline		5.00	1200.00	0.5-5	15.00	Cool
NEMA Standard		-	1200.00	-	-	-
KEBS Limit		5.00	1500.00	-	15.00	-

The temperature of water for sampled boreholes ranged between 20.33 \pm 1.20 $^{\circ}\text{C}$ and 31.17 \pm 1.04 $^{\circ}\text{C}$ in the wet season and between 19.3 \pm 0.20 $^{\circ}\text{C}$ and 29.1 \pm 0.06 $^{\circ}\text{C}$ in the dry season. For nearly all sampled boreholes, the measured TDS and conductivity for both seasons were all observed to meet WHO (2011), NEMA and KEBS drinking water standards. The colour standard value for WHO (2011) and KEBS is 15 TCU. The only borehole, which showed significantly higher value than the required standard, was in Kware, which gave 50 TCU during the dry season. This could be an indication of pollution arising from metallic ions or humus materials from decaying vegetation matter through seepage (Tan *et al.*, 2014). Water from this borehole may become objectionable to consumers due to poor aesthetic. The fact

that most boreholes were within WHO (2011) TCU guideline showed that the soil media is good enough to sieve most of the natural materials originating from humus, peat materials and other wastes.

Incorrect wastewater disposal, poor well construction, and inability to seal abandoned wells can pollute groundwater (Siriwardane-de Zoysa *et al.*, 2021). These allow water to flow downward into subterranean formations without natural infiltration. Large gaps in rocks, coarse gravel deposits, or constructed excavations can also cause contamination. Rapid urbanization, increased volumes taken from underlying urban aquifers, and high construction and maintenance costs associated with convectional-piped systems mean they are not viable solutions for the near future.

4.4.7.2 Water Consumption and Service Levels in Karengata and Ongata Rongai

According to Bouzid *et al.*, (2018) water quantity and service level are key factors for health outcomes. Based on the results obtained in this study majority of households studied have an intermediate access to water provision. The main source of water as indicated by the respondents was piped water supply to either the house or plot supplied by either Nairobi Water and Sewerage Company (for Karengata) or Ololaiser Water Company (Ongata Rongai). It was noted however; in the study findings in Table 4.16, that households in the study area supplement their water supply with borehole water sources.

The records of the Nairobi City Water and Sewerage Company provide the only readily available information on the trends of the water consumption and its

distribution by consumer categories. Customer billing reports for 2013-2018 was obtained from water supply department in Nairobi City Water and Sewerage Company. The data list included number of customers and monthly billed water use by customer category. Water use by customer category (Table 4.20) shows that domestic, commercial, and industrial category consumers were high throughout the entire period and consumed large volumes of water. The volumes of water consumed through boreholes also increased from 86800m³ in 2013 to 146867m³ in 2018,(Ref) hence showing the increase in consumption of water.

This upward trend of borehole water consumption has been attributed to supply constraints in other various sources of water. A number of challenges affecting the various stages of the water service chain has hindered water supply to Karengata. Changing weather patterns, deforestation, encroachment of water catchment areas, has resulted in lower yields in rivers, which supply Kikuyu Springs, Sasumua, Ruiru, Ngethu and Ndakaini, dams that provide Nairobi City Water and Sewerage Company with water.

Per-capita water consumption in Kenya is notably low which means it does not meet the water demand threshold of the urban populace (Cobbinah *et al.*, 2015). A study survey conducted by Gulyani *et al.* (2005) found that water use averaged about 40 litres per-capita per day (lpcd) with a median value of 30 lpcd for the three cities in their study. In Nairobi, the mean consumption was found to be 37 lpcd while the median was 30 lpcd. These figures are low not just compared to other countries, but also compared with previous consumption in Kenya. The study also indicated that, individual from poor households used an average of 33 lpcd compared with 44 lpcd for the non-poor. Consumption amongst the wealthiest 11-12% of households is

around 30% of the total domestic water supply, showing the disparity in regards to water consumption.

Table 4.19 Trends of billed water consumption by consumer categories for Karengata

Category	2013		2014		2015		2016		2017		2018	
	No.of Customers	Volume Billed (M ³)	No. of Customers	Volume Billed (M ³)	No. of Customers	Volume Billed(M ³)	No. of Customers	Volume Billed(M ³)	No. of Customers	Volume Billed(M ³)	No. of Customers	Volume Billed(M ³)
Domestic	3317	1,144,93	3,528	2,046,667	2,694	850,605	3109	749,797	3148	758,064	3204	878,402
Commercial	96	71,937	120	154,103	112	115,732	137	110,171	131	109,288	140	99,606
Industrial	28	15,335	29	15,701	28	9,168	31	17,908	23	14,373	23	9,213
Water kiosks	4	1,123	5	787	4	197	5	743	1	30	3	709
Community project	1	503	1	38	1	121	1	217	1	200	1	195
Government	1	54	2	189	1	509	1	1,011	1	2,164	1	39
Boreholes	4	86,800	8	209,844	7	103,285	9	62,600	18	123,918	20	146,867
Construction	8	1,450	33	4,890	43	10,051	68	10,275	79	15,487	82	15,086
Total	3459	1,322,136	3,726	2,432,219	2,890	1,089,668	3361	952,722	3402	1,023,523	3474	1,150,117

Source (Nairobi City Water and Sewerage Company, 2019)

The Cost of water consumption is high in Karengata area due to a number of reasons. Reduced water supply from the water sources because of destruction of catchment forests has reduced yields to the dams. Secondly, increased demand of water for domestic and agricultural use in the rural areas has seen conflict between source counties users and Nairobi users over user rights of this natural resource. Upper users have diverted the water for agricultural use thereby leaving less water entering the dams. Thirdly, population increase resulting from migration into Nairobi and into peri-urban areas of Karengata and Ongata Rongai has increased the demand for water against the diminishing water supply being shared among, domestic, commercial, industrial and building construction users.

Fourthly, Non-Revenue Water is a challenge to NCWSC and reduces revenue generated from the volume of water supplied due to illegal connections, leakages due dilapidated infrastructure and high number of outstanding water bills. Generally, demand is higher than supply and therefore this has resulted in changes in policy that is changes in price modifications of tariff structure. The proposed water tariffs indicate Kshs 45 per m³ for less < 60 m³ for domestic and commercial users while for schools the rate is 60 Kshs for >1200 m³. The tariffs for Water kiosks are 20 Kshs per m³ while for Water Service Providers for resale the rate is 30 Kshs per m³.

The summary of the billing amounts in Karengata area is as shown in Figure 4.3 below and from the observation, it is increasing. With every revision of the water tariff structure to increase prices there has been alot of complaints of high-water prices.

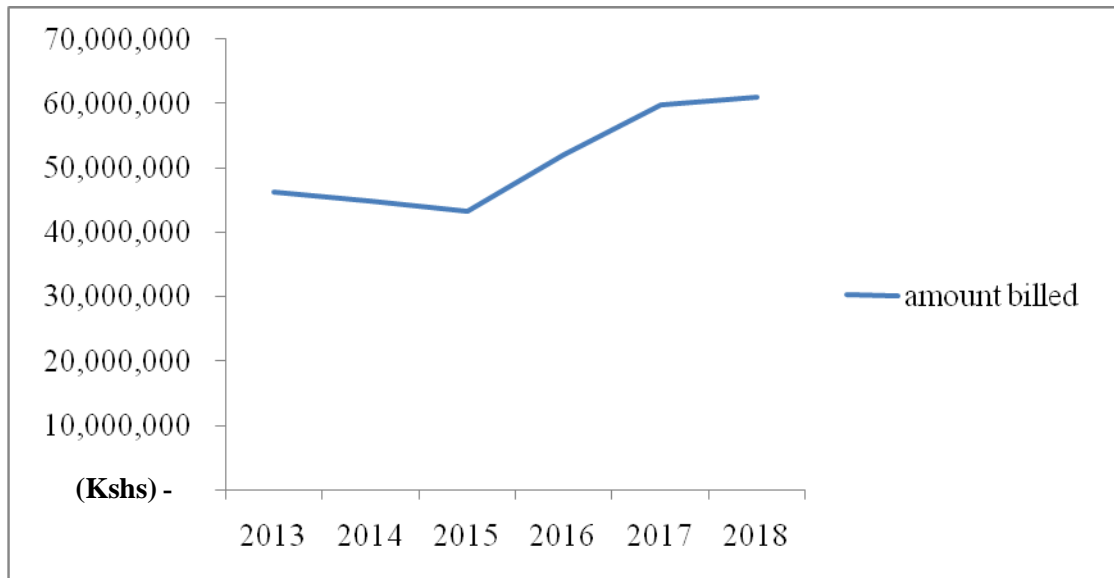


Figure 4.3 Amounts billed (Kshs) on the water consumed in Karengata between 2013-2018 (Source: NCWSC, 2019)

Water consumption standards require that water is accessible, adequate, affordable and and safe for consumption (GoK 2016). However, there has been a steady increase in the unit price of water, which will make it unaffordable and therefore inaccessible to the majority of users. Considering the important role of water in sanitation service chain, the cost increase will have implications on the access of water by households for use in operation and maintenance of sanitation systems. This then means end users cannot afford adequate water and have to reduce their usage and as such, sanitation and hygiene decline.

From studies carried out on Nairobi water billing system where Karengata area falls, it is evident that sewerage levy is the highest contributing cost of the water billed to customers. Sewerage is charged at 75% of the water billed for all customers with or without a sewer connection (Table 4.20). Currently, water bills containing a sewer charge are applied to users of onsite systems in Karengata who are not connected to Nairobi trunk sewer. Therefore, they will have to pay for vacuum tankers

withdrawals from their decentralised systems and this result in high wastewater management costs. The total billed amount for sewerage shown in Table 4.20 does not include the amount by Karengata residents to have their sewage withdrawn by private exhausters.

Table 4.20 Trends of sewerage billings by consumer categories for Karengata

Category	2013		2014		2015		2016		2017		2018	
	Volume (m ³)	Sewerage Billings (kshs)	Volume (m ³)	Sewerage Billings (Kshs)	Volume (m ³)	Sewerage Billings (Kshs)	Volume (m ³)	Sewerage Billings (Kshs)	Volume (m ³)	Sewerage Billings (Kshs)	Volume (m ³)	Sewerage Billings (Kshs)
Metered residential	81,562	2,204,274	92,955	2,578,793	102,822	3,232,305	99,732	4,177,173	96,419	4,017,603	93082.97	3938524
Commercial	22,473	793,121	83,668	3,233,433	41,372	1,603,055	52,645	2,445,020	52,191	2,390,422	39048.24	1797076
Industrial	5,559	196,488	4,741	69,394	332	8,826	178	6,256	203	8,654	429	17226
Water kiosks	-	-	-	-	-	-	-	-	-	-	97.8	3755
Community project	503	12,103	38	842	121	2,494	217	7,586	172	5,771	0	0
Government	-	-	1	842	509	19,352	1,011	47,590	2,164	98,833	195	6734
Boreholes	86,708	3,463,827	209,844	8,408,361	103,285	4,247,299	62,600	2,966,908	122,651	5,815,514	146362	6960604
Domestic construction	713	16,073	1,631	32,008	2,278	64,218	3,618	140,133	5,745	234,701	5690.8	25146865
Total	197,517	6,685,886	392,878	14,423,673	250,719	9,177,550	220,001	9,790,666	279,545	12,571,498	284906	12975387

Source: NCWSC 2019

4.4.7.3 Effluent Quality Analysis From Waste Stabilization Ponds

Waste stabilization ponds (WSPs) are wastewater treatment systems which employ natural processes to treat domestic wastewater, septage, and sludge, as well as animal or industrial wastes before releasing into water (WWAP, 2017). These ponds can be used in centralized or semi-centralized sewerage systems, serving cities or towns; they can also be used as decentralized systems serving a single entity (e.g., residential building, institutional complex, community centre, etc.). WSPs are frequently used in combination with other sanitation technologies. The most common types of WSPs are anaerobic ponds, facultative ponds, maturation ponds, aerated ponds, and high-rate algal ponds (HRAPs). From the field work analysis, there are four stabilizations ponds in Karengata areas Karen Oxidation Pond, Multi Media University wastewater stabilization ponds, Marist University College wastewater stabilization ponds, and Catholic University of Eastern Africa wastewater stabilization ponds and none in Ongata Rongai area. The four ponds discharge their effluents into streams, which drain into Nairobi National Park.

Wastewater is liquid waste that has been generated from domestic, industrial and commercial sources as a result of daily usage, production and consumption activities (WWAP, 2017). The wastewater needs to be properly handled and treated as it causes health problems. The important physical characteristic of wastewater is its total solid content, which is composed of floating matter, settleable matter, colloid matter, and matter in solution. Other important physical characteristics include odour, temperature, colour, and turbidity. The Karen waste stabilization pond is malfunctioning as evidenced by odour emanating from it. This was established from questionnaire surveys, odour concentration measurement and desk research (a

detailed study is described in subsequent sections). The ponds have accumulated large quantities of unpleasant, non-biodegradable sewage-based solids, which are not removed periodically for drying or burial that good management practice calls for. The ponds are found near the source of Mokoyeti River (Plate 4.3) and results in the pollution of the river and negative impacts on public health. Samples from the stabilization ponds in Karengata area were taken from the ponds and sewage analysis was done. The analysis was as follows:

I. Temperature

The temperature of the samples was measured on site in which influent and effluent temperature values were found to range from 22.2 to 27.1 °C and 22.0 to 27.3 °C respectively as shown in Table 4.21. The influent temperature for sample from Karen Oxidation Pond was 27.1 °C, which was higher than the subsequent samples, which had 23.5, 23.4 and 22.2 °C respectively.

Table 4.21 Results for temperature analysis for four WSPs in Karengata

WSP	Influent (°C)	Effluent (°C)	Primary Clarifier (°C)	Standard for discharge into public sewer (°C)	Standards for discharge into environment (°C)
Karen Oxidation Pond	27.1 ±0.2	27.3 ±0.3	27.8 ±0.4	20-30	Ambient Temp ±3
Multi Media University	23.5 ±0.3	22.5 ±0.6	24.0 ±0.6		
Marist University College	23.4 ±0.1	23.5 ±0.4	23.3 ±0.2		
Catholic University of Eastern Africa	22.2 ±0.4	22.0 ±0.2	21.9 ±0.5		

II. PH

Analyses of the pH were done on site. The findings were recorded as shown in Table 4.22. Sample from Karen Oxidation Pond recorded relatively lower pH value of 6.2 for influent as compared to the other samples. The pH values for the primary clarifier and effluent were also within the NEMA provided standards.

Table 4.22 Results for pH analysis for four WSPs in Karengata

WSP	Influent pH	Effluent pH	Primary Clarifier pH	Limits for discharge into public sewer	Limits for discharge into environment
Karen Oxidation Pond	6.2 ±0.04	6.7 ±0.02	6.3 ±0.07	6-9	6.5-8.5
Multi Media University	6.8 ±0.02	7.0 ±0.04	6.6 ±0.09		
Marist University College	6.8 ±0.01	7.2 ±0.03	6.8 ±0.06		
Catholic University of Eastern Africa	7.0 ±0.04	7.1 ± 0.03	7.2 ±0.02		

III. Color

The colour value for influent for Marist University College WSP sample was 40 H.U and was higher than the rest of the samples. The values for the effluent were also within the standards as shown in Table 4.23. The fact that the values obtained

were within the maximum allowable limits meant that the plant effectively handled turbidity of the influent.

Table 4.23 Results for color analysis for four WSPs in Karengata

WSP	Influent (H.U)	Effluent (H. U)	Reduction Efficiency (%)	Primary Clarifier	Compliance index	Remark
Karen Oxidation Pond	30 ±0	5 ±0	83.3	10 ±0	0.333	Compliant
Multi Media University	30 ±0	7.5 ±0	75.0	10 ±0	0.5	Compliant
Marist University College	40 ±0	7.5 ±0	81.3	17.5 ±0	0.5	Compliant
Catholic University of Eastern Africa	30 ±0	5.0 ±0	83.3	10 ±0	0.333	Compliant

IV. Conductivity

Conductivity values obtained showed great variations on the samples. Comparing the influent and the effluent values for sample, there is significant reduction in conductivity between the influent and the effluent except for Marist University College wastewater stabilization ponds sample in which the conductivity reduced with a very small margin as shown in Table 4.24. This observed decrease could be due to decrease in total dissolved solids responsible for conductance.

Table 4.24 Results for conductivity analysis for four WSPs in Karengata

WSP	Influent (mS/m)	Effluent (mS/m)	Primary Clarifier (mS/m)
Karen Oxidation Pond	6.32 ±0.01	6.30 ±0.02	7.06 ±0.02
Multi Media University	5.43 ±0.03	6.34 ±0.04	6.23 ±0.03
Marist University College	1.13 ±0.01	0.80 ±0.03	0.86 ±0.04
Catholic University of Eastern Africa	1.10 ±0.04	0.5 ±0.01	0.74 ±0.01

V. Turbidity

The turbidity values for the influent for all the samples were higher compared to the clarifier and effluent values as shown in Table 4.25. However, the wastewater was more turbid in sample from Marist University College wastewater stabilization ponds recording 665.5 NTU for the influent.

Table 4.25 Results for turbidity analysis for four WSPs in Karengata

WSP	Influent (NTU)	Effluent (NTU)	Percentage Reduction Efficiency	Primary Clarifier (NTU)
Karen Oxidation Pond	413 ±6	23 ±2	94.4	44 ±2
Multi Media University	446 ±5	62.4 ±0.2	86.0	123.5 ±4.2
Marist University College	665.5 ±6.6	12.85 ±0.1	98.1	57.05 ±0.9
Catholic University of Eastern Africa	498 ±7	11.7 ±0.3	97.7	39 ±1

VI. Total Dissolved Solids

Multi Media University WSP sample recorded the highest value of 33660 mg/l while Catholic University of Eastern Africa WSP sample recorded the lowest influent value of 680 mg/l as shown in Table 4.26. Samples from Karen Oxidation Pond and Multi Media University wastewater stabilization pond recorded the highest values of 26,122 mg/l and 33 660 mg/l respectively compared samples from Marist University College wastewater stabilization pond and Catholic University of Eastern Africa wastewater stabilization pond, which recorded 700 mg/l and 680 mg/l respectively.

Table 4.26 : TDS analysis from Months of February to May 2019 for four WSPs in Karengata

WSP	Influent (mg/l)	Effluent (mg/l)	Reduction Efficiency (%)	Primary Clarifier ml/l	Compliance index	Remark
Karen Oxidation Pond	26122 ±123	26040 ±130	0.03	29180 ±100	21.7	Non compliant
Multi Media University	33660 ±200	39300 ±150	-16.8	38626 ±142	32.8	Non compliant
Marist University College	700±30	500 ±20	28.6	530 ±15	0.42	Compliant
Catholic University of Eastern Africa	680±20	310 ±5	54.4	460 ±10	0.26	Compliant

VII. Total Suspended Solids

Sample from Karen Oxidation Pond recorded a TSS value of 9189 mg/l while Sample Multi Media University wastewater stabilization pond recorded 3690 mg/l for the influent. Catholic University of Eastern Africa WSP sample recorded TSS value of 2800 mg/l as shown in Table 4.27. However, there was general decrease in the values of TSS. This could be due to dilution of the wastewater by storm waters resulting into decrease in the TSS.

Table 4.27 Total Suspended Solids analysis ranging from Months of February to May 2019 for four WSPs in Karengata

WSP	Influent mg/l	Effluent (mg/l)	Reduction Efficiency %	Primary Clarifier (mg/l)	Compliance index	Remark
Karen Oxidation Pond	9189 ±40	8818 ±31	4.0	8993 ±34	293.3	Non compliant
Multi Media University	3690 ±20	60 ±3	9.8	52 ±3	2.0	Non compliant
Marist University College	2980 ±11	1470 ±10	50.7	2230 ±15	49	Non compliant
Catholic University of Eastern Africa	2800 ±12	40 ±2	98.6	560 ±7	1.3	Non compliant

VIII. Dissolved Oxygen

Dissolved Oxygen for the Influent values increased gradually. Sample Multi Media University wastewater stabilization pond had DO value of 5.8 mg/l O₂ for the influent shown in Table 4.28. This implied that the influent quality improved with time and this could be attributed to the steady flow of influent resulting to aeration of the wastewater. The effluent values were higher than the influent values. This meant improved water quality of the wastewater leaving the plant.

Table 4.28 Results for DO analysis for the period ranging from Months of February to May 2019 for four WSPs in Karengata

WSP	Influent mg/l O ₂	Effluent mg/l O ₂	Primary Clarifier mg/l O ₂
Karen Oxidation Pond	5.5 ±0.1	5.7 ±0.1	5.8 ±0.1
Multi Media University wastewater stabilization ponds	5.2 ±0.1	5.8 ±0.1	4.8 ±0.1
Marist University College wastewater stabilization ponds	5.6 ±0.1	6.1 ±0.1	5.9 ±0.1
Catholic University of Eastern Africa wastewater stabilization ponds	5.8 ±0.1	6.7 ±0.1	5.8 ±0.1

IX. Chemical Oxygen Demand (COD)

Sample from Multi Media University wastewater stabilization pond recorded COD value of 4000 mg/l for the influent while Sample from Catholic University of Eastern Africa wastewater stabilization pond recorded 600 mg/l (Table 4.29). The values of the clarifier were higher compared to the effluent values, that is, 420 mg/l and 180 mg/l respectively.

Table 4.29 Results for COD analysis for the period ranging from Months of February to May 2019 for four WSPs in Karengata

WSP	Influent mg/l	Effluent mg/l	Reduction Efficiency (%)	Primary Clarifier mg/l	Compliance Index	Remark
Karen Oxidation Pond	1200±20	212±1	82.3	296 ±3	4.2	Non compliant
Multi Media University	4000±10	280±2	93.0	420±5	5.6	Non compliant
Marist University College	1080±15	315±3	70.8	305±2	6.3	Non compliant
Catholic University of Eastern Africa	600±5	170±1	71.7	180±1	3.4	Non compliant



Plate 4.2 Karen Wastewater Stabilization Pond with adjacent developments



Plate 4.3 River Mokoyeti receiving effluent from Karen Wastewater Stabilization Pond

Wetlands for sewage treatment

There are medium-scale sewage treatment wetlands at Karen Golf and Country Club and Karen Roses. The wetland in Karen Golf and Country Club is estimated to treat about 180m³ per day (Plate 4.4). The Karen Roses wetland consists of meandering

channel that passes wastewater through three filtration cells, which naturally treat effluent from pack houses before returning it back into the biodiversity area.



Plate 4.4 Horizontal sewage treatment wetland in Karen Golf and Country Club

4.4.8 Hypothesis Testing

The alternative hypothesis (H_1) for this study was Sanitation systems in Karengata and Ongata Rongai are compliant to existing sanitation standards. Whereas the null hypothesis (H_0) was, sanitation systems in Karengata and Ongata Rongai areas are not compliant to existing sanitation standards. The independent variable in this hypothesis is sanitation standards and the dependent variable is implication on compliance of sanitation systems in use in Karengata and Ongata Rongai areas to sanitation standards. Independent t-test statistics technique was used to test this hypothesis. The results are as presented in Table 4.30.

Table 4.30 T-Test on compliance to sanitation standards

Location	N	Mean (Compliant)	SD	t-cal
Karengata	160	9.14	1.91	0.0019
Ongata Rongai	240	7.43	0.87	

*p<0.05, d.f= 474, crit t=1.96

T-test (Table 4.30) shows that the calculated t-value of 0.0019 is less than the critical value t-value of 1.96 at 0.05 level of significance with 474 degrees of freedom. Therefore, the null hypothesis is accepted since $0.0019 < 1.96$; hence sanitation systems in use in Karengata and Ongata Rongai areas are not compliant to existing sanitation standards. Specifically, sanitation in use in Karengata areas ($\bar{X} = 9.14$) has a higher compliance rate in comparison to Ongata Rongai areas ($\bar{X} = 7.43$). The variation in the means of compliance between Karengata and Ongata Rongai is due to population density and size of land between the two areas.

Pair wise comparison according to zones revealed that building separation of pit latrine from the property boundary line showed that there is significance in Karengata and Ongata Rongai area in relation to distance of the pit latrine ($p=0.000 < 0.05$) and septic tank ($p=0.01 < 0.05$) from the building line.

Table 4.31 Analysis of variation of the sanitation standards in Karengata and Ongata Rongai areas

Standard	Siting	Study-Area	Requirement	N	Mean	SD	F	Sig
Building line	Pit latrine	Karen-Gata	3m	132	2.16	1.77	64.26	0.00
		Ongata Rongai		93	1.62	0.51		
	Septic tank	Karen-gata	1.5m	35	2.26	1.05	6.82	0.01
		Ongata Rongai		42	2.18	2.19		
Separation from boundary	Pit latrine	Karen-Gata	3m	32	3.51	12.2	14.12	0.03
		Ongata Rongai		42	2.13	1.73		
	Septic tank	Karen-Gata	3m	32	2.47	0.45	8.04	0.18
		Ongata Rongai		42	1.72	1.02		
Separation from dwelling	Pit latrine	Karen-Gata	10m	32	10.51	12.2	24.13	.001
		Ongata Rongai		42	0.93	1.40		
	Septic tank	Karen-gata	1.5m	100	1.06	4.00	8.65	.074
		Ongata Rongai		51	2.82	2.20		
Water consumption		Karen-Gata	100 l/c/d	104	91.87	21.3	7.88	.065
		Ongata Rongai	100 l/c/d	143	62.43	11.7		

Significance = >0.05

This shows that the two areas are similar in relation to separation of the sanitation facilities from the boundary line (Table 4.31).

Standards on separation distance of sanitation facility from boundary show that there is significance in pit latrine ($p=0.003<0.05$) and no significance in septic tank ($p=0.180>0.05$). This shows that there is the separation of the pit latrine from the plot boundary in Karengata and Ongata Rongai areas are similar while on the other

hand there are differences in separation distance of the septic tank from the plot boundary.

In relation to separation of the sanitation facilities from the dwelling, study findings show that there is no significance in the separation of septic tank from the dwellings ($p=0.074$) in Karengata and Ongata Rongai areas. This shows that the separation of septic tanks from the dwellings in Karengata and Ongata Rongai areas is different while the separations of the pit latrines from the dwellings are not different. Lastly, the variation of water consumption in Karengata and Ongata Rongai areas is not significant ($p=0.065$), hence there are differences in water consumption.

In comparing the mean differences of the siting standards from the two areas, one-way sample t-test was used. The summary of the findings is as shown in Table 4.32.

Table 4.32 One-way Sample t-Test

	Test Value = 0.05					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Distance from the plot Boundary	23.79	309	.000	3.799	3.48	4.11
Distance from the building line	15.77	309	.000	6.798	5.95	7.65
Separation from dwelling	18.65	309	.000	7.535	6.74	8.33

Analysis of the findings shows that the mean differences of the sanitation standards in Karengata and Ongata Rongai areas are significant ($p=0.000$). This shows that there is a similarity of the sanitation provisions in both areas.

The ANOVA test was used to examine the variation in compliance to sanitation standards between Karengata and Ongata Rongai areas. The compliance of the sanitation systems to distance from the plot boundary and distance from the building line shows that there is significance ($p=0.004<0.05$) and ($p=0.029$), and thus there is compliance to standards (Table 4.33).

On the other hand, compliance of the sanitation standards with reference to separation from dwellings shows that there is no significance ($p=0.776>0.05$). This shows that the separation of the sanitation facilities from dwellings in Karengata and Ongata Rongai does not comply with sanitation standards.

Table 4.33 ANOVA Test on Compliance to sanitation standards in Karengata and Ongata Rongai areas

Standard	Sum of Squares		Df	Mean Square	F	Sig.
Distance from the plot Boundary	Between Groups	160.990	7	22.999	3.044	0.004
	Within Groups	2281.582	302	7.555		
	Total	2442.572	309			
Distance from the building line	Between Groups	890.716	7	127.245	2.274	0.029
	Within Groups	16899.898	302	55.960		
	Total	17790.61	309			
Separation from dwelling	Between Groups	205.977	7	29.425	0.576	0.776
	Within Groups	15433.507	302	51.104		
	Total	15639.49	309			

The ANOVA test is used to determine whether the model is important in predicting the compliance to sanitation standards. At 0.05 level of significance the ANOVA test indicated that in this model the independent variables namely; existing

sanitation standards, sanitation provision in use, and factors influencing the adoption of sanitation standards variables were predictors of compliance to sanitation standards as indicated by significance value=0.021 which is less than 0.05 level of significance ($p=0.021<0.05$) (Table 4.34).

Table 4.34 ANOVA Table

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	5826.804	4	1456.701	33.122	.021 ^a
	Residual	13721.669	312	43.980		
	Total	19548.473	316			

a. Independent Variables: Existing sanitation standards, sanitation systems in use, and Factors influencing the adoption of sanitation standards

b. Dependent Variable: Compliance

From the findings in Table 4.35; at 5% level of significance, existing sanitation standards is not a significant predictor of compliance to sanitation standards where ($p=0.730>0.05$). The standards are found in various legislations and policies and are not consolidated into one policy document taking into account the local setting and physical conditions of each area. Sanitation systems in use was a significant predictor of compliance to sanitation standards where ($p=0.040<0.05$). Sanitation systems are better indicators of compliance because the features required for the system to treat wastewater are present in the system design. Thus if the system is not having these features such as soak aways, the system will not treat wastewater and implications of non-compliance will result. Factors influencing adoption of sanitation standards was a significant predictor of compliance to sanitation standards where ($p=0.000<0.05$). This shows that sanitation in use and factors that influence compliance are key in compliance to sanitation standards.

Table 4.35 Model coefficients on compliance existing sanitation system to standards in place

Model	Unstandardized Coefficients		Standardized Coefficient	T	Sig
	B	Std. Error	Beta		
1 (Constant)	21.134	2.942		7.184	.00
Existing sanitation standards	.003	.179	.030	.628	.73
Sanitation provision in use	.361	.054	.342	6.714	.04
Factors influencing adoption of sanitation standards	.438	.050	.438	8.750	.00

a. Dependent Variable: Compliance sanitation standards

From Table 4.35, the p value of the coefficient to existing sanitation standards is $0.73 > 0.05$. In this case, the decision is to accept the null hypothesis that sanitation systems in Karengata and Ongata Rongai are not compliant to existing sanitation standards. Based on such findings, the study concludes that existing sanitation standards in Karengata and Ongata Rongai areas were not compliant (t-statistic=.628, p-value = $0.73 > 0.05$). Thus, for every unit increase in existing sanitation standards there was a corresponding decrease in compliance to sanitation standards by 0.003.

(From the research, sanitation standards are scattered in various Acts and subsidiary legislation and are domiciled in various government ministries and institutions. It was established that there is a lack of a cohesive and integrated document for sanitation service delivery, difficult to access, time consuming and complex. Furthermore, they were unenforceable due to multiplicity of roles, conflict of roles and bureaucratic delays among key institutions). It should be noted that since a one-

unit increase in existing sanitation standards causes a less than one unit in compliance to standards, the relationship could be considered weak.

In summary, the distance of the sanitation systems from the plot boundary was compliant in Miotoni (3.80), while Karen Plains (2.88), Mbagathi (2.28), Gataka (1.86), and Bogani (1.97), Kware (1.38) and Maasai Lodge (1.42) zones are not compliant with reference to the distance of the sanitation systems from the plot boundary. The summary of the comparison of the zones under study and their compliance to sanitation standards is as shown in Table 4.36.

Table 4.36 Summary of the compliance to sanitation standards

Zone	Average water consumption \geq 100 l/day	Distance from the plot Boundary	Distance from the building line	Separation from dwelling	
Kware	Mean	77.10	1.38	1.75	1.27
	Std.	23.245	1.054	1.309	0.761
	Deviation Std.	3.587	0.163	0.202	0.117
	Error of Mean				
Laiser	Mean	81.18	1.43	1.51	2.52
	Std.	21.011	0.788	0.682	1.970
	Deviation Std.	3.364	0.126	0.109	0.315
	Error of Mean				
Gataka	Mean	88.32	1.86	1.62	1.94
	Std.	16.554	1.012	0.669	1.158
	Deviation Std.	2.585	0.158	0.104	0.181
	Error of Mean				
Maasai Lodge	Mean	80.11	1.42	1.57	1.44
	Std.	19.207	0.840	0.825	0.759
	Deviation Std.	3.116	0.136	0.134	0.123
	Error of Mean				
Bogani	Mean	79.32	1.97	2.18	2.03
	Std.	28.143	1.247	1.485	1.371
	Deviation Std.	4.565	0.202	0.241	0.222
	Error of Mean				
Mbagathi	Mean	88.75	2.28	2.31	2.09
	Std.	18.940	1.314	1.331	1.344
	Devia				

	Mean	89.49	2.88	2.83	2.72
	Std. Deviation	21.329	1.360	1.537	1.530
	Std. Error of Mean	3.415	.218	0.246	.245
Karen Plains	Mean	89.97	3.80	3.55	3.42
	Std. Deviation	29.713	2.197	2.114	1.935
	Std. Error of Mean	4.885	.361	0.348	.318
Miotoni	Mean	84.18	2.11	2.15	2.16
	Std. Deviation	22.915	1.494	1.466	1.542
	Std. Error of Mean	1.301	0.085	0.083	0.088
Total	Mean	89.49	2.88	2.83	2.72
	Std. Deviation	21.329	1.360	1.537	1.530
	Std. Error of Mean	3.415	.218	0.246	.245

On testing the homogeneity of variances of the means of the study findings, analysis of the results shows that there is significance on the average water consumption ($p=0.019<0.05$) and distance from the plot boundary ($p=0.020<0.05$). On the other hand, there is no significance to standards in relation to distance from the building line ($p=0.072>0.05$) and separation of the sanitation systems from the dwellings ($p=0.067>0.05$). This shows that there is a big difference in average water consumption and distance from plot boundary sanitation standards in the study zones (Table 4.37)

Table 4.37 Test of Homogeneity of Variances

Standard	Levene Statistic	df1	df2	Sig.
Average water consumption (litres\day)	2.734	7	302	.019
Distance from the plot Boundary	11.883	7	302	.020
Distance from the building line	11.044	7	302	.072
Separation from dwelling	10.356	7	302	.067

Analysis of the variance of the means shows that there no significance on average water consumption in Karengata and Ongata Rongai areas ($p=0.076>0.05$), distance from the plot boundary ($p=0.052>0.05$), distance from the building line ($p=0.068>0.05$), and separation from dwelling ($p=0.071>0.05$). Therefore, sanitation systems in use in Karengata and Ongata Rongai areas are not compliant to existing sanitation standards. Though sanitation in use in Karengata areas has a higher compliance rate in comparison to Ongata Rongai areas, the variation in the means of compliance between Karengata and Ongata Rongai is due to population differences in land use between the two areas. The combined means shows that Karengata and Ongata Rongai areas are not compliant to sanitation standards.

Karengata is not connected to Nairobi trunk sewer system and thus most of the households use septic tanks without soak-pit and hire private exhauster companies for sewage disposal (Kazungu *et al.*, 2011). This makes them to be non-compliant. The summary of the results is as shown in Table 4.38.

Table 4.38 ANOVA results for the combined means on compliance to sanitation standards of sanitation systems in Karengata and Ongata Rongai areas

Standard	Sum of Squares		Df	Mean Square	F	Sig.
Average water consumption (l/c/d)* Zone	Between Groups (Combined)	7783.023	7	1111.860	2.174	.076
	Within Groups	154469.497	302	511.488		
	Total	162252.519	309			
Distance from the plot Boundary* Zone	Between Groups (Combined)	191.919	7	27.417	16.62	.052
	Within Groups	498.168	302	1.650		
	Total	690.086	309			
Distance from the building line* Zone	Between Groups (Combined)	139.133	7	19.876	11.43	.068
	Within Groups	525.282	302	1.739		
	Total	664.415	309			
Separation from dwelling* Zone	Between Groups (Combined)	131.923	7	18.846	9.446	.071
	Within Groups	602.563	302	1.995		
	Total	734.486	309			

Generally, the higher mean compliance to sanitation standards in Karengata is attributed to better compliance to standards by the various sanitation systems. As previously stated in Table 4.7, most of the individuals in Ongata Rongai do not adhere to building a sanitation facility 3m away from the property boundary. The provisions set by standards indicate that the separation distance for septic tank from dwelling should be 1.5m from any building. Non-compliance is evident in Ongata Rongai. This is shown by the 57.5% Non-compliance and 42.5% compliance in residences in Ongata Rongai (Table 4.8).

4.5 Odour Impact from Karen Brooks Stabilization Pond in Karen Plains

Upon evaluating compliancy of decentralized sanitation systems to sanitation standards, it was established that non-compliancy results in negative implications on the air quality and aesthetic quality of the environment. According to WHO (1998) the definition of environmental health is the “quality of life that is determined by physical, biological, social and psychological factors in the environment and these factors are inclusive of noise and odour.”

From the analysis of the findings of both Karengata and Ongata Rongai areas, 47% of the individuals from Karen Plains zone experiences odour problems (Table 4.39). Further investigation was carried out to determine the cause of odour in Karen plains zone and residents interviewed identified the odour emanating from the Karen wastewater stabilization pond in Karen Brooks Estate within the Karen Plains zone as the source (Plate 4.2, 4.3, 4.5).

Table 4.39 Percentage of respondents experiencing odour problems within the study area

Zone	Yes (%)	No (%)
Bogani	3	97
Karen plains	47	53
Mbagathi	15	85
Miotoni	21	79
Kataka	35	65
Kware	33	67
Laiser	29	71
Maasai lodge	39	61

The residents gave various reasons as to why this occurs. One of these reasons was, “the pond which was built over six decades ago was designed to treat the wastewater for only five shops at Karen commercial center (Plate 4.5). However, the urbanisation process has seen the growth of the commercial center, which now has

several businesses and households” (Resident, 2016). While an NWSC official stated “The capacity of the pond has not been expanded to cater for the increased magnitude of wastewater from these commercial buildings and households and it is failing. This failure results in higher concentrations of odour compounds including Hydrogen Sulphide and Ammonia” (Research, 2016).

Based on chemical analysis of the sink and outlet water from the pond there is high levels of BOD which produce hydrogen sulphide. Also there is high TSS and COD found on the samples indicating higher than normal sediment load and likely high turbidity while COD indicates high organic waste in the pond which produce odour. Fluoride and Phosphorous compounds in the sample (Appendix IX) were found also to be higher than the required amount for effluent from wastewater stabilization ponds (at 1.50ppm and 2.0ppm respectively). Excessive phosphorous, which contaminates water bodies resulting in rapid build-up of algae was also identified in turn affects aquatic life. High faecal coliforms and an oil film on the surface of the water were also observed (see Appendix IX). The high algae levels result in high microbial activity due the decomposition of algae when they die. The decomposition processes in these effluents results in high odour concentration within the area.



KEY

- Oxidation Pond
- 200 metre Buffer Zone
- Homes safe from hazard zone
- Homes within polluted zone
- Main Roads
- Survey Points

Plate 4.5 Karen Stabilization pond in Karen Brooks Neighborhood

4.5.1 Odour Concentration within Karen Brooks Estate

The study adopted EN 13725 European standard to determine the compliance limits for odour impact levels in Karen Brooks Estate within Karen plains zone. This standard was used instead of the NEMA air quality regulations because the technologies specified in the regulations are not available to the researcher at the time of the study due to limited financial resources and time. However, odour perception analysis using the KEBS certified SM 100 field olfactometer was found to be more appropriate due to its ease of use, practical for field measurement of odour concentration with high accuracy levels.

Analysis of the odour readings shows that non compliance ($p=0.003<0.05$) to the separation distance requirement of 200m from the stabilization pond results in presence of odour. The increase in population densities in Karen Brooks area hampers the adherence to sanitation standards. On analyzing the distribution of the odour concentration within the Karen Brooks Estate, 21% of the blank concentration were lower than the instrumentation quantification limit of 12 ouE/m³ (as required by EN 13725 standard) while 79% were more than 12 ouE/m³ which indicates a significant odour concentration. This European standard states the concentration above which odour becomes a nuisance is 30 ouE/m³ (Brancher *et al.*, 2016). The analysis of the distribution samples was as shown in Table 4.40.

Table 4.40 Distribution of odour concentration in Karen Stabilization Pond

Odour concentration (ouE/m ³)	Frequency (Number of events)	Percentage (%)
<12	99	21
13-30	63	13
31-50	117	25
51-70	85	18
71-90	0	0
91-120	109	23
Total	473	100%

From the study results, records of above 30 (ouE/m³) were observed in 66% of the 473 events. This depicts that the area experiences high density of odour concentration, of which should be a major concern to the local authorities. The summary of the recorded odour concentration in Karen Brooks is shown below in figure 4.6.

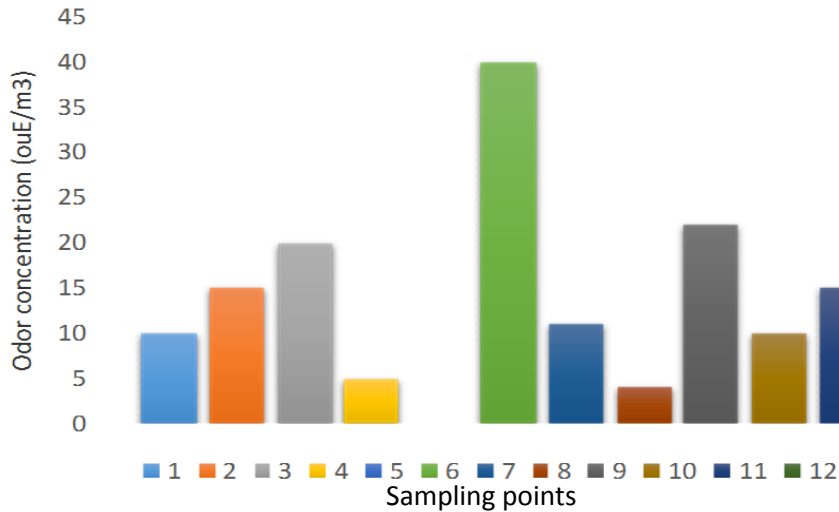


Figure 4.4 Karen Brooks' odour concentration measurements

During odour testing using the SM 100 field olfactometer, an interesting phenomenon was observed on analysis of odour readings. During the day, the residences closest to the pond experience the highest concentrations of odour

whereas during the night, the houses furthest from the pond experience the highest concentrations of odour. Figure 4.5 shows the results of the odour intensity measurements.

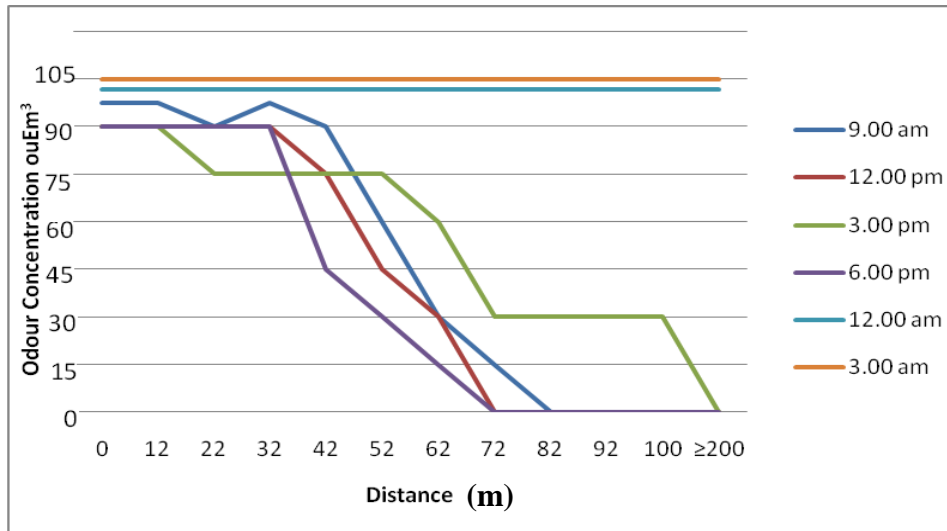


Figure 4.6 Odour concentration vs. distance from Karen stabilization pond in Karen Brooks Neighborhood

Further analysis of the odour intensity measurements shows that during the day (9.00am-6.00pm), the wind velocity is low compared to the nighttime (7.00pm-3.00am). High daytime temperatures, greater solar radiation, low wind velocity of less than 2-3m/s, causes the pungent plume not to move far. At night, the pungent plume moves much further as wind velocity increases and this resulted in the residents furthest from the pond experiencing pungent odour during the night. Moreover, during the analysis, for significant events, the components of odour were determined to be Hydrogen Sulphide and Ammonia derived from wastewater deposition.

Results from the field survey in this study and media reports (Mbira, 2012), documented residents' complaints of difficulty breathing, poor concentration,

recurrent headaches, dizziness and fatigue, which are odour related symptoms. Upon further investigation on the management of the stabilization pond by interviewing officials from key institutions involved, it was evident that their roles have not been well defined. There has been conflicting interests and shifting of responsibility between; the Nairobi City County Government, National Environment Management Authority (NEMA), Athi Water Services Board (AWSB) and the Nairobi City Water and Sewerage Company (NCWSC). The residents are not able to address their plight since none of the institutions stated above accepts responsibility. The pond was to be decommissioned before year 2000 (GOK 2006) and the sewer system to be installed. However, to date, residents are still using the pond and the sewer system is yet to be built.

4.6 Factors influencing (Non)Compliance of Sanitation Systems to Sanitation Standards in Karengata and Ongata Rongai

Sanitation standards exist to aid developers, planners and homeowners in the siting and design of sanitation facilities, which have measures put in place to protect environment and the public health. The standards as seen in Table 2.1-2.7, show siting standards, water consumption standards and density standards. Some zones were found to be compliant and others non-compliant. Studies have shown the linkage between non-compliance to these standards and implications to environmental and public health.

The non-compliance has been attributed to factors such as economic (including poverty and household income), level of awareness of standards, government interventions and geological and topographical conditions

4.6.1 Economic Factors

The study linked the land ownership, plot size, water supply with the ability to pay based on household income, which in turn determines the sanitation system chosen. Table 4.1 shows the sanitation systems used in Karengata users of septic tank at 75% where residents were able to afford larger plot sizes, water supply and installation costs for septic tanks. In Ongata Rongai, users of septic tanks are 50% while users of pit latrines are also 50%. This is attributed to the distribution of income groups that vary according to zone. In Maasai lodge and Laiser zones the users of septic tanks were higher than the other zones. Residents in Gataka and Kware zones opted for pit latrines at 50% due to most of the residents being in the lower economic bracket. The Government infrastructure such as sewer system, water supply, treatment plant; is a major determinant of the choice of sanitation system as costs of operating a septic tank is higher than connecting to a sewer, however due to the unavailability of sewer system in the two areas residents opt for onsite systems.

A case study on impacts of odour on inhabitants living within a 200m radius of Karen wastewater stabilization pond in Karen Brooks of Karengata area found that cases of respiratory illnesses as well as headache, concentration difficulties, unusual tiredness, and head heaviness were common among residents living near the waste stabilisation pond. The odour emanating from the pond was found to be higher than the minimum odour detection limit concentration of 12 ou/E and the observed health impacts are the implications resulting from this.

4.6.2 Public Awareness to Sanitation Standards

Knowledge and understanding of the sanitation standards by residents, developers and public in general contributes heavily to compliance of these standards to sanitation provisions. From interviews with officials from the department of planning and urban development in Nairobi County Government and Kajiado County Government, it was ascertained that “the awareness of the standards is very low especially those found in the building code and physical planning act because they are not easily accessible to the public and therefore compliance is limited”. This results in sanitation systems, which do not meet standards and are injurious or dangerous to public health. In addition, sanitation systems are being situated close to boreholes as developers are not aware of the required siting standards and incidences of contamination of groundwater have been found in the study. According to the KLDA, lack of public education and training on the planning requirements due to lack of collaboration of between Nairobi County Government and residents’ associations results in developers not complying with sanitation standards. As a result this low level of awareness of the sanitation standards requirements leads to construction of buildings without safe and adequate sanitation systems.

4.6.3 Physical Aspects Influencing Sanitation Compliance Standards

Ongata Rongai and Karengata are two very different zones; the soil type, rock formation and hydrology vary and the impact of these factors is evident in the performance of onsite systems in the disposal of effluent. The topography of Karengata is subdued with elevations falling to the east. The most prominent topographic feature is the river valley of Mbagathi River, which forms the southern boundary. The soils in the area are varied from deep well formed red soils in the

north west to relatively shallow sodic alkaline soils in the south east, which are predominantly loamy and black cotton soils.

In Ongata Rongai, which has predominantly black cotton soils the internal drainage or the ability of the soil to absorb water is generally low since the water table is very shallow. The soil is shallow, with bedrock within one meter from the surface, poorly to very poorly drained and does not allow for treatment of effluent before entry into the aquifer. The disposal of wastewater through onsite systems in areas with black cotton soils presents a health hazard to the community due to groundwater pollution (as indicated in Table 4.15 and 4.16). People consume water from boreholes for drinking, the location of boreholes are fairly close to pit latrines and soakaways to nearby households, consumption of water from these boreholes promotes sanitation related illnesses transmission from the onsite disposal site through groundwater from the boreholes.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This section gives a summary of findings based on research objectives. The objectives of the study were; assess sanitation standards governing sanitation provisions in use in Karengata and Ongata Rongai areas, examine the types of sanitation systems in use in Karengata and Ongata Rongai areas, evaluate compliance of sanitation systems to sanitation standards in Karengata and Ongata Rongai areas, determine the implications of compliance or non-compliance to sanitation standards to the physical and human environment in Karengata and Ongata Rongai areas and establish the factors influencing adoption of sanitation standards in Karengata and Ongata Rongai areas. Finally propose recommendations based on research findings.

5.1.1 Sanitation Standards Governing Decentralized Sanitation Systems

The first objective of the study was to assess sanitation standards in development controls governing sanitation systems in use in Karengata and Ongata Rongai areas in Kenya. In general, sanitation standards in Karengata and Ongata Rongai did not differ greatly from established international principles from WHO, World Bank, WASH, and Water Aid that have been adopted by Kenya's sanitation standards. In this study, the sanitation standards were established to be siting standards of decentralised sanitation systems, water consumption standards integrating domestic and sanitation needs and density standards including number of users utilising sanitation systems per unit area and the sanitation systems per unit area.

The findings revealed that, sanitation standards are available and are in various National legislations and County laws and policies. The sanitation standards are however scattered in various Acts and subsidiary legislation and are domiciled in various government ministries and institutions. From data acquired through interviews with key government officials, sanitation sector experts, homeowners and developers, the study established, there is a lack of a cohesive and integrated document for sanitation service delivery. To the developer or property owner, adoption of these standards becomes a challenge due to difficulties in access of the standards, time constraints and incomprehensibility of the standards. There is a low degree of public knowledge due to a lack of public sensitization and overreliance on experts for information about the standards. Furthermore, the enforcement institutions are unable to perform their functions due to multiplicity of roles, conflict of roles and bureaucratic delays, which further compound the problem.

5.1.2 Sanitation Systems in Use in Karengata and Ongata Rongai

The second objective of the study examined the types of sanitation systems in use in Karengata and Ongata Rongai areas. As per the findings of the study, there is no centralized sewer network in Karengata and Ongata Rongai, necessitating the usage of decentralised sanitation systems. The systems in the area were found to be septic tanks, which were the most commonly utilized sanitation system in Karengata, followed by pit latrines in Ongata Rongai. Pit latrines without slabs and ventilated improved pit latrines were the least utilised facilities in the research area. Pit latrines with slabs were the most common form, and septic tanks without soakaway (conservancy tanks or vaults) were the most popular septic tank type in the research area. From observations and interviews with residents from high density settlements

in the study area, it was established that there were ablution blocks in Kware, Kuwinda and Kambi Kisii settlements however access to them was a challenge due the distance between the ablution blocks and the residential units being greater than 100m and were few in number.

From the study, it was observed that as the population of Ongata Rongai increased, the settlement type also changed from peri-urban to urban character without commensurate expansion of sanitation infrastructure to cater for the population. Decentralised sanitation systems, which are the dominant type of system in the area, are not compatible with this increase in density and therefore this will result in failure of the wastewater treatment systems and widespread wastewater disposal problems affecting local rivers, streams and terrestrial environments.

5.1.3 Compliance of Decentralized Sanitation Systems to Sanitation Standards in Development Control

The third objective assessed compliance of decentralised sanitation systems to sanitation standards in development controls applicable in Karengata and Ongata Rongai areas in order to determine the resulting implications to the environment arising from non-compliance of these sanitation systems to the sanitation standards. The role of governance in decentralised sanitation is to create an enabling environment to promote compliance of sanitation systems to sanitation standards (Ross *et al.*, 2014). The findings demonstrate that compliance with sanitation standards varies in the Karengata and Ongata Rongai areas. Karengata has a greater level of compliance with all sanitation standards than Ongata Rongai. Compliance of decentralised sanitation systems to siting standards is dependent on the plot size, which makes it a prerequisite for sufficient land to be available for separation

distance requirements of property boundary to dwelling, pit latrines and septic tanks to dwelling and to water sources. Compliance to minimum plot-size requirements yielded similar findings, with Karengata being more compliant than Ongata Rongai, due to the fact that Karengata is designated as a low-density zone with more space available for plot ratio and plot coverage requirements and the minimum plot size specified by GoK 2014 as 0.25 of an acre. Ongata Rongai is designated as a high-density zone (GoK, 2013) and it was observed to have higher non-compliance rates to siting standards since plot sizes were mostly 1/8 to 1/16 of an acre, which were inadequate to accommodate separation distances of decentralised sanitation systems to main plot features.

Compliance to water consumption standards was not achieved in both Karengata and Ongata Rongai. This was due to water supply shortfalls from water service providers in both areas. Karengata zones however had higher compliancy as compared to Ongata Rongai due to higher volumes of water supply by Nairobi Water and Sewerage Company and private boreholes. It was also observed that there was high reliance on water from boreholes for domestic use in both study areas and therefore there was a need to protect potable water sources from contamination from untreated wastewater being discharged into abandoned quarries and open fields.

5.1.4 Implications of (Non)Compliance of Sanitation Systems to Sanitation Standards

The fourth objective assessed the implications of compliance or non-compliance to sanitation standards to the environment in Karengata and Ongata Rongai areas. The study highlighted odour as a key non-compliance implication of sanitation systems to sanitation standards that affected the inhabitants negatively. Another negative

impact was loss of aesthetic amenity of neighbourhoods where discharge of untreated sludge emptied from conservancy tanks in the study areas, was being disposed of in open fields, drainage and quarries. Sewage examination of waste effluents from the Karen Wastewater Stabilization Ponds revealed that the discharges from the ponds are hazardous and can pose a health risk. It was also observed that there was groundwater pollution in Kware as high TCU values of borehole water sampled in the area showed high quantities of metallic ions from wastewater seepage (Tan *et.al.*, 2014).

From the study, the p value of the coefficient to existing sanitation standards was $0.73 > 0.05$. In this case, the decision is to accept the null hypothesis that sanitation systems in Karengata and Ongata Rongai are not compliant to existing sanitation standards. This shows that compliance to standards in Karengata and Ongata Rongai areas is still a big issue that needs to be addressed.

5.1.5 Factors Influencing Adoption of Sanitation Standards and Sanitation Systems in Karengata and Ongata Rongai

In this study, factors influencing adoption of standards were established to be economic factors (owner/tenant and household income), public awareness (sanitation standards availability and complexity) and physical aspects soil, hydrology, topography (compatibility of the sanitation systems to soil conditions for treating wastewater). The economic factors included land ownership issues such as tenants had limited choice on sanitation systems. Property owners favoured sanitation systems, which had lower costs for operation and maintenance for example in Gataka pit latrines were favoured by landowners due to reduced desludging costs. Furthermore, the costs for desludging of conservancy tanks were

too high and this was the motivating factor for the illegal pumping of wastewater into open drainage, which drains into the local rivers.

5.2 Conclusion

Ultimately, safely treated wastewater is an output from a system comprising of several components which work together to make the entire sanitation system function as efficiently as expected. When the output does not meet the expected results (safely treated wastewater), it is evident that one or more of the components is failing to perform its function. The evidence of failure of decentralised sanitation systems in study area was the discharging of untreated effluent into open drainage channels, which drain into River Mbagathi and Kandisi River and into abandoned quarries in Ongata Rongai area. Additionally, in Karengata there was evidence of odour pollution in Karen Brooks's neighbourhood resulting from failure of Karen Stabilization Ponds.

The research has established the wastewater pollution issue identified in the research area is as a result of decentralised systems malfunction and non compliance of the systems to sanitation standards. The pollution issue extends beyond the study area to other counties or regions, such as Makueini and Machakos counties, as Mbagathi River, which is one of the tributaries of Athi River, originates from the study area.

5.3 Recommendations

Upon analyzing the research findings and on reaching to the conclusion that the presence of untreated wasted water in the environment was as a result of desentralised sanitation systems not complying with sanitation standards, the following recommendations were proposed;

1. The sanitation standards in Kenya are fixed and not adapted to the local physical conditions of the area where physical developments in human settlements are taking place. The National and County Governments to consolidate all sanitation standards found in various Statutes, and align them to the local physical and soil conditions in order to enable end users to adopt sanitation systems that are suited to the local conditions.
2. The decentralised sanitation systems adopted in the study area particularly in Ongata Rongai are malfunctioning and not carrying out treatment as evidenced by the untreated wastewater in the environment. The Kajiado county government should review their decentralised sanitation based approach for Ongata Rongai which has changed from peri urban to urban character due to population increase, to semi centralised or centralised sanitation systems. Partnership between the county government and local community (consisting of developers and property owners and other stakeholders) is required in financial support, capacity building and training, for the proposed sanitation systems to be successful.
3. The study proposes Public Private Partnership to reduce costs of wastewater treatment and management through investment in provision of sanitation service chain operations vis containment, emptying and transport, disposal and reuse.
4. The County Governments should encourage wastewater treatment service provider performance through monitoring their service delivery. Particularly, desludging services should be monitored to ensure sanitation service providers have the required, documented, standard operating procedures for

emptying septic tanks and latrines, transportation to the licensed treatment sites. Therefore, ensuring disposal into illegal sites ceases in order to protect public health and environment.

5. Both County governments should undertake the construction of multiple small semi-centralized wastewater treatment plants (activated sludge) near Karengata and Ongata Rongai, which should be commensurate to the population increase and land availability. This will reduce the desludging costs, which was identified as one of the causes of the illegal wastewater discharge in the study area.
6. The Nairobi County government should undertake a maintenance program of the decommissioned Karen Brooks waste stabilisation pond (which is still being used) in Karengata. Address of the pond malfunctioning due exceeding of the pond design population capacity through, prevent surface inflow into the pond, repair of leakage from the berm and inside surface, check and maintain sludge level to required standards.
7. National and County governments and Sanitation Service Providers (e.g. Athi Water Services Board and Ololaiser Water Company) should collaborate with International donor organizations to construct trunk sewer infrastructure with compensation arrangements to private owners of land where easements will be designated.
8. To increase awareness and exposure, the stakeholders in the provision of sanitation services should collaborate with neighborhood associations in order to sensitize the public on the sanitation standards contained in various legislation and policies in Kenya.

5.4 Areas for Further Research

1. Conduct soil, rock, hydrological and socio-economic surveys studies in Karengata and Ongata Rongai and the data can be made available to developers to enable them to comply with local sanitation standards.
2. Conduct a periodical study on the impacts of haphazard disposal of sewage in open quarries and discharges to the local rivers on ground water, which is a major source of drinking water in both Karengata and Ongata Rongai.
3. A study on the effects of discharge of effluent into Mbagathi and Kandisi rivers, which are tributaries of Athi River, should be done to ascertain pollution water levels.

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APPENDICES

Appendix I: Local Statutes Governing Sanitation Systems

Government of Kenya Statute	
<p>1. Physical and Land Use Planning Act 2019:</p>	<p>1. Physical Planning Handbook Chapter 6 Planning standards for residential use a) Plot size: 0.2 ha (Low density), 0.045ha (Medium density), 0.03 ha (High density), 0.025 ha (Slum) b) Maximum Plot coverage: 50%(Low density), 65%(Medium density),70%(High density) c) Building line: 3m from plot boundary d) Sewers: settlements >3000ppl e) Lagoons: settlements 3000 ppl Setbacks for sanitation system from building f) Septic tank: 1.5m from building g) Sewerage: 15m sewer line reserve</p>
	<p>2. Building Code (2009) Section B Physical planning, siting and site preparations a. Building line:3m from plot boundary b. Percolation rate <30min for soakaway Section O Water services, drainage, waste disposal and stormwater Subsection OO16 Conservancy tanks, septic tanks, soak pits a. Septic tank setback from building and boundary line: 3m b. Pit latrine setback from building and boundary line:3m Number of users a. Pit latrine: 1 latrine per 12 person</p>
<p>2. Water Act 2016</p>	<p>Section 70 Water services regulatory board (WASREB) Section 72: subsection1(a)-(b) (a) determine and prescribe national standards for the provision of water services and asset development for water services providers; (b) evaluate and recommend water and sewerage tariffs to the county water services providers and approve the imposition of such tariffs in line with consumer protection standards; (c) set licence conditions and accredit water services providers Practice manual for sewerage and sanitation services (GoK, 2008) Water quantity: section 3.4(2) a. Septic tank: 100l/c/d b. Pit latrine : 20l/c/d Water supply: Section 6.6 a. Low density housing (having 3 or more taps per HH, >2WC per HH): water quantity 200l/c/d b. Medium density housing (2 taps per HH; >1 WC per HH) water quantity 150l/c/d c. High density housing(1 tap per HH, sharing WC water quantity 70l/c/d Siting: section 5.12.2 a. Septic tank <ul style="list-style-type: none"> • 3m from building; • 50m from groundwater source, • 3m to plot boundary • 30m from wells • Depth to ground water table is 1.5m b. Soakaway</p>

	<ul style="list-style-type: none"> • Depth to ground water table is 1.5m • 30m from wells • 3m from building • 1.5m from plot boundary <p>c. Pit latrine:</p> <ul style="list-style-type: none"> • 50m from groundwater source • 3m to plot boundary <p>d. Lagoon</p> <ul style="list-style-type: none"> • setback from dwelling: 200m • situated in clayey soils <p>e. Sewer</p> <ul style="list-style-type: none"> • 60m from municipal sewer line <p>Density: section 3.4(1)</p> <p>a. Septic tank: 120-300 ppl/ha</p> <p>b. Soakaway: 120 ppl/ha</p> <p>c. Pit latrine: No of users 1latrine/12 persons</p>																		
<p>3. Environmental Management and Coordination Act 2015</p>	<p>Environmental Management and Coordination (Water quality) Regulations 2006</p> <table border="0"> <thead> <tr> <th style="text-align: left;">Effluent discharge standards</th> <th style="text-align: left;">Limits</th> </tr> </thead> <tbody> <tr> <td>Total coliforms</td> <td><400 MPN per 100ml</td> </tr> <tr> <td>Total Suspended Solids (TSS)</td> <td>35mg/l</td> </tr> <tr> <td>Temperature</td> <td>40 mg/l</td> </tr> <tr> <td>pH</td> <td>5-9</td> </tr> <tr> <td>Colour</td> <td>- Not objectionable</td> </tr> <tr> <td>Chemical Oxygen Demand (COD)</td> <td>120 mg/l</td> </tr> <tr> <td>Nitrate as N</td> <td>10 mg/l</td> </tr> <tr> <td>Biochemical Oxygen Demand (BOD₅)</td> <td>40mg/l</td> </tr> </tbody> </table>	Effluent discharge standards	Limits	Total coliforms	<400 MPN per 100ml	Total Suspended Solids (TSS)	35mg/l	Temperature	40 mg/l	pH	5-9	Colour	- Not objectionable	Chemical Oxygen Demand (COD)	120 mg/l	Nitrate as N	10 mg/l	Biochemical Oxygen Demand (BOD ₅)	40mg/l
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Appendix II: Compliance at household level and plot areas

ZONE	AREA (m2)	X_CORDS	Y_CORDS	BUILDNG LINE (m)	>=3m
Karengata					
Bogani	20239.01	249001.1	9850755.44	10.5	Compliant
Bogani	20191.7	248999.4	9850686.95	12	Compliant
Bogani	19958.45	248707.91	9850530.67	10	Compliant
Bogani	19958.45	248829.077	9850520.13	15	Compliant
Bogani	19957.93	248934.44	9850523.65	10	Compliant
Bogani	311819.3	250730.51	9850945.19	30	Compliant
Bogani	20683.48	251139.76	9850967.93	12	Compliant
Bogani	44253.6	251308.01	9850995.21	30.5	Compliant
Bogani	20090.06	248999.41	9851329.65	15.3	Compliant
Bogani	20381.73	249094.23	9851324.38	15	Compliant
Bogani	3753.6	248823.81	9851391.11	3.5	Compliant
Bogani	3689.88	248802.73	9851257.65	2.5	Non-Compliant
Bogani	3840.16	248922.14	9851382.33	5	Compliant
Bogani	6398.16	248330.38	9851099.61	11	Compliant
Bogani	1849.48	248351.44	9851034.64	6	Compliant
Bogani	1859.23	248309.3	985103464	9	Compliant
Bogani	42531.53	250649.3	9850717.8	21	Compliant
Bogani	20878.71	250768.64	9850656.67	16.5	Compliant
Bogani	3973.33	247001.96	9851054.36	5	Compliant
Bogani	3974.68	247002.3	9851019.04	12.1	Compliant
Bogani	3858.8	246883.63	9850947.22	12	Compliant
Karen Plains	1899.34	245710.31	9853900.28	2	Non-Compliant
Karen Plains	1899.34	245710.32	9853900.29	4.5	Compliant
Karen Plains	1897.7	245686.09	9853878.97	4.5	Compliant
Karen Plains	2176.3	2545813.04	9853802.41	4.5	Compliant
Karen Plains	2033.85	245869.25	9853791.75	6	Compliant
Karen Plains	2076.19	245849.87	9853825.67	5	Compliant
Karen Plains	2056.7	245756.83	9853964.24	5.5	Compliant
Karen Plains	41684	249030.25	9852165.2	21	Compliant
Karen Plains	41286.58	250619.87	9852417.53	15	Compliant
Karen Plains	41585.09	250593.4	9852189.99	22	Compliant
Karen Plains	2341.63	246486.63	9852826.81	3.8	Compliant
Karen Plains	2063.61	246555.71	9852880.33	4	Compliant
Karen Plains	2063.5	246602.41	9852886.17	4	Compliant

Karen Plains	2347.93	246559.61	9852886.17	3	Compliant
Karen Plains	2176.3	245813.04	9853802.41	5	Compliant
Karen Plains	41974.71	246754.2	9852322.8	5	Compliant
Karen Plains	45931.76	250818.3	9852502.19	50	Compliant
Karen Plains	5689.44	247385.32	9853619.05	9	Compliant
Karen Plains	4326.13	247400.19	9853508.9	10	Compliant
Karen Plains	41990.63	246875.83	9852326.69	25	Compliant
Karen Plains	2044.39	250004.38	9852802.45	5	Compliant
Karen Plains	6157.75	250096.43	9852760.15	5	Compliant
Karen Plains	2715.03	250064.71	9852699.82	3.8	Compliant
Karen Plains	2031.66	250003.13	9852757.04	3.5	Compliant
Karen Plains	2357.78	249991.32	9852711.63	1.5	Non-Compliant
Karen Plains	46886.49	250011.32	9852563.05	19	Compliant
Karen Plains	21020.71	251035.26	9853454.7	22	Compliant
Karen Plains	20935.97	251032.61	9853311.82	21.5	Compliant
Karen Plains	20935.97	251029.97	9853184.82	5	Compliant
Karen Plains	20852.2	250855.34	9853174.24	6	Compliant
Karen Plains	20741.24	250865.93	9853335.63	4.8	Compliant
Karen Plains	20935.76	250881.8	9853478.51	9	Compliant
Karen Plains	25744.97	250675.43	9853142.49	15	Compliant
Karen Plains	20583.41	250704.53	9853280.07	12	Compliant
Karen Plains	1994.74	248815.05	9853015.67	3.6	Compliant
Karen Plains	1974.89	248863.78	9853014.22	3	Compliant
Karen Plains	2211.74	247248.94	9853584.08	3	Compliant
Karen Plains	2828.73	247241.08	9853659.26	2	Non-Compliant
Karen Plains	1697.24	247246.32	9853620.8	3	Compliant
Karen Plains	18791.07	248991.39	9852470.46	6	Compliant
Karen Plains	2100.65	247735.38	9852824.96	2.5	Non-Compliant
Karen Plains	2063.86	247769.93	9852319.2	3.5	Compliant
Karen Plains	2098.97	247751.01	9852780.54	4	Compliant
Karen Plains	7682.79	247857.12	9852773.14	8	Compliant
Mbagathi	16704.87	244583.7	9852797.78	6.8	Compliant
Mbagathi	25715.56	242521.13	9852369.97	16	Compliant
Mbagathi	10730.1	244463.16	9852602.25	5.5	Compliant
Mbagathi	8262.79	244471.98	9852546.39	6.7	Compliant
Mbagathi	4904.88	242424.11	9847336.56	3.5	Compliant
Mbagathi	18939.41	244666.03	9850764.73	11	Compliant
Mbagathi	3978.86	246995.48	9848049.13	4.2	Compliant
Mbagathi	4200.55	248862.63	9850983.71	6	Compliant

Mbagathi	3937.23	246869.54	9850235.82	5.7	Compliant
Mbagathi	3937.75	246864.79	9850235.83	3	Compliant
Mbagathi	3995.55	246860.08	9847371.66	5.8	Compliant
Mbagathi	19149.13	249998.41	9847403.25	10	Compliant
Mbagathi	21669.71	250030.24	9848841.96	16	Compliant
Mbagathi	21474.43	250880.97	9848922.14	12.9	Compliant
Mbagathi	20985.34	250981.01	9848925.53	18	Compliant
Mbagathi	41781.57	250216.96	9850683.25	7	Compliant
Mbagathi	4175.54	250172.84	9850097.85	6	Compliant
Mbagathi	4175.54	250223.69	9849850.2	4.8	Compliant
Mbagathi	61295.12	245411.72	9849353.91	31.2	Compliant
Mbagathi	15462.04	249066.21	9849164.4	19	Compliant
Mbagathi	10639.06	249125.89	9849585.31	33.8	Compliant
Mbagathi	24507.39	248263.26	9849499.03	15	Compliant
Mbagathi	183742.75	247177.02	9849336.26	27.9	Compliant
Mbagathi	10318.25	248431.91	9847429.58	11	Compliant
Mbagathi	10277.72	248433.87	9847438.36	13	Compliant
Mbagathi	41173.74	248459.36	9848175.49	20.5	Compliant
Mbagathi	22064.46	248911.76	9848196.55	18	Compliant
Mbagathi	22734.98	249004.79	9848764.35	15	Compliant
Mbagathi	19731.87	248809.97	9851020.21	22.6	Compliant
Mbagathi	21323.68	248932.83	9850977.83	20	Compliant
Mbagathi	131597.59	247646.92	9850938.98	46	Compliant
Mbagathi	3685.11	246981.36	9850114.91	3.6	Compliant
Mbagathi	3685.11	246973.11	9850218.08	7.5	Compliant
Mbagathi	3685.11	246958.98	9850938.98	8	Compliant
Mbagathi	20637.11	247377.31	9850114.91	9	Compliant
Mbagathi	10318.41	247393.04	9850218.08	16	Compliant
Miotoni	1770.77	241909.26	9856175.51	11.5	Compliant
Miotoni	1686.16	241952.89	9856167.16	10.2	Compliant
Miotoni	1745.28	241938.77	9856124.18	9.5	Compliant
Miotoni	2462.48	241890.66	9856128.67	12	Compliant
Miotoni	22222.92	245546.15	9855204.67	18.5	Compliant
Miotoni	22273.07	245599.07	9855105.44	15.3	Compliant
Miotoni	20003.27	243335.1	9854378.33	10.6	Compliant
Miotoni	20002.01	243424.46	9854284.26	9.3	Compliant
Miotoni	38213.66	244313.59	9854944.18	33.2	Compliant
Miotoni	16748.08	242881.72	9854812.26	20.3	Compliant
Miotoni	7837.31	241133.79	9855411.39	6.2	Compliant

Miotoni	7989.89	241210.75	9855394.9	5.5	Compliant
Miotoni	7117.29	244352.06	9854790.28	5.3	Compliant
Miotoni	21271.84	242955.92	9855010.15	22.3	Compliant
Miotoni	19130.41	243277.47	9854248.86	12.3	Compliant
Miotoni	3886.69	242799.63	9853174.41	4.8	Compliant
Miotoni	34525.98	245489.89	9855329.12	33.6	Compliant
Miotoni	25257.01	242702.58	9853116.54	18.5	Compliant
Miotoni	12064.88	242861.71	9853213.59	4.8	Compliant
Miotoni	20743.63	244028.21	9855686.07	11	Compliant
Miotoni	266502.85	241853.53	9854942.73	52.2	Compliant
Miotoni	1992.83	244061.38	9855586.57	3.6	Compliant
Miotoni	1948.2	242721.26	9853272.05	3.2	Compliant
Miotoni	8786.22	242017.05	9856242.24	9	Compliant
Miotoni	20885.68	243485.6	9854180.79	22.6	Compliant
Miotoni	20887.43	243386.83	9854180.79	19.8	Compliant
Miotoni	8850.95	242870.72	9854938.68	6.9	Compliant
Miotoni	21556.63	242016	9856059.99	16	Compliant
Miotoni	20661.12	241131.74	9855340.19	11	Compliant
Miotoni	17746.87	241262.96	9855491.09	21	Compliant
Miotoni	25306	241265.71	9855570.8	35	Compliant
Rongai					
Kataka	18355.04	250545.08	9846612.5	3.6	Compliant
Kataka	2345.89	250934.33	9846256.86	2	Non-Compliant
Kataka	3191.82	250983.63	9846239.56	6	Compliant
Kataka	1040.92	250983.01	9846295.68	2	Non-Compliant
Kataka	955.88	250985.9	9846323.49	0	Non-Compliant
Kataka	997.39	250948.82	9846307.85	3	Compliant
Kataka	6460.45	245907.24	9848530.66	1.5	Non-Compliant
Kataka	15470.47	245907.24	9848467.86	7	Compliant
Kataka	26851.46	246477.21	9848136.56	8.7	Compliant
Kataka	25870.63	246988	9847762.38	6	Compliant
Kataka	7778.94	250152.45	9846356.43	9	Compliant
Kataka	87811.3	247907.27	9847310.201	8	Compliant
Kataka	11695.97	246666.07	9847619.72	2	Non-Compliant
Kataka	22139.9	251373.83	9846325.89	2.5	Non-Compliant
Kataka	4959.46	250890.39	9846332.8	1	Non-Compliant
Kataka	8333.66	250081.67	9846346.99	3	Compliant
Kware	581.46	250587.79	9845877.21	0	Non-Compliant
Kware	1192.78	250659.44	9845917.02	0	Non-Compliant

Kware	916.7	250696.26	9845921.5	0	Non-Compliant
Kware	888.98	250652.48	9845986.18	0	Non-Compliant
Kware	7604.97	248548.81	9845849.97	2.5	Non-Compliant
Kware	104375.37	248843.07	9845695.84	10	Compliant
Kware	898.7	249296.97	9845592.61	0	Non-Compliant
Kware	798.55	249273.38	9845593.66	0	Non-Compliant
Kware	955.56	249248.75	9845596.81	0	Non-Compliant
Kware	744.9	249251.9	9845630.87	0	Non-Compliant
Kware	577.42	249272.34	9845625.11	0	Non-Compliant
Kware	790.13	250587.29	9845855.82	0	Non-Compliant
Kware	1076.18	250585.8	9845828.45	1.5	Non-Compliant
Kware	1180.07	250255.65	9845538.93	2	Non-Compliant
Kware	1060.92	250221.9	9845561.43	3	Compliant
Kware	1500.46	250633.57	9845878.21	1	Non-Compliant
Kware	786.94	249800.43	9846023.28	0	Non-Compliant
Kware	661.75	249806.09	9846046.87	0	Non-Compliant
Kware	604.96	250741.04	9845965.78	0	Non-Compliant
Kware	721.93	250683.32	9845976.23	0	Non-Compliant
Kware	318.14	250713.18	9845987.18	0	Non-Compliant
Kware	734.63	250644.02	9845958.82	0	Non-Compliant
Kware	843.96	250163.77	9846153.52	0	Non-Compliant
Kware	1030.83	250174.16	9846175.23	0	Non-Compliant
Kware	805.73	250107.15	9846220.52	0	Non-Compliant
Kware	995.56	250097.71	9846195.04	0	Non-Compliant
Kware	644.07	249763.62	9846059.14	0	Non-Compliant
Kware	655.4	249736.254	9846067.64	0	Non-Compliant
Kware	485.8	249520.85	9845831.48	0	Non-Compliant
Kware	340.21	249552.14	9845798.97	0	Non-Compliant
Kware	827.97	248747.72	9846124.95	0	Non-Compliant
Kware	631.99	248771.13	9846118.64	1	Non-Compliant
Kware	612.02	248777.45	9846146.52	1	Non-Compliant
Kware	640.1	248799.55	9846140.74	1	Non-Compliant
Kware	903.92	248758.24	9846082.86	1.5	Non-Compliant
Laiser	6148.44	248421.01	9845989.33	0	Non-Compliant
Laiser	1315.18	248357.11	9845953.98	0	Non-Compliant
Laiser	1390.58	248389.74	9845930.87	0	Non-Compliant
Laiser	1709.78	248410.81	9845958.74	0	Non-Compliant
Laiser	6897.46	248380.22	9845890.76	2	Non-Compliant
Laiser	99681.66	247399.27	9847126.05	5	Compliant

Laiser	12933.74	247063.18	9847480.93	5.5	Compliant
Laiser	30497.52	247554.75	9845724.77	10	Compliant
Laiser	18545.06	247496.92	9846118.02	6	Compliant
Laiser	12957.46	246934.02	9846089.11	5	Compliant
Maasai Lodge	752.94	247569.32	9845249.81	0	Non-Compliant
Maasai Lodge	813.14	247611.47	9845252.99	0	Non-Compliant
Maasai Lodge	708.57	248526.39	9845519.83	0	Non-Compliant
Maasai Lodge	708.6	248551.53	9845518.59	0	Non-Compliant
Maasai Lodge	1148.38	248624.46	9845514.06	1.1	Non-Compliant
Maasai Lodge	1951.29	248561.41	9845487.28	0	Non-Compliant
Maasai Lodge	7070.47	249287.96	9845081.22	0.5	Non-Compliant
Maasai Lodge	880	249280.06	9844976.6	0	Non-Compliant
Maasai Lodge	1090.4	249321.42	9844970.69	0	Non-Compliant
Maasai Lodge	6658.72	250812.78	9845014.34	5	Compliant
Maasai Lodge	3289.16	250827.04	9844979.22	1.5	Non-Compliant
Maasai Lodge	1559.64	250853.39	9844958.37	1	Non-Compliant
Maasai Lodge	4148.84	250872.05	9844911.18	0	Non-Compliant
Maasai Lodge	3502.66	250808.39	9844908.98	0	Non-Compliant
Maasai Lodge	1210.24	251529.84	9845534.61	0	Non-Compliant
Maasai Lodge	1131.97	251528.86	9845510.6	1	Non-Compliant
Maasai Lodge	800.6	251567.56	9845532.65	0	Non-Compliant
Maasai Lodge	723.44	251570.99	9845509.62	0	Non-Compliant
Maasai Lodge	745.29	251599.89	9845532.65	0	Non-Compliant
Maasai Lodge	670.15	251599.89	9845512.56	0	Non-Compliant
Maasai Lodge	4158.74	252517.51	9846037.42	1.5	Non-Compliant
Maasai Lodge	2077.12	250579.66	9844644.62	0.5	Non-Compliant
Maasai Lodge	8037.79	252590.33	9846008.67	3	Compliant
Maasai Lodge	2005.65	252547.51	9845994.94	2	Non-Compliant
Maasai Lodge	9856.79	252617.16	9846090.11	1	Non-Compliant
Maasai Lodge	11748.95	251857.01	9846022.21	5	Compliant
Maasai Lodge	1021.44	250624.2	9844669.21	2	Non-Compliant
Maasai Lodge	918.87	250622.35	9844685.45	0	Non-Compliant
Maasai Lodge	3354.68	249356.74	9845021.19	2.2	Non-Compliant
Maasai Lodge	761.78	251644.03	9844752.86	0	Non-Compliant
Maasai Lodge	555.35	251665.01	9844757.6	0	Non-Compliant
Maasai Lodge	254.4	251668.95	9844780.08	0	Non-Compliant

Appendix III: Separation distance from Plot Boundary of sanitation facilities

Sanitation Facility Separation from Plot Boundary (M)				
ZONE	Septic	Latrine	Septic: >=1.5m	Pit Latrine: >=3m
Karengata				
Bogani	13		Compliant	
Bogani	11.5		Compliant	
Bogani	8		Compliant	
Bogani	18		Compliant	
Bogani	6		Compliant	
Bogani	24		Compliant	
Bogani	5		Compliant	
Bogani	26		Compliant	
Bogani	11		Compliant	
Bogani	14		Compliant	
Bogani		5	Compliant	Compliant
Bogani		3	Compliant	Compliant
Bogani	5		Compliant	
Bogani	20		Compliant	
Bogani	6		Compliant	
Bogani	4		Compliant	
Bogani	10		Compliant	
Bogani	30		Compliant	
Bogani	2		Compliant	
Bogani	8		Compliant	
Bogani	10		Compliant	
Karen Plains		2	Non-Compliant	Non-Compliant
Karen Plains	3		Compliant	
Karen Plains	4.5		Compliant	
Karen Plains	8		Compliant	
Karen Plains		6		Compliant
Karen Plains	5		Compliant	
Karen Plains		7		Compliant
Karen Plains	6		Compliant	
Karen Plains	21		Compliant	
Karen Plains		6		Compliant
Karen Plains	2	2	Compliant	Non-Compliant
Karen Plains	8		Compliant	
Karen Plains	6		Compliant	
Karen Plains		4		Compliant
Karen Plains	6		Compliant	
Karen Plains	11		Compliant	
Karen Plains		15		Compliant
Karen Plains	13		Compliant	
Karen Plains	10		Compliant	
Karen Plains		21		Compliant
Karen Plains		6		Compliant

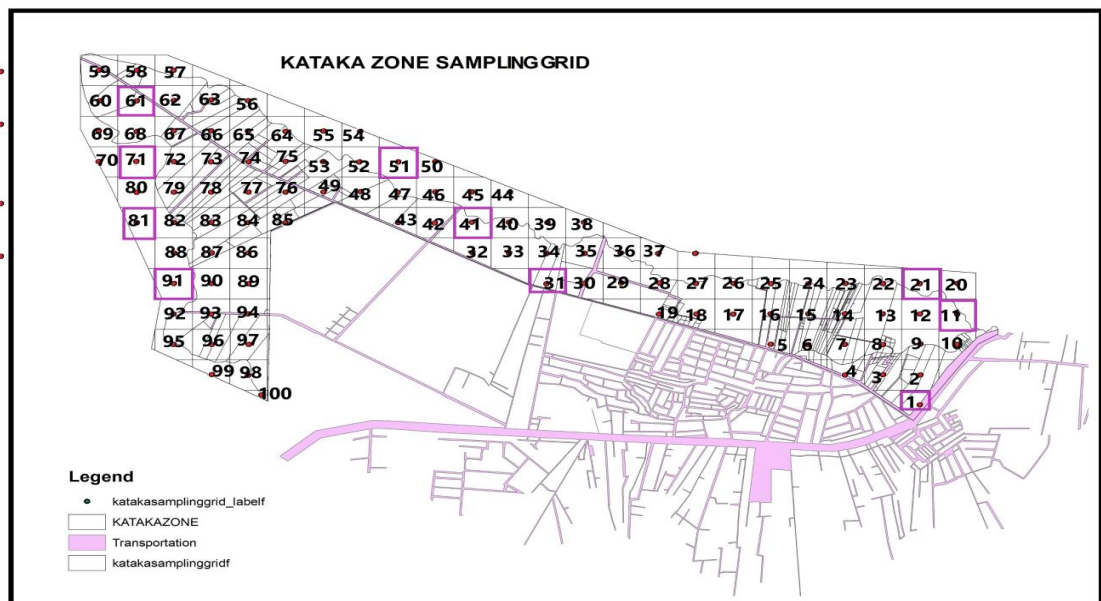
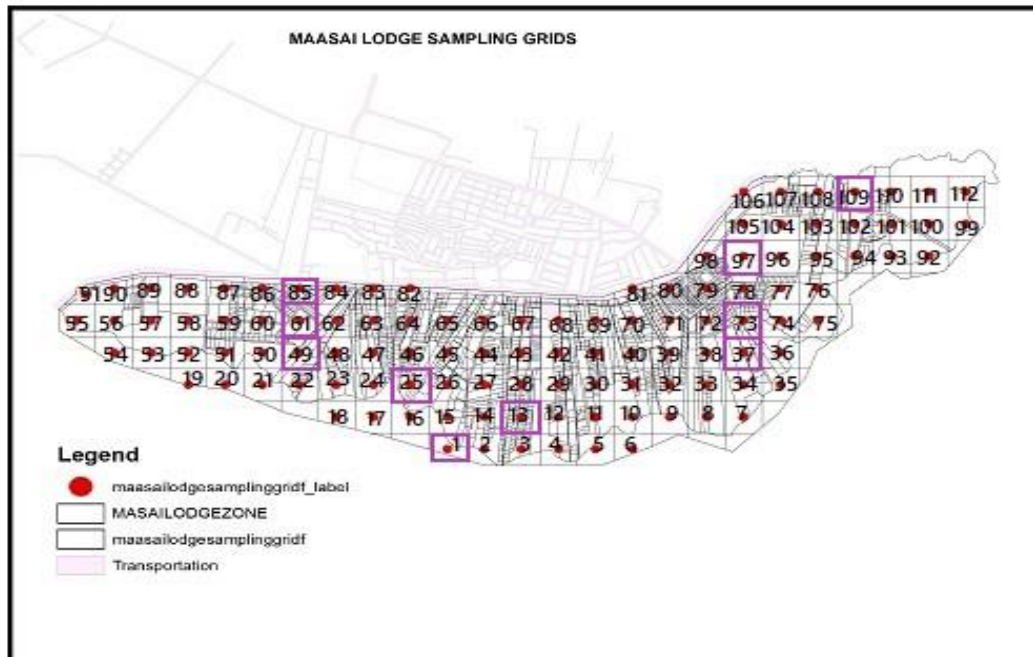
Karen Plains		9		Compliant
Karen Plains	6			Compliant
Karen Plains	9			Compliant
Karen Plains	3	6		Compliant
Karen Plains	13			Compliant
Karen Plains	15			Compliant
Karen Plains		18		Compliant
Karen Plains	2			Compliant
Karen Plains		15		Compliant
Karen Plains	6			Compliant
Karen Plains		11		Compliant
Karen Plains	15			Compliant
Karen Plains	8			Compliant
Karen Plains		4		Compliant
Karen Plains	1.5			Compliant
Karen Plains	2			Compliant
Karen Plains		2		Non-Compliant
Karen Plains	5			Compliant
Karen Plains		5		Compliant
Karen Plains		3		Compliant
Karen Plains	6			Compliant
Karen Plains	3			Compliant
Karen Plains		11		Compliant
Mbagathi	8			Compliant
Mbagathi	15			Compliant
Mbagathi		7		Compliant
Mbagathi	13			Compliant
Mbagathi	5			Compliant
Mbagathi	18			Compliant
Mbagathi	11			Compliant
Mbagathi		6		Compliant
Mbagathi	5			Compliant
Mbagathi		3		Compliant
Mbagathi	6			Compliant
Mbagathi	10			Compliant
Mbagathi	16			Compliant
Mbagathi	10			Compliant
Mbagathi	23			Compliant
Mbagathi	8			Compliant
Mbagathi	4			Compliant
Mbagathi	2			Compliant
Mbagathi	19			Compliant
Mbagathi	10			Compliant
Mbagathi	50			Compliant
Mbagathi	10			Compliant
Mbagathi	13			Compliant
Mbagathi		11		Compliant

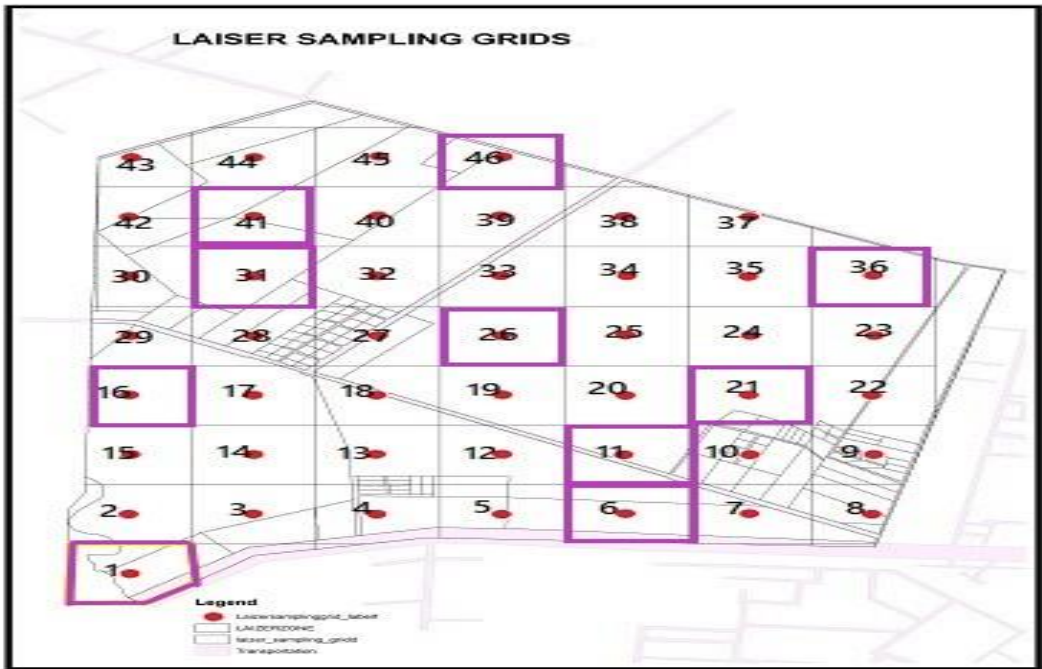
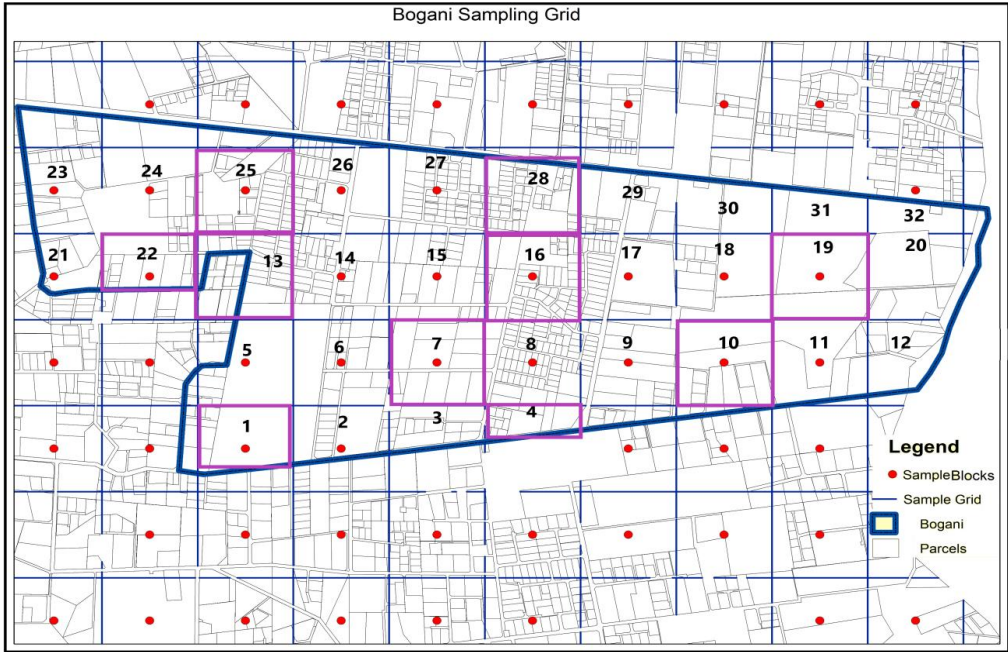
Mbagathi	12		Compliant	
Mbagathi	15		Compliant	
Mbagathi	9		Compliant	
Mbagathi	10		Compliant	
Mbagathi	31		Compliant	
Mbagathi	20		Compliant	
Mbagathi	63		Compliant	
Mbagathi		5		Compliant
Mbagathi		7		Compliant
Mbagathi		11		Compliant
Mbagathi		10		Compliant
Mbagathi	21		Compliant	
Miotoni	18		Compliant	
Miotoni	6		Compliant	
Miotoni	9		Compliant	
Miotoni	8		Compliant	
Miotoni	13		Compliant	
Miotoni	15		Compliant	
Miotoni	21		Compliant	
Miotoni		9		Compliant
Miotoni	48		Compliant	
Miotoni	15		Compliant	
Miotoni		8		Compliant
Miotoni	8		Compliant	
Miotoni		3		Compliant
Miotoni	15		Compliant	
Miotoni	11		Compliant	
Miotoni	5		Compliant	
Miotoni	35		Compliant	
Miotoni	19		Compliant	
Miotoni		5		Compliant
Miotoni	10		Compliant	
Miotoni		88		Compliant
Miotoni	5		Compliant	
Miotoni	5		Compliant	
Miotoni	9		Compliant	
Miotoni	20		Compliant	
Miotoni		25		Compliant
Miotoni	6		Compliant	
Miotoni	10		Compliant	
Miotoni	15		Compliant	
Miotoni	20		Compliant	
Miotoni	30		Compliant	
Ongata Rongai				
Kataka	3		Compliant	
Kataka		2		Non-Compliant
Kataka	6		Compliant	

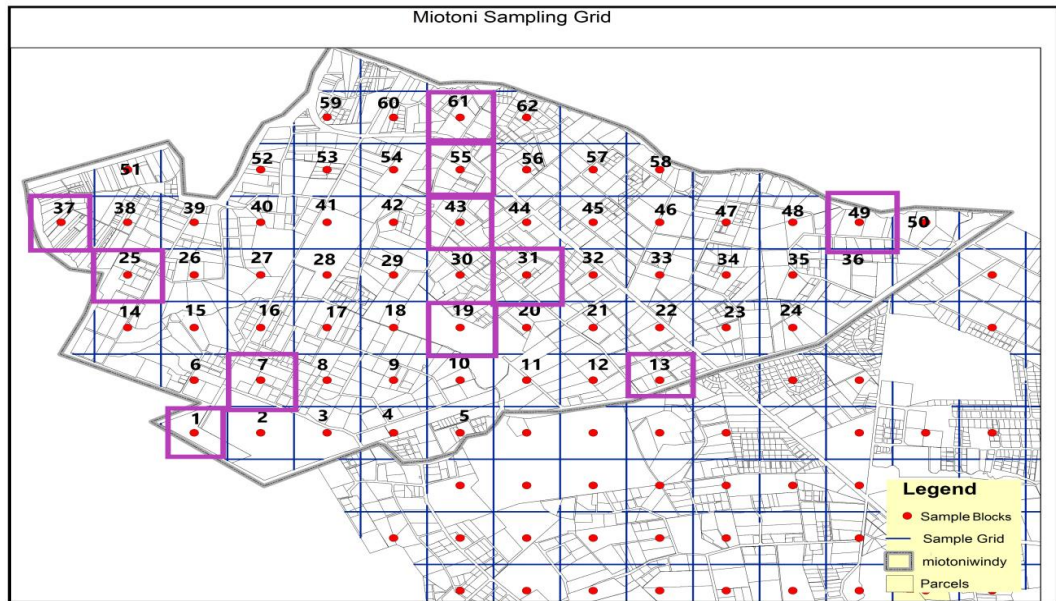
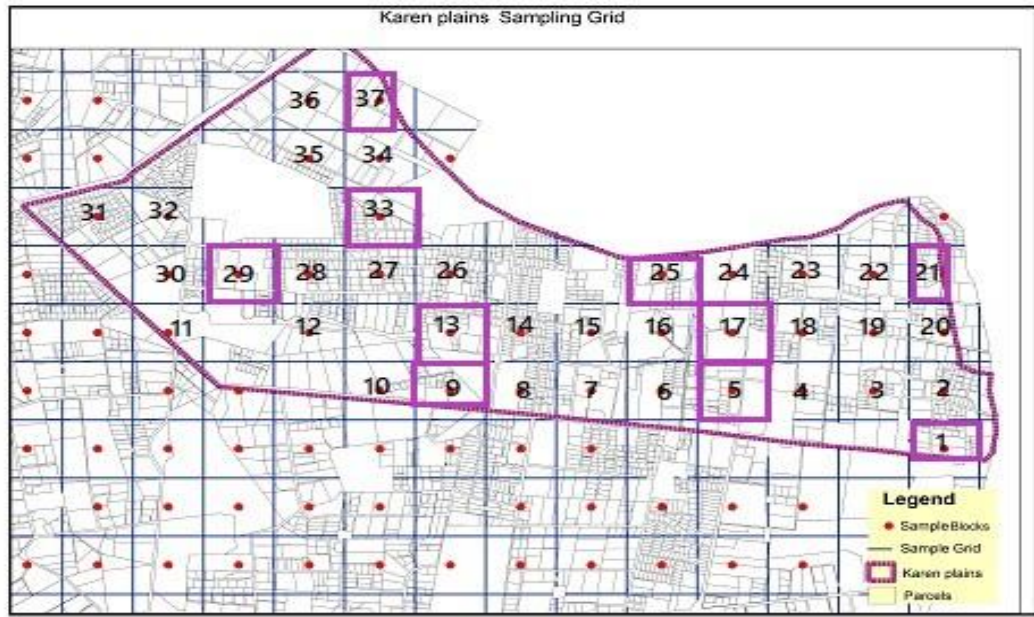
Kataka		3		Compliant
Kataka		0		Non-Compliant
Kataka		4		Compliant
Kataka		2		Non-Compliant
Kataka	9		Compliant	
Kataka	11		Compliant	
Kataka		5		Compliant
Kataka	7		Compliant	
Kataka	6		Compliant	
Kataka		1		Non-Compliant
Kataka		3		Compliant
Kataka		0		Non-Compliant
Kataka	5		Compliant	
Kware		6		Compliant
Kware		5		Compliant
Kware		3		Compliant
Kware		0		Non-Compliant
Kware	2		Compliant	
Kware	3		Compliant	
Kware	0		Non-Compliant	
Kware	0		Non-Compliant	
Kware		3		Compliant
Kware	0		Non-Compliant	
Kware	3		Compliant	
Kware		3		Compliant
Kware		1.5		Non-Compliant
Kware		3		Compliant
Kware		3		Compliant
Kware		1		Non-Compliant
Kware	6		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware	0		Non-Compliant	
Kware	6		Compliant	
Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware	5		Compliant	
Kware		0		Non-Compliant
Kware	6		Compliant	
Kware		4		Compliant
Kware	3		Compliant	

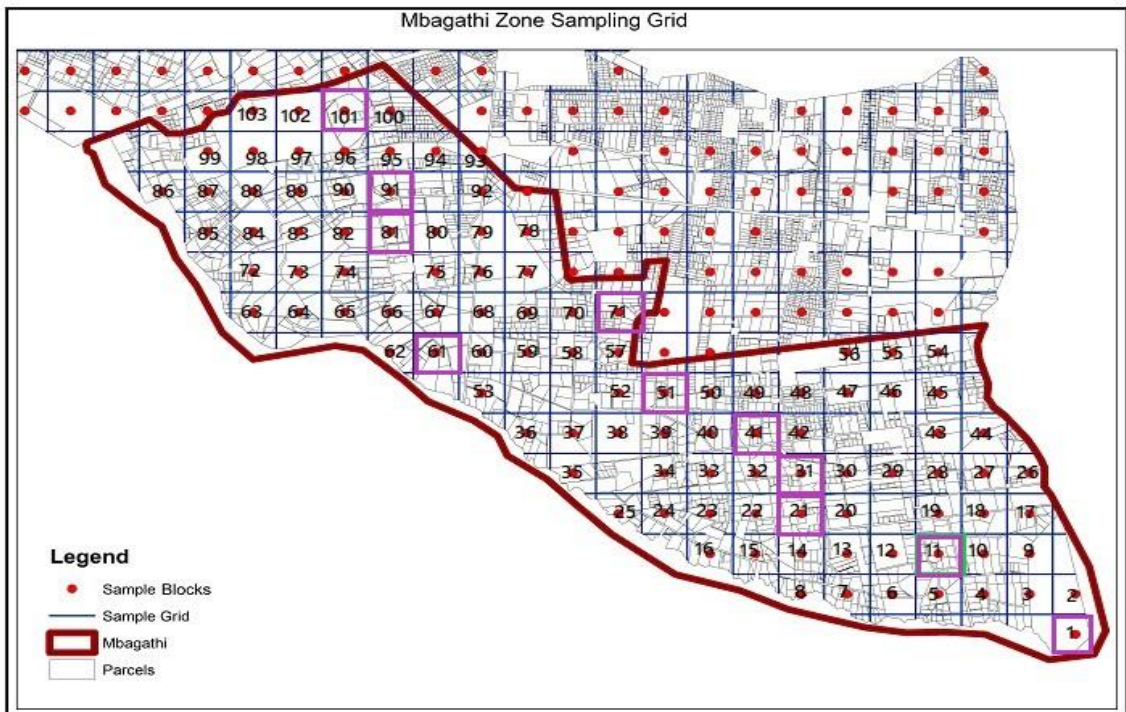
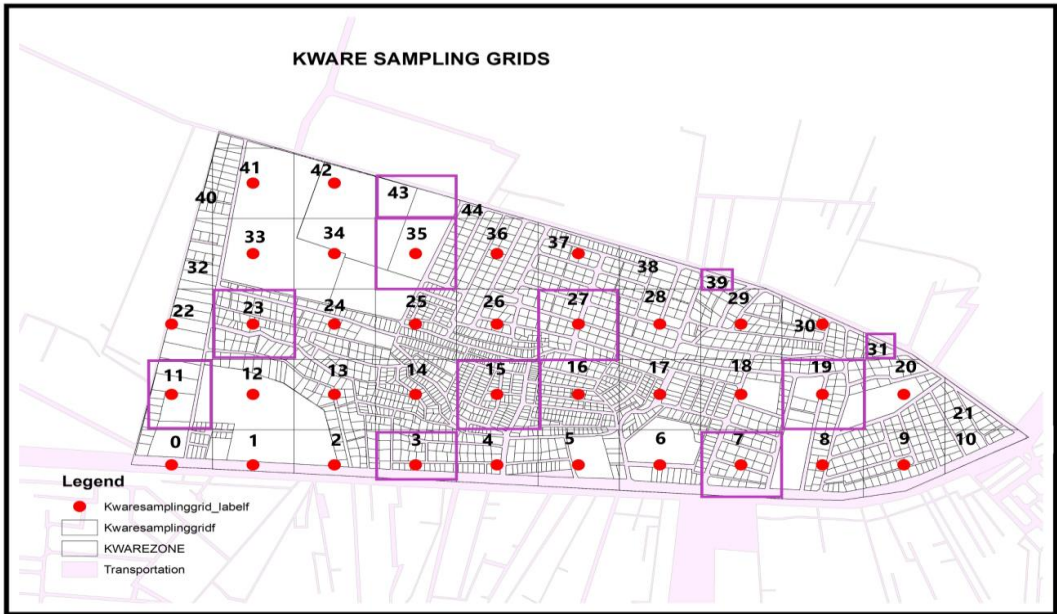
Kware		0		Non-Compliant
Laiser		6		Compliant
Laiser	5		Compliant	
Laiser		3		Compliant
Laiser		6		Compliant
Laiser		6		Compliant
Laiser	9		Compliant	
Laiser	11		Compliant	
Laiser	13		Compliant	
Laiser	9		Compliant	
Laiser		5		Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge		3		Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge	6		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge	3		Compliant	
Maasai Lodge		0		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge	11		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge	7		Compliant	
Maasai Lodge	5		Compliant	
Maasai Lodge	5		Compliant	
Maasai Lodge		0		Non-Compliant
Maasai Lodge		6		Compliant
Maasai Lodge	2		Compliant	
Maasai Lodge	2		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge		4		Compliant
Maasai Lodge	3		Compliant	
Maasai Lodge	3		Compliant	
Maasai Lodge	3		Compliant	
Maasai Lodge	2		Compliant	
Maasai Lodge		0		Non-Compliant
Maasai Lodge	8		Compliant	
Maasai Lodge	2		Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	3		Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0		Non-Compliant	

Appendix IV: Sampling Grids for 8 Zones in the Area of Study









Appendix V: SM100 Field Olfactometer description

During the course of the research, odour was a nuisance to most of the residents. However simply stating that a place smell is not enough to analyse such. As a result, the olfactometer, sourced from Canada at a cost of \$ 10,000 (IDES CANADA, 2013) was used for odour measurements. The Scentroid SM100 field olfactometer is designed to provide accurate in-field odour measurement of ambient air and stack emissions. It uses compressed air from a high-pressure carbon-fibre tank to dilute sample air prior and present it to the panellist. Sample is drawn using vacuum generated by the flow of compressed diluting air through a venture pump. Dilution ratio of clean air to sample air is controlled via Scentroid's patented flow regulator valve. Panellist can select 15 discrete dilution ratios. The overall range of the unit is selectable via changeable restrictor plates. Minimum dilution is two and maximum dilution is 30000.

Air-supply backpack

The air-supply backpack houses the high-pressure compressed air tank, the pressure regulator and the active carbon filter. A high accuracy pressure regulator is used to ensure a constant flow of diluting air through the device. An active-carbon odour filter is placed in the airflow path to ensure no background odour is transferred from the air tank. Majority of fill stations are equipped with odour filters, therefore, this filter acts as a second barrier to ensure zero background odour in the diluting air.

Flow regulator and the venture vacuum pump

The diluting air flows through a venture vacuum pump to create the necessary suction to draw in the sample (IDES CANADA, 2013). The venture vacuum pump

also creates the turbulent flow to mix the drawn sample air with the diluting air from the tank. The amount of sample air that is pulled in and mixed with the diluting air is controlled via the flow regulator valve. The user can select between 15 dilution levels within the devices dilution range. The current dilution is determined by reading the indicator number off the flow regulator valve and cross-referencing the calibration chart (Figure 3.3) (IDES CANADA, 2013).

Face mask

The mask is designed to provide a comfortable flow of diluted sample air at 20 litres per minute with an average velocity of 2.5 meters per second at the nosepiece (IDES CANADA, 2013). The body of the mask is made of ABS and is triple Teflon® coated to ensure zero odour contamination. The constant 20 litres per minute of air ensures that there is always positive pressure inside to prevent ambient air from entering the mask (IDES CANADA, 2013). The mask comes in three sizes: small, medium (default size which comes with the device) and large. The user should select the correct size to minimise the gap between the mask and the bridge of his or her nose. After each use, the mask is cleaned using unscented soap water, alcohol, or wiped using a disinfecting wipe. In the unlikely event that a strong and persistent odour lingers on the mask surface, hydrogen peroxide is used to deodorise the mask (IDES CANADA, 2013).



SM 100 overview, A; Air supply backpack, B; Shut off valve, C; Ergonomic handle with Educator underneath, D; Dilution regulator valve, E; Face mask

Certificate of Calibration

Date of Issue:
2012

Jan 22nd, 2012

Date of Calibration: Jan 22nd,

Name of Device:

Portable Odour Measurement Apparatus – 10 min Carbon

Part #:

SM100

Conditions:

T: 21.5°C ± 2°C P: 80 PSI ± 1 PSI

Plate #s:

H,A,3,2,1

Results:

Position	H	A	3	2	1
1	101	678	656	3600	30000
2	60	319	328	1441	15000
3	45	176	219	1201	10000
4	35	98	164	721	7500
5	28	62	131	600	6000
6	24	35	109	515	5000
7	19	24	94	450	4300
8	13	17	82	390	3750
9	11	13	73	350	3330
10	9	10	66	300	3000
11	7	8	60	280	2700
12	6	7	55	260	2500
13	5	6	51	235	2300
14	4	5	47	222	2140
15	3	4	44	200	2000
NP	2	2	2	2	2

Uncertainty of Measurement:

±5% of TARGET value based on a confidence =95%.

Example of certificate of calibration: (IDES CANADA, 2013)

Appendix VI : Separation Distance from Dwellings

Sanitation Facility Separation from Building (M)				
ZONE	SEPTIC	LATRINE	Septic: >=3m	Latrine: 10m
Karengata				
Bogani	2.5		Compliant	
Bogani	0.5		Non-Compliant	
Bogani	2		Compliant	
Bogani	3		Compliant	
Bogani	4		Compliant	
Bogani	6		Compliant	
Bogani	7		Compliant	
Bogani	4.5		Compliant	
Bogani	4.3		Compliant	
Bogani	1		Non-Compliant	
Bogani		3.5		Non-Compliant
Bogani		2.5		Non-Compliant
Bogani	0		Non-Compliant	
Bogani	11		Compliant	
Bogani	0		Non-Compliant	
Bogani	5		Compliant	
Bogani	11		Compliant	
Bogani	13.5		Compliant	
Bogani	3		Compliant	
Bogani	4.1		Compliant	
Bogani	2		Compliant	
Karen Plains		2		Non-Compliant
Karen Plains	1.5		Compliant	
Karen Plains	0		Non-Compliant	
Karen Plains	3.5		Compliant	
Karen Plains		6		Non-Compliant
Karen Plains	0		Non-compliant	
Karen Plains		5.5		Non-compliant
Karen Plains	15		Compliant	
Karen Plains	6		Compliant	
Karen Plains		22		Compliant
Karen Plains	1.8		Compliant	
Karen Plains	4		Compliant	
Karen Plains	2		Compliant	

Karen Plains		3		Non-Compliant
Karen Plains	1		Non-Compliant	
Karen Plains	6		Compliant	
Karen Plains		50		Compliant
Karen Plains	4		Compliant	
Karen Plains	0		Non-Compliant	
Karen Plains		25		Compliant
Karen Plains		5		Non-Compliant
Karen Plains		5		Non-Compliant
Karen Plains	2.2		Compliant	
Karen Plains	5.5		Compliant	
Karen Plains	1.5		Compliant	
Karen Plains	6		Compliant	
Karen Plains	7		Compliant	
Karen Plains		21.5		Compliant
Karen Plains	3		Compliant	
Karen Plains		6		Non-Compliant
Karen Plains	1.2		Non- Compliant	
Karen Plains		9		Non- Compliant
Karen Plains	0		Non- Compliant	
Karen Plains	4		Compliant	
Karen Plains		3.6		Non- Compliant
Karen Plains	1.5		Compliant	
Karen Plains	1		Non- Compliant	
Karen Plains		2		Non- Compliant
Karen Plains	2		Compliant	
Karen Plains		6		Non- Compliant
Karen Plains		2.5		Non- Compliant
Karen Plains	2.5		Compliant	
Karen Plains	1		Non- Compliant	
Karen Plains		8		Non- Compliant
Mbagathi	1.2		Non- Compliant	
Mbagathi	1		Non- Compliant	
Mbagathi		5.5		Non- Compliant
Mbagathi	6.3		Compliant	
Mbagathi	1.5		Compliant	
Mbagathi	7		Compliant	
Mbagathi	6.8		Compliant	
Mbagathi		6		Non- Compliant

Mbagathi	0.7		Non- Compliant	
Mbagathi	3		Compliant	
Mbagathi	0.2		Non-Compliant	
Mbagathi	0		Non-Compliant	
Mbagathi	0		Non-Compliant	
Mbagathi	2.9		Compliant	
Mbagathi	5		Compliant	
Mbagathi	1		Non- Compliant	
Mbagathi	2		Compliant	
Mbagathi	2.8		Compliant	
Mbagathi	12.2		Compliant	
Mbagathi	9		Compliant	
Mbagathi	16.2		Compliant	
Mbagathi	5		Compliant	
Mbagathi	14.9		Compliant	
Mbagathi		11		Compliant
Mbagathi	1		Non- Compliant	
Mbagathi	5.5		Compliant	
Mbagathi	9		Compliant	
Mbagathi	5		Compliant	
Mbagathi	8.4		Compliant	
Mbagathi	0		Non- Compliant	
Mbagathi	17		Compliant	
Mbagathi		3.6		Non- Compliant
Mbagathi		7.5		Non- Compliant
Mbagathi		8		Non- Compliant
Mbagathi		9		Non- Compliant
Mbagathi	5		Compliant	
Miotoni	6.5		Compliant	
Miotoni	4.2		Compliant	
Miotoni	0.5		Non- Compliant	
Miotoni	4		Compliant	
Miotoni	5.5		Compliant	
Miotoni	0.3		Non- Compliant	
Miotoni	10.4		Compliant	
Miotoni		9.3		Non- Compliant
Miotoni	14.8		Compliant	
Miotoni	5.3		Compliant	
Miotoni		6.2		Non- Compliant

Miotoni	2.5		Compliant	
Miotoni		5.3		Non- Compliant
Miotoni	7.3		Compliant	
Miotoni	1.3		Non-Compliant	
Miotoni	0.2		Non-Compliant	
Miotoni	1.4		Non-Compliant	
Miotoni	0.5		Non-Compliant	
Miotoni		4.8		Non-Compliant
Miotoni	1		Non- Compliant	
Miotoni		52.2		Compliant
Miotoni	1.4		Non- Compliant	
Miotoni	1.8		Compliant	
Miotoni	0		Non-Compliant	
Miotoni	2.6		Compliant	
Miotoni		19.8		Compliant
Miotoni	0.9		Non- Compliant	
Miotoni	6		Compliant	
Miotoni	4		Compliant	
Miotoni	1		Non- Compliant	
Miotoni	5		Compliant	
Ongata Rongai				
Kataka	0.6		Non-Compliant	
Kataka		2		Non- Compliant
Kataka	0		Non- Compliant	
Kataka		2		Non-compliant
Kataka		0		Non- Compliant
Kataka		3		Non- Compliant
Kataka		1.5		Non- Compliant
Kataka	2		Compliant	
Kataka	2.3		Compliant	
Kataka		6		Non- Compliant
Kataka	2		Compliant	
Kataka	2		Compliant	
Kataka		2		Non- Compliant
Kataka		2.5		Non- Compliant
Kataka		1		Non- Compliant
Kataka	2		Compliant	
Kware		0		Non-Compliant
Kware		0		Non-Compliant

Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware	0.5		Non- Compliant	
Kware	7		Compliant	
Kware	0		Non- Compliant	
Kware	0		Non- Compliant	
Kware		0		Non- Compliant
Kware	0		Non- Compliant	
Kware	3		Compliant	
Kware		0		Non- Compliant
Kware		1.5		Non- Compliant
Kware		2		Non- Compliant
Kware		3		Non- Compliant
Kware		1		Non- Compliant
Kware	6		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware	4		Compliant	
Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware		0		Non-Compliant
Kware	0		Non- Compliant	
Kware	6		Compliant	
Kware		0		Non- Compliant
Kware		0		Non- Compliant
Kware	5		Compliant	
Kware		0		Non- Compliant
Kware	5		Compliant	
Kware		1		Non- Compliant
Kware	2		Compliant	
Kware		1.5		Non- Compliant
Laiser		0		Non- Compliant
Laiser	5		Compliant	
Laiser		0		Non-Compliant
Laiser		0		Non-Compliant
Laiser		2		Non-Compliant
Laiser	4		Compliant	

Laiser	5.5		Compliant	
Laiser	3		Compliant	
Laiser	3		Compliant	
Laiser		5		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge		0		Non-Compliant
Maasai Lodge	4.9		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge	2.5		Compliant	
Maasai Lodge		0		Non- Compliant
Maasai Lodge		0		Non- Compliant
Maasai Lodge	6		Compliant	
Maasai Lodge	4.5		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge	5		Compliant	
Maasai Lodge	5		Compliant	
Maasai Lodge		0		Non- Compliant
Maasai Lodge		1		Non- Compliant
Maasai Lodge	2		Compliant	
Maasai Lodge	2		Compliant	
Maasai Lodge	6		Compliant	
Maasai Lodge		0		Non- Compliant
Maasai Lodge	1.5		Compliant	
Maasai Lodge	2.5		Compliant	
Maasai Lodge	0		Non- Compliant	
Maasai Lodge	0		Non- Compliant	
Maasai Lodge		1		Non- Compliant
Maasai Lodge	3		Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0.8		Non-Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0		Non-Compliant	
Maasai Lodge	0		Non-Compliant	

Appendix VII: Water usage in a day in Karengata and Ongata Rongai

ZONE	NOHHINBL	No of members in HH	Water Usage (Litres)
Karen			
Bogani	5	4	500
Bogani		5	
Bogani	1	6	67
Bogani	8	1	30
Bogani		1	20
Bogani	3	8	40
Bogani	1	4	120
Bogani	1	6	
Bogani	1	10	
Bogani		4	
Bogani	4	13	200
Bogani	1	10	
Bogani	1	10	
Bogani	5	2	120
Bogani	1	8	
Bogani	1	4	200
Bogani	1	4	
Bogani		8	
Bogani		3	
Bogani	1	3	
Bogani	2	8	400
Bogani		3	
Bogani		6	70
Bogani	1	5	
Bogani	1	7	
Bogani		10	
Bogani	1	1	100
Bogani	1	6	250
Bogani	2	11	
Bogani	3	5	40
Bogani	1	4	500
Bogani	1	2	200
Bogani		100	300
Bogani	1	600	14,000
Bogani		20	

Bogani	1	22	
Bogani	1	30	16,000
Bogani	1	15	200
Karen Plains		7	33
Karen Plains		4	160
Karen Plains		2	40
Karen Plains		4	
Karen Plains		1	80
Karen Plains		5	100
Karen Plains		4	
Karen Plains		1	20
Karen Plains		6	30
Karen Plains	12	6	40
Karen Plains		3	20
Karen Plains		4	40
Karen Plains		5	40
Karen Plains	2	6	150
Karen Plains	8	1	20
Karen Plains		6	30
Karen Plains		1	20
Karen Plains	1	14	100
Karen Plains		6	100
Karen Plains	1	3	80
Karen Plains		4	
Karen Plains		12	
Karen Plains	1	2	50
Karen Plains	1	4	100
Karen Plains		5	80
Karen Plains		5	40
Karen Plains		1	20
Karen Plains		1	60
Karen Plains		5	30
Karen Plains		1	80
Karen Plains		3	100
Karen Plains		4	200
Karen Plains		3	20
Karen Plains		3	
Karen Plains	1	4	100
Karen Plains	1	4	

Karen Plains	1	6	20
Karen Plains	1	5	100
Karen Plains		1	40
Karen Plains		24	200
Mbagathi	1	4	
Mbagathi	1	1	20
Mbagathi	230	3	435
Mbagathi	1	10	33
Mbagathi	1	5	
Mbagathi	1	4	
Mbagathi	1	2	
Mbagathi	1	10	
Mbagathi	1	4	33
Mbagathi	1	1	
Mbagathi	1	3	
Mbagathi	2	5	
Mbagathi	1	2	200
Mbagathi	1	4	100
Mbagathi	1	4	50
Mbagathi	1	7	200
Mbagathi	23	2	80
Mbagathi	1	3	100
Mbagathi	5	7	200
Mbagathi	1	4	
Mbagathi	3	6	125
Mbagathi	2	4	20
Mbagathi	1	10	300
Mbagathi	1	8	
Mbagathi	1	14	500
Mbagathi		3	500
Mbagathi	1	1	200
Mbagathi	1	1	
Mbagathi	8	3	
Mbagathi	1	6	
Mbagathi	1	4	33
Mbagathi	1	7	
Mbagathi	1	5	100
Mbagathi	1	3	80
Mbagathi	1	10	500

Mbagathi		500	100000
Miotoni	1	5	33
Miotoni		1	80
Miotoni		4	
Miotoni	3	1	40
Miotoni		6	20
Miotoni		8	20
Miotoni		6	50
Miotoni		3	
Miotoni		7	400
Miotoni		3	
Miotoni	1	2	
Miotoni		8	30
Miotoni	1	3	200
Miotoni	1	4	50
Miotoni		1	20
Miotoni		14	35
Miotoni		6	100
Miotoni		3	20
Miotoni		5	100
Miotoni	5	5	500
Miotoni	1	4	60
Miotoni		4	
Miotoni	1	3	40
Miotoni		4	20
Miotoni		6	200
Miotoni		6	20
Miotoni	1	4	250
Miotoni	6	9	300
Miotoni		4	100
Miotoni		1	
Miotoni		4	100
Miotoni		5	20
Miotoni	3	150	200
Miotoni		300	
Miotoni		28	
Miotoni		80	30
Miotoni		20	300

Ongata Rongai			
Kataka	8	3	80
Kataka		2	40
Kataka	2	6	60
Kataka	6	4	120
Kataka	10	2	60
Kataka	42	2	20
Kataka	80	1	40
Kataka	70	2	40
Kataka	40	2	60
Kataka	20	2	60
Kataka	7	2	40
Kataka		7	120
Kataka	4	1	80
Kataka	1	3	120
Kataka	1	4	100
Kataka	1	4	220
Kataka	3	5	20
Kataka		4	20
Kataka		3	60
Kataka	3	3	60
Kataka	1	5	500
Kataka	1	5	570
Kataka	5	6	80
Kataka		7	20
Kataka		2	160
Kataka		3	20
Kataka		1	80
Kataka	10	3	80
Kataka	1	5	
Kataka	26	2	20
Kataka	1	5	167
Kataka	2	6	667
Kataka	1	5	60
Kataka	5	1	40
Kataka	40	5	200
Kataka	6	10	40
Kataka		13	20

Kataka		4	200
Kataka	3	3	20
Kataka		5	60
Kataka		42	2,000
Kware	13	4	60
Kware	1	3	40
Kware	4	1	100
Kware	1	4	100
Kware		3	50
Kware		6	100
Kware	11	5	60
Kware	4	3	
Kware	15	4	100
Kware	5	4	40
Kware	9	2	20
Kware		3	100
Kware	6	4	60
Kware	33	3	20
Kware	6	3	20
Kware	12	7	60
Kware	7	4	80
Kware	20	4	60
Kware		3	140
Kware	30	3	60
Kware	7	1	20
Kware	4	1	40
Kware	16	5	100
Kware	18	2	60
Kware		9	100
Kware	7	3	60
Kware	10	4	120
Kware	16	3	100
Kware		15	60
Kware	14	4	60
Kware		4	550
Kware	1	5	100
Kware	1	3	50
Kware		5	20
Kware	65	3	40

Kware	3	4	
Kware	8	3	100
Kware		11	60
Kware	7	3	100
Kware		1	20
Kware		24	1,800
Laiser	1	4	400
Laiser	2	6	120
Laiser	1	5	300
Laiser	12	2	
Laiser	1	6	20
Laiser	1	6	250
Laiser	1	1	
Laiser	12	4	100
Laiser	1	4	100
Laiser	1	3	60
Laiser	1	5	
Laiser		6	20
Laiser	3	2	
Laiser	1	5	70
Laiser	1	5	100
Laiser	1	1	
Laiser		2	40
Laiser	1	3	50
Laiser	1	6	20
Laiser		5	20
Laiser	1	5	20
Laiser	1	5	
Laiser	1	2	30
Laiser	1	4	50
Laiser	1	7	60
Laiser	1	3	60
Laiser	1	1	20
Laiser	4	5	100
Laiser	5	4	80
Laiser	1	6	
Laiser	10	4	100
Laiser	7	1	80
Laiser	1	5	

Laiser	15	2	60
Laiser		4	40
Laiser	1	5	20
Laiser	2	2	60
Laiser		5	50
Laiser	1	5	200
Maasai Lodge		5	80
Maasai Lodge	20	2	60
Maasai Lodge		2	60
Maasai Lodge		1	20
Maasai Lodge	1	4	200
Maasai Lodge		5	50
Maasai Lodge	6	1	
Maasai Lodge		4	
Maasai Lodge		5	120
Maasai Lodge		4	200
Maasai Lodge		10	20
Maasai Lodge		2	
Maasai Lodge		4	80
Maasai Lodge		6	75
Maasai Lodge		2	25
Maasai Lodge		3	40
Maasai Lodge	3	4	20
Maasai Lodge	6	3	233
Maasai Lodge	18	2	40
Maasai Lodge		3	80
Maasai Lodge	1	10	333
Maasai Lodge	1	5	400
Maasai Lodge		4	100
Maasai Lodge	1	6	200
Maasai Lodge	6	3	40
Maasai Lodge	7	4	
Maasai Lodge	1	5	50
Maasai Lodge	5	4	80
Maasai Lodge	2	4	120
Maasai Lodge	32	2	67
Maasai Lodge	10	2	40
Maasai Lodge	60	3	80
Maasai Lodge	56	2	40

Maasai Lodge	20	2	320
Maasai Lodge	3	7	120
Maasai Lodge	15	5	100
Maasai Lodge	19	5	60
Maasai Lodge	19	5	

**Appendix VIII: Stabilization pond separation distance of 200m from dwelling
in Karen Brooks of Karen Plains Zone**

Residence	Distance Meters	Compliance
Household 01	10m	Non-compliant
Household 02	15m	Non-compliant
Household 03	63m	Non-compliant
Household 04	92m	Non-compliant
Household 05	150m	Non-compliant
Household 06	175m	Non-compliant
Household 07	230m	Compliant
Household 08	259m	Compliant
Household 09	295m	Compliant
Household 010	340m	Compliant
Household 011	350m	Compliant
Household 012	384m	Compliant
Household 013	425m	Compliant
Household 014	438m	Compliant
Household 015	495m	Compliant
Household 016	460m	Compliant
Household 017	417m	Compliant
Household 018	395m	Compliant
Household 019	340m	Compliant
Household 020	315m	Compliant
Household 021	255m	Compliant
Household 022	215m	Compliant
Household 023	240m	Compliant
Household 024	275m	Compliant
Household 025	325m	Compliant
Household 026	365m	Compliant
Household 027	450m	Compliant
Household 028	415m	Compliant
Household 029	370m	Compliant
Household 030	251m	Compliant
Household 031	209m	Compliant
Household 032	180m	Non-compliant
Household 033	155m	Non-compliant
Household 034	200m	Compliant
Household 035	210m	Compliant
Household 036	205m	Compliant
Household 037	235m	Compliant
Household 038	274m	Compliant
Household 039	219m	Compliant
Household 040	445m	Compliant
Household 041	480m	Compliant
Household 042	350m	Compliant
Household 043	300m	Compliant
Household 044	310m	Compliant
Household 045	272m	Compliant
Household 046	177m	Non-compliant
Household 047	170m	Non-compliant
Household 048	115m	Non-compliant
Household 049	132m	Non-compliant
Household 050	160m	Non-compliant
Household 051	190m	Non-compliant
Household 052	195m	Non-compliant
Household 053	200m	Compliant

Household 054	238m	Compliant
Household 055	250m	Compliant
Household 056	277m	Compliant
Household 057	287m	Compliant
Household 058	10m	Non-compliant
Household 059	12m	Non-compliant
Household 060	10m	Non-compliant
Household 061	12m	Non-compliant
Household 062	140m	Non-compliant
Household 063	155m	Non-compliant
Household 064	110m	Non-compliant
Household 065	85m	Non-compliant
Household 066	65m	Non-compliant
Household 067	114m	Non-compliant
Household 068	125m	Non-compliant
Household 069	140m	Non-compliant

Appendix IX: Karen Brooks oxidation pond Analabs analysis



Your Reliable Partner in Testing, Analysis and Diagnosis

Receipt, Analysis and Report Form

Facility/Client :Name: Phillip Kiama P.O Box: 27541 Town: Nairobi Email : p_kiama@yahoo.com Contact person: Phillip Phone:	Sample Name: Effluent A Sample ID: 5618 Source: Date and Time of sampling: 02/04/16 Time: Sampling/Submitting Officer: Phillip Phone: Email: p_kiama@yahoo.com Preferred Results Delivery Method: 1. Mail 2. Email 3. Fax 4. Give to Submitter 5. Others, specify Email
Sample Receipt Details [For Laboratory Use Only] Received by: Fanuel Oyule Phone : 0727531230 Sample : <u>Accepted</u> /Rejected/ On Hold/Rejected but Overridden Client/s will be notified if their sample/s do not meet quality standards for testing Date/Time of Receipt: 02/04/16 Time: 14.00	

Select Tests	Methodology	Units	Results	Reference Ranges	Flags	Tech Initials
Microbiological test						
Faecal coliforms	ISO 9308 – 2 2012	MPN index/ ml	>180		High	F.O
<i>E.coli</i>	ISO 9308 – 2	MPN	<1		Optimum	F.O

	2012	index/ ml				
Chemical tests						
PH	Potentiometric	PH scale	7.15	6.5-8.5	Optimum	F.O
Ammonium	Colorimetric	ppm	9.11	<100	Optimum	F.O
Total Dissolved Solids	Potentiometric	ppm	329	<1200	Optimum	F.O
Total suspended Solids	Gravimetric	ppm	116	<30.0	High	F.O
Colour	Colorimetric	HU	<10.0	<15.0	Optimum	F.O
Oil and Grease	Gravimetric	ppm	0.20	<0.05	High	F.O
B.O.D	Incubation	ppm	90.0	<30.0	High	F.O
C.O.D	Reflux	ppm	160	<50.0	High	F.O
Total N	Colorimetric	ppm	14.5	<100	Optimum	F.O
Nitrate N	Colorimetric	ppm	5.37	<100	Optimum	F.O
Nitrite N	Colorimetric	ppm	0.025	<100	Optimum	F.O
phosphorus	Spectroscopy	ppm	0.82	<2.00	Optimum	F.O
Sulphur	Spectroscopy	ppm	9.23	<84.0	Optimum	F.O
Chlorides	Colorimetric	ppm	36.6	<250	Optimum	F.O
Fluorides	Colorimetric	ppm	3.63	<1.50	High	F.O
Zinc	Spectroscopy	ppm	<0.01	<0.5	Optimum	F.O
Copper	Spectroscopy	ppm	<0.01	<1.00	Optimum	F.O
Boron	Spectroscopy	ppm	0.037	<1.00	Optimum	F.O
Electrical Conductivity	potentiometric	mS cm -1	0.52	<1.50	Optimum	F.O
Arsenic	Spectroscopy	ppm	<0.007	<0.02	Optimum	F.O
Cadmium	Spectroscopy	ppm	<0.002	<0.01	Optimum	F.O
Chromium	Spectroscopy	ppm	0.004	<1.00	Optimum	F.O
Lead	Spectroscopy	PPm	<0.009	<0.20	Optimum	F.O
Mercury	Spectroscopy	Ppm	<0.001	<0.05	Optimum	F.O
Nickel	Spectroscopy	Ppm	<0.003	<0.30	Optimum	F.O
Selenium	Spectroscopy	Ppm	<0.02	<0.02	Optimum	F.O
Aluminium	Spectroscopy	ppm	0.27	<5.00	Optimum	F.O
<u>Overall comments</u>						
High fluoride levels can result in development of dentofluorosis.>High TSS indicates higher than normal sediment load and likely high turbidity. >Oil film on the water surface reduces the amount of Dissolved Oxygen which affects higher aquatic life						

forms, microbial activities, pollution of breeding ground for some fish species. >BOD may cause suffocation of fish and aquatic organisms that require oxygen to survive. > High chemical oxygen demand is an indicator of high organic waste in the water

Name: Fanuel Oyule

Designation: Analyst

Sign

Date: .11.03.2016

Quality Assurance Review

Date/Time of Receipt: 02/04/16 **Time:** 14.00 **Date/Time of Results:** 11.04.2016 **Time:** 16.00

Turn Around Time [TAT]: 9 days

TECHNICAL NAME/SIGN.	REVIEW	TIME/DATE	QA REVIEW NAME/SIGN	TIME/DATE

ANALABS LIMITED	VERSION:10	EFFECTIVE DATE:04.04.2016	DOCUMENT NO: AN – FDH – FM – 06
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These results only apply to the above sample number; the comments and action recommended in this report are Analabs opinion

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Receipt, Analysis and Report Form

Facility/Client :Name: Phillip Kiama P.O Box: 27541 Town: Nairobi Email : p_kiama@yahoo.com Contact person: Phillip Phone:	Sample Name: Effluent B Sample ID: 5619 Source: Date and Time of sampling: 02/04/16 Time: Sampling/Submitting Officer: Phillip Phone: Email: p_kiama@yahoo.com Preferred Results Delivery Method: 1. Mail 2. Email 3. Fax 4. Give to Submitter 5. Others, specify Email
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Sample Receipt Details [For Laboratory Use Only]

Received by: Fanuel Oyule **Phone :**0727531230

Sample : Accepted/Rejected/ On Hold/Rejected but Overridden

Client/s will be notified if their sample/s do not meet quality standards for testing

Date/Time of Receipt: 02/04/16 **Time:** 14.00

Select Tests	Methodology	Units	Results	Reference Ranges	Flags	Tech Initials
Microbiological test						
Faecal coliforms	ISO 9308 – 2 2012	MPN index/ ml	>180		High	F.O
<i>E.coli</i>	ISO 9308 – 2 2012	MPN index/ ml	<1		Optimum	F.O
Chemical tests						

PH	Potentiometric	PH scale	7.01	6.5-8.5	Optimum	F.O
Ammonium	Colorimetric	ppm	17.9	<100	Optimum	F.O
Total Dissolved Solids	Potentiometric	ppm	347	<1200	Optimum	F.O
Total Suspended Solids	Gravimetric	ppm	68.0	<30.0	High	F.O
Colour	Colorimetric	HU	<10.0	<15.0	Optimum	F.O
Oil and Grease	Gravimetric	ppm	0.14	<0.05	High	F.O
B.O.D	Incubation	ppm	20.0	<30.0	Optimum	F.O
C.O.D	Reflux	ppm	30.0	<50.0	Optimum	F.O
Total N	Colorimetric	ppm	18.4	<100	Optimum	F.O
Nitrate N	Colorimetric	ppm	0.50	<100	Optimum	F.O
Nitrite N	Colorimetric	ppm	0.028	<100	Optimum	F.O
phosphorus	Spectroscopy	ppm	2.01	<2.00	High	F.O
Sulphur	Spectroscopy	ppm	6.63	<84.0	Optimum	F.O
Chlorides	Colorimetric	ppm	41.4	<250	Optimum	F.O
Fluorides	Colorimetric	ppm	3.59	<1.50	High	F.O
Zinc	Spectroscopy	ppm	<0.01	<0.5	Optimum	F.O
Copper	Spectroscopy	ppm	<0.01	<1.00	Optimum	F.O
Boron	Spectroscopy	ppm	0.041	<1.00	Optimum	F.O
Electrical Conductivity	potentiometric	mS cm -1	0.55	<1.50	Optimum	F.O
Arsenic	Spectroscopy	ppm	<0.007	<0.02	Optimum	F.O
Cadmium	Spectroscopy	ppm	<0.002	<0.01	Optimum	F.O
Chromium	Spectroscopy	ppm	<0.004	<1.00	Optimum	F.O
Lead	Spectroscopy	PPm	<0.009	<0.20	Optimum	F.O
Mercury	Spectroscopy	Ppm	<0.001	<0.05	Optimum	F.O
Nickel	Spectroscopy	Ppm	<0.003	<0.30	Optimum	F.O
Selenium	Spectroscopy	Ppm	<0.02	<0.20	Optimum	F.O
Aluminium	Spectroscopy	ppm	0.34	<5.00	Optimum	F.O

Overall comments

Excess P may contaminate water bodies resulting in rapid buildup of algae which in turn affects aquatic life.> High fluoride levels can result in development of dentofluorosis.>High TSS indicates higher than normal sediment load and likely high turbidity.> Oil film on the water surface reduces the amount of Dissolved Oxygen which affects both higher aquatic life forms, microbial activities, pollution of breeding ground for some fish species.

Name: Fanuel Oyule	Designation: Analyst	Sign
Date: 11.04.2016		

Quality Assurance Review

Date/Time of Receipt: 02/04/16 **Time:** 14.00 **Date/Time of Results:** 11.04.2016 **Time:** 16.00

Turn Around Time [TAT]: 9 days

TECHNICAL NAME/SIGN.	REVIEW	TIME/DATE	QA REVIEW NAME/SIGN	TIME/DATE

ANALABS LIMITED	VERSION:10	EFFECTIVE DATE:04.04.2016	DOCUMENT NO: AN – FDH – FM – 06
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These results only apply to the above sample number; the comments and action recommended in this report are Analabs opinion

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Receipt, Analysis and Report Form

Facility/Client :Name: Phillip Kiama P.O Box: 27541 Town: Nairobi Email : p_kiama@yahoo.com Contact person: Phillip Phone:	Sample Name: Effluent C Sample ID: 5620 Source: Date and Time of sampling: 02/04/16 Time: Sampling/Submitting Officer: Phillip Phone: Email: p_kiama@yahoo.com Preferred Results Delivery Method: 1. Mail 2. Email 3. Fax 4. Give to Submitter 5. Others, specify Email
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Sample Receipt Details [For Laboratory Use Only]

Received by: Fanuel Oyule **Phone :** 0727531230

Sample : Accepted/Rejected/ On Hold/Rejected but Overridden

Client/s will be notified if their sample/s do not meet quality standards for testing

Date/Time of Receipt: 02/04/16 **Time:** 14.00

Select Tests	Methodology	Units	Results	Reference Ranges	Flags	Tech Initials
Microbiological test						
Faecal coliforms	ISO 9308 – 2	MPN	>180		High	F.O

	2012	index/ ml				
<i>E.coli</i>	ISO 9308 – 2 2012	MPN index/ ml	<1		Optimum	F.O
Chemical tests						
PH	Potentiometric	PH scale	7.01	6.5-8.5	Optimum	F.O
Ammonium	Colorimetric	ppm	18.3	<100	Optimum	F.O
Total Dissolved Solids	Potentiometric	ppm	353	<1200	Optimum	F.O
Total Suspended Solids	Gravimetric	ppm	10.0	<30.0	Optimum	F.O
Colour	Colorimetric	HU	<10	<15.0	Optimum	F.O
Oil and Grease	Gravimetric	ppm	0.12	<0.05	High	F.O
B.O.D	Incubation	ppm	20.0	<30.0	Optimum	F.O
C.O.D	Reflux	ppm	22.0	<50.0	Optimum	F.O
Total N	Colorimetric	ppm	20.5	<100	Optimum	F.O
Nitrate N	Colorimetric	ppm	2.15	<100	Optimum	F.O
Nitrite N	Colorimetric	ppm	0.036	<100	Optimum	F.O
phosphorus	Spectroscopy	ppm	2.07	<2.00	High	F.O
Sulphur	Spectroscopy	ppm	6.21	<84.0	Optimum	F.O
Chlorides	Colorimetric	ppm	34.3	<250	Optimum	F.O
Fluorides	Colorimetric	ppm	3.67	<1.50	High	F.O
Zinc	Spectroscopy	ppm	<0.01	<0.5	Optimum	F.O
Copper	Spectroscopy	ppm	<0.01	<1.00	Optimum	F.O
Boron	Spectroscopy	ppm	0.035	<1.00	Optimum	F.O
Electrical Conductivity	potentiometric	mS cm -1	0.56	<1.50	Optimum	F.O
Arsenic	Spectroscopy	ppm	<0.007	<0.02	Optimum	F.O
Cadmium	Spectroscopy	ppm	<0.002	<0.01	Optimum	F.O
Chromium	Spectroscopy	ppm	<0.004	<1.00	Optimum	F.O
Lead	Spectroscopy	PPm	<0.009	<0.20	Optimum	F.O
Mercury	Spectroscopy	Ppm	<0.001	<0.05	Optimum	F.O
Nickel	Spectroscopy	Ppm	<0.003	<0.30	Optimum	F.O
Selenium	Spectroscopy	Ppm	<0.02	<0.20	Optimum	F.O
Aluminium	Spectroscopy	ppm	0.24	<5.00	Optimum	F.O
<u>Overall comments</u>						

Excess P may contaminate water bodies resulting in rapid buildup of algae, which in turn affects aquatic life.> high fluoride can result in development of dentofluorosis. > oil film on the water surface reduces the amount of dissolved oxygen which affects both higher aquatic life forms, microbial activities, pollution of breeding ground for some fish species.

Name: Fanuel Oyule

Designation: Analyst

Sign

Date: .11.04.2016

Quality Assurance Review

Date/Time of Receipt: 02/04/16 **Time:** 14.00 **Date/Time of Results:** 11.04.2016 **Time:** 16.00

Turn Around Time [TAT]: days

TECHNICAL REVIEW NAME/SIGN.	TIME/DATE	QA REVIEW NAME/SIGN	TIME/DATE

These results only apply to the above sample number; the comments and action recommended in this report are Analabs opinion

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Appendix X: Odour measurement results during a six day period between March 2016-April 2016

Day 1

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	60	45	45	28	11	11	9	7	6
12.00pm	101	101	60	60	60	60	45	11	11	11	11
15.00pm	101	101	101	60	60	60	45	45	45	60	60
18.00pm	60	45	45	35	28	28	11	11	7	6	6
00.00am	101	101	101	101	101	60	60	60	60	60	60
3.00am	101	101	101	101	101	60	60	60	60	60	60
6.00am	101	45	45	35	28	28	11	11	9	7	6

Day 2

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	60	45	45	28	11	9	7	6	6
12.00pm	101	45	60	45	45	35	28	28	11	7	6
15.00pm	101	101	60	60	60	60	45	45	28	28	28
18.00pm	101	101	45	35	35	28	28	11	11	7	6
00.00am	101	101	101	60	60	45	45	45	45	45	45
3.00am	101	101	101	101	101	60	45	60	60	60	60
6.00am	101	101	60	45	60	60	60	45	45	35	35

Day 3

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	101	101	101	60	60	45	45	45	45
12.00pm	101	60	60	35	28	28	11	11	7	7	6
15.00pm	101	101	60	45	45	45	35	35	28	28	11
18.00pm	101	35	35	35	28	28	11	11	7	6	6
00.00am	101	101	101	101	101	60	60	60	60	60	60
3.00am	101	101	101	101	60	60	60	45	45	45	60
6.00am	101	60	60	60	45	60	60	60	60	45	45

Day 4

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	101	101	101	101	60	60	60	60	60
12.00pm	101	45	45	35	35	35	28	28	11	7	7
15.00pm	101	45	45	35	35	35	28	28	28	11	7
18.00pm	101	101	45	35	35	28	28	28	11	7	7
00.00am	101	101	101	60	60	60	60	60		45	45
3.00am	101	101	101	101	60	60	60	60	60	45	45
6.00am	101	45	60	60	60	45	60	60	60	60	60

Day 5

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	101	101	101	101	45	45	45	45	45
12.00pm	101	60	60	45	45	35	35	28	11	11	7
15.00pm	101	45	35	45	28	28	11	7	7	7	7
18.00pm	101	60	60	60	45	45	28	11	11	7	7
00.00am	101	101	60	60	60	60	60	60	60	60	60
3.00am	101	101	101	101	101	60	60	60	45	45	45
6.00am	101	101	60	60	45	60	60	60	60	45	45

Day 6

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	60	60	101	101	101	60	60	45	45
12.00pm	101	60	60	45	45	45	45	28	11	7	7
15.00pm	101	60	45	45	45	45	28	28	11	7	7
18.00pm	101	60	45	45	35	28	28	11	11	7	6
00.00am	101	101	101	60	101	101	101	60	60	60	60
3.00am	101	101	60	101	60	101	101	60	60	60	60
6.00am	101	60	45	60	45	60	60	45	45	45	45

Day 7

Time	0m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
9.00am	101	101	60	45	45	28	11	9	7	6	6
12.00pm	101	101	60	45	45	35	28	28	11	7	6
15.00pm	101	101	60	60	60	60	45	45	28	28	28
18.00pm	101	60	60	45	45	45	45	45	35	35	28
00.00am	101	101	101	60	101	101	101	60	60	60	60
3.00am	101	101	101	101	101	101	101	60	60	60	60
6.00am	101	60	60	45	45	35	45	28	28	28	11

Appendix XI: Meteorological data for rainfall temperature and humidity for March and April 2016 period

Date	Rainfall mm		Temperature °C		Humidity %				Wind Run Km/day	
	March	April	March	April	March		April		March	April
					9:00 AM	3:00 PM	9:00 AM	3:00 PM		
1	0	20.1	17.1	15.8	82	54	91	47	136.9	134.4
2	5.7	65.9	16.6	16.6	91	49	86	94	164.8	56.3
3	0	2.6	17.5	16	82	41	86	62	173.1	111.4
4	0	21	17.2	16.5	84	38	92	66	167.3	76.5
5	0	0.8	15.4	15.4	78	41	79	55	162.4	128.7
6	0	0.5	16.8	16.2	78	43	91	62	119.9	196.7
7	0	0	17.6	16.2	91	41	92	57	126.7	138.3
8	0	0	17.3	12.2	73	65	68	46	139.3	86.0
9	15.1	3	16.6	16.5	91	47	86	46	61.9	73.1
10	0.6	0	15.6	16	83	43	81	56	147.3	104.5
11	0	1.1	17.5	16.7	86	40	81	56	219.1	111.3
12	0	0	17.1	16.8	59	39	89	53	166.7	134.9
13	0	0	13	16.5	71	27	88	51	178.7	103.1
14	0	0	12.5	16.2	57	26	83	51	155.6	68.0
15	0	0	14.2	16	73	26	80	51	139.3	170.1
16	0	6.2	13.5	16.3	68	29	86	50	122.3	127.3
17	0	0	16.4	16.3	79	34	91	57	130.4	100.2
18	0	45.2	18	16.7	62	35	84	54	103.3	117.8
19	0	0	16	15.7	75	35	88	56	162.5	74.4
20	0	8.9	17	17	63	37	79	73	160.0	77.1
21	0	7.4	15.8	16.4	62	40	93	70	142.9	83.8
22	0	0.3	15.5	16.5	58	33	91	48	137.0	121.7

23	0	11.7	17.8	17	71	41	91	46	128.5	110.6
24	0	0.6	15.1	16.5	92	41	96	78	206.7	67.5
25	0	34.4	16.7	16.5	84	43	94	83	181.2	59.0
26	0	1.3	13.9	16.4	70	33	91	53	170.4	67.8
27	0	2.5	13.2	15.5	65	22	78	53	147.7	71.6
28	0	26.7	15.6	15.7	71	29	90	67	114.1	72.2
29	0	51.3	16.6	15.8	68	37	86	68	156.1	87.0
30	0	4.2	18.4	16.5	75	43	95	89	179.5	56.4
31	96	N/A	17.4	N/A	77	44	N/A	N/A	189.5	N/A

- f) Cart water vendors Yes No
- g) Truck water vendors Yes No
- h) River Yes No
- i) Any other Yes No

4. In your opinion how do you rate the quality of water in terms of the following

- i. Taste good fair bad
- ii. Colour good fair bad
- iii. Odour good fair bad

a) Do you treat your water in any way to make it safe to drink?
 Yes No

b) If yes, what methods do you use
 (Explain).....

5. How much water do you use in a day (in litres or jerricans)

6. On average, how much do you spend on water per month
 (Kes).....

7. What challenges do you face in terms of water supply and provision?

8. What kind of toilet facility do you use?

Pour flush into;

- a) Piped sewer system
- b) Septic tank
- c) Pit latrine

Others.....

- d) Ventilated Improved Pit latrine
- e) Pit latrine

- f) Pit latrine with slab
- g) Pit latrine without slab
- h) Composting toilet
- i) Bucket
- j) Hanging toilet/latrine
- k) No facilities or bush or field
- Others (specify).....

9. Do you share this facility with other households?

- Yes No

10. If yes, how many persons many share this toilet facility?

11. What method of sanitation disposal system do you use?

- a) Sewerage system
- b) Septic tank without Soakaway pit
- c) Septic tank with Soak away pits
- d) Pit latrine
- e) Open drainage
- f) Lagoons

12. Please state what factors influenced your decision in choosing your sanitation system

.....

.....

.....

.....

13. If septic tank system is used who is responsible for emptying of the septic tank

- Owner Tenant

14. Who are the service providers for emptying septic tank /pit latrines?

- a) County Government

- b) Private
- c) Manual emptier

15. What period between desludging of septic tanks/pit latrine?

- a. Once a month or less
- b. Twice per year
- c. Less than once a year
- d. Every two years
- e. Other (specify).....
- f. Never

(explain).....

.....

.....

16. What is the annual cost of operation and maintenance of your sanitation system?.....

.....

....

17. Have you experienced problems with your sanitation facilities? If so, state the problem.....

.....

...

18. What is the size of plot...

19. What is the type of house erected on the property?

Type of house	Single Dwelling	Multiple dwelling
Mud house	<input type="checkbox"/>	<input type="checkbox"/>
Timber house	<input type="checkbox"/>	<input type="checkbox"/>
Stone house	<input type="checkbox"/>	<input type="checkbox"/>

20. What is the approximate plot coverage?

- a) 0-25%

- b) 26%-50%
- c) 51%-75%
- d) 76%-80%
- e) 90%-100

21. What is the separation distance of the sanitation facility from the following features?

Item	Sanitation Facilities				
	Septic Tank (m)	Soakaway (m)	Pit latrine	Lagoons	Sewer
Building					
Property boundary					
Well					
Stream					
Cuts or Embankment					
Water Pipe					
Paths/ Road					
Large Trees					

22. What is the population served by sanitation facilities in your institution?

Number of users served	Institution sanitation facilities	
	Male	Female
Staff		
Students	Boys	Girls

23. Have any of your family members been treated for any of these diseases in last 3 months?

- | | | | | |
|-----------------|-----|--------------------------|----|--------------------------|
| a) Cholera | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| b) Typhoid | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| c) Bilharzias | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| d) Diarrhoea | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| e) Skin disease | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| f) Malaria | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| g) Other..... | | | | |

24. Is there any discharge of sewage in open drains or open sewer in the neighbourhood?

Yes No

If yes, how has this affected you, your household and community?

.....
.....
.....

25. . Have you experienced any foul odour in your neighbourhood?

Yes No

26. If yes, what is the source of odour? (Specify)

.....
.....
.....

Appendix XIII: Baseline Household Questionnaire

I am carrying out a survey titled “Sanitation Standards and their implications on sanitation provision in Karengata and Ongata Rongai”. Any information provided will be strictly confidential.

Date.....

Sublocation.....

Estate.....

Name.....

Male Female

1. Details of respondent: Husband Wife Other

(specify).....

RELATIONSHIP	AGE	SEX		OCCUPATION	LEVEL OF EDUCATION	HOUSEHOLD INCOME						
		M	F			>5000	5000-10000	10001-25000	25001-50000	50001-100000	>100000	

7. What kind of toilet facility do you use?

a) Pour flush into

i. Piped sewer system

ii. Septic tank

iii. Pit latrine

iv. Elsewhere

b) Pit latrine

i. Pit latrine with slab

ii. Pit latrine without slab

iii. Ventilated Improved Pit latrine

c) Composting toilet

d) Bucket

e) Hanging toilet/latrine

f) No facilities or bush or field

g) Others

(specify).....

8. Do you share this facility with other households? Yes No

9. If yes, how many households share this toilet facility?

.....

10. How often do you empty the septic tank?

a. Once a month

- b. Less than once a year
- c. Every two years

11. If you are an owner-occupier, please state what factors influenced your decision in choosing your sanitation system

.....

.....

12. Who are the service providers for emptying septic tank and pit latrines?

- a) Local Authority
- b) Private

13. Has one of your family members suffered from any of these diseases?

- a) Cholera Yes No
- b) Typhoid Yes No
- c) Bilharzias Yes No
- d) Diarrhoea Yes No
- e) Other.....

14. Do you notice any open sewer in the neighbourhood?

- Yes No

15. Do you notice any bodies of dirty stagnant water in your neighbourhood?

- Yes No

16. Have you experienced any foul odour in your neighbourhood?

- Yes No

Appendix XIV: Interview Schedule For Nairobi County Government

1. Who is responsible for wastewater management for Karengata? (Water and sanitation)
2. What is the policy on wastewater management/handling?
3. Can you estimate the daily quantity of sewage produced in Karengata? (Do you have data?)
4. What percentage of this waste is collected/handled in Karengata?
5. Where and how do you handle (at household and street level) wastewater in the Karengata? How is this waste disposed?
6. How do you manage runoff/storm water in the Karengata?
7. What area of the Karengata is covered with the infrastructure for municipal sewerage?
8. What is the situation concerning onsite sanitation?
 - a) What are the policies and regulation governing onsite sanitation i.e. regulations governing onsite systems such as minimum area for septic tank use, number of facilities per specific population?
 - b) What are the regulations for discharging waste water from industries and public institutions like schools, hospitals, colleges to the environment?
9. How can you describe compliance to these sanitation regulations and standards with regards to protection, conservation, promotion of the environment in Kenya?
10. In each case, which measures do you take when these regulations are violated?
11. What constraints do you face in improving urban environmental infrastructure in the Karengata?
12. What future plans do you have to improve municipal sanitation systems in Karengata?

Appendix XV: Interview Schedule For Kajiado County Government

1. Who is responsible for wastewater management for Kajiado North? (Water and sanitation)
2. What is the policy on wastewater management/handling?
3. Can you estimate the daily quantity of sewage produced in Ongata Rongai ? (Do you have data?)
4. What percentage of this waste is collected/handled in Ongata Rongai?
5. Where and how do you handle (at household and street level) wastewater in the district? How is this waste disposed?
6. How do you manage runoff/storm water in Ongata Rongai?
7. What area of the Ongata Rongai is planned for municipal sewerage infrastructure?
8. What is the situation with regards to onsite sanitation?
9. What are the policies and regulation governing onsite sanitation i.e. regulations governing onsite systems such as minimum area for septic tank use, number of facilities per specific population?
10. What are the regulations for discharging wastewater from industries and public institutions like schools, hospitals, colleges to the environment?
11. How can you describe compliance to these sanitation regulations and standards with regards to protection, conservation, promotion of the environment in Kenya?
12. In each case, which measures do you take when these regulations are violated?
13. What constraints do you face in improving urban environmental infrastructure in the Ongata Rongai?
14. What future plans do you have to improve municipal sanitation systems in the Ongata Rongai?

Appendix XVI: Research Authorization from National Government



**OFFICE OF THE PRESIDENT
MINISTRY OF INTERIOR AND COORDINATION
OF
NATIONAL GOVERNMENT**

Telegrams: "DISTRICTER", Kajiado
Telephone: 0203570295
Fax: 0202064416
E-mail: kajiadocc2012@yahoo.com
kajiadocc2012@gmail.com
When replying please quote

THE KAJIADO COUNTY COMMISSIONER
P.O BOX 1-01100
KAJIADO

Ref.No.KJD/CC/CON/ADM/45/(2)

27th August, 2013

The Deputy County Commissioner
KAJIADO NORTH

RE: RESEARCH AUTHORIZATION

Mr. Philip Mbugua Kiama is a student at Kenyatta University and has been authorized to carry out research in both Karen, Langata and Ongata Rongai areas on **"Sanitation standards and their implications on sanitation provision in Nairobi metropolitan areas of Karen, Langata and Ongata Rongai"** for the period ending 31st December, 2013.


Kindly accord him the necessary assistance.

Attached is a letter from the University for your information and necessary action.

Albert Kobia Wakamau
COUNTY COMMISSIONER
KAJIADO COUNTY

Enclosures

Appendix XVII: Research Authorization from Kenyatta University



KENYATTA UNIVERSITY
SCHOOL OF ENVIRONMENTAL STUDIES
DEPARTMENT OF ENVIRONMENTAL PLANNING AND MANAGEMENT

Our Ref: KU/EPM/STU/10
Your Ref:

P.O. Box 43844
NAIROBI
Tel. 8710901-19
Ext. 57221
Fax: 811575/811242
Website: www.ku.ac.ke


9th May 2013

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION

This letter is to confirm that **PHILLIP MBUGUA KIAMA** of REG. NO. N85/22657/2011 is a Ph.D student in the Department of Environmental Planning and Management at Kenyatta University. Currently the student is in his data collection phase in preparation for his research project titled "*Sanitation Standards and their Implications on sanitation Provision in Nairobi Metropolitan Areas of Karengata and Ongata Rongai*".

Kindly accord him any assistance he may require particularly with regard to acquisition of data and academic literature.




Chair, Environmental Planning and Management

PKK/enm

Appendix XVIII: Research Authorization from NACOSTI

REPUBLIC OF KENYA



NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telephone: 254-020-2213471, 2241349, 254-020-2673550
Mobile: 0713 788 787, 0735 404 245
Fax: 254-020-2213215
When replying please quote
secretary@ncst.go.ke

P.O. Box 30623-00100
NAIROBI-KENYA
Website: www.ncst.go.ke

Our Ref: NCST/RCD/17/013/13

Date: 20th May 2013

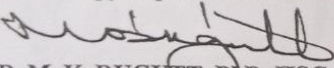
Philip Mbugua Kiama
Kenyatta University
P.O Box 43844-00100
Nairobi.

RE: RESEARCH AUTHORIZATION

Following your application dated 2nd May, 2013 for authority to carry out research on *“Sanitation standards and their implications on sanitation provision in Nairobi metropolitan areas of Karen, Lang’ata and Ongata Rongai.”* I am pleased to inform you that you have been authorized to undertake research in Nairobi Province for a period ending 31st December, 2014.

You are advised to report to the District Commissioners, District Education Officers and District Medical Officers of Health in Nairobi and Kajiado Districts before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.


DR. M. K. RUGUFF, PhD, HSC.
DEPUTY COUNCIL SECRETARY

Copy to:
The District Commissioner *County Commissioner*
The District Education Officer
The District Medical Officer of Health

“The National Council for Science and Technology is Committed to the Promotion of Science and

Appendix XIX: Research Permit

PAGE 2


THIS IS TO CERTIFY THAT:
Prof./Dr./Mr./Mrs./Miss/Institution
Phillip Mbugua Klama
of (Address) Kenyatta University
P.O. Box 43844-00100, Nairobi
has been permitted to conduct research in
Karen, Lang'ata and
Ongata Rongai Location
District
Nairobi, Rift Valley Province

on the topic: Sanitation standards and their
implications on sanitation provision in
Nairobi metropolitan areas of
Karen, Lang'ata and Ongata Rongai

for a period ending December 31, 2011

PAGE 3

Research Permit No. NCST/RCD/17/013/11
Date of issue 20 May 2013
Fee received KSh. 2,000



Applicant's Signature
Secretary, National Council for Science and Technology

1. You must report to the District Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.

2. Government Officers will not be interviewed without prior appointment.

3. No questionnaire will be used unless it has been approved.

4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.

5. You are required to submit at least two (2) / four (4) bound copies of your final report for Kenyans and non-Kenyans respectively.

6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

GPK60553mt102011

(CONDITIONS—see back page)