Chapter 1

Introduction

'the significant problems we face cannot be solved at the same level of thinking we were at when we created them'

Albert Einstein

1.1 BACKGROUND

A quick run through history will reveal that sanitation management evolved from the Industrial Revolution and mimicked the linear economic model of production and consumption of the era to develop linear conventional sanitation technological solutions. These linear models of sanitation management have achieved a great deal of success over the years, but they seem to be increasingly challenged by indications that deeper changes in the operating systems are necessary (Ellen MacArthur Foundation, 2012, 2013). The efficiency and effectiveness of these resource-intensive linear sanitation systems (whether sewer or non-sewer) have been questioned and thus created rising concerns about sustainability as well as the ability to actually expand access and improve service. These are huge concerns as the current global statistics for sanitation indicate that a wide margin still exists between desired results and reality (Fam & Mitchell, 2012; Hutton & Varughese, 2016; Lopes *et al.*, 2012). The MDGs aimed to halve the 2.4 billion people without adequate sanitation, but today we still have an estimated 2.3 billion people without improved sanitation facilities and about 892 million practising open defecation (Giné-Garriga *et al.*, 2017; Joint Monitoring Programme (JMP), 2015; O'Reilly *et al.*, 2017; WHO & UNICEF, 2017). In fifteen years of the MDGs, however, all efforts and resources did not even come near halving the 2.4 billion and now the Sustainable Development Goals (SDGs) aspire for universal access and improved services across the globe for adequate and equitable sanitation (WHO & UNICEF, 2017). But then, these could be just lofty ideals as the SDGs do not actually give particular attention to sanitation, which seems to be considered an afterthought to water and wastewater.

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The risk here is that sanitation could again be overlooked by the water targets, as was the case for the MDGs (Andersson & Minoia, 2017). It is expedient that sanitation be addressed on its own core platform and extracted from the clutches of water and hygiene (health) because managing sanitation and providing required services are truly not the same as managing water and hygiene. Doing things the same way will always yield the same results as 15 years of the MDG has revealed, with over 2.3 billion people still without basic sanitation. The risks are far-reaching too with grave impacts on water quality, health and the environment (note: controlling these risks is not the same as providing sanitation solutions, but rather protection for water, health and the environment from sanitation as well as other practices). It is, therefore, essential to push forward in the direction of sanitation solutions that yield increased efficiency and effectiveness, reduced costs and risks, livelihood support and ecological sustainability as well as accelerated drive towards expanded access and improved services by 2030.

Clearly, sanitation needs to head away from the conventional approach of techno-focus that has been predominant over the years and during the MDGs era without much-needed success. It will not be easy to transition from these rigid, locked-in conventional sanitation technologies characterized by incremental progression along existing trajectories rather than radical innovations, but transformation to holistic, integrated and systemic solutions that address the whole spectrum of sanitation is essential (Fam & Mitchell, 2012; Lopes *et al.*, 2012). Technological innovations are not enough to bring the progressive results desired in the sanitation arena, but mutually reinforcing institutional, psycho-social, ecological, cultural and resource-oriented transformations is required (Geels, 2005). There is overwhelming evidence that focusing on technology or infrastructure (small and large) alone will not provide needed solutions as many 'failed technologies' in sanitation did not fail due to technical deficiencies only, but also, and even more so, on system misfit in terms of scale, or the social, geographical, cultural or even economic contexts in which they were implemented (van Vliet *et al.*, 2011). Studies have shown how psycho-social-economic, cultural conditions and lock-in effects prevent uptake of new technologies due to their lack of integration into the existing technical and institutional structure. This is because new technology might negatively impact the existing sociotechnical systems if it contradicts other interests and could lead to a dead end (Hiessl *et al.*, 2003; Panebianco & Pahl-Wostl, 2006; van Vliet *et al.*, 2011). Some examples of challenges in the absence of systemic-holistic-integrated perspectives in sanitation programming are illustrated in Boxes 1.1 to 1.4.

BOX 1.1 UGANDA

An Agenda 21 project in Jinja involving community latrines with a digester producing biogas as an energy source for domestic cooking and lighting failed soon after its start in 2001. The households complained about bad odours and were reported to be reluctant to use their own human waste for cooking, and so eventually someone removed the pipes. The project failure can hardly be attributed to the hardware itself; rather the way it was implemented as well as prevailing social and cultural conditions (UN-Habitat, 2002; van Vliet *et al.*, 2011).

BOX 1.2 SOUTH AFRICA

Conventional gravity sewerage installed in Cape Town's informal settlements proved difficult due to various social, built and natural environment challenges (Sonnenberg, 2013; Taing *et al.*, 2013). In order to resolve this problem, the Officials of the City of Cape Town (CoCT) decided to explore vacuum sewer technology as an alternative solution. However, the vacuum sewer failed immediately after its commissioning in early 2009 and so residents demanded its removal and that its flush toilets be replaced with previously phased-out bucket toilets (Taing, 2017). The Vacuum Sewer System (VSS) was hampered from inception by users' and service providers' (CoCT's) poor management and governance (DWAF, 2008a, b; Taing *et al.*, 2013).

BOX 1.3 THE NETHERLANDS

The city of Wageningen in 2002 suffered the same fate as Cape Town, South Africa. It became apparent to both the municipality and project proponents, even before allocation of the accommodation to residents, that all was not well with the vacuum sewerage and anaerobic treatment system in a new residential site. At the start of the project, many aspects of the experiment with vacuum toilets and anaerobic treatment systems were still unresolved, from seemingly trivial issues like the shape and colour of toilets to more crucial aspects of management and transfer of technology. Both the municipality and project developers decided in 2003 to withdraw, causing the project to fail even before the technology could be installed (van Vliet, 2006; van Vliet *et al.*, 2011).

BOX 1.4 SWEDEN

The Urine Diversion (UD) toilet systems in Sweden revealed the significance of human-centred issues relating to pyschosociocultural acceptance and governance support as sine qua non for the process of sanitation access expansion and service improvement. The Swedish experience, which installed about 135,000 UD units over the last two decades (Kvarnström *et al.*, 2006), was the primary source of influence and inspiration for UD projects globally. The engagement of end users as critical stakeholders was a key determinant in the successful adoption of the UD systems, as the most enduring UD systems in Sweden are those that were collaboratively organized and/or managed by end users (e.g. cooperative housing estates, eco-villages and private summer houses) as well as the strong endorsement of the coastal municipality of Tanum, the first to mandate UD systems for all new housing development (Fam & Mitchell, 2012). However, while the concept of UD is gaining global momentum, the advancement of UD within Sweden (the birthplace of the modern UD toilet) is slowing down since its peak in the mid-1990s with a number of high-profile pilot projects dismantled and two manufacturers of UD systems ceasing production. This decline is due to dwindling support from Tanum Municipality due to planning and development of large scale wastewater treatment plants connecting households to centralized sewers, which reduced the appeal for small-scale systems such as UD for nutrient recovery (Fam & Mitchell, 2012).

Current sanitation infrastructural designs are at odds with today's environmental, economic and social sustainability paradigms (Apul, 2010) as well as meeting the aspiration of the goals and targets of SDG no. 6. Developed countries are just as affected as the conventional centralized linear systems that were substantially revamped after World War Two are close to or past their useful design lifespan (usually considered to be 50–60 years) and need to undergo major rehabilitation/refurbishment (Capodaglio, 2017; van Vliet *et al.*, 2011). Thus, developed countries, due to resource constraint, are confronted with the twin challenges of retrofitting and upgrading ageing and decaying sanitation infrastructures (Ashley *et al.*, 2011; Bracken *et al.*, 2006; Brands, 2014; Butler & Parkinson, 1997; Delleur, 2003; Drangert, 1998; Wilsenach *et al.*, 2003; WWAP, 2017). To address the contemporary sanitation dilemma, systemic-holistic-integrated strategies must be considered across the sanitation spectrum and interlinkages to agriculture, carbon cycles, environment and health, resource reuse and recovery, psycho-social, economic and cultural factors, ecological sustainability, institutions and governance, and the myriad roles of stakeholders in the process of sanitation (Brands, 2014; Marshall & Farahbakhsh, 2013; van Vliet *et al.*, 2011).

In the face of all these, a new approach to sanitation management and solutions design named Regenerative Sanitation (ReGenSan) is proposed. ReGenSan aims to provide the foundation for a new way of thinking by adapting the principles of regeneration and functional-living-system theory to the specific context of sanitation. To this effect, *sanitation is regenerative when it integrates the psycho-socio-ecological elements (place, scale, culture/religion, status, economy and governance), resource recovery (reuse, recycling), ecosystem (geographical and ecological) and technological elements (storage, collection, transport, treatment, reuse) perspectives into one systemic whole for the rejuvenation and revitalization of human excreta/urine management in a manner that mimics and contributes to nature's system.* Therefore, ReGenSan could provide the opportunity to systematically address complex sanitation challenges from multi- and transdisciplinary perspectives, as it approaches solution provision from a holistic-integrated perspective with an ecological systemic worldview. ReGenSan is designed to be place-/scale-based where comprehensive sanitation solutions and management are provided within what is termed 'sani-sheds' and with the intent to mimic nature and be psycho-socially acceptable and affordable, livelihood-supportive and technically appropriate as well as enabled by specific governance mechanisms. It aims to offer strategies that support the development of novel and place-peculiar sanitation facilities, restoration and upgrade of old, dysfunctional and unimproved sanitation infrastructure, ensuring continuous maintenance of existing improved sanitation facilities as well as recovery and reuse of valuable resources from excreta, urine and wastewater management in order to expand access and improve services. This is in consonance with the idea of the circular economy, which is redefining products and services to eliminate waste, while minimizing negative environmental impacts (Capodaglio, 2017; EMF, 2012, 2013; IWA, 2016; TBC, 2016) and contributing in a greater measure to resource conservation (Lia Buarque, 2012). Thus, technology will no longer just be about storage, collection, transport, treatment and reuse; focus will be on the most reliable, sensible, acceptable, appropriate and resourceful ways to implement technology.

ReGenSan aspires to ensure that sanitation systems do not transfer ecological and public health burdens and do not mix human waste with other wastes, but align sanitation facilities with ecological processes to ensure 'zero' or 'near minimal' discharge, and ensure that sanitation systems provide net benefits to the people and environment. It is common knowledge that current sanitation practices have large negative effects on ecosystem services, especially in the urban centres of developing and developed countries. But sanitation systems can be designed to benefit particular ecosystems in order to mitigate or reduce such negative impacts (Graham, 2003; Rees, 1999; Zari, 2012). Moreover, ReGenSan could contribute positively to ecosystem services by ensuring benefit-sharing and focused reduction on environmental and public health impacts. In addition, regenerative goals demand that processed-waste volumes do not exceed the capacity of the environment, thus ensuring that there is no-transfer-of-burden (NToB) (Lyle, 1994).

1.2 PERSPECTIVES OF THE REGENERATIVE PHENOMENA

The design of ReGenSan was drawn from interdisciplinary and multidisciplinary analysis of literature on regenerative science, biology, medicine, development, designs, built environment and architecture, industrial, ecology, agriculture, economics and sustainability. The regenerative concept has been used extensively in the fields of biological and medical sciences, urban development, agriculture, economics, architectural design and the built environment, but not yet in sanitation management. ReGenSan particularly draws insights from the following.

1.2.1 Regenerative science and medicine

Medical, biological and ecological sciences have been exploring the regenerative capacities of living systems like plants, animals and humans, resulting in major advances in medical treatment such as cancer, ecological preservation and restoration and endangered species protection. Regenerative science investigates the interaction of living tissues with other materials and the ability of animal tissues to rebuild and recover internally and without external effort (Aida & Carrel, 2014; Illingworth, 1974; Kragl *et al.*, 2009; Sampogna *et al.*, 2015) and supports the idea that life is always in a constant state of renewal, restoration, replacement or repair (Graham, 2003; Guterstam & Todd, 1990; Kibert *et al.*, 2002; Lenhoff & Lenhoff, 1991; Maienschein, 2011; McHarg, 1969; Mitsch, 1993; Mitsch & Jørgensen, 1989, 2003; Porcellini, 2009; Sunderland, 2008, 2010, Van der Ryn & Cowan, 2007; Whitman *et al.*, 1997). Findings from such investigations contributed to the use of the ecosystem approach in waste treatment as encapsulated in the principles of ecological engineering and biomimicry, which stand as core principles of ReGenSan (Todd & Josephson, 1996; Todd & Todd, 1980, 1984, 1994). Relatively, ecological and nature-based sanitation technologies have attributes that separate them from conventional technologies and are unique in their application to a wide range of sewage treatment technologies (Lyle, 1994; Mitsch, 1993; Todd & Josephson, 1996) in that the restorative capacity of the ecological system is reinforced (du Plessis & Brandon, 2015) to improve system integrity and performance for the purpose of impeding the rate of depletion and degradation (Mang & Reed, 2012a).

Therefore, ReGenSan utilizes the 'listen and learn' principle of regenerative science and medicine to learn from nature and align sanitation solutions with nature's potential to create new (nouveau) solutions, restore and retrofit previously damaged sanitation systems and recover valuable resources from human waste. In essence, restorative, renewal and replace strategies could be valuable tools for innovative repair and rehabilitation of sites and locations damaged by previous and current sanitation practices (SER, 2004).

1.2.2 Regenerative development and design

Regenerative development and design aims to create systems that are capable of restoring health to both human communities and ecosystems, especially in the fields of architecture and urban development (Zari, 2012). The application of regenerative design in the built environment engages the natural world as the medium and generator of human settlement. It focuses on conservation and performance through reduction in environmental impacts of buildings as well as treatment of the environment as an equal shareholder in the built environment (Littman, 2009; Reed, 2007). Figure 1.1 depicts regenerative design in the built environment and shows the movement from the reductionist-mechanistic design thinking on the lower left to natural systems design thinking on the upper right, which is all part of the journey to a regenerative system (Fullerton, 2015; Mang & Reed, 2012b).

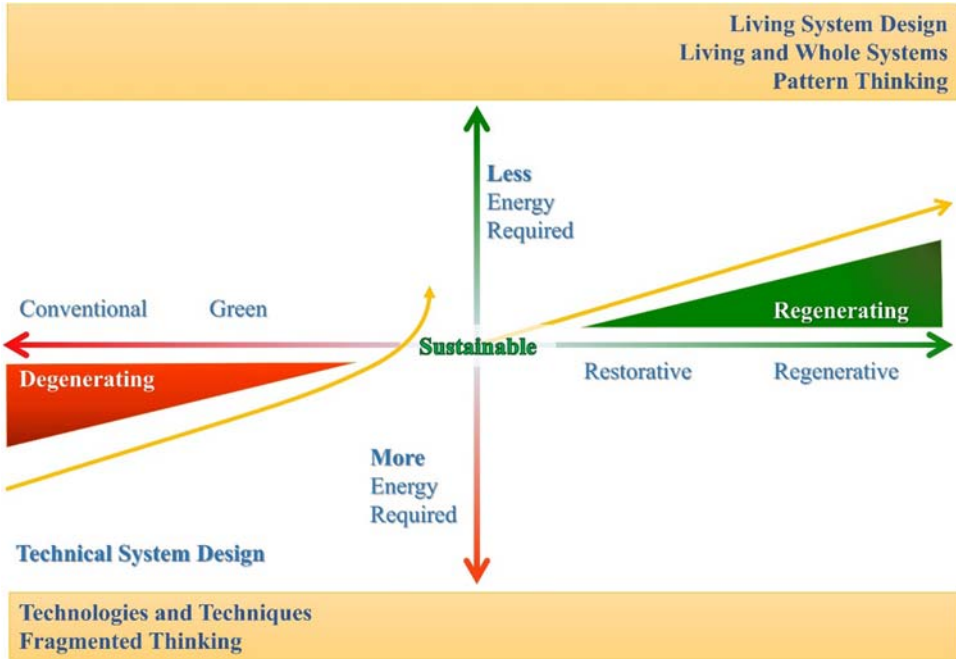

Figure 1.1 Contrast of technical system design and living system design (*Source*: Mang & Reed, 2012b).

Regenerative design and development pushes beyond sustainable development principles by seeking to redevelop systems with absolute effectiveness while allowing for the co-evolution of human species with other species (Lyle, 1994) with a net positive approach to sustainability that departs from the dominant sustainability narratives (Cole *et al*., 2012; Robinson & Cole, 2015). It seeks to create systems that integrate the needs of society with the integrity of nature through processes that restore, renew and revitalize their own sources of energy and materials. Regenerative design acknowledges that humans are more entangled with the complex systems of environment and the biosphere than the conventional mode of linear cause and effect thinking, which argues that the best design guides for regenerating our environments are ecological principles i.e. the fundamental laws inherent to the natural world (Vester, 2004). Furthermore, regenerative design is a system of technologies and strategies based on an understanding of the inner workings of ecosystems to generate designs that regenerate rather than deplete underlying life support systems and resources within socioecological wholes, while regenerative development refers to technologies and strategies for generating a patterned whole-system understanding of the self-evolving and self-organizing capacities of a 'place' (Mang & Reed, 2012a, b; Reed, 2007).

Thus, regenerative design and development investigates how humans can participate in ecosystems through development to create optimum health for both human communities (physically, psychologically, socially, culturally and economically) and other living organisms and systems (Jenkin & Pedersen, 2009). It can be aptly said that regeneration is more about a process of engagement than a set of outcomes and this process of engagement has significant environmental, economic, social and cultural benefits (Jenkin & Pedersen, 2009). By ensuring that human and natural systems are adequately coordinated to produce positive impacts (Akturk, 2016), it emphasizes the importance of the unique and diverse human and non-human elements of each ‘place’ (socioecological systems) (Cole *et al.*, 2006). The idea of ‘place’ is a way for people to envision the unity of humans and natural systems (Mang *et al.*, 2016; Zari & Jenkin, 2010). In each ‘place’ on earth, natural and cultural systems express themselves uniquely and differently and this implies that sanitation systems should be tailored to the unique characteristics of the ‘place’ by exploring the opportunities and solutions that are indigenous to the specific ‘place’. Regenerative design and development asserts that development can and should contribute to the capacity of all natural, cultural and economic systems that affect a ‘place’ (to grow and evolve their health and ongoing viability), as shown in Figure 1.2.

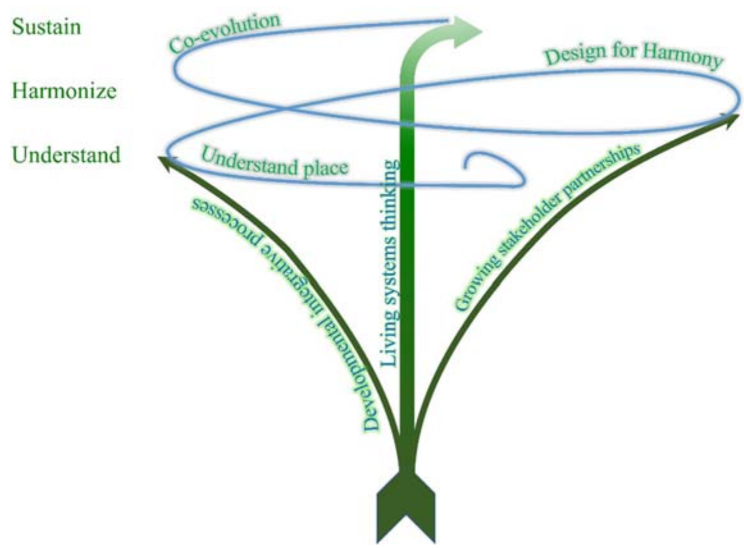

Figure 1.2 Overall framework of regenerative development and design (*Source*: Mang & Reed, 2012a).

Figure 1.2 depicts the three regenerative design and development phases – understanding/conceptualizing right relationship to ‘place’, design for harmony and co-evolution and three development processes of growing stakeholder partnerships, living systems thinking and integrative developmental processes – that are ke to creating and sustaining the holism required to actualize the concept (Mang & Reed, 2012a, b). According to Lyle (1994), the regenerative concept replaces the present linear system with cyclical flows and provides for continuous replacement through self-functional processes of the energy and materials used in its operations. In the functional order of natural ecosystems, materials are always reused through the process of conversion, distribution, assimilation, filtration, storage and production to continue their roles in nature’s cycle. There are strong links between the concept of regenerative design, development and sustainability with current calls for systemic, holistic and integrative sanitation solutions and management.

A shift from the reductionist-mechanistic worldview (Renger *et al.*, 2015) of previous and current approaches to sanitation to an ecological-systemic worldview that embraces the complex and dynamic nature of sanitation is suggested, whereby interacting units are integrated and inter-synergistically linked for improved performance. This will shift the focus of users and service providers from toilets and treatment systems to a true integration of human dimension that will provide more adaptive and comprehensive, improved sanitation solutions. It is interesting to note that sanitation systems are complex processes and interactions between physical, social, economic, technological and ecological components, which interlink and influence each other (Mele *et al.*, 2010; Seadon, 2006, 2010; Tilley *et al.*, 2014a, b). In addition, it is not the sanitation infrastructure itself that is regenerated in the literal sense of self-healing and self-organizing attributes, but the acts of providing sanitation solutions such as technology, psycho-social-cultural contexts, economic and institutional issues as well as resource recovery that are regenerative and provide the needed catalyst for positive change (Robinson & Cole, 2015).

1.2.3 Regenerative agriculture

Regenerative agriculture is a holistic systems approach to agriculture that aims to improve the resources it uses and avoid resource depletion and destruction. It is designed to improve soil health and restore degraded soil biodiversity through organic practices such as, among others, residual mulching and composting (Rodale Institute, 2017). It is assumed that regenerative agriculture, also called regenerative organic agriculture practices, could positively impact carbon and water cycles, integrate crop farming with animal farming and increase biodiversity and ecosystem health and resilience as well as improve soil fertility and total health (Rodale Institute, 2017). Core principles of regenerative agriculture resonate with the call for change in sanitation perspectives, especially in working with wholes and not parts, context-specific designs and holistic decisions; and focus on the specificity of the 'place' and integrating crop and animal farming to mutual benefits. Regenerative agriculture is a relatively new paradigm in the field of agriculture that borrows largely from the general living system theory, agro-ecology, organic agriculture, permaculture and holistic management (Rodale Institute, 2017).

1.2.4 Regenerative economy and capitalism

Proponents of regenerative economy are focused on designing an economic and investment model that serves humanity while also preserving the ecosystem. It is a shift towards an ecological systemic, holistic and integrative worldview and paradigm with principles that focus on the peculiarities of place, cooperation between man and the earth's system, empowered participation and wholeness (Brown & Garver, 2008; Lietaer *et al.*, 2012). According to Fullerton (2015) regenerative economy should promote and sustain human prosperity and well-being in an economy of permanence because economic sustainability cannot simply depend on measuring designed outputs; economy and financial systems should be based on principles that ensure enduring system health. In addition, reliable inputs and healthy outputs are to be maintained by preserving and protecting all key parts of the broader societal and environmental systems of the economy as well as strengthening human networks to preserve vitality and resilience. One argument that connects with the new thinking on sanitation is that regenerative economy does not argue for or against capitalism or socialism, just as there are no arguments for decentralized or centralized sanitation or even existing frameworks. The aim is to achieve an effective integration of the best of both paradigms with an infusion of an understanding of how natural living systems' principles can be adopted to produce shared vitality and prosperity. In a regenerative economy, the network of human interactions with each other and the natural world is the 'system'.

Therefore, economic and financial growth goes beyond gross domestic product (GDP) or gross national product (GNP) to the presumption that economic vigour is rather dependent on human and societal vitality, rooted in ecological health and the inclusive development of human capabilities and potentials (Fullerton, 2015). It thrives on willingness to learn, adapt to change and continually evolve as a whole system. Regenerative capitalism is the product of a regenerative economy that works with the symbiotically related principles of regenerative economy to determine how to disburse and pursue capital investment.

Five out of these eight principles as enumerated by Fullerton (2015) relate closely to the regenerative concept adapted in architectural design, urban development and agriculture, which were adopted for this work. They include:

(I) Recognizing that humanity is also a part of an interconnected whole inclusive of the ecosystem and all global localities,
(II) Wealth is viewed holistically as it concerns all parts of the whole with all forms of capital,
(III) Innovation, adaptiveness and responsiveness are crucial,
(IV) All parts of the whole are empowered to participate in systems' growth and how they benefit from it, and
(V) Honours community and place by respecting specific peculiarities in ecology, geography, society, culture, history etc.

1.3 REGENERATIVE SANITATION WORLDVIEW

The above regenerative perspectives are derived from a shift in worldviews that has led conceptualization in the same direction. New knowledge, new thinking and new technology are built by developing successful ideas based on a set of premises and values (i.e. paradigms drawn from a worldview), which remain true until they are challenged. Sanitation technological solutions and management need a shift in worldview and paradigmatic conceptions (Du Plessis & Brandon, 2015). To improve the overall sanitation system performance and achieve strong sustainability, a worldview shift is essential from the reductionist-mechanistic linear conventional sanitation worldview to more cyclical-integrated-systemic-ecological perspectives (Marshall & Farahbakhsh, 2013; Thibodeau *et al.*, 2014; Tilley *et al.*, 2014a). A worldview can be described as a collection of concepts, theorems and assumptions that provides a coherent way of looking at and thinking about the world (Aerts *et al.*, 2007; Kearney, 1984) as well as interconnected systems of belief (DeWitt, 2010) that act as a filter through which phenomena are perceived and comprehended (Miller & West, 1993). According to Aerts *et al.* (2007), worldview shapes how individuals interpret and interact with the world around them, defining what can be known or done and how and what goals should be, or whether they should even be pursued (Mang & Reed, 2012a; Koltko-Rivera, 2004).

The reductionist-mechanistic worldview is essentially the Newtonian-Cartesian modern civilization philosophy, operating on the assumption that the properties of the whole can be reduced to and deduced from the sum of the properties of the parts (as is possible with mechanical and other complicated cybernetic systems) and it places a high emphasis on prediction and centralized control to ensure system performance (Du Plessis & Cole, 2011; Heylighen, 2006; Robertson & Choi, 2010). At the core of this worldview is the assumption that the universe as a whole and all of its material components, including living organisms, function like mechanical systems that are governed by universal laws (Benne & Mang, 2015).

The ecological-systemic worldview, on the other hand, draws on an understanding of nature and its processes and relationships (Capra, 1997). It is a much broader concept than that encapsulated in classical ecology or even ecological economics. 'Ecological' implies an understanding that we are dealing with living systems and all that comes with such systems, including connections, flows, relationships, interdependence, evolution and consciousness (Du Plessis & Brandon, 2015). The ecological-systemic worldview emphasizes interconnectedness and its orientation is more holistic in nature, recognizing that a thorough understanding of any system requires knowledge of the nature of the interactions among its parts as well as the nature of its interdependencies with other parts of the larger system being embedded in the whole (Checkland, 1997; Robertson & Choi, 2010). It recognizes the self-organizing capacity inherent in all natural systems (Jantsch, 1980), which are self-managing and self-regulating in that their distinct and diverse parts engage in patterns of interaction that maintain a dynamic equilibrium (Kauffman, 1995) of the whole while emphasizing the co-evolutionary and mutually reinforcing dynamics with their environments (Capra, 2002). The ecological-systemic worldview, which incorporates the general living system theory (von Bertalanffy, 1968), considers systems as integrated wholes and focuses on interactions among the parts and the larger environment in which they are embedded (Robertson & Choi, 2010; Unsal, 2016).

Sanitation systems designed from the reductionist-mechanistic worldview normally optimize the efficiency of the individual constituent elements by identifying discrete performance requirements, setting specific measurable goals and targets and following designated formulas, rules and criteria. The sustainable performance of the whole is optimized by aggregating the solutions for the different parts and generic technocentric design, and top-down solutions and approaches are prescribed to similar circumstances with accommodations for regional distinctions and cultural differences. Humans are often seen as outsiders from nature and are responsible for being good stewards of natural resources and protecting them from harmful human activities through conservation activities. These approaches do not recognize or leverage the interconnectivity and dynamic nature of socio-ecological systems, and thus have limited impacts on the sustainability, vitality and resilience of the systems (Benne & Mang, 2015). Meanwhile, designing sanitation solutions from the ecological-systemic worldview is based on concepts, designs and processes that draw on an understanding of the unique dynamics and potential of how life works in a 'place' and of the distinctive role and value-contributing potential of the sanitation systems (Benne & Mang, 2015). Thus, the ecological-systemic worldview seeks to provide better understanding of the knowledge of interconnections among the sanitation subsystems, dimensions and components as well as holistically integrating methodologies that address the interlinkages of the sociocultural, environmental, economic and technical spheres (Marshall & Farahbakhsh, 2013). It adopts an integrated perspective that addresses improved sanitation planning, takes advantage of economic opportunities, incorporates specialized and appropriate technology and follows up with behavioural change, which could ensure access and sustainable use as well as operations and maintenance of sanitation intervention (Tilley *et al.*, 2014a).

However, the ecological-systemic worldview does not necessarily negate the reductionist-mechanistic worldview, but adds to the knowledge base by providing a different perspective that reveals different types and kinds of knowledge to improve sanitation services. Both worldviews could provide valuable insights when applied within the appropriate context of analysis and its realm of validity (Du Plessis & Brandon, 2015; Wilber, 2000). The knowledge and laws of sanitation systems revealed by the reductionist-mechanistic worldview are still immensely useful when it comes to engineering and technology, while the ecological-systemic worldview works towards ensuring systemic and holistic integration of all sanitation components without separating technology from the economic and psycho-social contexts (Altaf, 2011; Du Plessis & Brandon, 2015; Nilsson & Olsson, 2014). This book proposes the ecological-systemic worldview as an overall worldview that incorporates the necessary principles from the reductionist-mechanistic worldview so as to come up with regenerative sanitation technology and management solutions.

1.4 PARADIGMS OF SANITATION

Consequently, a shift in worldview will also cause a shift in paradigm and recent years have seen an increase in discussion and debates about a paradigm shift in sanitation management. From the conventional traditional linear sanitation technological approaches of 'flush and discharge' or 'drop and store'

(Andersson *et al.*, 2016a, b; Esrey, 2001) to more systemic-integrated approaches between physical, pyschosocial, economic, ecological and technological aspects (IWA 24:2016; Marshall & Farahbakhsh, 2013; Schübeler, 1996; Seadon, 2006; Spaargaren *et al.*, 2007, van Vliet *et al.*, 2011). A paradigm is a subset of a worldview that provides accepted models or patterns of ideas or basic assumptions (within the context of that worldview) about how something should be perceived, thought about, valued, done or made (Benne & Mang, 2015; Harman, 1970). It is also an agreed way of thinking about the world or an agreed set of valid approaches to investigating a scientific and technological phenomenon (Pahl-Wostl *et al.*, 2011). It provides insights into what is to be observed and scrutinized, kinds of research questions to ask and answer, how questions are to be structured and how results of scientific investigations are to be interpreted (Halbe *et al.*, 2013; Kuhn, 1962). Paradigms also provide an intellectual and operational environment for scientific and technological research to take place and shape the nature of the problems to be addressed (Leclerc, 2005; Pahl-Wostl, 2011).

In this case, sanitation paradigms (SaPs) are the different accepted forms and approaches of conceptualizing and handling sanitation management and technology over the years. A SaP trails processes and systems development for research, technology and management design and implementation of sanitation solutions and services. Most existing SaPs are technocentric, resource-oriented, service-oriented, hygiene-focused, water-quality-focused, participatory-focused and behavioural-change focused. There have, however, been calls for a paradigm shift, especially with the dismal results of the sanitation targets in the MDGs. The rationales for this call for a paradigm shift include:

(I) Sanitation systems are increasingly recognized as complex and integrated in processes between physical, social, economic, ecological and technological aspects (IWA 24:2016; Marshall & Farahbakhsh, 2013; Schübeler, 1996; Seadon, 2006; Spaaragaren *et al.*, 2007; van Vliet *et al.*, 2011);

(II) Contextual factors such as culture, economy, institutional control and climate are considered as critical elements that can affect public acceptance of technical and infrastructural feasibility for innovation (Domènech & Saurí, 2010; Larsen *et al.*, 2010; McConville *et al.*, 2014; Whittington *et al.*, 1993);

(III) Technological development processes and approaches are now highly contextual and dependent on a number of sociocultural-economic and ecological factors (Balkema *et al.*, 2002; Hegger *et al.*, 2007; McConville *et al.*, 2014; Raven, 2007);

(IV) Nature-based solutions such as ecological engineering and eco-technologies are known to represent plausible sustainable approaches for solving global sanitation problems, especially in the use of constructed wetlands and other ecosystem solutions (Barros *et al.*, 2008; Elzein *et al.*, 2016; European Commission, 2015; Guterstam & Todd, 1990; Lens *et al.*, 2001; Mahmood *et al.*, 2013; Nesshöver *et al.*, 2017; Polprasert & Koottatep, 2017; Vymazal, 2005; Wu *et al.*, 2016);

(V) Governance is considered a critical success and supporting mechanism that provides the enabling environment for effective and efficient service delivery, and financing sustainability (Hallerod *et al.*, 2013; Joshi *et al.*, 2015; Rodic, 2015; Schertenleib, 2005; Speer, 2012);

(VI) Resource recovery and reuse are acknowledged as key components of comprehensive integrated sanitation solutions with the potential for natural resource conservation, and have the capacity to leverage the long-term efficacy of treatment schemes and livelihood support (Benetto *et al.*, 2009; Cofie *et al.*, 2016; Hu *et al.*, 2016; Keraita *et al.*, 2014; Murray & Buckley, 2009; Nikiema *et al.*, 2014; Otoo *et al.*, 2016; Rao *et al.*, 2016; USEPA, 2012; Werner *et al.*, 2009; WWAP, 2017);

(VII) Technology-based indicators for determining 'improved' and 'unimproved' sanitation instead of functional-service-based indicators constrain innovation (Banerjee & Morella, 2011; Domènech & Saurí, 2010; Kuznyetsov, 2007; Kvarnström *et al.*, 2011; Larsen *et al.*, 2010; McConville *et al.*, 2014; Potter *et al.*, 2011; Sutton, 2008; van Vliet *et al.*, 2011; WSP, 2008); and

(VIII) Inadequate and dysfunctional sanitation infrastructures are due to structural failures, material degradation, poor construction and workmanship as well as ageing facilities and lack of appropriate operations and maintenance (Brikke, 2000; Brepolsa *et al.*, 2008; Cookey *et al.*, 2016). These dysfunctionalities and inadequacies are costly for society and its economic impacts are estimated to cost 18 African countries a colossal sum of USD 5.5 billion per year (Bartram & Cairncross, 2010; Bos & Gijzen, 2005; Cheng *et al.*, 2012; Ekane *et al.*, 2014; Fewtrell *et al.*, 2005; Pruss *et al.*, 2002; Prüss-Üstün *et al.*, 2008; UNDP, 2006; WSP, 2014; Yardley, 2010). Strategic and innovative plans and programmes to retrofit these systems could accelerate the targets of SDG no. 6 on sanitation.

The major paradigms that have influenced sanitation research, science, technology, management, policy and practice have graduated from one level to another and produced several kinds of technological solution (Cooper, 2001; O'Reilly *et al.*, 2017; Persson, 2017; Zeldovich, 2017). These sanitation paradigms include: conventional sanitation paradigm (sanitation 1.0); ecological sanitation paradigm (sanitation 2.0); and sustainable sanitation paradigm (sanitation 3.0).

1.4.1 Conventional sanitation paradigm (sanitation 1.0)

The conventional paradigm approach to sanitation falls under the category of either waterborne 'flush and discharge' or dry 'drop and store' (Werner *et al.*, 2009) systems technology based on the linear flow premise that excreta is waste suitable only for disposal, which makes recycling impossible (Andersson *et al.*, 2016a, b; Esrey, 2001) (Figure 1.3).

Although there are innovative approaches within this system incorporating resource recovery and reuse as incremental improvement strategies, paradigm shifts are being advocated for overcoming these challenges, especially through the adoption of integrated sanitation solutions that go above and beyond the focus of technology (Geels, 2006; Larsen, 2011; Marshall & Farahbakhsh, 2013; Otterpohl, 2002; Thibodeau *et al.*, 2014; Tilley *et al.*, 2014a; Zeeman, 2009).

1.4.2 Ecological sanitation paradigm (sanitation 2.0)

The ecological paradigm approach to sanitation is based on an overall view of material flows of the 'closed-loop system' designed for incremental progression over the conventional systems (Mang & Reed, 2012a; Werner *et al.*, 2009) (Figure 1.4). It can also be described as a resource-oriented, ecological and source separation-based sanitation approach. It is a reconceptualization of conventional sanitation from 'flush and discharge' to 'drop and reuse' models (Haq & Cambridge, 2012; Hu *et al.*, 2016; Langergrabera & Muelleggera, 2005) and is designed to close the nutrient loop between sanitation and agriculture even though the technologies are not ecological per se (Esrey, 2001; Langergrabera & Muelleggera, 2005; Werner *et al.*, 2004, 2009). The major drawback is basically the cost and cultural constraints on the usage of treated excreta and sewage (Hu *et al.*, 2016). In any case, it is still based on the reductionist-mechanistic worldview of the conventional sanitation paradigm and so focuses on technology and the back end of the loop.

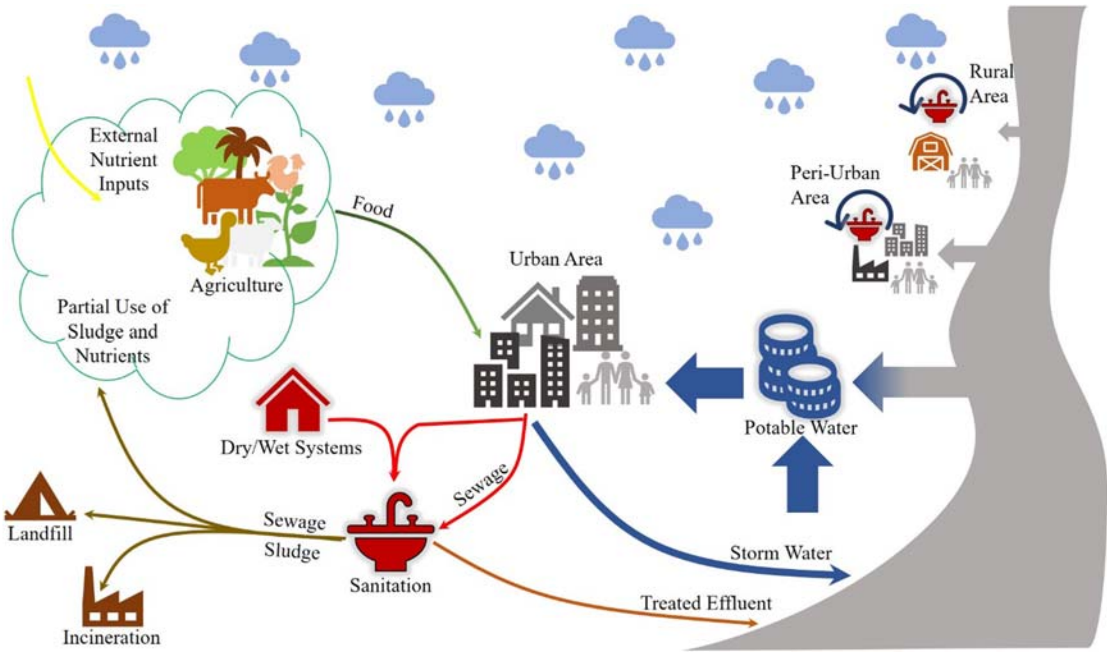

Figure 1.3 Conceptual diagram of conventional sanitation. Arrows are non-quantitative representations of resource (water, nutrients, organic matter) flows associated with conventional sanitation and connected processes (*Source*: GTZ, 2002).

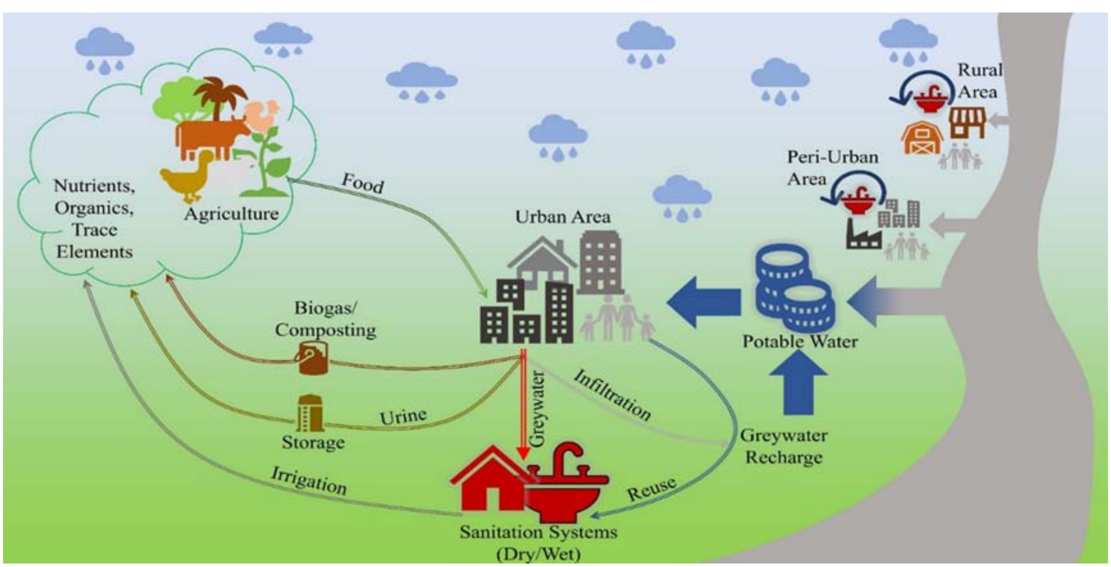

Figure 1.4 Conceptual diagram of ecological sanitation/source separation and decentralization. Arrows are non-quantitative representations of resource (water, nutrients, organic matter) flows associated with sanitation and connected processes (*Source*: GTZ, 2002).

1.4.3 Sustainable sanitation paradigm (sanitation 3.0)

The sustainable sanitation paradigm recognizes not only technology, but also social, environmental and economic aspects of sanitation (SUSANA, 2008). It includes means of recycling human excrement that have no negative impact – or even a positive impact – on local and global resources (Brands, 2014). Its core principles include: human health protection, affordability, environmental sustainability and institutional appropriateness (Chinyama *et al.*, 2012; Mara *et al.*, 2007). Sustainable sanitation aims to address the challenges of conventional and ecological sanitation by adopting the generic principles of sustainable development (SD), but it is constrained by oversimplification of complex dynamic problems such as sanitation technology and management (Marshall & Farahbakhsh, 2013). Sanitation sustainability cannot be achieved in the absence of the whole-system thinking and fit-for-purpose solutions that can only be found by addressing challenges at a system level to reveal mutually inter-synergistic advantageous interactions as well as undesirable ones (Anarow *et al.*, 2003; Rocky Mountain Institute, 2006) (Figure 1.5).

Figure 1.5 Key sustainability dimensions in sustainable sanitation management. (Adopted from Andersson *et al.*, 2016a, b).

1.4.4 The paradigm shift

Several scholars and practitioners have suggested the need for a paradigm shift towards holistic, integrated, multidimensional-transdisciplinary perspectives (Galli *et al.*, 2014; Marshall & Farahbakhsh, 2013; Seadon, 2010; van Vliet *et al.*, 2011; Zeeman, 2009). Some proposed nomenclatures for this new paradigm, but did not really come up with a clear framework to guide this transition. For instance, Agudelo-Vera *et al.* (2012), Swart and Palsma (2013) and Wielemaker *et al.* (2016) called it 'new sanitation' (or in Dutch 'nieuwe sanitatie'); Fan *et al.* (2017) proposed 'sanitation 2.0'; Heggar *et al.* (2007) and van Vliet *et al.* (2010, 2011) named it 'hybrid or modernized mixture'; Verstraete *et al.* (2009) and Nansubuga *et al.* (2016) suggested 'cluster decentralized systems' and Marshall and Farahbakhsh (2013) and Tilley *et al.* (2014a) proposed 'integrated approach'; while Galli *et al.* (2014) suggested 'whole-system approach'. Evidently, the need for a paradigm shift in the field of sanitation technology and management is long overdue. To this effect, a paradigm shift towards regenerative sanitation is proposed to capture the essence of the change advocated beyond technology. The word 'regenerative' here implies complete revitalization and rejuvenation of the entire sanitation system to improve service and expand access as well as a deliberate partnership with nature (Figure 1.6).

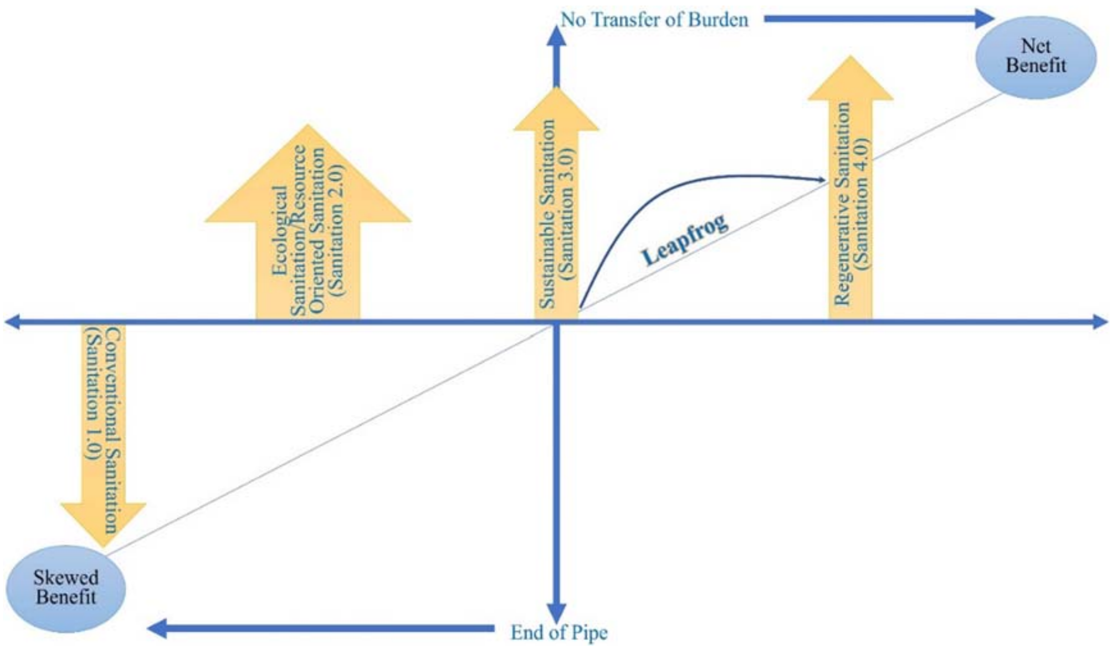

Figure 1.6 Trajectory of sanitation paradigms.

Figure 1.6 shows the progression of paradigms that influenced design and infrastructure solutions for sanitation management over the years and presents a new paradigmatic influence for the future of sanitation. The paradigms are grouped into four levels (Sanitation 1.0–4.0) and fall between two divides i.e. 'end-of-pipe to skewed-benefits' and 'no-transfer-of-burden to net benefits'. On the lower left, the conventional sanitation paradigm (Sanitation 1.0), which was mainly based on the reductionist-mechanistic worldview, focused on end-of-pipe technologies that produced benefits skewed towards environmental and public health only. Subsequently, incremental progress led to the concepts built from the ecological sanitation paradigm (Sanitation 2.0), which found it difficult to move beyond pilot-scale levels due to psycho-social challenges, and then the sustainable sanitation paradigm (Sanitation 3.0) based on the concept of maintaining the status quo (i.e. no harm-no gain) whereby focus is on ensuring that sanitation practice does not cause harm without seeking any gains from it. However, in spite of the ecological and sustainable paradigms, the reductionist-mechanistic worldview persisted and focus remained on end-of-pipe technologies with skewed benefits. Consequently, the regenerative sanitation paradigm (Sanitation 4.0) is proposed as a holistic, integrated and systemic management of all sanitation components (and not just technology) to ensure no-transfer-of-burden on environmental and public health and deliver net benefits to areas including agriculture, aquaculture, economies and livelihoods.

1.4.5 Regenerative sanitation paradigm (sanitation 4.0)

The paradigm of ReGenSan, called sanitation 4.0, does not aim to present an undebatable truth (Meadows, 1999), but addresses the need for a change in the way sanitation is viewed considering the growing and seemingly giant-like challenges of 2030 and beyond. It is about learning new ways, seeking fresh answers from old ways, adapting to change with resilience and flexibility, thinking before acting and working to integrate and synergize the whole process of sanitation management into a whole system (and not just working from individual parts). The ReGenSan paradigm (sanitation 4.0), therefore, is conceptualized based on the principles of systemic internal processes for restoration and sustainability and addresses sanitation as a comprehensive and holistic integrated system incorporating all the unique characteristics of sanitation management from the starting point of a specific and peculiar 'place' (location). It sees sanitation as resource/service management rather than problem management. At its core is a process trail that works from within the system and the peculiarities of the 'place' to ensure resilience and adaptability. ReGenSan is at the same time a paradigm, framework and perspective for sanitation solutions. The overall aim of ReGenSan is to refocus the perspectives of researchers, professionals, practitioners, advocacy agents, policymakers and solution-providers from attacking a problem (of health, hygiene and water quality) to providing services and solutions; and ultimately, expand access as well as improve service towards achieving SDG no. 6 by 2030. The corresponding conceptual framework presented in this book is designed to reflect the process for the kind of sanitation practice that would fulfil this ambitious goal. It is hoped that this conceptualization will contribute to the success of sanitation management globally.

1.5 SANITATION CONCEPTUAL FRAMEWORKS

Concepts towards providing solutions or understanding phenomena are derived from existing paradigms. A conceptual framework is a domain-specific language tailored to a specific knowledge area or study discipline (Abelson & Sussman, 1987; Bentley, 1986; Hinkel *et al.*, 2014; Hudak, 1998). The elements of a framework are concepts, which are terms associated with a meaning and the conceptual relationship between them (Hinkel *et al.*, 2014). Therefore, a conceptual framework facilitates the exchange of arguments about a knowledge domain through having clear and unambiguous accounts of the concepts at stake and their relationships (Hinkel, 2008; Ionescu *et al.*, 2009; Wolf *et al.*, 2013). Sanitation conceptual frameworks (SCF) provide the premises and the parameters for research, investigations, interpretation, programme development and implementation of action plans for improving service and expanding access to meet SDG no. 6 by 2030.

A SCF will lay out key factors, constructs or variables, and presume the relationships among them (Campbell *et al.*, 2015; Miles & Huberman, 1994), as well as provide a template used for acknowledging and organizing the elements of related systems of interest to support further investigations. They will also illustrate the connected parts and potential interdependencies between broad system variables (Binder *et al.*, 2013; Repella, 2014) and support the formulations and comparisons of hypothesis, models and theories as well as provide general sets of concepts assumed to be applicable to the whole (Ostrom, 2005). The goal of such framework development is to stay as neutral as possible to allow the representation of different theories within the framework (Hinkel *et al.*, 2014). It is, therefore, expedient to investigate and understand some existing conceptual frameworks in the field of sanitation, such as:

(I) Sanitation ladder – the most popular and one of the oldest, which has been used in many forms and cases ranging from toilets/latrines provision, full service chain delivery, hygiene behaviour, human right issues, financing sanitation, latrine ownership and MDG/SDG Joint Monitoring

Programmes as well as in the community-led total sanitation for the eradication of open defecation (Exley *et al.*, 2014; Gine *et al.*, 2011; JMP, 2010; Kar & Chambers, 2008; Kvarnström *et al.*, 2011; Obeng *et al.*, 2015; O'Reilly *et al.*, 2017; Potter *et al.*, 2011; Verhagen & Carrasco, 2013; WHO/UNICEF, 2017);

(II) Sanitation service chain – used in the analysis of physical flow of faecal waste through sewered and non-sewered systems, development of faecal waste flow matrix and diagrams to summarize city- or community-level outcomes and highlight bottleneck in faecal waste management. It is also used for business analysis of faecal sludge management and in the development of the global sanitation service technology filter tool (Blackett *et al.*, 2014; Chowdhry & Kone, 2012; Rao *et al.*, 2016; Strande *et al.*, 2014; Trémolet & Rama, 2012; USAID, 2016; WSP, 2014).

(III) Decision support – used in designs, testing, selections, sustainability and performance modelling of technologies from centralized to decentralized sanitation systems (Kalbermatten *et al.*, 1980, 1982; Katukiza *et al.*, 2010, 2012; Libralato *et al.*, 2012; Loetscher & Keller, 2002; Magid *et al.*, 2006; Maurer *et al.*, 2012; Massoud *et al.*, 2009; McConville *et al.*, 2014; Ramoa *et al.*, 2015; Roefs *et al.*, 2017; Simha *et al.*, 2017; Stenström *et al.*, 2011; Tilley *et al.*, 2014b; Tobias *et al.*, 2017; Zurbrügg & Tilley, 2007, 2009);

(IV) Designing for service – focused on resource utilization options for sanitation systems. These include concepts that deal with resource-oriented sanitation, recovery and reuse, integrated resource management, cradle-to-cradle, ecological sanitation and circular flow as well as recirculation of nutrients and organic matter (McDonough & Braungart, 2001a, b; Brands, 2014; Hodges, 2006; Langergrabera & Muelleggera, 2005; Larsen *et al.*, 2009, 2011; Murray & Buckley, 2009; Wang *et al.*, 2006; Werner *et al.*, 2009; Wilsenach *et al.*, 2003; Wielemaker *et al.*, 2016);

(V) Spatial planning diagnostics – provides approaches and methodologies for detailed assessment of sanitation situations of regions, cities, urban, formal and informal settlement as well as rural areas to determine appropriate levels of intervention activities for programme implementation (ASHWAS, 2011; Bright-Davies *et al.*, 2016; GHK Research & Training, 2000; ISF-UTS & SNV, 2016; IWA, 2014; Kerstens *et al.*, 2016; Lüthi *et al.*, 2011a, b; Parkinson *et al.*, 2014; Schmitt *et al.*, 2017);

(VI) Equity and inclusion – designed to improve access to sanitation services for the society's vulnerable groups and people with disabilities (Desai *et al.*, 2016; Gosling, 2010; Patkar & Gosling, 2011);

(VII) Behavioural change – this software tool is used in various sanitation, hygiene and handwashing programmes, community-led total sanitation (CLTS) as well as sanitation solutions adoption and uptake (Dreibelbis *et al.*, 2013; Dwipayanti *et al.*, 2017; Kar & Chambers, 2008; Kvarnström *et al.*, 2004; O'Reilly & Louis, 2014; Peal *et al.*, 2010; Whittington *et al.*, 1993); and

(VIII) Capacity development assessment – designed to assess effectiveness and efficiency of sanitation capacity development programmes (Barat *et al.*, 2014; Crocker *et al.*, 2016; Gunawardana *et al.*, 2013; Mvulirwenande *et al.*, 2013; Ngai *et al.*, 2014; Pascual Sanz *et al.*, 2013).

These conceptual frameworks, however, are primarily technocentric and basically designed for implementation of conventional sanitation and to some extent ecological sanitation paradigms. Furthermore, there are no specific frameworks for governance and participation in sanitation management. Therefore, a holistic, integrated and systemic sanitation conceptual framework that embraces the complexities inherent in providing sanitation solutions rather than simplistic recipes is demanded to enhance access expansion and improved service delivery (Meinzen-Dick, 2007; Pahl-Wostl, 2007; Pahl-Wostl *et al.*, 2010). Hence, the main contribution of this book is to provide such a framework (or model) known as the regenerative sanitation framework, which is not technocentric and toilet-latrine-focused but where all key critical aspects of sanitation subsystems, dimensions and components are interlinked for total rejuvenation and revitalization of the whole spectrum of sanitation management systems as well as for the development and implementation of innovative solutions. Providing comprehensive sanitation solutions for the current global challenges depends not only on availability of technology, but also on many other factors like management of sanitation delivery, quality of institutions that manage them, prevailing psycho-socio-cultural, economic and ecological conditions that influence sanitation planning, technology design and development, management processes and practice, as well as financial and governance mechanisms (Starkl *et al.*, 2015; Tilley *et al.*, 2014a; Zurbrugg & Tilley, 2009).

Sanitation in this book is used to mean the systemic integration of measures for managing human waste in a safe and resourceful pattern adapted to fit specific and peculiar contexts (Box 1.5). It is a systemic integration in that it flows from the 'place' of human interactions (pyschosocio-cultural-economic) with the ecosystem (ecological, bio-geo-physical) to interconnect with the governance (institutional, policy and regulatory mechanisms), resource recovery (recovery and reuse of excreta/urine-flushed water i.e. black and greywater) and technology (infrastructure-utilities) to improve service delivery and access expansion.

BOX 1.5 IN SUMMARY

Sanitation is the treatment and management of by-products of human digestion.

The issue at present is not whether such an approach is desirable, but rather how can this be achieved in the real world? The central idea is the need for broader integration with all the system components of sanitation, minimized transport, local orientation, hybridization of centralized and decentralized systems, source separation and resource recovery, management and governance (Agudelo-Vera *et al.*, 2012; Larsen & Maurer, 2011; Lens *et al.*, 2001; Kujawa-Roeleveld & Zeeman, 2006; Larsen *et al.*, 2009; Maurer *et al.*, 2012; Nansubuga *et al.*, 2016; Tchobanoglous & Leverenz, 2013; van Vliet *et al.*, 2010, 2011; Zeeman, 2012).

1.6 CHANGE IS IMPERATIVE

For the SDG to do better than the MDG in sanitation, new strategies and concepts must be developed. ReGenSan offers a new perspective in debates at various levels on sanitation and its management towards the need for a paradigm shift. Nevertheless it is not quite new per se, as shall be seen in subsequent chapters, but builds on the strengths of historical successes in combination with an understanding of current trends to offer a new kind of prerogative outlook. It attempts to avoid the argument of what is wrong or right, but weaves around existing concepts and ideas to create an integrative system to guide thoughts towards greater and enduring successes.

In addition, instead of seeing sanitation as a problem or rather a storehouse of resource, it views sanitation as an entity in itself that is resourceful, with psycho-social, economic, cultural and ecological angles that could support livelihood and societal interactions. In fact, a sanitation economy could be envisaged in that there will be producers, consumers, service providers, policymakers and regulators. ReGenSan works as a complex and dynamic phenomenon that is influenced by society, livelihood, status, economy, culture, tradition, geography and ecology, all of which can change gradually or suddenly. This implies the need for continuous and constant change to match the changes in society, geography and ecology, especially with climate change and livelihoods concerns.

1.7 EXERCISES

(I) What is the regenerative sanitation paradigm and how does it differ from the other pre-existing paradigms?
(II) What is the relationship between the ecological-systemic worldview and the regenerative paradigm and how does it support the regenerative sanitation concept?
(III) How does regenerative sanitation relate to:
  (a) Regenerative science and medicine
  (b) Regenerative development and design
  (c) Regenerative agriculture
  (d) Regenerative economy and capitalism
(IV) What are the common features in the five fields above and how are they uniquely applied?
(V) Why do you think the conventional sanitation paradigm has been predominant through the years?
(VI) Why do you think sanitation solutions have been more technology-focused and less systemic-holistic-integrative in all pre-existing paradigms?
(VII) What worldview and paradigms are the highlighted conceptual frameworks (and any others you can identify) based on, in your opinion, and why?
(VIII) In your opinion, why do we need a paradigm shift in sanitation? How will this affect the provision of sanitation services and infrastructure? What are the possibilities of such a shift and its impact on the way sanitation is perceived and addressed? And how will this affect sanitation technologies?
(IX) Where do you see technology design and development in a concept like regenerative sanitation? What do you think is involved in the design process of sanitation technologies in a regenerative future?
(X) Do you agree that change in the way of sanitation is handled is imperative if we are to meet SDG no. 6 goals and targets for sanitation by 2030?
(XI) How do you think regenerative sanitation can impact the sanitation targets of SDG no. 6?
(XII) What determines the dynamics of a transition from the reductionist-mechanistic conventional sanitation paradigm to a more systemic, holistic and integrative technological and management solution? What are the barriers and the drivers needed for this transition?

1.8 RECOMMENDATIONS FOR FUTURE RESEARCH

There are a number of knowledge gaps around the application of the concept of regenerative design and development in sanitation research; therefore further research is needed for better understanding of the ReGenSan concept:

(I) Investigate the ways worldviews and existing paradigms affect sanitation management and technology design.
(II) Empirical investigation of existing sanitation conceptual frameworks to determine their efficacy, effectiveness, efficiency and fitness for purpose as well as optimization.

(III) Explore the possibilities of the interlinkages between the existing frameworks for synergistic results.
(IV) Explore further research on pre-existing paradigms as well as research to deepen understanding and create a mix for conceptualization.
(V) Critical review to determine the meaning of sanitation, what it entails, how it works and its impacts on humanity and ecosystem.

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