Linkages between Sanitation and the Sustainable Development Goals: A Case Study of Brazil

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Abstract

This paper identifies opportunities from targeted and integrated sanitation action to achieve the Sustainable Development Goals (SDGs). This is contextualised to the case of Brazil through a systematic approach applied to the sanitation sector that considers the range of infrastructure, management services and people involved in different phases of the service chain, from municipal wastewater containment to safe disposal or re-use. Articulating the social, economic and environmental dimensions of sanitation, this study analyses their links with each of the 169 SDG targets. We demonstrate that 87 targets across 16 goals require action in Brazil's sanitation sector to achieve the SDGs. Furthermore, we identify synergies between sanitation and 124 targets in four domains: basic services for resilience building, equity and empowerment, pollution reduction and waste reuse, and economic well-being. Key results include the need for Brazil to invest in closed-loop systems that valorise waste as a resource, and the need to multiply efforts in the integrated provision of basic services in low-income areas most affected by the lack of access to adequate sanitation. The links identified are supported by the compiled evidence of published research. The analysis of linkages through this structured approach aims to highlight opportunities for strategic governance action to support policy harmonisation and partnerships across Brazil's sanitation sector and beyond. With this research, we show that establishing linkages among the SDGs provides an adaptable framework that can support policy-makers and practitioners seeking to deliver on the 2030 Agenda.

1. Introduction

Sanitation still receives limited attention despite the wide-ranging positive impacts it can achieve in social, economic and environmental development. We argue that where poor sanitation conditions persist along the 'service chain' (i.e. containment, transport, treatment, reuse or disposal), they hinder many other sustainable development achievements. Sanitation deficiencies also have inherent socio-political complexities. Where sanitation services are lacking, they often reflect patterns of exclusion of particular segments of the population (Rusca, Alda-Vidal, & Kooy, 2017). Annually, inadequate sanitation is estimated to kill 432,000 people globally through diarrhoeal diseases, which particularly affects more vulnerable populations (WHO, 2019). Furthermore, the unsafe disposal of human waste into the environment represents an ecological concern which affects land and marine ecosystems, and disrupts biodiversity over the long-term. In economic terms, LIXIL, WaterAid and Oxford Economics (2016) reported that, globally, sanitation service gaps cost US$222.9 billion in 2015 in relation to mortality, healthcare expenditures and productivity losses.

In Brazil, sanitation is one of the bases of what defines 'public health', encompassing services and infrastructure for drinking water supply, wastewater collection and treatment, drainage and solid waste management (Ministério das Cidades, 2014). In 2014, the Ministry of Cities set an objective to achieve at least 92% access to safely managed sanitation by 2033, which means improving sanitation access for about 200 million people (Ministério das Cidades, 2017). Brazil's voluntary national review on the SDGs stated:

> *"Ensuring access to basic sanitation – sewage treatment and solid waste management – should receive significant attention, as it is the most frequent type of environmental degradation in Brazilian cities and has very adverse impacts on the health of the population"* (Government of Brazil, 2017, p. 74).

As of 2020, the sewage of over 100 million of people (52% of the total population) is still not treated and disposed into the environment (Whately, Lerer, & Jardim, 2020). Sanitation problems continue to persist to the point of hindering the country's potential to pursue other development goals.

While sanitation inadequacies have created many barriers in Brazil, we argue that taking action to address these gaps can unlock many opportunities. For this, the Sustainable Development Goals (SDGs) represent a useful set of guiding principles that comprehensively cover 169 interconnected targets arranged around 17 goals. SDG6 to "ensure availability and sustainable management of water and sanitation for all" encompasses targets for both water and sanitation, but is mostly focused on the former. This study is centred on *sanitation,* and is framed around the range of infrastructure and systems managing wastewater along the sanitation chain. This focuses on municipal wastewater, here means the management of domestic liquid wastes. We also frame sanitation around socio-political aspects, including the need for services to reflect the diversity of the population, and reflect on required changes in sanitation governance in order to meet the SDGs.

This standalone and systematic approach to sanitation demonstrates how action on sanitation can be integrated into multiple development pathways set by a range of targets across all SDGs. We examine connections and thereby show how poor sanitation poses obstacles to the achievement of a multitude of sustainable development targets, but also how action on sanitation can unlock opportunities for achieving multiple and wide ranging benefits. We demonstrate how published evidence can support the links between sanitation and the SDG targets, and provide a holistic perspective of these connections to help inform decision-making in sanitation and across sectors. This assessment provides a contextual application of the methodology developed by Parikh et al. (2020) to Brazil, which is particularly relevant to explore specific opportunities and barriers for innovative sanitation interventions that can subsequently help the country achieve the SDGs.

2. Sanitation in Brazil: an overview

The institutionalisation of sanitation services in Brazil started in the 1940s when the government created institutions dedicated to their supply. During the 1950s and 1960s, the characterisation of sanitation as a local service gained importance. The National Water Supply and Sanitation Plan (PLANASA) in 1971 came with a complete restructuring of the system, the centralisation of action and the creation of sanitation companies at state-level. Since 1988, the provision of sanitation services has been recognised as a basic human right according to the Federal Constitution. Furthermore, the Federal Basic Sanitation Law adopted in 2007 introduced what became a key legal instrument to account for the provision of basic sanitation services, defined in Brazil as services of clean water supply, wastewater collection and treatment, stormwater management and urban drainage, and solid waste management (Trata Brasil, 2019). The principle of universalisation is highlighted in the Basic Sanitation Law and in the 2013 National Plan for Sanitation (PLANSAB), and presumes that sanitation services must reach everyone in the country (Ministério das Cidades, 2014). This shows alignments between the Brazilian sanitation agenda and the SDGs which commit to 'leave no-one behind' (Sachs, Schmidt-Traub, Kroll, Lafortune, & Fuller, 2019b).

However, Brazil's sanitation sector is still lagging, and while international reports depict a relatively positive picture of the country's progress towards SDG6, figures need to be understood in context. Official United Nations reports indicate that 86.1% of Brazil's population has access to at least basic sanitation services, meaning access to improved sanitation facilities that are not shared with other households. This differs from the definition of basic sanitation services adopted in Brazil's Federal Law (Sachs et al., 2019b; Sachs, Schmidt-Traub, Kroll, Lafortune, & Fuller, 2019a). UN indicators that tend to focus on the coverage of infrastructure overlook a large part of the sanitation picture when applied to the context of Brazil. Although official reports state that the country would be on track to achieve water and sanitation targets (Sachs et al., 2019a), critical issues remain around waste management

beyond the provision of toilet facilities which evaluation systems and reported data do not necessarily unveil.

Indeed, when it comes to the safe disposal of sewage, and more generally of wastewater, data paint a different picture. In particular, there is a large difference between the proportion of wastewater generated, the proportion of wastewater collected by utilities, and the proportion that is actually treated in Brazil. On municipalities' sewage (i.e. domestic wastewater transported by sewers), the government reports that only 46.3% of the generated sewage is treated[1] (SNS/MDR, 2019). In the North Region of the country, this rate falls to 21.7% (ibid). Only 14% of Brazilian municipalities actually treat 60% (or more) of the sewage they collect and transport (Whately et al., 2020). Around 16% of households use septic tanks, but considering that on-site systems rarely provide legally required treatment, it can be estimated that the sewage of 107 million people are directly disposed of into the environment (ibid). While there are disagreements about these figures, if we also consider rural and industrial wastewater, it is clear that significant quantities of untreated wastewater or sludge end up in the natural environment.

If current practices persist, it is likely that SDG6 will not actually be met in Brazil (Scott et al., 2017). In 2014, the then Ministry of Cities reported that the total investment requirement for sewage infrastructure and services in Brazil would be R$182 billion (US$ 43.6 billion[2]) within the 2014-2033 timeframe (Ministério das Cidades, 2014). Yet, political action is lacking on several fronts. For example, only 32.4% of municipalities have policies for sanitation (Whately et al., 2020). Where they exist and are implemented, municipal plans often suffer from delays, leading to the non-completion of projects and inability to spend public water and sanitation funds (OECD, 2018). The lack of municipal plans for sanitation reinforce inequalities, including among populations in settlements known as *favelas,* where an estimated 11.4-13.6 million people live (Agência IBGE, 2011; da Costa, 2020). Since sanitation access in favelas is intrinsically linked to other issues, such as land tenure and property access, it is essential to consider investment in sanitation alongside other investment needs.

An important obstacle to access to sanitation in Brazil, relates to governance and disagreement about responsibilities between municipalities, state and federal governments and service providers (whether state-owned, private or semi-private). Conflicting roles regarding infrastructure management and lack of supervision in the investments and operations have long caused tensions in the sector (Dias, Rosa, Gomez, & D'avignon, 2018; Leoneti, do Prado, & de Oliveira, 2011). Furthermore, the institutional landscape is in flux; political restructuring including the merger between the Ministry of Cities and the Ministry of National Integration to form the Ministry of Regional Development in 2019; and revisions to sanitation regulatory and decision-making mechanisms, including the Basic Sanitation Law N° 4.162/2019 (Whately et al., 2020). Such changes have led to debate about the efficiency and effectiveness of the sector's governance and have reignited discussion about where decision-making power lies. Analysis of the future of Brazil's sanitation sector is urgently required, which must encompass understanding of how changes will impact other sectors.

3. Methodology

[1] The figure refers to the population of administrative authorities that shared data with the National Sanitation Information System which conducted the study in 2018. These include the large majority of (but not all) the country's *municípios*.

[2] As of 24th January 2020 (https://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To=BRL)

This research identifies links between sanitation and the 169 targets of the 17 SDGs for Brazil. This is based on the methodology developed by researchers from University College London (UCL). It was initially developed by Fuso Nerini et al. (2018) who mapped out links between energy and the SDGs, and by Parikh et al. (2020) who adapted the methodology to sanitation, both at global scale. The present paper builds on these studies through an application of the methodology to a specific context. In so doing, it demonstrates the value of the approach in identifying opportunities for integrated action at scale. It also contributes to the body of research that has explored the way the targets interact with each other, several of which have called for context-specific case studies (see for example Dawes, 2020; Nilsson, Griggs, & Visbeck, 2016; Pham-Truffert, Metz, Fischer, Rueff, & Messerli, 2020; Pradhan, Costa, Rybski, Lucht, & Kropp, 2017; Singh et al., 2018; SuSanA, 2017; Tremblay, Fortier, Boucher, Riffon, & Villeneuve, 2020) and to research on sanitation in the context of Agenda 2030 in Brazil (e.g. P. G. M. de Carvalho, Barcellos, & Marques, 2018; P. Carvalho & Spataru, 2018; Dias et al., 2018; Urbanvinicius et al., 2018).

Our study follows four main steps illustrated in Figure 1. For each SDG target, we explored if there was a call for action in sanitation to achieve the target (Step I). We then examined two-way positive connections with sanitation for each target, i.e. whether action in sanitation could support the achievement of the target, and if achievement towards the target could support sanitation objectives (Step II). We repeated this step to identify negative links or 'trade-offs'. For Step II, we provide at least one publication to support each link identified. The study does not, therefore, analyse the strength of the links identified, nor does it intend to analyse causalities between sanitation and the targets, but rather has the purpose of demonstrating the breadth of connections and thereby lays ground for integrated interventions. Results were reviewed and discussed among the research team for validation (Step III) and compiled in a tabulated spreadsheet (Appendix 1) (Step IV); these steps were repeated until a consensus was reached. The evidence gathered during Steps I and II was found through searches in academic and non-academic online research databases. Academic books and journal articles were prioritised, but conference papers, academic theses and grey literature, such as reports from non-governmental organisation, were also included. Evidence was collected in both Portuguese and English.

We framed sanitation objectives to build on both the UN's objectives (as defined by SDG6 "*by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations*"), and Brazil's institutional definition as set in the Federal Basic Sanitation Law mentioned above. We consider sanitation systems as the range of infrastructure, management services and people (including users) involved in different phases of the sanitation chain. This provides a holistic definition that is applicable to the Brazilian context. Therefore, when asking the question "are there synergies and trade-offs between the target and action in sanitation?", we refer to the range of actions which seek to change sanitation systems managing wastewater in Brazil, from containment to disposal or re-use.

We mostly look into blackwater (urine and faeces) as part of domestic wastewater but also greywater (wastewater from sinks, washing machines, etc.), and stormwater to which it is sometimes discharged into despite the government's legislation calling for the strict separation of domestic wastewater from rainwater. Although Brazilian institutions tend to include solid waste in their definition of sanitation (Ministério das Cidades, 2014; WHO & UN-Water, 2014), we chose to narrow down the study by excluding links with solid waste, and thereby focus on sanitation interventions that relate to human excreta and other liquid wastes. Drainage is considered for situations of sewage meeting stormwater, whether formally or informally, for example to highlight the need for action regarding combined sewer overflows. Beyond the 'hardware', we consider literature that covers 'software' interventions. These

encompass the links between sanitation and its associated social determinants for which we identified literature on topics such as gender equality and community empowerment.

Figure 1: Step-by-step methodology to identify the links between sanitation and SDG targets

4. Results

4.1. Overview of results and the identification of 'domains of action'

The mapping exercise identified 87 calls for action across 16 goals, as well as 124 synergies and 38 trade-offs across all 17 goals. Figure 2 represents the number of linkages per goal, whether in terms of calls for action (blue), synergies (yellow) or trade-offs (red). A much higher number of synergies than trade-offs was identified, thereby demonstrating the potential leverage of action on sanitation . It is worth highlighting the multiple links identified between sanitation and health (SDG3), although some health targets were unrelated to sanitation (e.g. 3.6 on road traffic accidents). No calls for action were identified in relation to SDG7 on energy but positive links with sanitation were found with every SDG7 target, particularly through opportunities to support renewable energy production with the use of human waste. The detailed compilation of results with supporting evidence is presented in Appendix 1.

Based on the social, environmental, and economic aspects of sanitation, and considering the SDG framework as a network of connected targets across the goals (Le Blanc, 2015), the links identified are presented under four domains. Different targets of the same goal were grouped under different domains. Domain 1 includes links related to immediate basic needs, while Domain 2 relates to longer-term equity. Domain 3 encompasses the multiple links between sanitation and environment-related targets, including through pollution control as well as waste recycling. Finally, Domain 4 groups the links between sanitation and economic development, including around objectives for more decent work conditions as well as entrepreneurship. Governance-related targets were categorised separately including those related to policy-making, knowledge exchange and capacity-building mechanisms. These include targets under the overarching goal SDG17 'Partnerships for the goals' (Waage et al., 2015).

The rest of this section provides an overview of key linkages between sanitation and the SDG targets under each of the four domains, as well as under the 'governance and partnerships' separate sub-section. Appendix 1 provides the full list of connections identified. Furthermore, Figure 3 presents examples of targets that are linked to one another (i.e. 'interlinkages') through sanitation. The figure was created to show how different targets have comparable objectives in relation to sanitation under the four domains identified. While the list of connections represented is not exhaustive, it seeks to highlight how integrated approaches that include sanitation can unlock opportunities to achieve one or more targets simultaneously.

Figure 2: Spider-web representation of three types of links between sanitation each goal (calls for action, synergies and trade-offs). The 17 lines linking the centre to the goals range from 1 to 100, therefore circles mark percentages at 20, 40, 60 80 and 100. Note that this representation should not be seen as a comparative qualitative analysis between the goals, but rather as a demonstration of the wide-ranging linkages between sanitation and each of the Sustainable Development Goals.

Figure 3: Selected synergistic SDG interlinkages through the lens of sanitation in Brazil's context. The figure highlights that synergies between sanitation and SDG targets exist for all 17 goals, but also that sanitation interventions can unlock opportunities to achieve targets of different goals at the same time. These identified sets of links are categorised under 4 recurrent domains of action. SDG17 is represented separately as an overarching goal.

4.2. Domain 1: Sanitation and basic services for resilience-building

In Brazil, more than 6% of the population – or about 13.6 million people – live in favelas (Agência IBGE, 2011; F. N. da Costa, 2020). These low-income areas require action in sanitation as the population is typically deprived of vital necessities and exposed to illness, both of which deepen economic vulnerability (Londe, Coutinho, Di Gregório, Santos, & Soriano, 2014). Favelas typically lack sewage systems that would create a barrier between waste and people and the environment (UN-Habitat, 2013). As a result, illnesses, including water-borne diseases, spread rapidly due to shorter transmission routes. Once illness affects productivity, it may reduce household income generation. As healthcare expenditure increases, it can exacerbate poverty; savings (where they exist) decrease, and so do opportunities to invest in sanitation-related goods and services to prevent future illnesses (Medland, Cotton, & Scott, 2015; Moser, 1998). Therefore, poor sanitation is both a causal agent and a result of recurring vulnerabilities.

Understanding vulnerability cycles leads to the need to establish links between sanitation and multiple targets and goals, such as poverty reduction (1.1-5), health (3.3, 3.9), and cities and communities (11.1, 11.5). Several publications were found on the existence of these links in Brazil. For example, Chiarini (2006) establishes a statistical significant relationship between poverty and different dimensions of the urban environment in Brazil, including sanitation in low-income areas. Other research demonstrates how diseases, such as diarrhoea, as well as mosquito-borne viral infections such as dengue and Zika, are more prominent in low-income parts of cities with poor sanitation infrastructure and stagnant water bodies (A. S. de Almeida, Medronho, & Valencia, 2009; L. S. Almeida, Alves de Araújo, Cota Soares, & Rodrigues Freitas, 2019; de Melo et al., 2008; Larrea-Killinger, 2001; Nunes, 2019). These provide evidence that action on sanitation is necessary to break these links.

Vulnerable populations are also disproportionately impacted by disasters such as climate-related events, meaning that the occurrence of the sanitation-poverty cycle in low-income areas is more acute in the face of 'shocks'. During rainy seasons, floods strongly affect favelas by spreading diseases more easily, for example where sanitary effluents are informally discharged into stormwater drainage systems and cause combined sewer overflow (Reda, Ferreira, Mendes, & Beck, 2014). Larrea-Killinger (2001) discusses how this occurs in Salvador where septic tanks are a common sanitation infrastructure in favelas. Action on sanitation can support those who are most in need to build more resilient infrastructure and prepare them to better face such risks (11.5). This will also help contribute to SDG13 on climate action, particularly through target 13.1 which calls for strengthening adaptive capacity to climate-related hazards and natural disasters. Klug, Marengo and Luedemann (2016), for instance, argue that laws and regulations for urban areas of Brazil will help build resilience through a preventive approach, including with climate-proof infrastructure. Also from a structural approach, Londe *et al.* (2014) show how better planning for water-related disaster risk management, including sanitation interventions, will help reduce people's vulnerabilities.

4.3. Domain 2: Sanitation and equity and empowerment

Vulnerability is not only a result of infrastructural distribution and service access, but is also related to social, economic and political factors which cause inequalities in Brazil. This refers to income as described above, but also to gender, disabilities, ethnicity and other social identity categories. This was identified through mapping evidence on inequalities (SDG10) but also targets across other goals that seek to reduce discrimination against specific groups, including indigenous communities. For target 3.2, we identified research showing how indigenous children are disproportionally more at risk of infant mortality due to lower sanitation access (Coimbra et al., 2013; Escobar et al., 2015; Raupp, Cunha, Fávaro, & Santos, 2019). In relation to target 4.7 on education for sustainable development,

there is evidence showing that the planning, execution, and evaluation of sanitation interventions is often carried out without recognition of cultural specificities which actually reinforce the marginalisation of indigenous populations due to a lack of culturally differentiated care (Pena & Heller, 2007; Teixeira & da Silva, 2019).

We also identified research on the links between sanitation and gender inequalities, for example regarding public sanitation facilities that are not suitable for Menstrual Hygiene Management (MHM) as researched by Coswosk et al. (2019) whose work is relevant for SDG5 on gender equality (5.1-2) and SDG4 on education (4.5, 4.a). Similarly, academics have researched how poor sanitation conditions increase risks to maternal health, particularly among low-income groups, and how health education being integrated into health programmes in Brazil can support better hygiene practices (targets 5.6, 3.7) (Victora et al., 2011; Villela & Monteiro, 2005). This suggests the need to understand sanitation from an intersectional perspective since modes of discrimination are often formed by the combination of different social categories and relations such as gender, class and race. Multiple scholars have emphasised how poor sanitation can cause, be the result of, or reinforce multidimensional inequalities in Brazil (Justino, Litchfield, & Niimi, 2004).

Considering these different types of exclusion, sanitation can also be a means to give recognition to marginalised groups, and a means of empowerment. Within SDG6, target 6.B calls for supporting and strengthening communities' participation, in line with target 11.3 of the cities and communities goal (SDG11). There is evidence of synergies in relation to the participation of low-income communities in the implementation and maintenance of sanitation interventions in Brazil, for example of condominial sewage systems (Mara & Alabaster, 2008; Nance & Ortolano, 2007; Watson, 1995). Furthermore, research demonstrates how sanitation interventions can be positively impacted by female leadership (target 5.5) (Moraes & Perkins, 2007; Watson, 1992). This suggests that sanitation can enable the reduction of various forms of exclusion, as well as create opportunities for decision-making at all levels and thereby help achieve inclusive societies for sustainable development (16.7) (Nance & Ortolano, 2007; Ostrom, 1996).

4.4. Domain 3: Sanitation and pollution reduction and waste reuse

A range of targets related to unsafe waste disposal and pollution call for action in the sanitation sector. SDG6 calls for halving the proportion of untreated wastewater and protecting and restoring the environment (6.3, 6.6). Brazil needs to develop national and local waste management systems along the sanitation chain in order to achieve these targets and protect the quality of surface and groundwater. Numerous cities in the North Region have very poor sewage systems. For example, the capital city of Manaus in Amazonas State only treats 30% of the waste collected and transported by sewers (ABES, 2018). As only 10% of households are connected to the 500 km-long sewage network, and on-site treatment systems are not widespread, most sewage generated across the city is directly released into streams or other water bodies. Investments towards collection and treatment will help meet these targets. This will also support achievements towards SDG14 (14.1-2, 14.5) on reduced disposal of contaminated effluents currently affecting marine ecosystems, which represents a considerable problem for the country's coastal areas (CETESB, 2018; Jablonski & Filet, 2008).

Protecting water resources requires joint action amongst different sectors to also conserve soil systems and improve agricultural practices, and thereby help meet SDG2 targets on food and hunger. CONAMA Resolution No. 430/2011 sets national conditions and standards for effluent discharge and prescribes that effluent treatment must remove 60% of Biochemical Oxygen Demand (BOD) for direct discharge into receiving bodies (CONAMA, 2011). Yet, the vast majority of Brazilian cities (4,801 cities, totalling 129.5 million inhabitants) have organic load removal levels that are far below 60%, especially

in the North and Northeast (ANA, 2017). Only 769 cities (14% of the total), principally in the Southeast region, have BOD removal levels above 60%. The agricultural industry of Brazil needs to make substantial improvements in water reuse practices to ensure safer food production. There is no national legislation in Brazil for water reuse, although CONAMA Resolution No. 375/2006 seeks to regulate sewage sludge application in agriculture (CONAMA, 2006).

Therefore, the prioritisation, institutionalisation and regulation of treated wastewater reuse in Brazil will participate in creating synergies with goals seeking to safeguard human (SDG3) and ecological health (SDG14-15). Currently, irrigation accounts for 72% of the total amount of water consumed in Brazil, and projections show this figure is expected to increase (ANA, 2016). The planned reuse of treated wastewater in agriculture is considered an important measure to mitigate water crises and help reduce pressure on water and soil ecosystems (J. T. de Sousa, van Haandel, Cavalcanti, & Figueiredo, 2005). This will be especially important in arid and semi-arid parts of the country, particularly the Northeast region but also in regions where water extraction patterns exceed recharge rates (Magrin et al., 2014). Therefore, working towards the protection of soil and water systems will also contribute to SDG12 and SDG15 on the environmentally sound management of water and soil systems (12.4, 15.1, 15.4-5).

The use of waste, approached as a resource, has been identified as a key ecological and economic opportunity, but biogas recovery practices remain limited in Brazil due to a mix of social, political and economic factors. High population concentrations in large urban centres means that there are considerable quantities of sludge available to be used in conjunction with agriculture effluents to produce biogas (Leite, Hoffmann, & Daniel, 2019). In 2016, the Brazil-German Probiogás project estimated Brazil's biogas for energy potential from sludge at 1,409 MWh per year (Ministério das Cidades, 2016). The country currently has a very small installed capacity, but this scenario may change rapidly given its strong biogas production potential which may attract foreign investment (CIBiogás, 2019). Several Wastewater Treatment Plants (WWTP) have started to produce energy from biogas, including in Riberão Preto, Belo Horizonte, Belém and the Ouro Verde WWTP in Foz do Iguaçu (Valente, 2015; Zanin, Becker, & Santos, 2014). Valente (2015) estimated that WWTPs designed to serve 200,000 to 450,000 inhabitants could have up to 80% internal rates of return. Continued efforts towards biogas production supported by an enabling legal framework could help enhance current achievements against SDG7 targets and help meet the growing demand for renewable energy (7.1-7.B).

4.5. Domain 4: Sanitation and economic well-being

Research has explored how poor sanitation in Brazil impacts the economy at multiple levels. It was estimated that R$121 million (about US$56 million[3]) was spent in 2013 on hospitalisations caused by gastrointestinal infections (CEBDS and Trata Brasil, 2014). This also has a link with economic productivity: 849,500 workdays were lost in 2012 due to absence caused by diarrhoea and/or vomiting, leading to an estimated R$1.112 billion (about US$570 million[4]) of hours paid but not effectively worked (ibid). Universalising access to water and sanitation would lead to a 23% reduction in the total number of days missed due to diarrhoeal diseases and increase income by R$258 million per year (about US$120 million per year[5]). This will support achievements towards a more productive economy (8.2) and better employment and remuneration (8.5) (ibid). Since poor on-site sanitation

[3] 1 USD = 0.465 BRL in 2013 https://www.x-rates.com/average/?from=BRL&to=USD&amount=1&year=2013
[4] 1 USD = 0.514 BRL in 2012 https://www.x-rates.com/average/?from=BRL&to=USD&amount=1&year=2012
[5] As per the USD-BRL exchange rate in 2013, the year of the study. However, note that current exchange rates fluctuations would need to be considered for updated estimations.

conditions also affect health and productivity of workers, investment made to improve working environments including for migrants exposed to precarious employment would help protect labour rights (8.8).

Given the current sanitation deficit in Brazil, the universalisation of sanitation services requires significant investments, at least over the short-term (8.1). At the regional level, investment costs in the distribution of treated water and in sewage collection for the Northeast were estimated at R$76 billion or 13.7% of the region's GDP (CEBDS and Trata Brasil, 2014). Further economic challenges could emerge if universalisation strategies require investment costs to be borne at the household level (1.1-2). While these estimations focus on infrastructural aspects of sanitation actions, many investment opportunities exist in relation to educational programmes. Research has investigated how health education can lead to disease prevention through behaviour change (4.7). Schall (1995) argues that health education programmes in Brazil have supported the control of diseases, such as schistosomiasis, since the 1960s. Through the cases of Campo Grande and Dourados municipalities, Iorio *et al.* (2009) advocate for continued educational programmes, including environmental education, to stimulate transformative social action with regard to sanitation practices for sustainable development. Among the numerous benefits, Kloos *et al.* (2008) argue these will contribute to safeguarding the health of the Brazilian workforce.

Investment in innovation has been identified as a potential boost for the sanitation sector. Research shows that technology development, for example for more effective, integrated water quality management systems, can support sanitation together with environmental conservation and urban populations' quality of life (9.B) (Heller and Nascimento, 2005; Ribeiro, 2018; OECD, 2018). Cost benefits associated with green/blue infrastructure development are increasingly gaining recognition (9.1, 6.6, 15.1, 15.A). For example, for the Cantareira reservoir in São Paulo, net benefits from forests (then referred to as 'natural infrastructure') were evaluated at $69 million over 30 years (Ozment et al., 2018). Although less well documented, a large number of independent Small and Medium-sized Enterprises (SMEs) contribute to sanitation in Brazil, whether formally or informally, and many of which employ or are led by women (Arroio, 2014). Many of these provide 'non-conventional' solutions (e.g. nature-based solutions for water treatment), together with software solutions (e.g. community mobilisation and empowerment) (e.g. Castagna & Goldeinstein, 2018). Long-term support to such enterprises will help meet targets around entrepreneurship (8.3, 9.3) (Albuquerque, 2011). The landscape for investment in SMEs remains limited as finance is more accessible to large utilities, which may fail to fill service gaps, particularly for low-income communities (Vargas & Lima, 2004). While Brazil is an attractive country for private equity and venture capital investment in infrastructure projects, SMEs continue to face a challenging business environment regarding the credit market, taxation and regulatory complications (Dâmaso, Turolla, & Teixeira, 2017; Moon, 2019; OECD, 2020).

4.6. Governance and partnerships for sanitation

Various initiatives to improve access to sanitation in Brazil, including the National Sanitation Plan, have been negatively affected by conflicts of interest amongst different stakeholders, most notably municipal and state actors. However, realising the opportunities to maximise synergies and limit trade-offs requires partnerships between actors. SDG17 seeks to provide a means for these partnerships to be leveraged to support objectives around financial mobilisation and investment, technology and knowledge transfer, capacity-building, policy and institutional coherence, monitoring and accountability. Such partnerships include those between government and civil society, public-private and public-public, both at national and international levels. The development of networks is a strategic form of governance. For example, RESAG, the national water supply and sanitation network, was created by the Brazilian Federal Government to support science technology innovation through

training, accreditation and access to laboratory material (Ponçano & Plonski, 2017). Since private companies play a strong role in the Brazilian sanitation sector, dynamic networks for SMEs can help with access to resources and information-sharing. Increasing accountability and transparency through better engagement with civil society will also improve decision-making processes (Serageldin et al., 2005).

In relation to political investment, policies and regulations, research shows that sanitation is a sector for which investment needs to be prioritised, and also requires more accountancy and transparency (16.6) (Burrier, 2019; de Oliveira, 2018). Crucially, data and monitoring processes remain poor and unreliable in the sanitation sector and must be improved to support and guide policy, planning and resource allocation (17.18 and 17.19) (de Miranda & Marinho, 2004; OECD, 2017; Whately & Diniz, 2009). There is also progress to be made on policy coherence, a gap that has been analysed by the OECD (2018) in relation to PLANSAB, water resources planning, and various other policies. The OECD argues that decision-making for water resource management is particularly complex in large Brazilian cities, in which case co-operation will enhance cost-effectiveness, efficiency and security of service supply, while reducing negative spillover effects on public health and the environment (16.7, 17.14). To reduce inequalities, pro-poor initiatives in Brazil have included sanitation tariff mechanisms supported by cross-subsidies. However, municipalities without real fiscal independence cannot fully benefit from this system, which has disproportionate effects on the poorest populations (de Sousa & Costa, 2016). The pursuit of poverty eradication and sustainable devlopment objectives which both link to sanitation commitment will therefore require stronger coordination between actors at different governance levels (17.15).

5. Discussion and recommendations

5.1. From understanding the links towards strategic action

The findings presented above are the result of a structured approach to reviewing published evidence on sanitation in Brazil and exploring the linkages to the SDG targets. This structured process identified key areas of action in sanitation , synergies as well as trade-offs. Results align with those of Parikh et al. (2020) who identified 83 calls for action, 130 synergies and 28 trade-offs. There are some differences, however, explained by the application of the methodology to a specific context – that of Brazil. This study is not exhaustive as it draws on a limited number of sources, particularly academic papers. Therefore, there is scope to expand the evidence base beyond sources available in the public realm to gain further insights into the complexity and diverse aspects of the sanitation sector, e.g. testimonials from practitioners and citizens, before developing approaches and solutions.

Our study confirms how sanitation has synergistic links with all 17 SDGs in Brazil. There is an opportunity to benefit from synergies by adopting nexus approaches. For example, wastewater treatment and reuse can significantly help ensure safe, nutritious and sufficient food production and thereby help tackle environmental pollution and malnutrition. The challenge is to scale up safe human waste recycling techniques to make this viable across Brazil. As seen in various Brazilian cities, integrated approaches are particularly important in low-income settlements where a range of services beyond sanitation are lacking, which deepens vulnerabilities to climate change. Targeted action is required to build resilience in such areas through technically appropriate, sustainable and socio-culturally acceptable sanitation services. Slum upgrading programmes need to consider how action on sanitation can be supported alongside interventions around water management, housing and education. This will require equitable and participatory solutions for sanitation services to ensure inclusion of all and engagement of communities for improved ownership and maintenance of services.

The value of this context-specific analysis lies in unveiling existing evidence for important linkages between sanitation and the SDG targets that need to be considered in future efforts to meet the UN 2030 Agenda. Indeed, identified synergies should not be interpreted as the norm across the entire country, but rather as potential opportunities to be harnessed in the planning of future interventions. Similarly, the documented trade-offs are largely warning signals for potential negative implications that emphasise the need for integrated efforts across the SDGs and their constituent targets. A number of trade-offs were identified in relation to newly introduced sanitation management systems that fail to manage waste safely, both from a human and environmental health perspective. Other trade-offs include those related to poverty reduction programmes which risk perpetuating or introducing new socio-economic vulnerabilities over the short- and long-term. More detailed, context-specific analysis will be required to fully understand how these synergies and trade-offs will manifest in different settings. Overall, the significantly smaller number of trade-offs in comparison to synergies is largely explained by the broadness of the targets. We expect that the application of this methodology at project-scale would lead to the identification of more trade-offs. Given the varying understandings and definitions of 'sanitation', the further application of the methodology also requires clear framing of what is considered under sanitation interventions. Brazil's definition of sanitation is an opportunity for action on several fronts, but can also create confusion if it is not clearly interpreted.

5.2. Governance recommendations

This paper reveals that action is needed at multiple levels, ranging from infrastructure development and management to community engagement, and from economic investment and partnerships to data management. In order to achieve stronger policy coherence for sustainable development, Georgeson and Maslin (2018) point out the importance of considering risks at different governance levels. In Brazil, that includes risks to be mapped out at state level, but also at municipal and community level, including that of inter-governmental and inter-organisational conflicts. Research demonstrates how multi-level and cross-sectoral partnerships are necessary for integrated actions to reach development co-benefits, in which sanitation interventions will play a role. Sanitation requires an alignment of objectives with other sectors through integrated policies supported by national-level plans that are regularly monitored and evaluated to reduce implementation barriers for local institutions. It also requires a re-evaluation of investment needs, where resources can be jointly allocated. As emerging trade-offs require negotiations between ministries working on different agendas, the idea of strategies developed around 'nexuses' can help overcome such risks. Co-ordinated shared learning between institutions from different cities, states and regions on policy-making and management systems, will also support such policy coherence.

The achievement of the SDGs in Brazil will require revisiting mechanisms of collaboration between governments and private and semi-private companies involved in water supply and sanitation provision, and across sectors. Accountability and transparency will continue to improve with further advances made towards integrated sanitation management approaches to tackle the problem of waste collection, transport, treatment and disposal/reuse, which is currently fragmented. While Brazilian regulations exist, enforcement mechanisms remain problematic. Tackling sanitation gaps whilst considering the sanitation value chain in its entirety means there are opportunities for collaboration with actors that are typically not considered in sanitation governance, especially if strategies are developed around waste reuse. This includes waste-to-resource businesses working with the food and energy industries for which further incentives need to be created, including operational support mechanisms and investment in research and development, and accompanied by a supporting fiscal, regulatory and policy system.

Actors involved in waste management in low-income areas also require more visibility and engagement given their knowledge of local needs and opportunities for action. This will help fill persistent data gaps in low-income areas. Such strategies will unlock the potential of formal and informal SMEs as well as informal workers playing a role in the delivery of basic sanitation services. Brazilian institutions can benefit from the use of tracking tools developed to help monitor progress towards the SDGs. Improved data tracking and monitoring will be required in Brazil to leverage the benefits of sanitation services and ensure that affordable services are accessible for all, including marginalised groups. Changes in the governance landscape will need to ensure that the economic burden of sanitation services does not fall on the poorest households as this can result in further disparities. Finally, to continue build knowledge that informs sanitation governance, our compilation of research documents can be used as a basis for further discussion and research, including to identify where empirical studies that demonstrate linkages between sanitation and each aspect of the SDGs are needed and can stimulate decision-making.

6. Conclusions

Brazil is characterised by deep regional and socio-economic inequalities, which are reflected in the disparate provision of public services including sanitation. While the Brazilian constitution recognises sanitation as a basic human right, this assessment has shown that access to sanitation services across the country is highly varied. In particular, people living in informal settlements and in poorer regions of Brazil are most affected by the lack of access to adequate sanitation.

This paper makes an important contribution to the literature by demonstrating the applicability and relevance of the previously developed sanitation assessment frameworks conducted by Parikh et al. (2020) to a specific country context. For Brazil, the assessment calls for action on sanitation across 16 SDGs, with 87 targets. The assessment also found evidence of 124 synergies and 38 trade-offs between sanitation and the 169 Targets of the UN 2030 Agenda, covering all 17 SDGs. This demonstrates the wide-ranging linkages of the SDGs with sanitation, in domains as diverse as poverty reduction (SDG1) and life below water (SDG14). The identification of synergies and trade-offs can help to ensure that these linkages are considered within projects, programmes and policies designed to deliver access to sanitation, and sustainable development more generally. In so doing, planning should support the realisation of opportunities, while minimising potential trade-offs .

While the assessment has taken sanitation as the focus, it has highlighted the integrated and indivisible nature of the SDGs and sanitation itself. It has shown that action on sanitation has implications for other sectors, and vice versa. Evidence specific to the Brazilian context underpins the importance of action to delivery access to adequate sanitation across the country, as well as aiding understanding of context-specific risks, evidence gaps and opportunities. Sanitation is one of the acceleration goals for achieving the UN 2030 Agenda. By systematically mapping the linkages between sanitation and all 169 Targets of the SDGs, this assessment provides a tool that can support policy makers and practitioners seeking to deliver on the UN 2030 Agenda. In contrast to sectoral approaches, it enables the identification of linkages to other sectors that may not typically be considered by sanitation specialists. This is vital because investment in sanitation is not seen as a high priority – in Brazil or elsewhere. By highlighting the linkages to sectors beyond sanitation, this assessment provides evidence to support the development of broad partnerships for equitable and inclusive sanitation to ensure that no-one is left behind in Brazil and globally.

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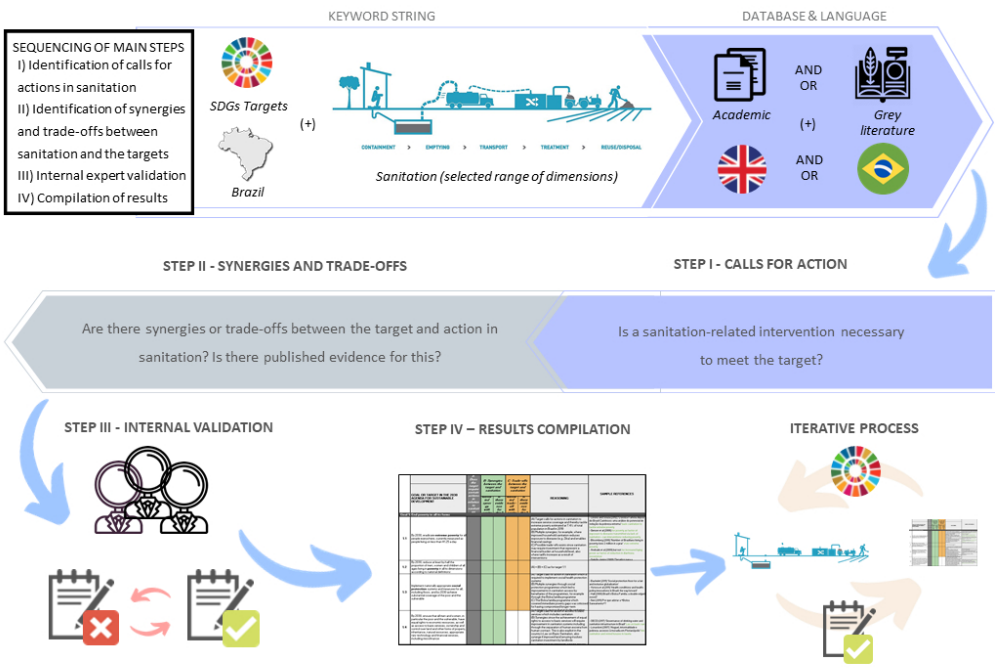

Figure 1: Step-by-step methodology to identify the links between sanitation and SDG targets

270x203mm (96 x 96 DPI)

Figure 2: Spider-web representation of three types of links between sanitation each goal (calls for action, synergies and trade-offs). The 17 lines linking the centre to the goals range from 1 to 100, therefore circles mark percentages at 20, 40, 60 80 and 100. Note that this representation should not be seen as a comparative qualitative analysis between the goals, but rather as a demonstration of the wide-ranging linkages between sanitation and each of the Sustainable Development Goals.

Figure 3: Selected synergistic SDG interlinkages through the lens of sanitation in Brazil's context. The figure highlights that synergies between sanitation and SDG targets exist for all 17 goals, but also that sanitation interventions can unlock opportunities to achieve targets of different goals at the same time. These identified sets of links are categorised under 4 recurrent domains of action. SDG17 is represented separately as an overarching goal.

338x190mm (96 x 96 DPI)