Sustainable Drainage in Challenging Environments

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ABSTRACT

The provision of Water, Sanitation and Health (WASH) is recognised by the UN as a human right. However, drainage is not. The lack of drainage leads to flooding and can impact on quality of life and human health. This is particularly true in the most vulnerable of populations who live in informal settlements, favelas and refugee camps. This paper shows the potential of sustainable drainage systems or SuDS to address issues of excess surface water and lack of greywater management in these challenging of environments. SuDS mimic nature by encouraging infiltration, storage and slow conveyance of water to attenuate the storm peak, reduce flooding, improve water quality and provide opportunities for amenity and biodiversity. A layer of complexity is added when considering disease vectors such as mosquitoes which may be prevalent in these environments. By encouraging water underground and reducing puddling of water between dwellings and on the street, their breeding sites are reduced, providing a means of reducing their impacts on health due to zika, dengue or chikungunya. Due to the lack of governance, land tenure and any form of planning, residents of informal settlements and favelas need to be actively engaged in improving the quality of their surroundings. Refugee camps, on the other hand, are formally set up by the UNHCR with WASH installed, thus there is potential to influence policy, to encourage installation of drainage at the same time as WASH so that WASH becomes WASH'D, possibly a first step in recognising drainage as a human right.

Keywords: Sustainable drainage, slum, favela, informal settlement, refugee camp, greywater.

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doi: 10.18278/nwpp.4.1.3

摘要

水、环境卫生和个人卫生（Water, Sanitation and Health，WASH）被联合国视为一项人权。然而，这项人权并不包含排水。缺乏排水会导致洪水，并影响生活质量和人民健康。这对居住在非正式居住区、贫民窟和难民营的弱势群体而言更是如此。本文展示了可持续排水系统（sustainable drainage systems，SuDS）的潜在能力，它能在上述困难地区处理多余地表水和灰水管理缺乏等问题。SuDS通过促进水渗透、储存和慢输送的方式模仿自然，减弱风暴高峰的影响，减少洪水，提高水质量，同时为生活便利设施和生物多样性提供了机遇。当考虑到疾病这一方面，例如在贫民窟这些环境下经常出现蚊子时，则增加了一层复杂性。通过鼓励地下水和减少居住区之间以及街道上的水坑，蚊子的繁殖区将会减少，进而减少其对健康造成的影响，例如寨卡病毒、登革热或基孔肯雅热。由于缺少治理、土地使用权和计划，非正式居住区和贫民窟的区民需要积极参与提高生活环境的质量。在另一方面，联合国难民署（UNHCR）正式建立了难民营，并为其安装了WASH项目，因此存在影响政策的可能性，即鼓励在安装WASH时一起安装排水系统，这样一来WASH会成为WASH'D，为认可排水系统是一项人权提供了开始的可能。

关键词：可持续排水，贫民窟，贫民窟（favela），非正式居住区，难民营，灰水

Resumen

El suministro del agua, sanidad y salud (WASH) es reconocido como un derecho humano por la ONU. Sin embargo, el drenaje no lo es. La falta de drenaje causa inundaciones y puede impactar la calidad de vida y salud de los humanos. Es particularmente cierto en las poblaciones más vulnerables viven en asentamientos informales, favelas y campos de refugiados. Este documento muestra el potencial de los sistemas de drenaje sustentables, o SuDS, para enfrentar los retos de exceso de agua en la superficie y falta de gestión de "aguas grises" en estos ambientes exigentes. Los SuDS imitan a la naturaleza ya que fomentan la infiltración, el almacenamiento y el movimiento lento del agua para atenuar el pico de agua pluvial, reducir las inundaciones, mejorar la calidad del agua y proporcionar oportunidades para la amenidad y la biodiversidad. Se vuelve más complejo cuando se consideran los vectores de enfermedad como los mosquitos, que pueden prevalecer en estos ambientes. Al facilitar que el agua esté

bajo tierra y reducir la formación de charcos entre los hogares y en la calle, sus sitios de apareamiento se reducen, así proporcionando una forma para que se reduzca su impacto en la salud debido al zica, dengue o chikunguña. Debido a la falta de gobernanza, titulación de tierras y otras formas de planeación, los residentes de asentamientos informales y favelas tienen que estar activamente involucrados en mejorar la calidad de su entorno. Los campos de refugiados, por otro lado, están formalmente establecidos por el ACNUR con WASH establecido, por ello hay potencial para influenciar las políticas, para fomentar la instalación de drenaje al mismo tiempo que el WASH para que el WASH mejore, lo cual es un posible primer paso para el reconocimiento del drenaje como un derecho humano.

Palabras clave: drenaje sustentable, barrios bajos, favela, asentamientos informales, campos de refugiados, aguas grises.

1. Introduction

The world is facing the perfect storm in terms of challenges to society and the environment. Increasing populations are crowding into cities challenging infrastructure and services; industrialisation, urbanisation and vehicular traffic are adversely affecting environmental quality and driving climate change. Strong governance, policy and planning are undoubtedly needed to face these challenges, but to support these, strong *physical strategies* are also needed which are flexible and have multiple benefits.

Resolution 64/292, 2010 of the United Nations General Assembly explicitly recognises *as a human right*, access to water and sanitation, and that clean, safe drinking water and sanitation underlie the ability to achieve all human rights. The Resolution particularly focuses its attention on developing countries, asking States to financially support capacity-building and technology transfer to enable the provision of supplies of safe, clean, accessible and affordable drinking water as well as sanitation for all. Nowhere in these aims do the words "flood" or "drainage" occur, implying that drainage of settlements and resilience to flooding is not necessarily a human right. In Albuquerque, 2012, the Constitutional Chamber of Costa Rica is quoted as equating the flooding of dwellings in Villa Flores with wastewater in 2007 with poor maintenance of the sewerage system and thus the population's constitutional right to health had been violated. However, once again, drainage is not addressed in this document.

This paper illustrates the drainage and greywater management challenges faced by those living in "precarious settlements" which are informal, and also for-

mal settlements set up temporarily for refugees, suggesting that Sustainable Drainage approaches may provide some answers to these issues.

2. Sustainable Drainage Systems

Sustainable Drainage Systems or SuDS mimics natural systems in that it encourages the infiltration of water into the ground, its short-term retention or long-term detention, and its slow conveyance to the receiving waterbody (Charlesworth and Booth, 2017). These processes are carried out via various devices which address the SuDS square of benefits, shown in Figure 1, which balances equally: attenuation of the storm peak thereby reducing flooding, improvement of water quality, provision of amenity benefits for the populace and promotion of biodiversity (Woods Ballard et al., 2015). This balance is achieved via various individual devices which can be used alone, or can be designed together into a management or treatment train (see: Charlesworth, 2010). These devices include pervious surfaces such as porous or permeable paving systems (PPS), swales, filter strips, green walls and roofs, wetlands and ponds; for further details see Charlesworth and Booth (2017). If designed properly, and with cognisance taken of local conditions, SuDS can be installed into the most challenging of environments: informal settlements and refugee camps.

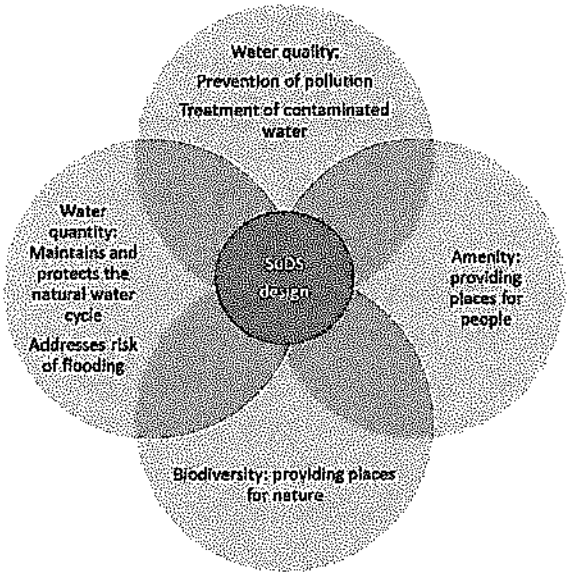

Fig 1 The SuDS equal balance between water quality, water quantity, biodiversity and amenity (after Woods Ballard et al., 2015).

3. Challenging Environments

3.1 The tropics

SuDS are relatively easy to design into temperate environments (see Watkins and Charlesworth, 2014), but challenges arise with the intense, relatively short duration rainfall experienced in tropical regions allied with disease vectors such as mosquitoes and nuisance animals including snakes. The importance of suitable

SuDS design under these circumstances cannot be overstated. Devices therefore have to have the capacity to cope with tropical storms, but must also ensure water is kept underground to prevent mosquitoes from breeding. Such devices have been designed in Malaysia by Sidek et al., (2002) and Zakaria et al., (2003). Called BioEcods, they are based on swales, but water is kept below the surface (Charlesworth and Mezue, 2017) in an aggregate-filled modular box. The vegetated surface of the swale is native Cow grass (*Axonopus compressus*), and it is important that native vegetation is utilised when considering green SuDS devices.

3.2 Informal settlements

Fig 2 illustrates the proportion of people living in slums globally from 1990 to 2014 for Nigeria, Brazil, South Africa and Iraq, and whilst populations are decreasing for the first 3 countries, by 65, 60 and 50% respectively, generally the population has stabilised between 2007 and 2014 at more than 20% for South Africa and Brazil and more than 50% for Nigeria. In the case of Iraq, however, populations have increased by nearly three times, probably due to the influx of refugees and the setting up of refugee camps. Problems here are around the lack of infrastructure and hence problems with surface water flooding and greywater management. Exacerbating these problems are a lack of services, as waste is not collected and thus it accumulates, blocking existing drainage infrastructure (Armitage et al., 1998). Fig 3a show a slum, or informal settlement in Lagos, Nigeria, with accumulated waste on the lower slopes and Figs 3b and c illustrate the lack of maintenance of any existing drainage infrastructure with vegetation overgrowth and the accumulation of waste blocking the passage of water.

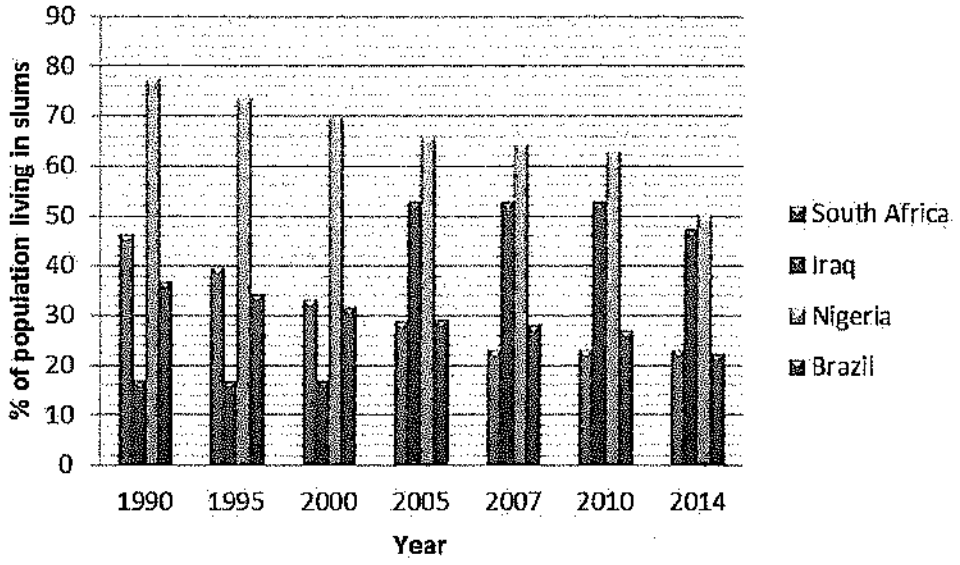

Figure 2 Proportion of individual country's urban population living in slums (UN-Habitat definition) from: World Bank, United Nation's Millennium Development Goals database. Available from: (https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS?end=2014&start=2014&view=map) .

Residents install some structures themselves in a "reactive" approach whereby when flooding occurs, tyres, sand bags or plastic trays are used to hold back flood waters and provide stepping stones within and outside of dwellings (Fig 4). Mixed in with the flood waters is greywater (sullage from kitchens and bathing) as this tends to be disposed of by throwing directly into the street (Armitage et al., 2008). Pools of standing water therefore tend to accumulate providing breeding grounds for disease vectors, such as mosquitoes in areas where these are prevalent (see Fig 5). Added to the mix may also be human waste, should toilet facilities not be available or useable and where open defecation is practiced (Tumwebaze et al., 2013; Tsinda et al., 2013).

Fig 3a) Typical informal settlement, Lagos, Nigeria. **3b and c)** Makoko, Lagos (b) Vegetation growing in a drainage channel due to lack of maintenance (c) drainage canal blocked with waste either carried there in surface water or deliberately placed there.

Fig 4 Tyre "stepping stones" in front of a house, Iwaye, Lagos, Nigeria.

SuDS is relatively unknown in Lagos, however some progress has been made in an informal settlement located 90km north of Cape Town, in Franschhoek, South Africa. In this case, bioretention, tree micro catchments and a form of infiltrating pavement have been used (Fig 6) as well as community greywater disposal whereby the water is infiltrated into the ground via perforated pipes and aggregate-filled ditches. All of these strategies are to encourage the water underground, discouraging the formation of standing water and the human and environmental health consequences this may have.

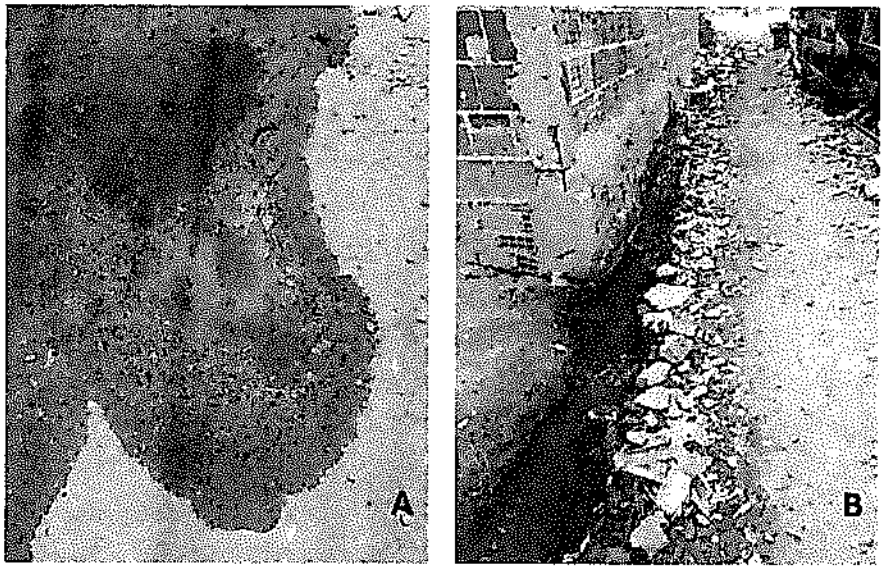

Fig 5

Favela in NE Brazil.

A.) Standing pools of waste water containing mosquito larvae.

B.) Wastewater flows between dwellings.

Fig 6 SuDS and greywater management installed in an informal settlement, Franschhoek, South Africa.

3.3 Refugee camps

There are many refugee camps in the Kurdistan Region of Iraq (KRI). These are initially set up by the UNHCR (United Nations High Commissioner for Refugees) who have responsibility for infrastructure planning and implementing the majority of refugee camps in KRI. However, once established, the camps are then managed by the local government or agencies such as Board of Relief for Humanitarian Affairs (BRHA) who are located in Dohuk Governate and who oversee the future development of the camps, managing new arrivals and new infrastructure as necessary. In Erbil Governate, the Erbil Joint Crisis Co-ordination is responsible for managing camps located there, although the management culture and priorities

vary from organisation to organisation. Once again, these are set up "temporarily", but can become permanent dependant on their context. WASH (Water, Sanitation and Hygiene) is designed into the camps as a matter of course (The Sphere Project, 2011), and whilst the latter publication clearly identifies 'Drainage' as a component of the WASH cluster, it is seldom achieved, often being the last to be constructed, if at all, resulting in costly retrofits of still ineffective drainage once wastewater (combination of grey and surface waters, not usually containing sewage) and flash flooding problems are identified. Large drainage ditches, open concrete drains and pipes may be installed to direct the water "to another environment" which is not ideal (Tota-Maharaj, 2016). It would be more environmentally sustainable to encourage infiltration of the water into the ground, coupled with greywater reuse to reduce surface water flows. The problems with solid waste encountered here are similar to those found in informal settlements, as shown in Fig 7 which also shows it accumulating in one of the wastewater streams.

Fig 7 Chamishko refugee camp, KRI. Wastewater stream and discarded waste.

An approach used successfully to manage greywater is that of Stabilisation Agriculture (Adam-Bradford et al., 2016) whereby greywater can be used to water gardens, rather than being disposed of into the street. Figure 8 shows a garden supported by greywater which can produce ornamental plants as well as vegetables. The owner of this garden stated: "This garden reminds me of my childhood, my land. It also provides me with food, but it connects me to my homeland."

Fig 8 Greywater irrigated garden, Domiz refugee camp, KRI.

4. Conclusions

Some of the challenges in these environments are similar and some are different, and Table 1 summarises these. The main difference is that refugee camps are planned, but informal settlements are not. In the case of the former, there are therefore opportunities for knowledge exchange and the possibility of changing policy. For both settlements, the focus must be on community engagement, more so where they are informal, as to improve their environment, the residents of informal settlements need to be proactive and install measures themselves, whereas in refugee camps, there is an opportunity to include drainage at the first stages of planning, rather than reacting to flooding once people have moved into the camp. Sustainable drainage can be designed into these settlements, using native vegetation and locally available materials and can have multiple benefits and be flexible, addressing not only drainage but also providing a better quality of life for residents (Reed, 2017).

Table 1 Summary of the similar and different drainage challenges in informal settlements and refugee camps

Informal settlements	Refugee camps
Temporary: self-build	Temporary: set up formally by NGO
Can become permanent	
Located in developing countries	
No WASH infrastructure unless installed by the community	WASH installed
Waste disposal an issue	
Little-no surface water/ greywater management	
Flooding and fire problems not addressed	Flooding addressed with ditches and pipes: Not fit for purpose
No overall governance/ management	Governance/ management by Governate in which the camp is located
Limited understanding of SuDS, but reactive structures at the individual shack or community scale	Limited of understanding of SuDS
No guidelines	Guidelines for camp planning, very little addresses drainage
Population stabilised/decreasing	Population increasing
House the poorest, engage in service and tourism industries	House the displaced under crisis conditions
Disease vectors and nuisance animals can be a problem	
No planning	Drainage needs to be included at the earliest stage of planning

Whilst WASH measures are considered to be a basic human right, as discussed in the Introduction, that of drainage is not, and yet the lack of it has the potential to impact negatively on environmental quality and human health. Winter (2015) therefore suggested that there is a need for a change in policy such that

WASH incorporates drainage and becomes WASH'D, and that drainage does actually become a human right.

Acknowledgements

South African informal settlements sponsored by the National Research Foundation; refugee camps sponsored by the Humanitarian Innovation Fund; Brazil (Zika) sponsored by the Newton Fund.

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