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POLICYBRIEF

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Wastewater As a Resource: The Water-Waste-Energy Nexus in Sub-Saharan Africa

Paul Gremillion (UNU-FLORES) and
Tamara Avellán (UNU-FLORES)

Highlights

- The population of Sub-Saharan Africa (SSA) is expected to double to 2.1 billion by 2050, mainly in urban and peri-urban areas. SSA relies overwhelmingly on solid fuels for household energy needs, causing deforestation and environmental degradation in many places.
- Wastewater can provide a resource for irrigation, fertilisation, and energy: Humans produce about 12 m^3 of water, 4.5 kg of nitrogen, and 0.6 kg of phosphorous per person per year. A community of 500 can irrigate about a hectare of agricultural land and fertilise five to seven hectares. Harvested plants from constructed wetlands for wastewater treatment can provide 12% of a village's cooking fuel needs.
- About 40% of the world's croplands are in or within 20 km of cities. In SSA, less than 20% of these peri-urban lands are irrigated; most are supported only by rainfall. Application of treated wastewater provides the potential for expansion of peri-urban agriculture.
- By applying the Nexus Approach resources can be linked to more than one use. This minimises losses of material and energy and maximises resource use impact, which can lead to sustainable development.

The Challenge

Massive demographic changes underway in Sub-Saharan Africa (SSA) place urban and peri-urban areas at the intersection of a range of resource demands and threats to public health and ecosystem stability. The population of SSA is expected to double to 2.1 billion by 2050 (UNDESA 2015). SSA now has a relatively low level of urbanisation. However, the region is undergoing some of the most rapid urban growth in the world at 3.9%, compared with the world average of 2.1% (World Bank 2013). Areas around cities will become a crowded mosaic of people, livestock, and agricultural lands. About 40% of the world's croplands are in or within 20 km of cities. In SSA, less than 20% of these peri-urban agricultural lands are irrigated; most are supported only by rainfall (Thebo, Drechsel, and Lambin 2014). Inadequate and unsustainable energy resources result in a landscape stripped away for cooking fuel, with deforestation and soil loss at the top of a long list of negative impacts. Wastewater treatment is inadequate or non-existent, with potentially catastrophic health and environmental impacts.

A Nexus Approach centred on wastewater treatment and recovery can link cycles of water, waste, and energy. Rich in carbon and nutrients, wastewater has the potential to supply greenhouse gas (GHG) neutral energy for households and irrigate and fertilise crops. Capturing the resources contained in wastewater can improve human and ecosystem health, reduce GHG emissions, and improve SSA's food and energy security.

Energy and Sanitation Needs

SSA relies overwhelmingly on firewood and charcoal for household energy needs. Less than 10% of the population has access to modern fuels, such as electricity, natural gas, or liquid fuels (UNDP and WHO 2009). This demand has resulted in unsustainable levels of deforestation and associated detrimental impacts, including erosion, net releases of GHGs, and losses in biodiversity (Mohammed, Bashir, and Mustafa 2015). Traditional alternatives to wood-based fuels have also been problematic. Livestock waste and agricultural residues, the most common replacement for wood and charcoal, are better suited to fertilise and stabilise agricultural fields. In their absence, lower fertility, soil erosion, and poor water retention impair agricultural production.

Other renewable bioenergy sources can replace wood-based fuels and fulfil at least some of the demand for the latter. In SSA, the most common alternatives have been biogas produced by forest, animal, and agricultural residues and industrial biodegradable waste (Mohammed, Mustafa, and Bashir 2013). Soil health and productivity ultimately declines, when using organic wastes for fuel instead of soil amendments (Schwärzel et al. 2016). Energy crops, such as corn, sunflower, and grasses are effective biofuel resources (Liu, Chang, and Gu 2012), but these crops compete with food crops for arable land, water, and labour (Strzepek and Boehlert 2010).

At its most basic level, bioenergy is derived from organic carbon. Wastewater provides an alternative to traditional forest or agricultural carbon sources. Wastewater treatment and recovery systems can supply energy for communities while improving sanitation conditions and irrigating and fertilising agricultural lands (Box 1).

Box 1: Using Constructed Wetlands for Pollution Control in Egypt

Reuse of wastewater from agricultural, municipal, and industrial sources is a must for food production in water-scarce Egypt. Irrigation efficiency increased from below 50% to above 80% through the reuse of wastewater. The 50,000 km-long drainage and irrigation system is often directly fed with municipal sewage as wastewater treatment systems are lacking in most rural areas. Building small in-stream constructed wetlands as well as one of a larger scale in the northern lakes showed very promising removal efficiency for different types of pollution. In-stream wetlands do not require additional area, and as a simple and cheap technique, can be applied in parallel at different sites. Non-governmental organisations should be enlisted to help establish a suitable dissemination and capacity development programme, which may result in considerable progress towards improving water quality and irrigation practices (Hettiarachchi and Ardakanian 2016).

Access to sanitation remains a global challenge, although progress is being made. A 2015 evaluation of the Millennium Development Goals indicated that 68% of the global population now uses improved sanitation (flush toilets and latrines designed to contain solid waste, known as improved latrines). While this approaches the 2015 target of 77%, among the nations of SSA, only Ethiopia achieved even moderate progress toward this goal (UNICEF and WHO 2015). A transition to improved sanitation is necessary to help prevent the spread of waterborne diseases and protect ecosystems from damage caused by nutrients. In SSA, improved sanitation is primarily used in urban areas. As of the late-2000s, almost 30% of the urban population of SSA, or about 81 million people, used flush toilets (World Bank 2013). Most of the population in SSA still uses unimproved sanitation (latrines or open defecation). Progress toward sanitation and other development goals is now tracked through the Sustainable Development Goals (Box 2).

Box 2: Sustainable Development Goals

The Sustainable Development Goals (SDGs) aspire to achieve the three pillars of sustainable development: environmental, social, and economic. Of the 17 SDGs, water, waste, and energy cut across all, but two goals are directly related to the water-waste-energy nexus: Goal 6: Ensure access to water and sanitation for all, and Goal 7: Affordable and clean energy. An objective of the Nexus Approach is to support synergies and minimise conflicts among SDG targets. For example, attaining sustainable food production systems [2.4] (Goal 2, Target 4); reducing the risk of waterborne diseases [3.1-3.3, 3.9]; and ensuring the conservation, restoration, and sustainable use of freshwater ecosystems and their services [15.1-15.5] are all supported by conditions that meet SDG Goal 6. However, ensuring access to energy services and increasing substantially the share of renewable energy [7.1, 7.2] may impair water quality or otherwise introduce pollution into the environment.

Wastewater As a Resource

Urban and peri-urban population growth in SSA provides opportunities for the implementation of sanitation systems that collect, treat, and reuse wastewater. A spectrum of wastewater treatment technologies exists, from wetlands and lagoons to industrialised treatment plants (Metcalf & Eddy 2007). Low-technology systems have the advantage of low operation and maintenance needs, but the disadvantages of low or variable pollutant removal and the need for large surface areas. Conventional wastewater treatment plants provide high levels of pollutant removal and occupy a relatively small area, but are expensive to construct and maintain, and require a power source and personnel trained for their operation.

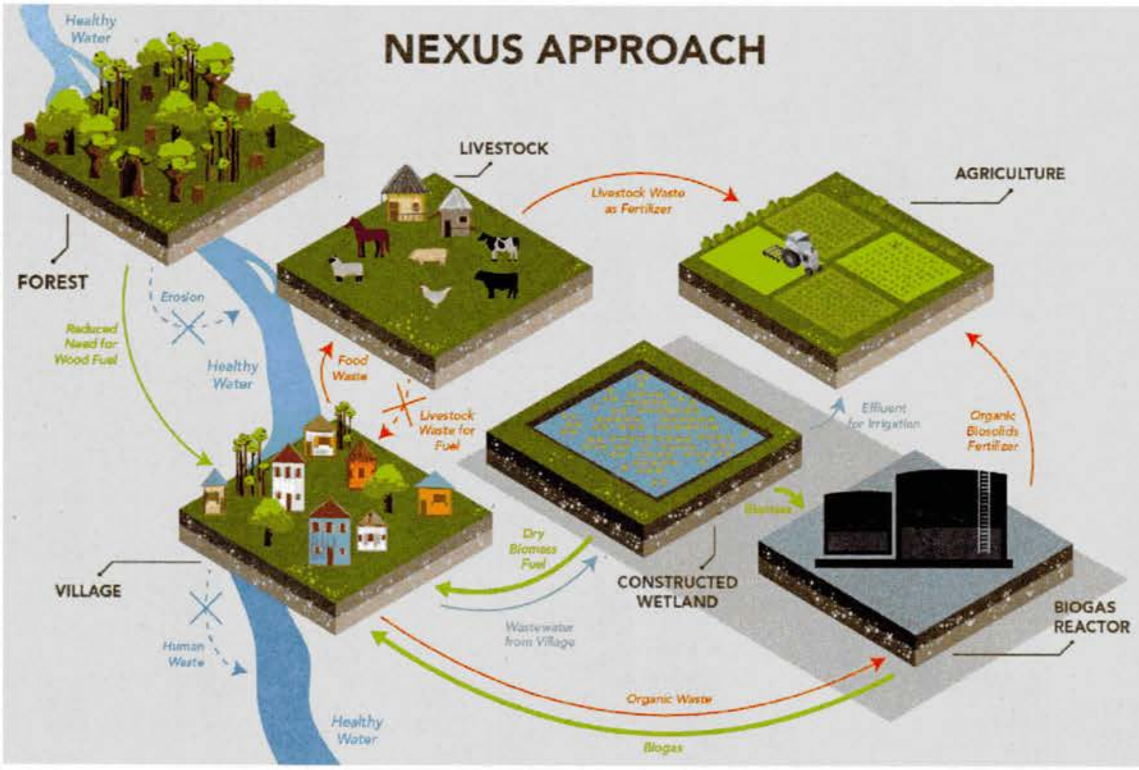

Figure 1: *Applying the Water-Waste-Energy Nexus improves sanitation, reduces energy dependence on forests, and improves food security. (Design: UNU-FLORES/Claudia Matthias)*

Wastewater reuse is being adopted in water-scarce parts of the world, notably Australia, the United States, and Namibia. The uses for reclaimed wastewater vary from irrigation to direct use as drinking water (see for example, Hettiarachchi & Ardakanian, 2016). The least complex application of reclaimed wastewater, however, is for agricultural irrigation. Treatment standards, primarily concerning elimination of pathogens, vary based on the intended use of the water, with non-food crops requiring the lowest level of disinfection and raw vegetable crops, such as leafy vegetables, requiring the highest (WHO 2006).

Wastewater provides three fundamental resources: Water, nutrients, and energy. In SSA the output of 6 to 17 m^3 per person per year could irrigate about a hectare of agricultural lands in a community of 500 persons (Steduto et al. 2012). Humans produce about 4.5 kg nitrogen and 0.6 kg phosphorus per person per year (Mateo-Sagasta, Raschid-Sally, and Thebo 2015). Thus, wastewater from a community of 500 persons could fertilise five to seven hectares of agricultural land.

Wastewater treatment is usually focused on removing biochemical oxygen demand (BOD). This is soluble carbon that is converted to methane and carbon dioxide in treatment plants. These GHGs are rarely recovered in developing countries, but have the potential to create a significant energy source. In conventional wastewater treatment plants, BOD is converted to microbial biomass, which can then be concentrated into organic sludge. Some treatment plants digest this sludge to generate biogas.

Applying a Nexus Approach to Resource Management

One low-technology alternative is to use wetlands to treat the wastewater and harvest the wetland plants as an energy source. A community of 500 people requires a wetland area of about 3,500 m^2 to treat their wastewater. This wetland can supply the community with about 84 gigajoules (GJ) of energy per year. An average household in Ethiopia requires about 1.4 GJ per person per year for cooking (Tucho and Nonhebel 2015), so the annual energy requirement for this community is about 700 GJ. Biofuel produced by the wetland can therefore supply about 12% of the cooking fuel needs of the village.

Collection and treatment of wastewater provides the thread that can tie together the components of the water-waste-energy nexus (Figure 1). Wetlands to treat wastewater provide a biomass source for fuel, and nutrient-rich effluent to irrigate and fertilise crops. If biogas processes are used, residue from biogas reactors provides additional fertilisation. Biomass fuel from wastewater relieves stress on forest resources and reduces the use of organic material that can be used as fertiliser and protects soil quality. Nutrients that would otherwise be released into surface water or groundwater can be captured and used in agricultural lands, offsetting the need for artificial fertiliser and improving the quality of ecosystems.

Policy Recommendations

Implementing the interconnected system shown in Figure 1 requires investment in infrastructure to treat wastewater and produce bioenergy, and adoption of flush toilets. Nearly all of the other components can fall into place once these challenges have been met. Population growth in peri-urban areas provides both the population density that can make wastewater recovery systems economical, and a "market" for the resources. Governance and policy strategies to achieve these goals include the following:

1. Coordinate the activities of involved ministries in a Nexus Approach.
2. Provide a locally-adapted regulatory path for the safe use of wastewater and its residues.
3. Establish technical guidance for communities to implement strategies that match wastewater treatment level to the type of use. For example, no pollutants when released to small streams, but higher levels of nutrients and no pathogens when being used on leafy vegetables.
4. Assess the value of ecosystem services provided by wastewater treatment and reuse. Benefits that can be quantified include improved soil, forest and wetland resources; nutrients, water, and energy recovered; GHG emissions reduced, and improved human health.
5. Establish incentives for communities to encourage them to implement a Nexus Approach and to cooperate in its implementation. For example, identify how operation costs and the resources produced are shared across the community.

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Ammonstrasse 74, 01067 Dresden, Germany
Tel.: + 49-351 8921 9370
Fax: + 49-351 8921 9389
e-mail: flores@unu.edu

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