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Prospects of Wastewater Reclamation and Reuse for Water Scarcity Mitigation and Environmental Pollution Control in Sub-Saharan Africa

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Abstract

This paper discusses wastewater and proven techniques for wastewater remediation and reuses from the sub-Saharan Africa (SSA) perspective. Water scarcity and polluted water sources contribute to the death of a large population of people daily; most of whom are living in SSA. The vast availability of non-recycled wastewater and poor waste management infrastructures in SSA is the major contributing factor to environmental degradation and water pollution. In this paper, the challenges confronting wastewater treatment and reuse towards improving water resource management in SSA are discussed. One major issue identified in this work is the socio-cultural perception of people in SSA to the emerging trend of wastewater reuse for water resource conservation and management. One recognized approach by which wastewater reuse can be encouraged in SSA is by validating the quality of the reclaimed water through public sensitization. Another method is by introducing incentives that will motivate public acceptability of recycled water from wastewater treatment.

Keywords: Water scarcity, Pollution control, Wastewater treatment and reuse, Sub-Saharan Africa (SSA), Environmental sustainability

1. Introduction: Water Scarcity and the Needs for Wastewater Reuse

Most regions of the world are facing water stress and groundwater depletion due to population explosion, rapid decline in water quality and low rainfall due to climate change. This has significantly altered the local hydrological cycle and inadvertently led to over-exploitation of the groundwater reserves (Vairavamoorthy et al., 2008). Water scarceness and pollution are inflicting serious health and environmental challenges on a large portion of world's over 7 billion population. Most of these people are dwelling in undeveloped nations especially the sub-Sahara Africa region. The reason for the despicable water and environmental situation in these regions can be attributed to the lack of good social infrastructure which is principally linked to poor or insufficient town planning. Wastewater and other effluents (fluid and solid) from domestic, agricultural, commercial and industrial activities are poorly managed; wastewater is often left untreated and most times polluting available spaces within the community (Eregno et al., 2017). Moreover, concerns for water shortage is rapidly growing around the globe due to the continuously growing rate of water consumption.

Due to the population explosion that occurred between the1900s and the 2000s, a significant increase from 14% of the global population to a whopping 58% of the total world population are without access to water in sufficient quantity, in general, and in the potable form, in particular; and this trend is increasing with Africa being the worst hit continent (Kummu et al., 2016; Lewis, 2019). The vicious cycle that seems to exist between human population growth and food and water resource availability has necessitated a significant need for food resource conservation and better water conservation and management practices. The continuous unrestricted growth of human population in developing countries has tremendous effect on both water poverty, as well as the amount of wastewater and sewage produced in these regions. Most of these untreated effluents are directly discharged into nearby surface waters leading to a significant level of environmental pollution and degradation (Hopfenberg &

Pimentel, 2001). Apart from the significant need for environmental protection by pollution reduction, the significant amounts of used water from domestic activities, agricultural and industrial processes can be a valuable water resource which can serve as a means of ameliorating the scarcity of useable water in developing regions, as it has been done in many developed nations.

Some of the polluting contents of domestic wastewater, when filtered out, can serve as credible sources of nutrients for crop production while the reclaimed water can be put to better levels of reuse based on the quality of the reclamation process. Miquel Salgot (Salgot & Folch, 2018) in his studies about wastewater treatment and its reuse attributed the continuous increase in the number of people moving into towns and cities as a prominent factor in the need for evolving wastewater treatment approaches at different points of human history. He posited that the most feasible, reliable and relatively cheap approach towards coping with water scarcity in developing nations is by investing in wastewater reclamation and reuse. Treated wastewater and effluents can provide alternative sources of water for farming, irrigation and some other water-consuming activities, especially for water-deficient regions, while keeping the clean sources of water for other hygienic usages. Depending on the level of treatment and sophistication of treatment facilities, the recovered water can be used for purposes ranging from horticulture to potable water supply (Voulvoulis, 2018). Hence, it is supported generally, that wastewater remediation remains an integral tool for water resource management and environmental sustainability, especially in the face of current world's shortage of water resources (National Research Council, 2012; Roccaro, 2018). In this paper, the authors seek to appraise the potential benefits of wastewater reuse towards water management and conservation in SSA region.

2. The Sources, Compositions, and Reclamation of Wastewater

Wastewater can be used to describe all forms of water which have been degraded in quality as a result of their overall usage. Wastewater has been exposed to contaminations and has been deprived of its potable uses either by industrial or domestic processes. Sewer inflow/infiltrations are also regarded as wastewater (Schrammel, 2014). Since the sources of wastewater differ, their composition would also be different and the active components for the different sources of wastewater generation would also differ. Hence, wastewater is classified based on the different sources from which they are generated which include domestic wastewater from the household, municipal wastewater from communities (also called sewage) or industrial activities (Haruvy, 1997). Wastewater is composed of the solid components which are usually less than 0.1% by weight and the other part of the composition which is majorly the liquid part is about 99% by weight; and the contaminating components of wastewater can be categorized as either physical, chemical and biological pollutants. Wastewater from households may sometimes be referred to as grey water and can be produced from flush toilets, sinks, dishwashers, washing machines, and showers while wastewater produced from contamination with human wastes such as urine and feces as well as other bodily fluids are referred to as black water. Wastewater produced from industrial activities is polluted with organic contaminants and could consist of heavy metals and other acidic components.

The term wastewater reuse or wastewater reclamation refers to situations whereby the various water-dependent processes are being done using water in the deteriorated (non-potable) yet pollution-free and disinfected form. The wastewater has been treated to the minimum level to avoid gross environmental pollution and the usage of wastewater at this level is restricted to areas that are not accessible to the general public such as farm and agricultural reserves etc. Actions like these reduce the demand on fresh water and control the amount of wastewater discharge into the environment; hence, it serves as an environmental pollution control mechanism. The different types of wastewater based on the nature of the source are presented in Table 1 and main characteristics of wastewater classifications are shown in Table 2 below:

Table 1. Wastewater types based on sources (Henze et al., 2008)

Direct: effluents from the society	**Indirect: generated in water treatment facilities**
Domestic wastewater	Thickener supernatant
Wastewater from institutions	Digester supernatant
Wastewater from industries	Reject water from sludge dewatering
Infiltration into sewers	Drainage water from sludge drying beds
Storm water	Filter wash water
Leachate	Equipment cleaning water
Septic tank wastewater	
Agricultural by-products	

Table 2. Characteristics of wastewater based on constituents (Henze et al., 2008; Tzanakakis et al., 2007)

Physical Characteristics	**Chemical Characteristics**	**Biological Characteristics**
Turbid	Low Oxygen composition	Biochemical oxygen demand [BOD]
Colored	A high concentration of organic Carbon	Oxygen required for Nitrification
Odor/smell	Trace Elements: N, P, Cl, SO^{2-} , *etc.*	High microbial population.
solid residues/sludge	High Alkalinity (pH)	
Temperature/heated	contains heavy metals: Pb, As, Cd, Fe, *etc.*	

3. Learning from the Past: Historical Perspective to Wastewater Reclamation and the Environmental Impacts

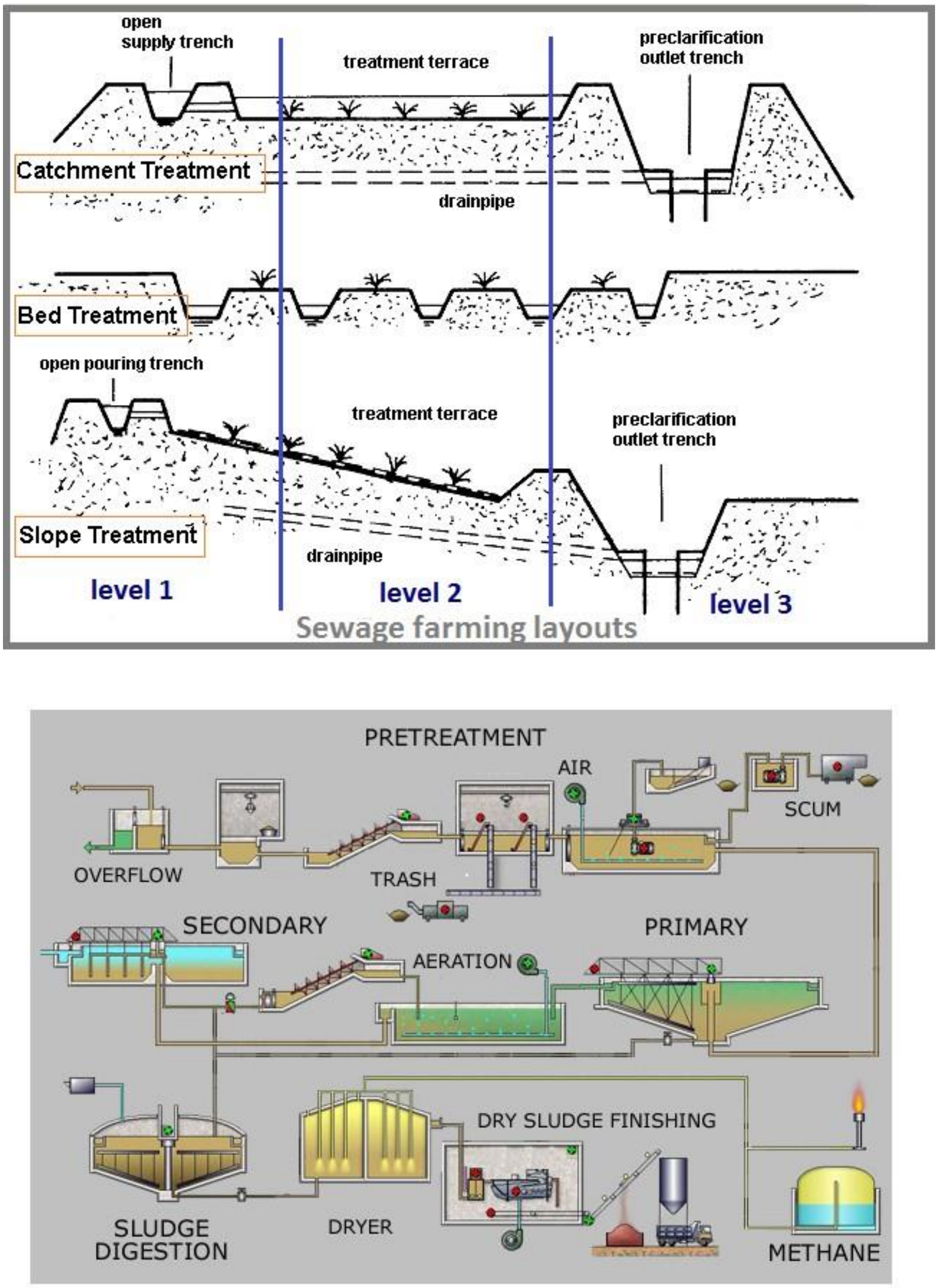
Wastewater reuse techniques have gone through many evolutionary changes and developmental stages over the years. Some of these techniques have become popular and have been significantly adopted in water-deficient regions to support groundwater recharge and facilitate alternative uses of used water. The oldest practice used for wastewater management and environmental pollution control is the land treatment approach. This involves spreading out of wastewater over the soil for crop irrigation and fertilization purposes. This alternative use of mainly domestic wastewater dated back to the prehistoric civilizations of the Bronze Age period (about 3200-1100 BC). During this period, wastewater from domestic uses is significantly adopted for disposal, irrigation, and fertilization purposes and these practices continued throughout the Hellenic civilization and the Greco-Roman technological era (Tzanakakis et al., 2007).

Sporadic increase rate of the world's population growth in the succeeding centuries led to a great increase in the volumes of wastewater production and sewage effluent into the environment, as well as the nature of their contaminants; and this caused a lot of socio-environmental problems. The contamination of water bodies due to poor wastewater effluence accounted for cholera outbreaks in many parts of the world in the 1800s, cholera outbreaks killed tens of thousands of people in London in 1832, 1849, and 1855 and the experience of the great stink of 1858 which occurred due to the unregulated discharge of untreated human waste in the river Thames was devastating (Reed et al., 1995). Hence, there arose a great need for finding socio-environmentally compliant and efficient approaches for sewage and wastewater treatment and disposal.

Sewage farming system which involves the systematic multi-levels removal of different types of contaminant from sewage effluents and wastewater (based on the size, texture, and nature of the contaminants), before the wastewater being used primarily for farming and other agricultural purposes, was developed. The sewage farming approach was introduced around the 16thcentury, first in Bunzlau (Germany) in 1531 and later in Edinburgh (Scotland) in 1650 (Angelakis & Snyder, 2015; Angelakis et al., 2018). This approach was seen as the most suitable solution for achieving a cheap disposal and controlled management of the enormous volumes of wastewater and sewage discharges.

The contaminants are removed at different levels of treatment which involves the combination of some physical, chemical and biological processes. This subsequently makes the effluent and their solid residue (sludge) more environment-friendly before discharging them into the immediate environment. A significant number of these techniques are still found operational until today. However, better sewage farm techniques have been progressively developed and adopted in different parts of the world such as the USA, France, India, Australia, Mexico, and Egypt at the turn of the new century (Saber et al., 2016). Common types of old sewage farm techniques and the layout of a modern sewage treatment plant are shown in Figure 1.

The sewage farm practice in France is one of the most advanced; the first large-size sewage farm which can process wastewater from the entire town of Paris was established at Gennevilliers in 1872. From that initial setup, several sewage farms have been developed into sewage treatment and fertilizer (manure) manufacturing plants. The use of the combined land treatment systems and sewage farm for wastewater management continued, evidently, into the 20th century in central Europe, USA, and it spreads out to other locations all around the world by the beginning of the 21st (Paranychianakis et al., 2015). However, the negative impacts of sewage farm on the environment makes it unacceptable at a point in time; making it necessary to devise a better approach for sewage and industrial wastewater control and management. The early 21st century witnessed a rapid increase in human population and a more vigorous movement of people from the rural areas to the urban areas in search of better living standard, all over the world. With this came huge increase in the amount of water consumption need and the number of wastewater effluents.



Modernized sewage treatment layout

Figure 1. Evolution of sewage treatment techniques

This led to the insufficiency of available water resources and the congestion of the existing infrastructures (water system facilities and environmental sanitation mechanism). Consequently, there are some drawbacks in the efficient adoption of sewage farm due to socio-environmental issues such as large area requirements, field operation problems, and the inability to meet the environmental hygiene requirements (Tzanakakis et al., 2014). Hence, the outbreaks of diseases, especially Cholera and Dysentery, as a result of poor individual and environmental hygiene at different parts of the world still make the development of better wastewater management techniques a crucial socio-technical issue.

4. Wastewater Reclamation, Treatment, and Reuse: Current Trends around the World

Water as a renewable resource within the hydrological cycle can be recycled by natural systems to provide a clean and safe resource (Ma et al., 2015). The level of deterioration of water is dependent on the degree of pollution and the level of contamination due to the extent of usage. However, water can be reclaimed and used again for different beneficial uses besides its initial potable use before deterioration. The quality of the used water and the specific purpose of reuse (or reuse objective) define the levels of treatment needed as well as the associated treatment costs. The various methods of wastewater treatment that are in practice today are devised in response to the needs to alleviate the hazardous effects of the indiscriminate environmental discharge of unhygienic wastewater on the public health and safety of the populace. As the population expands, the availability of land is increasingly becoming a limitation for setting up large-scale wastewater treatment plants. Also, the sudden surge in population is increasing the amount of wastewater generated in such a way that the self-purification capacity of the natural water bodies is being exceeded. Hence, it becomes expedient that improved methods of treatments are continually sourced under controlled environmental conditions. Traditional and conventional methods employed for wastewater remediation consist of the removal of heavy metals and trace elements by filtration, flocculation, activated charcoal, and ion exchange resins (Fu & Wang, 2011; Foroughi et al., 2011; Azimi et al., 2017). In general, most wastewater treatment objectives are concerned with (Topare et al., 2011):

[a] The removal of suspended and floatable material from wastewater,

[b] The treatment of biodegradable organics (BOD removal) and,

[c] The elimination of disease-causing pathogenic micro-organisms.

Figure 2 shows the different stages in wastewater reclamation and treatment techniques.

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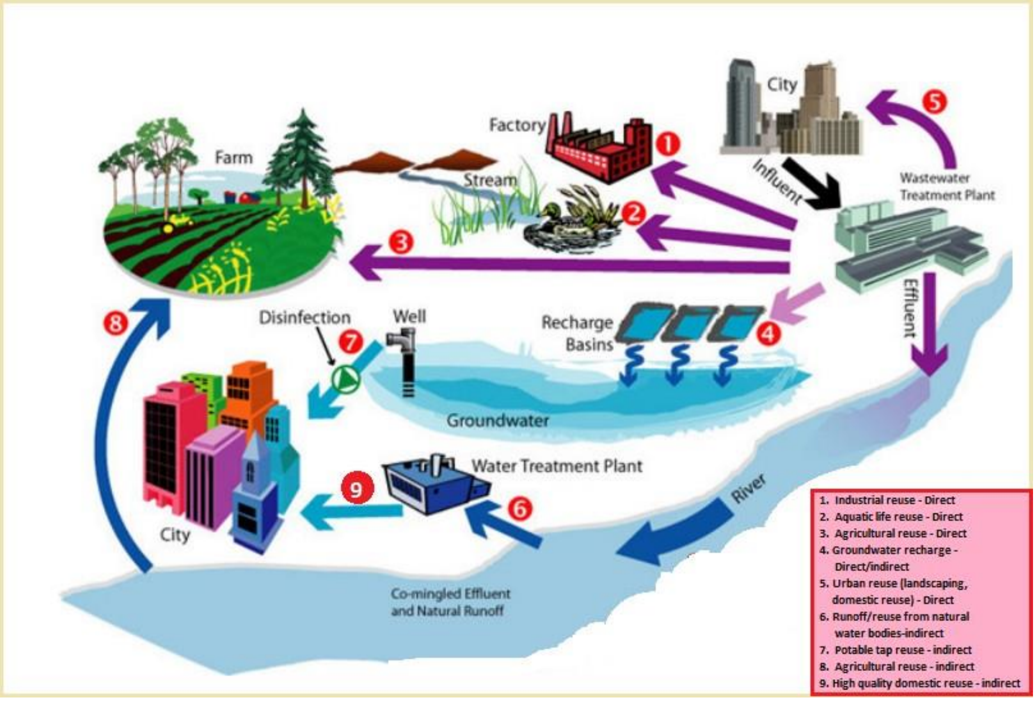

Figure 2. Common methods and stages of wastewater reclamation and reuse (Coast Learn, 2012)

4.1 Verified Methods of Wastewater Treatment

Some of the verified approaches for wastewater treatment at different hygienic levels of reuse are enumerated below:

1. Physical treatment process: Among the first treatment methods used were physical treatment operations, in which physical forces are applied to remove contaminants. Today, they still form the basis of most process flow systems for wastewater treatment (Sperling, 2007). The physical treatment processes include coagulation, mechanical flocculation, etc.

2. Chemical treatment process: Chemical processes used in wastewater treatment are designed to effect a physical change utilizing specific chemical reactions. They are always used in conjunction with physical and biological treatment processes. The inherent disadvantage of chemical treatment process compared to physical treatment is seen in their additive nature (Bhargava, 2016). This often increases the dissolved constituents of the reclaimed water; this is, at times, accompanied with slight color and taste change. The main chemical treatment processes include chemical precipitation, adsorption, disinfection, chlorination and de-chlorination, and other chemical processes.

3. Biological treatment process: Biological processes are used to convert the finely divided and dissolved organic matter in wastewater into flocculent and easily settling

organic and inorganic solids. In these processes, microorganisms, particularly bacteria, convert the colloidal and dissolved carbonaceous organic matter into various gasses and into cell tissue which is then removed in sedimentation tanks. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content measured as biological oxygen demand (BOD), total organic carbon (TOC) or chemical oxygen demand (COD) and nutrient content (notably nitrogen and phosphorus) of wastewater. Biological processes used for waste-water treatment may be classified under five major headings namely (Henze et al., 2008):

- Aerobic processes
- Anoxic processes
- Anaerobic processes
- Combined processes
- Pond processes

4. Natural treatment system: Natural systems for wastewater treatment are designed to take advantage of the physical, chemical, and biological processes that occur in the natural environment due to the interaction of the soil, plants, micro-organisms as well as the water (Rozkosny et al., 2014). Natural treatment systems comprise of the following components; land treatment, floating aquatic plants and constructed wetlands. All-natural treatment systems are preceded by some form of mechanical pre-treatment for the removal of gross solids.

4.2 Stages in the Modern Wastewater Treatment Process

In modern wastewater treatment plants, the unit operations and processes described earlier in the methods of wastewater treatment are grouped in certain varieties of combination to produce different levels of treatment. These are generally referred to as the preliminary, primary, secondary and tertiary or advanced stages of wastewater treatment (Sperling, 2007).

1. Preliminary stage: The preliminary treatment process is done to prepare wastewater effluent for further treatment by reducing or eliminating non-favorable wastewater constituents that might otherwise impede the speed of operation or cause damage to the mechanical parts of the wastewater treatment equipment. These include large solids and rags, abrasive grit, odors, and, in certain cases, unacceptably high peak hydraulic or organic loadings. Preliminary treatment processes involve the physical treatments such as screening and comminuting for the removal of debris and rags, grit removal for the elimination of coarse suspended matter, and flotation for the removal of oil and grease. Other preliminary treatment operations include flow equalization, septic tank handling, and odor control methods.

2. Primary stage: Primary treatment involves the partial removal of suspended solids and organic matter from the wastewater utilizing physical operations such as screening and

sedimentation. Mechanical flocculation with chemical additions can also be used to initiate the primary treatment process. The primary treatment acts as a precursor for secondary treatment. It is aimed mainly at producing a liquid effluent suitable for downstream biological treatment and separating solids as a sludge that can be conveniently and economically treated before ultimate disposal.

3. Secondary stage: At this stage, the removal of soluble and colloidal organics and suspended solids that might have escaped the primary treatment are targeted. This is typically done through biological processes, such as the treatment by activated sludge, fixed-film reactors or lagoon systems and sedimentation.

4. Advance/tertiary stage: Advanced wastewater treatment stage involves the removal of significant amounts of nitrogen, phosphorus, heavy metals, biodegradable organics, bacteria, and viruses. The combinations of processes involved in this stage include biological treatment such as coagulation, flocculation, and sedimentation. This is followed by filtration and activated Ceratophyllum demersum (Foroughi et al., 2011), and ion exchange and reverse osmosis for specific ion removal and reducing the amounts of dissolved solids (Shams et al., 2010). At this stage, the reclaimed water is of high quality and it is useful for user's that require high hygienic level such as cooking and even drinking.

4.3 General Reuse Practices of Reclaimed Wastewater

Some of the basic and extensive reuse practices of reclaimed wastewaters all over the world are summarized below (Elgallal, 2017; Mekala et al., 2008; Jaramillo & Tarquino, 2017):

1. Agriculture and aquaculture: From existing research, on a worldwide basis, it has been deduced that wastewater is the most widely used low-quality water for agricultural and aqua-cultural practices in most of the world (Jaramillo & Tarquino, 2017). Irrigation farming and livestock feeding can also be achieved using different levels of reclaimed wastewater. However, there are numerous socio-environmental risks to the use of untreated or poorly treated wastewater in agricultural practices. This ranges from changes to physicochemical and microbiological properties of soils to harmful impacts on human health (Alawode et al., 2019).

2. Urban usage: In urban areas, reclaimed wastewater has been used mainly for non-potable applications such as:

i. Irrigation of public parks, recreation centers, athletic fields, and playing fields, and edges and central reservations of highways.

ii. Irrigation of landscaped areas surrounding public, residential, commercial and industrial buildings.

iii. Irrigation of golf courses and public parks.

iv. Ornamental landscapes and decorative water features, such as fountains, reflecting pools and waterfalls.

v. Fire protection.

vi. Toilet and urinal flushing in commercial and industrial buildings.

4.4 Advanced Wastewater Reclamation and Reuse Actions

Advanced wastewater management systems were introduced in the first world countries around the mid-nineteenth century to improve the environmental hygienic impacts of wastewater treatment and to cope with the bane of urbanization and demands of modernization. The planning and design of better techniques and facilities for wastewater treatment and reuse is gaining consistent attention in many parts of the world. This complies with the mandatory stipulations and directives of the world health organization and other governmental and non-governmental agencies such as the United Nations, World Bank, etc. (United Nations Environment Programme, 2015). The goals are to facilitate environmental sustainability, promote hygienic societies, reduce water scarceness by curtailing wastage and promote the judicious use of available natural sources of fresh water. The third target of the UN sustainable development goal 6 (SDG target 6.3) is committed to reducing the quantity of untreated wastewater by half, thereby increasing water recycling and safe reuse significantly (United Nations Statistics Division, 2018).

Hence, in recent times, treated wastewater is found useful for several purposes ranging from strictly hygienically demanding uses such as cooking and drinking to mid hygienically demanding domestic uses such as toilet flushing and less demanding uses such as in agricultural and industrial productions. Countries such as USA, China, Japan, Spain, Israel, and Australia are rated topmost in the lists of countries with advanced water treatment and reuse facilities as shown in Figure 3. According to the environmental impact assessment report for the year 2012, the daily amount of municipal wastewater effluent discharged into the ocean and rivers is approximately 12 billion gallons out of the 32 billion gallons produced per day in the US (The National Academies of Sciences, Engineering, and Medicine, 2015); and about 80% of produced wastewater all around the world are discharged into waterways as of today (The International Water Association, 2018). In 2006, about 2.4% of the treated wastewater and sewage effluents in Europe were reused; with Germany (9.21%), France (10.28%), Italy (12.31%), Spain (15.58%), Greece (18.31%) and Cyprus (91.67%) leading the drive for wastewater reuse (Voulvoulis, 2018).

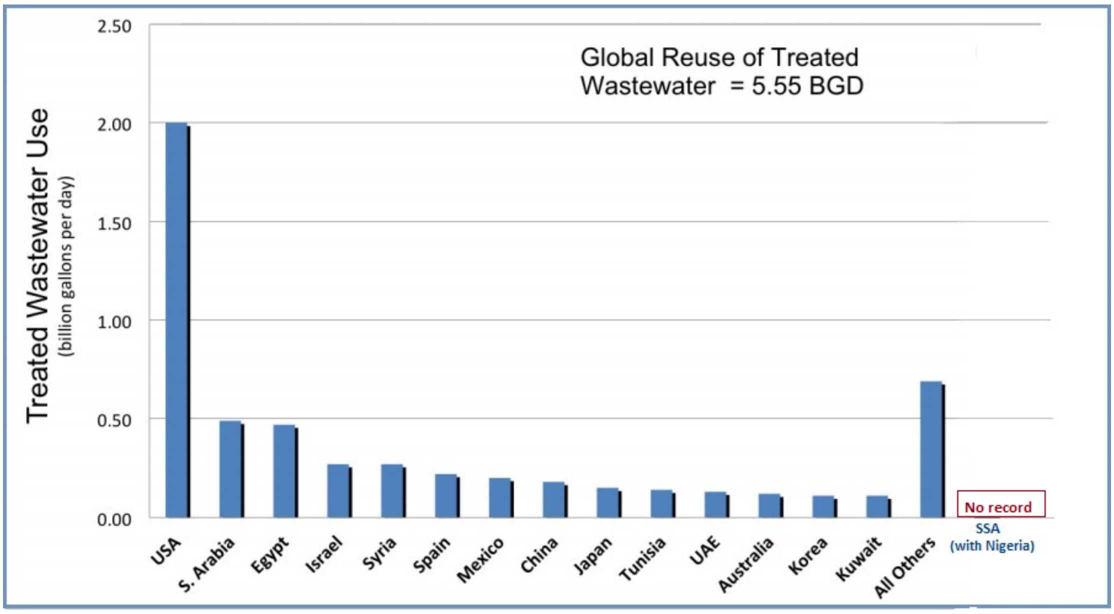

Figure 3. Global wastewater reclamation and reuse by countries

Several other countries, especially the arid and semi-arid countries, as well as the increasingly populated countries, are now giving better attention to developing ways of encouraging judicious water resource management; and improving and expanding wastewater reuse techniques. Recent efforts of mega cities such as Aqaba (Jordan), Bangkok (Thailand), Beijing (China), Chennai (India), Durban (South Africa), Kampala (Uganda), and others are reported in (The International Water Association, 2018). Their actions, backed up with well-documented water sector policies and reforms, in the aspect of increasing domestic and industrial wastewater treatment and reuse, sludge to fertilizer conversion, and so on, can serve as credible models for other cities all around the world, especially the increasingly populated cities in SSA.

5. Environmental Impacts of Water Scarcity and Wastewater Reuse Practices in Africa

According to a 2017 online report, 14 out of the 54 countries in Africa currently experiences severe water shortage issues and 11 more are under constant threat. Water-related health issues have killed more people on the continent than any other form of social, political or environmental mishaps. On average, a typical person in SSA consumes 2.6-5.2 gallons of water in a day, compared to about 160 gallons available to an average person in the developed countries (Ives, 2017). The few available sources of water have been contaminated by indiscriminate socio-cultural practice; the source of water for domestic purposes such as drinking and cooking is also the bathing place for people in the community and also serves as the drinking trough for livestock of roaming nomads. Increase industrialization, population burst, increase agricultural practices, multifarious mining practices, poor sanitation, deforestation, and so on, also constitute serious threats to the availability of clean water for people in SSA. Figure 4 shows some hardship and havoc caused by water scarcity on human lives and livestock in water-stressed and low-income regions of SSA.

Figure 4. Effects of water shortage on human life and livestock in water-stressed regions.
Source: Wikipedia images

Africa has been snail-paced in policy form elation and implementation of strategies toward achieving the UN SDG target 6.3 despite being the worst affected region. Close to 90% of generated wastewater in sub-Saharan Africa flow back into natural water bodies untreated, and the impact of poor/unhygienic wastewater handling has accounted for the loss of several lives due to disease epidemics.

Few reports are made available about wastewater management in most of Africa. However, going by the reported cases of Cholera outbreak, it can be posited that hygienic wastewater management systems are close to non-existent in many parts of sub-Sahara Africa. The uncluttered and indiscriminate disposal of wastewater and sewage is a common feature of environmental pollution and degradation in most African countries. The problem of cholera endemic remains a crucial public health concern in Africa to date. Mild and severe cases of cholera occur year-round, especially during the rainy seasons. In sub-Saharan Africa, the rivers and lakes serve as breeding spaces for disease-carrying pathogens due to poor wastewater management and control system. About 3.2 million suspected cases of cholera endemic within the African sub-region were reported to the World Health Organization between the 1970s and early 2000s. This represents 46% of all cases reported globally; sub-Saharan Africa accounted for 86% of the reported cases with 99% of deaths record in 2011 alone (Mengel et al., 2014). Figure 5 depict the reported cases of Cholera outbreak in SSA in recent years.

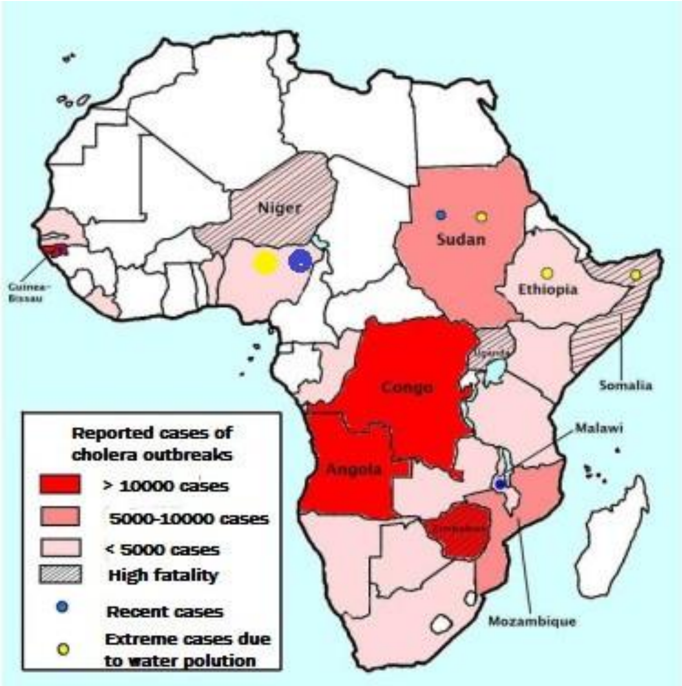

Figure 5. Water pollution management and reported cholera cases in Sub-Saharan Africa (Mengel et al., 2014)

Some North African countries such as Egypt, Tunisia, Morocco, and Algeria have taken bold steps towards the use of treated wastewater mainly for agricultural and aqua-cultural purposes. Reportedly 25% of wastewater in Morocco is subjected to one form of treatments or the other and most of this reclaimed water is limited to agricultural practices, industrial processes, and groundwater recharge. In Egypt, more sophisticated wastewater handling and treatment methods ensured that the reclaimed water can be used for more noble functions depending on its quality. SSA countries such as Ghana, Burkina Faso, and Senegal practice some form of wastewater reuse. However, these are done at a very low treatment quality and mostly unregulated and most times create more problems for the environment. Some of the common wastewater treatment practices are waste stabilization ponds otherwise known as activated sludge, and the efficiency of treatment is practically unattainable due to poor infrastructures (Nikiema et al., 2013).

6. Potential Benefits of Wastewater Reuse Policies and Practices in Sub-Saharan Africa

One of the goals of the United Nations Economic and Social Council policy on water usage is to ensure that the suitability of water for different applications should be based on the nature of the water and the purpose of usage. Hence, high-quality water should be reserved for highly hygienic use while low-quality water can be used for lesser alternatives. Richard Helmer and Ivanildo Hespanhol posited that water has become a limiting factor which significantly impedes the agricultural and industrial development of arid and semi-arid regions of the world (Hespanhol & Helmer, 1997). This has also been the situation in most developing nations where the uninhibited population growth is unmatched with adequate social infrastructural planning. Hence, it becomes urgently necessary for water resources managers, water engineers and the government to work together to devise suitable modalities for water resource management, utilization and conservation that consider the socio-environmental peculiarities and cultural practices of this water-stressed regions. In order to effectively combat the scarcity of water and to make the most use of the available water resources in these regions, the development of effective technologies to curtail wastewater wastage should be considered. This seems to be a logical means by which water use efficiency can be improved and sustained in these regions considering the daily amount of domestic wastewater being generated.

The reuse of wastewater constitutes an important element of water resources policy and strategic developmental efforts of the United Nations environmental programmes. In the light of the growing awareness of wastewater reclamation and reuse, many nations, particularly those in the arid and semi- arid regions such as the Middle Eastern countries, have come to take up the principle of wastewater reuse as an important concept in their overall water resources policy and planning. A judicious wastewater use policy has helped to transform wastewater from an environmental and health liability to an economic and environmentally sound resource in the arid part of the middle-east region (Elgallal, 2017), and the SSA can also benefit from this approach. Structures should, therefore, be put in place to establish more regulated wastewater reclamation and reuse within a broader framework of a national effluent use policy, which can go a long way in the conservation of national water resources in SSA, as it is obtainable elsewhere (United Nations Environment Programme, 2015). To ensure long-term sustainability and efficiency, sufficient attention must be given to the social, institutional and organizational (both governmental and non-governmental) aspects of wastewater effluent reuse. The socio-cultural, religious and political barriers that can obstruct the acceptance of remediated and properly treated wastewater and sewage effluents need to be addressed through concerted efforts, especially as the whole world is being faced with the gruesome realities surrounding the uncertainty facing the sufficiency of existing groundwater reserves in most regions of the world.

7. Overcoming the Challenges of Wastewater Conservation and Reuse in Sub-Saharan Africa

Generally, an effective water conservation and management approach involve five best practices which are water use avoidance, water use reduction, and used water storing, recycling used water and prioritizing the use of the recycled/reclaimed water. Several water-efficient devices/practices such as shower-head, toilet system, dishwasher, washing machine, landscaping, and so on have been adopted in several countries. There are stringent rules and established regulations that guide the amounts of water in liters or number of gallons that must be consumed during each water-based process and there is compensation for adherence and penalty for violation. This approach can be adopted in SSA and this calls for the provision of some sophisticated water management infrastructures which may be needed for adequate monitoring, control and billing which are not yet available in most parts of SSA. In another way, putting a high cost on the usage of fresh water while charging less for the same amount and quality of reclaimed water can help to curtail the indiscriminate overuse of both fresh and reclaimed water and it can also help to ensure that the reclaimed water is put into judicious usage base on prioritizing. More so, water exchange process whereby properly stored used water will be exchanged for a predefined amount of fresh water depending on the quality and turbidity of the used water can encourage people to store their used water instead of wasting it openly.

In 2016, Mohammed and El Bably (Mohammed & El-Bably, 2016) considered the inhibition to the spread of wastewater reuse in the developing countries, especially SSA and he attributed these inhibitions to the lack of dual distribution system and the high cost of the infrastructure for storing and transporting reclaimed wastewater. Other notable challenges are large organic contents and high flow rates of wastewater effluents, unregulated waste disposal, poor electricity supply to treatment plants and high energy cost, poor operation and maintenance of wastewater treatment plants and lack of re-investment. The use of decentralized collection and management system for wastewater in the urban centers, as well as setting up the wastewater treatment plants very close to the site at which the wastewater has been generated, is encouraged to reduce the overall cost. The issue of socio-cultural perception of people towards wastewater reuse is something that is critical to the implementation and acceptance of wastewater reuse in SSA.

Advanced technologies can help to curtail wastewater wastage and increase the reliability/quality of the reclaimed water. However, one major challenge that is facing the developing countries is the level of illiteracy and the arduous task of sensitizing and informing the public on their required actions towards curtailing wastewater wastage and towards the acceptance of reclaimed water. For wastewater recycling to be considered as a viable option in developing nations, the attitude of the public towards the reclaimed water must be changed in terms of willingness to buy the recycled water at a good price and willingness to limit the usage of freshwater to high-level hygienic demand (Jeuland, 2015). Also, the huge cost of setting up high-level wastewater treatment facilities requires that the investors are assured of sufficient patronage through government policies and public agreement.

8. Conclusion

This report presents the concept of wastewater, wastewater reclamation and reuses strategies for combating environmental pollution and water scarcity with a major focus on sub-Saharan Africa region. It contains a brief review of the various methods and stages involved in wastewater purification and treatment towards safe and effective reuse. A variety of options available for wastewater treatment are feasible for use in the developed countries through the combination of some low-technology and sophisticated approaches. However, there are currently limited options for wastewater treatment and utilization for the worst-affected regions such as SSA due to certain factors ranging from cost to lack of sustainable policies.

In this report, various wastewater reuse approach for sub-Saharan Africa has been discussed; especially in the broad view of the current increase of interest by environmental managers and engineers on the issues relating to environmental sustainability. This report also considered the emergent issues which borders on socio-cultural view, considerations for implementations and technological options related to the scale of wastewater collection and treatment systems in the concern regions. In conclusion, with better treatment techniques, low implementation cost and better public awareness, the problem of water scarcity that is ravaging the SSA region can be mitigated while the level of environmental pollution caused by wastewater mishandling can be grossly reduced.

References

Alawode, O. I., Ojo, O. I., & Adewuyi, O. B. (2019). Physico-Chemical Analysis and Social Impacts of Heavy metals from Landfill Leachates in Groundwater: A Case Study of Ogeese Community, Oyo State, Nigeria. *International Journal of Environmental Sciences Natural Resources*, 17(3), 1-6. [Online] Available: https://juniperpublishers.com/ijesnr/pdf/IJESNR.MS.ID.555964.pdf

Angelakis, A. N., & Snyder, S. A. (2015). Wastewater Treatment and Reuse: Past, Present, and Future. *Water, 7*, 4887-4895. https://doi.org/10.3390/w7094887

Angelakis, A. N., Asano, T., Bahri, A., Jimenez, B. E., & Tchobanoglous, G. (2018). Water Reuse: From Ancient to Modern Times and the Future. *Frontiers in Environmental Science, 6*(26), 1-17. https://doi.org/10.3389/fenvs.2018.00026

Azimi, A., Azari, A., Rezakazemi, M., & Ansarpour, M. (2017). Removal of Heavy Metals from Industrial Wastewaters: A Review. *Chem Bio Eng Reviews, 4*(1), 37-59, https://doi.org/10.1002/cben.201600010

Bhargava, A. (2016). Physico-Chemical Waste Water Treatment Technologies: An Overview. *International Journal of Scientific Research and Education, 4*(5), 5308-5319. http://dx.doi.org/10.18535/ijsre/v4i05.05

Coast Learn (2012). *Water quality management: Treated wastewater reuse*. [Online] Available: www.coastlearn.org/water_quality_management/practice-twr.html

Elgallal, M. M. (2017). *Development of an approach for the evaluation of wastewater reuse options for the arid and semi-arid area*. Ph.D. thesis, The University of Leeds.

Eregno, F. E., Moges, M. E., & Heistad, A. (2017). Treated Grey water Reuse for Hydroponic Lettuce Production in a Green Wall System: Quantitative Health Risk Assessment. *Water, 9*(7), 454. https://doi.org/10.3390/w9070454

Foroughi, M., Najafi, P., & Toghiani, S. (2011). Trace Elements Removal from Waster water by Ceratophyllum demersum. *Journal of Applied Sciences and Environmental Management, 15*(1). http://dx.doi.org/10.4314/jasem.v15i1.68441

Fu, F., & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review, *Journal of Environmental Management, 92*(3), 407-418. https://doi.org/10.1016/j.jenvman.2010.11.011

Haruvy, N. (1997). Agricultural reuse of wastewater: nation-wide cost-benefit analysis. *Agriculture, Ecosystems & Environment, 66*(2), 113-119.

https://doi.org/10.1016/S0167-8809(97)00046-7

Henze, M., Van Loosdrecht, M. C. M., Ekama, G. A., & Brdjanovic, D. (2008). *Biological Wastewater Treatment*. IWA Publishing, London, UK, 1 edn.

Hespanhol, I., & Helmer, R. (1997). *Water Pollution Control-A Guide to the Use of Water Quality Management*, E & FN Spon., Thomson Professional for WHO/UNEP.

Hopfenberg, R., & Pimentel, D. (2001). Human Population Numbers as a Function of Food Supply. *Environment, Development and Sustainability, 3*(1) 1-15. https://doi.org/10.1023/A:1011463231976

Ives, E. M. (2017). *Water pollution in Africa: reasons, effects, statistics*. [Online] Available: https://www.waterpebble.com/water-pollution-in-Africa

Jaramillo, M. F., & Tarquino, I. R. (2017). Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits, *MDPI sustainability, 9*(10). https://doi.org/10.3390/su9101734

Jeuland, M. (2015). Challenges to wastewater reuse in the Middle East and North Africa. *Middle East Developmental Journal, 7*(1), 1-25. https://doi.org/10.1080/17938120.2015.1019293

Kummu, M., Guillaume, J. H. A., de Moel, H., Eisner, S., Floerke, M., Porkka, M., Siebert, S., Veldkamp, T. I. E., & Ward, P. J. (2016). The world's road to water scarcity: Shortage and stress in the 20th century and pathways towards sustainability. *Scientific Reports, 6*, 38495. https://doi.org/10.1038/srep38495

Lewis, L. (2019). *Rural and urban water issues in Africa*. [Online] Available: https://thewaterproject.org/water-crisis/water-in-crisis-rural-urban-Africa

Ma, X., Xue, X., Gonzalez-Mejia, A., Garland J., & Cashdollar, J. (2015). Sustainable Water Systems for the City of Tomorrow-A Conceptual Framework. *MDPI sustainability, 7*(9), 12071-12105. https://doi.org/10.3390/su70912071

Mekala, G. D., Davidson, B., Samad, M., & Boland, A. M. (2008). *Wastewater reuse and recycling systems: a perspective into India and Australia*. IWMI Working Papers H041343, International Water Management Institute.

Mengel, M. A., Delrieu, I., Heyerdahl, L., & Gessner, B. D. (2014). Cholera Outbreaks in Africa. In Nair, G. B., & Takeda, Y. (Eds.), *Cholera Outbreaks: Current Topics in Microbiology and Immunology* (pp. 117-144), Springer.

Mohammed, A., & El-Bably, M. (2016). Technologies of Domestic Wastewater Treatment and Reuse: Options of Application in Developing Countries. *JSM Environmental Science & Ecology, 4*(3), 1-9.

National Research Council (2012). *Understanding Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*. The National Academies Press; https://doi.org/10.17226/13514

Nikiema, J., Figoli, A., Weissenbacher, N., Langergraber, G., Marrot, B., & Moulin, P. (2013). Wastewater treatment practices in Africa-Experiences from seven countries. *Sustainable Sanitation Practice, 14*, 26-34.

Paranychianakis, N. V., Salgot, M., Snyder, S. A., & Angelakis, A. N. (2015). Water Reuse in EU States: Necessity for Uniform Criteria to Mitigate Human and Environmental Risks. *Critical Reviews in Environmental Science and Technology, 45*(13), 1409-1468. https://doi.org/10.1080/10643389.2014.955629

Reed, S. C., Crites, R. W., & Middlebrooks, E. J. (1995). *Natural Systems for Waste Management and Treatment*. McGraw-Hill, Inc., New York, USA, 2 edn.

Roccaro, P. (2018). Treatment processes for municipal wastewater reclamation: The challenges of emerging contaminants and direct potable reuse. *Current Opinion in Environmental Science Health, 2*, 46-54. https://doi.org/10.1016/j.coesh.2018.02.003

Rozkosny, M., Kriska, M., Salek, J., Bodik, I., & Istenic, D. (2014). *Natural Technologies of Wastewater Treatment*. Global Water Partnership Central and Eastern Europe (GWP CEE).

Saber, M., Abouziena, H. F., Hoballah, E. M., Haggag, W. M., & Zaghloul, A. E. M. (2016). Sewage farming: Benefits and adverse effects. *Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7*(3), 297-313.

Salgot, M., & Folch, M. (2018). Wastewater treatment, and water reuse. *Current Opinion in Environmental Science Health, 2*, 64-74. https://doi.org/10.1016/j.coesh.2018.03.005

Schrammel, E. (2014). *A cost-benefit analysis of hydroponic wastewater treatment in Sweden*. Advanced level Degree thesis No 918, Swedish University of Agricultural Sciences.

Senate Department for Urban Development and Housing, Sewage Farms. [Online] Available: https://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ed110_02.htm

Shams, S., Anderson, W. B., & Huck, P. M. (2010). *Assessing Ion Exchange and Reverse Osmosis for Nitrate Removal from Drinking Water*. 2010 OWWA/OMWA Joint Annual Conference and Trade Show, Windsor.

The International Water Association (2018). *Wastewater Report 2018: The Reuse Opportunity*. [Online] Available: https://www.iwa-network.org/wp-content/uploads

The National Academies of Sciences, Engineering, and Medicine (2015). *Understanding water reuse: potential for expanding the nations' water supply through reuse of municipal wastewater*. [Online] Available: https://www.nas-sites.org/waterreuse

Topare, N. S., Attar, S. J., & Manfe, M. M. (2011). Sewage/wastewater treatment technologies: a review. *scientific Reviews Chemical Communications, 1*(1), 18-24.

Tzanakakis, V. E., Paranychianaki, N. V., & Angelakis, A. N. (2007). Soil as a wastewater treatment system: historical development. *Water Supply, 7*(1), 67-75. https://doi.org/10.2166/ws.2007.008

Tzanakakis, V., Koo-Oshima, S., Haddad, M., Apostolidis, N., & Angelakis, A. (2014). The history of land application and hydroponic systems for wastewater treatment and reuse. In A. Angelakis, & J. Rose (Eds.), *Evolution of Sanitation and Wastewater Management through the Centuries*. chap. 24, IWA, 1 edn., 459482.

United Nations Environment Programme (2015). *Regional wastewater management policy template, and toolkit*. CEP Technical Report: 88. [Online] Available: http://www.cep.unep.org/publications-and-resources/technical-reports

United Nations Statistics Division (2018). *The Sustainable Development Goals Report 2018*. [Online] Available: https://unstats.un.org/sdgs/report/2018

Vairavamoorthy, K., Gorantiwar, S. D., & Pathirana, A. (2008). Managing urban water supplies in developing countries-Climate change and water scarcity scenarios. *Physics and Chemistry of the Earth, Parts A/B/C, 33*(5), 330-339. https://doi.org/10.1016/j.pce.2008.02.008

Von Sperling, M. (2007). *Basic principles of Wastewater Treatment*. IWA Publishing, London, UK, 1 edn.

Voulvoulis, N. (2018). Water reuse from a circular economy perspective and potential risks from an unregulated approach. *Current Opinion in Environmental Science Health, 2*, 32-45. https://doi.org/10.1016/j.coesh.2018.01.005

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