Establishing the feasibility of alleviating water shortages in Cape Town using decentralised wastewater treatment plants

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Water of adequate quantity and quality is essential for socio-economic development (Blignaut and van Heerden, 2009; Qin, 2012; Zhuang, 2014). The challenge is that the sustainability of suitable water resources is threatened by a continuous rise in water demand as a result of urbanisation, population and economic growth, while suitable water resources are adversely affected by pollution and climate change (Blignaut and van Heerden, 2009; Wei et al., 2016). Stringent water conservation measures in South Africa have led to restricted water consumption and a rise in the use of alternative water sources to supplement constrained surface and - groundwater resources (Nel et al., 2017; CoCT, 2019). However, these supply and demand management actions alone may not be enough for ensuring sustainable water sources in the future (Drangert and Sharatchandra, 2017; Sgrio et al., 2018).

This paper explores the solutions within the reuse management sphere, with specific focus on circular economy principles that aims to extract value from waste streams within the urban water system. Large centralised wastewater reuse systems are well established in the urban water system, yet smaller decentralised wastewater systems within large urban regions are still relatively unexplored (Massoud, Tarhini and Nasr, 2008; Sgrio et al., 2018). To address this shortfall in the knowledge field, this paper investigates the impact of implementing decentralised wastewater reuse systems in densely populated urban regions to address looming water shortages in semi-arid regions. Using case study research and system dynamics (SD) modelling, the use of decentralised wastewater treatment (WWT) systems in water intensive commercial and industrial facilities in the City of Cape Town (CoCT) are explored.

To explore and understand the complex urban water system, robust case study research can be applied (Zainal, 2007). Investigation identified Old Mutual (OM) in Pinelands as a singular case in industry operating a decentralised wastewater treatment facility on-site to provide potable quality water for on-campus consumption in the CoCT (Borman, 2018). Since 2016 the OM Pinelands campus, referred to as *Mutualpark*, has conducted intensive efforts towards water conservation prior to installing a blackwater filtration plant in 2018. The real-world application of a decentralised system at Mutualpark in the CoCT serves as the basis on which the SD model is built. The stock-and-flow diagram consists of two stocks, *OM Storage Tanks* and *OM WWT Plant Capacity* with respective flows and auxiliary variables representing elements of the decentralised water system.

The validated model results present the financial feasibility and the annual water savings achievable by decentralised WWTP operating in the CoCT during normal, dry and drought conditions. The aim is to provide simulation results investigating several reuse scenarios affording decisionmakers with insight and understanding prior to investing in private water reuse systems.

Financial Feasibility: Water and sanitation tariffs vary with regulatory restriction levels which are based on average annual rainfall in the region. This varying tariff structures significantly influence the investment payback period, halving the return from normal rainfall periods to drought conditions in the CoCT. Reduced consumption losses and throughput improvements reduce the total potable water required from centralised sources, which also reduces the water and sanitation costs further. It is evident that extensive investment is required to construct and operate decentralised reuse systems within private industry. However, tax incentives and water pricing are used to drive sustainability agendas and innovation, especially in the water and sanitation sphere (Siebrits and Fundika, 2017).

Water Supply Stress: Decentralised water reticulation systems are implemented in response to the future water scarcity in the region, incremental rise in water tariffs and the drive towards zeroing waste (Adewumi et al., 2010). Although these systems do not necessarily prove to be economically feasible, goals and objectives for supplementing municipal potable water resources and internal water assurance can still be achieved (Adewumi et al., 2010). In addition, decentralised water reuse systems are rarely independent from centralised system, coexisting to address regional water shortages (Libralato, Ghirardini and Avezzu, 2011). To investigate the impact of decentralised WWT Plants (WWTPs) in an urban context, the OM SD model and test scenarios are refocused to evaluate the impact of decentralised water reuse on water supply stress in the CoCT. Where annual consumption varies with changes in conservation measures and tariff structures.

The effect of using decentralised WWTPs to alleviate water demand in the CoCT's industrial sector (which receives 30% of total CoCT urban allocation from the Western Cape Water Supply System) during constrained (drought) and unconstrained (normal) scenarios are explored. The simulation results for the on-site water filtration plants are based on an external input of 25% municipal treated effluent, 27% municipal potable water and zero groundwater, with internal consumption and production losses set at 47% and 5% respectively.

The results show a meaningful alleviation in water supply stress once more decentralised system in the CoCT contribute to the reducing municipal potable demand (more than 20 units). It is evident that during unconstrained periods, when water supply is enough and water tariffs are lowered, water supply stress is well below one (1) indicating that there is enough water in the region. Additional benefit can be extracted from the system by improving system throughput by utilising alternative onsite sources of non-potable water to supplement inflow into the WWT system. Based on the OM system, only 73% of total water requirements are met by the internal WWTP. The results reiterate the dependence of decentralised systems on the larger centralised networks and groundwater resources in urban regions. However, further exploration into the reuse of on-site urban rainwater runoff may serve to reduce the dependency of the system inflow on external sources such as municipal treated effluent.

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