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Decision support tool for assessing the sustainability of water reuse for portable applications in South African communities

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ABSTRACT

In South Africa (SA), freshwater scarcity can significantly be abated by the reuse of treated municipal wastewater for potable applications. However, the question of what a sustainable water reuse scheme is, and how the sustainability of the scheme can be assessed need to be answered. This is imperative to the overall success of water reuse schemes and the movement towards contributing to a low carbon, sustainable society. To achieve this goal, there is need to develop a decision support tool that would enable a balance between the institutional, social, economic, technical and environmental attributes involved in the sustainability of water reuse for potable applications. The aim of this research work is to develop an integrated sustainability index (ISI) as a Decision Support System (DSS) for assessing the sustainability of water reuse for potable applications in South African communities.

To address the issue of how much water is available for reuse; this study developed a linear regression model and a Bayesian Network model for predicting usable return flow (i.e. wastewater that can be treated and used for other beneficial purposes) from agricultural and domestic activities in SA water management areas. The result of the study shows that about 8% of the agricultural water use is potentially reusable while about 34% of the total domestic water use is potentially reusable. Furthermore, the study also shows that given the agricultural water use, the usable return flow from agricultural activities can be predicted with a reasonable accuracy as well as given the domestic water use and the population density; the usable return flow from domestic activities can be predicted with a reasonable accuracy.

A study was carried out for development and selection of criteria for the sustainability assessment process based on their relevance and degree of importance to the sustainability assessment process by consulting with 51 experts in SA water sector with knowledge on reuse. The preliminary group of criteria comprises of 22 primary criteria and 53 secondary criteria which were reduced and harmonized to 16 primary criteria and 27 secondary criteria based on experts' opinion. These criteria constitute the quantitative and qualitative sustainability assessment criteria modules of the ISI. The quantitative modules consist of economic, technical and environmental assessment criteria while qualitative modules consist of social and institutional assessment criteria. The quantitative module begins with an estimation of water

saving potentials for the selected case study sites namely Emalahleni, Hendrina and Beaufort West municipalities. The result of the water saving potential analysis indicates that water demand for domestic activities can be reduced by approximately 22.8 %, 47.3% and 29.3% in Emalahleni, Hendrina and Beaufort West municipalities respectively. With the challenges due to data availability, this module provides a quantifiable factor to illustrate potable water savings due to reuse as a justification for reuse project. For assessing energy intensity and operation and maintenance costs which are classified as quantitative environmental and economic criteria respectively, two models were developed: (i) an activity based energy utilization (ABEU) model for assessing the energy intensity of water reuse systems and (ii) an integrated cost analysis model for evaluating operational and maintenance costs of water reuse systems. The two models were applied to two water reclamation plants in Mpumalanga province, South Africa. The result of ABEU indicated that the overall energy utilized by plant A and B are 4.53kWh/m^3 and 2.1803kWh/m^3 for the production of an average volume of 19,295 m^3 and 14,236 m^3 of reclaimed water for potable application respectively. The result of the integrated cost analysis model indicated that overall operation and maintenance cost of production of reclaimed water for plant A and plant B respectively are 16.1 ZAR/m^3 and 11.4 ZAR/m^3 respectively. The social qualitative module of the ISI contains simplified questionnaire that was developed to evaluate social dimension of sustainability.

A hypothesized behavioral model was developed to investigate factors influencing intention to accept recycled/reclaimed water for potable applications. The results obtained from the application of the hypothesized model to Emalahleni and Hendrina municipalities show that factors such as knowledge of benefits of reuse, ethical awareness (subjective norms), credibility of water service authority, and risk perception were vital to intention to accept reuse for potable applications.

The application the ISI to Emalahleni, Hendrina and Beaufort West municipalities showed the tool to be a robust tool and provide a good assessment of both qualitative and quantitative criteria in the assessment of water reuse for potable applications. Beaufort West municipality has the highest score of 0.7484, followed by Hendrina municipality with a score of 0.7182 and Emalahleni municipality with the lowest score of 0.5891. The result of the individual sustainability dimension analysis shows that Beaufort West has the highest scores of 0.9179 and

0.8473 in social and institutional dimensions respectively in comparison with Hendrian and Emalahleni.

It can be deduced from the scores of the sustainability dimensions that economic dimension fares the worst with an average score of 0.4756 across the of the three case study sites. Hence, it appears that economic criteria contribute to challenges impeding the transition towards a sustainable state. A satisfactory score of 0.9190 in social dimension analysis was recorded for Hendrina as well with a moderate score of 0.6350 recorded for Emalahleni. Hence, in Emalahleni resources must be allocated to educate the public on reuse. Further analysis indicates that the relative strength of the three case study sites lies in the technical dimension, with score of 0.7756, 0.8409 and 0.8310 for Emalahleni, Hendrina, and Beaufort West respectively. On the other hand, economic dimension contributes the least to the overall scores of the case study sites, with scores as low as 0.3877, 0.5643and 0.4778 in Emalahleni, Hendrina and Beaufort West respectively. Based on the classification of the range of ISI scores and the corresponding interpretation, Emalahleni municipality falls into the category of "low potential for sustainability" at the period the assessment. On the other hand, Hendrina and Beaufort West municipalities falls under the category of "reasonable potential for sustainability" at the period the assessment was carried out.