Systems Dynamic of Portable Water Shortage in the Limpopo Province of South Africa

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Abstract

Limpopo is the hottest Province in South Africa and has less percentage of rain to fill up its dams and rivers. There is a higher chance for the communities to run short of water because the used water is not recycled. The villages use pit toilets, therefore, it becomes difficult to have a water recycling plant. The purpose of this study is to model the water supply chain to determine the solution for water delivery in rural areas of the Limpopo Province. A system dynamic model is developed using Vensim software. The system is simulated to develop a solution to water crises in the province. The systems dynamics modelling is discussed herein. The Vensim Model was to capture the interaction between the source of water, water treatment plant, water recycling, potable water transmission, commercial and domestic water distribution. The results show that the building of infrastructure for portable water without recycling plant, will partially solve the crisis of water shortage in the province. The recycling plant is found to be helpful in saving water for future purposes.

Keywords
Systems Dynamics, Model, System, Limpopo, Water Recycling.

1. Introduction

Limpopo is the hottest Province in South Africa. The most recent drought experienced by the country consequently caused a drop in rivers flow, which then resulted in dams drying out. A large amount of the land area in the province is occupied by rural settlements. The cause of the water supply problem in Limpopo Province is due to lack of facilities to accommodate the demand of water in communities. Most communities are finding it difficult to access the resource and the municipalities have not reached the people to provide services. The water in the areas is not drinkable. The low income communities in the province rely on pit latrines as their primary means of sanitation. The pit latrines cause human and ecological health impacts associated with microbiological and chemical contamination of groundwater [1]. It has become difficult to find means of cleaning the water themselves, this is mainly because of poor maintenance of the supply systems. The existing infrastructures do not meet the water supply demand. The population growth in the communities has caused some members of the community to find their source of water, mainly boreholes. There are no proper pumping systems to meet the water demands in the communities. The existing pumping system does not supply enough water and members in the communities do illegal connections [1, 3]. This has affected the water pumping system whereby the system is at risk of being damaged due to increased load which surpasses the designed system load. The pumps used to transport water from boreholes to the community are not well maintained [4, 5]. The water does not reach to entire communities due to failure of the pumps, elevations and pressure drops in the system [1, 7]. Also, for many years municipalities have been known to mismanage resources to water supply systems and slow in providing services. The systems dynamic analysis approach is used to assess the challenge of water supply in Limpopo Province.

2. Study Area

The study areas focus on villages in Greater Tubatse municipality. The municipality is in Limpopo Province of South Africa. The villages are Kgopaneng, Makubu, Malokela and Ga-Phala. The villages are located at the North-Western side of Greater Tubatse District Municipality and they are 52.1 km away from Burgersfort town. The study Areas depend more on boreholes and rain to get water. There is a shortage of water because the municipality could not provide enough water to meet the demand. The existing infrastructures do not meet the demand and again the water is not potable enough as a results, the health of community members get affected [6]. Furthermore the problem of acid mine drainage from abandoned mines affect rivers and streams in the study area [13 - 16].

3. Systems Dynamic Approach

The study areas currently access water from boreholes done by the municipality and some households have their own boreholes. Other households buy from houses with boreholes and it has become a challenge to households that cannot afford. The rain as well serves as a water source to the community hence during seasons with no rain they suffer the most. Figure 1 demonstrates the current water systems in the study areas. The communities access water from boreholes. The water is not treated before is distributed to the communities. The used water is not recycled and the inflow water drops because of water that is used without being recycled back into the system.

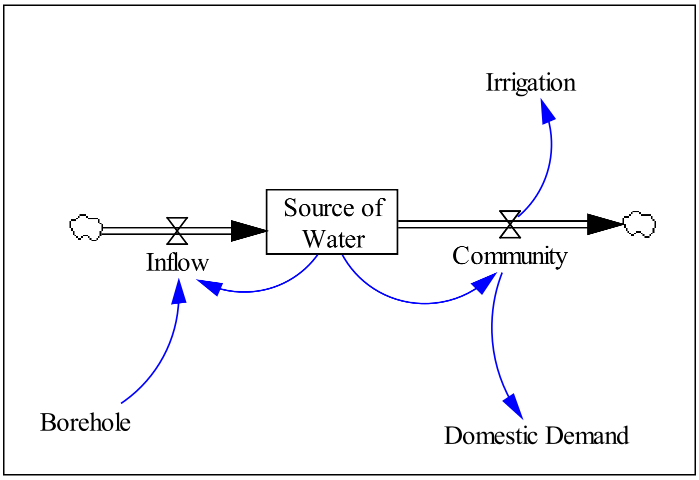

Figure 1: Stock and Flow Diagram of Water Supply in the Study Areas.

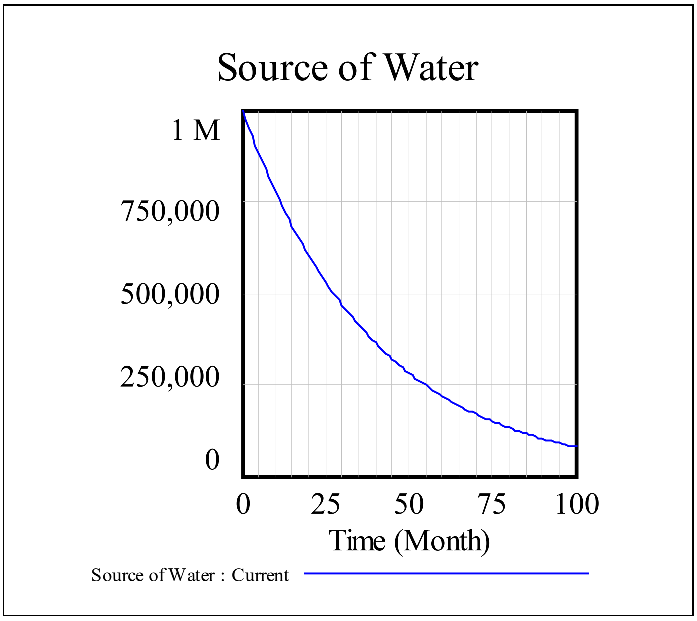

Figure 2: Impact of Domestic Demand and Agriculture on the Source of Water Over 100 Months Without Recycling.

The trend of the graph in Figure 2 shows the source of water dropping over 100 months due to the increase in population, climate change and shortage of water caused by lack of proper systems to manage water.

3.1 System Dynamic Approach to Assess Water Supply

The solution to the challenge of water supply in Limpopo Province is to develop a system dynamic model that will assist with providing bulk water that is portable. The system dynamic model in this paper is developed (refer to Figure 3) to capture the interaction between water source, water treatment plant, water storage, potable water transmission, commercial, water portable distribution. The portable water has to be distributed to the consumers for use. The used water needs to be recycled for irrigation and back to the river so that it can be abstracted again to purification plant for treatment. The system is good for rural and urban areas to have access to potable water and it will save water because the wastewater is recycled and reused in the system [6, 7]. The Vensim simulation is developed to bring the solution to the challenges of water supply in the study areas.

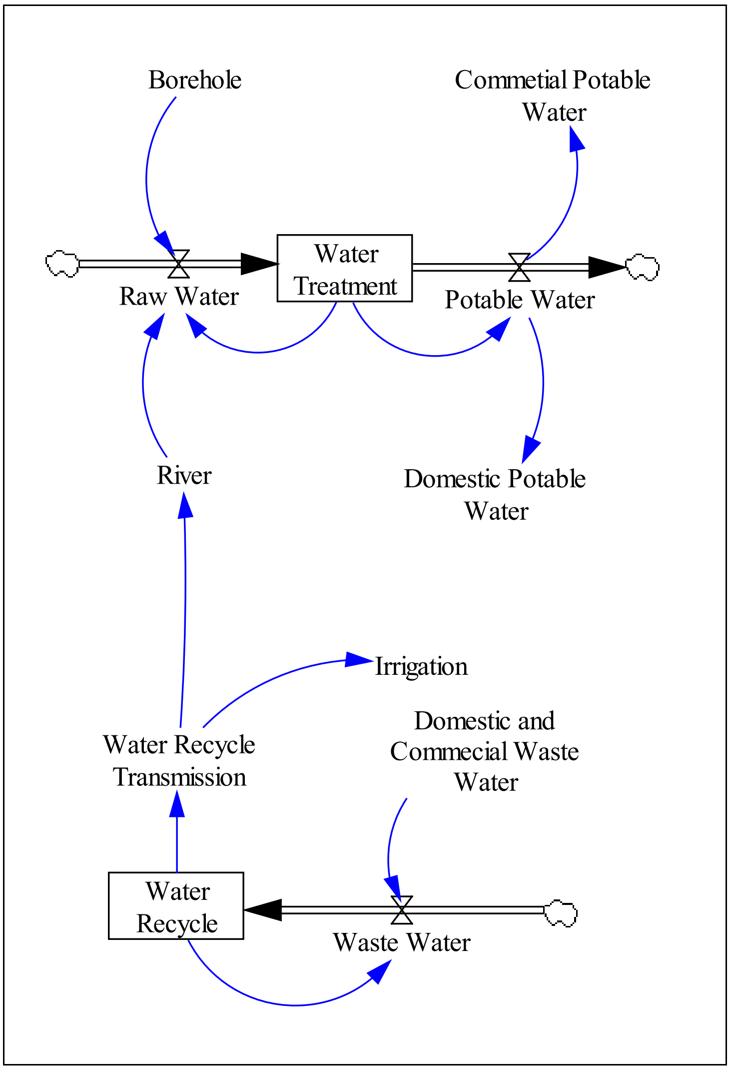

Figure 3: The Process of Water Supply for the Study Areas.

3.2 Water Treatment and Recycle

The treatment of water involves the process in which water is purified until it is suitable for domestic and commercial use. The water recycle plant is used for recycling of used water from domestic and commercial consumers. Figure 3 shows that the amount of water sent to the treatment process must be from different sources like rivers and boreholes so that if one source fails, another source can supply raw water for treatment. The health of the people in the communities is been considered by ensuring that the water from river and boreholes is purified.

The recycling process is introduced to save water for future purposes. The proposed system in Figure 3 will help with management of water.

4. Results and Discussion

In this study, comparison between the water supply cycle with the recycling process and less recycling is done. The system in Figure 1 does not solve the challenges communities has with water shortages, instead, it assesses the cause of water shortages. The water from the supplier is not always purified and the health of the community members are affected. There is also a drop in the water supply as illustrated in Figure 2. Figure 3 illustrates the solution proposed for the challenge of water supply in Limpopo Province. The comparison of system with recycling water and less recycle water is shown in Figures 4-8.
The red line in figure 4 shows the dropping of the recycling process for used water. It will affect the amount of raw water abstracted for treatment. It means that over time, the raw water supply will drop, see the red trend in figure 5. The dropping of raw water (refer from figure 6), it means the water to be treated and supplied for domestic and commercial use will be less, see the red trend in Figures 7 and 8.

The blue trend of the graph from Figure 4 shows the addition of Water Recycle to the system (refer in Figure 3). The recycling of water shows that there will be more raw water available for treatment, see the blue trend in figure 5 and 6. If there is more water being treated, it means that there will be enough water for domestic and commercial use, see the blue trend in Figures 7 and 8.

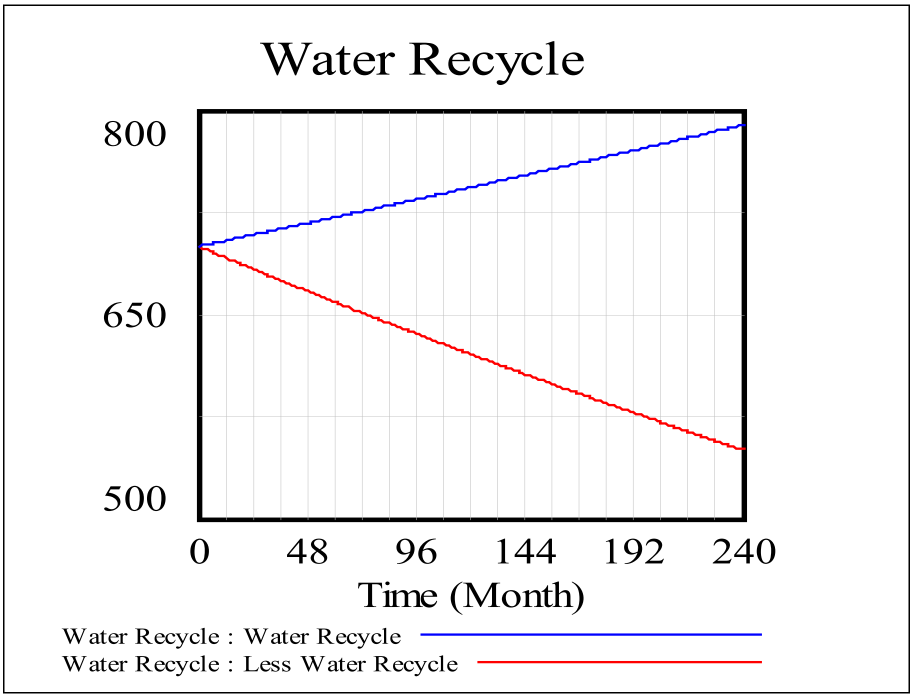

Figure 4: The Water Recycle and Less Recycle Process.

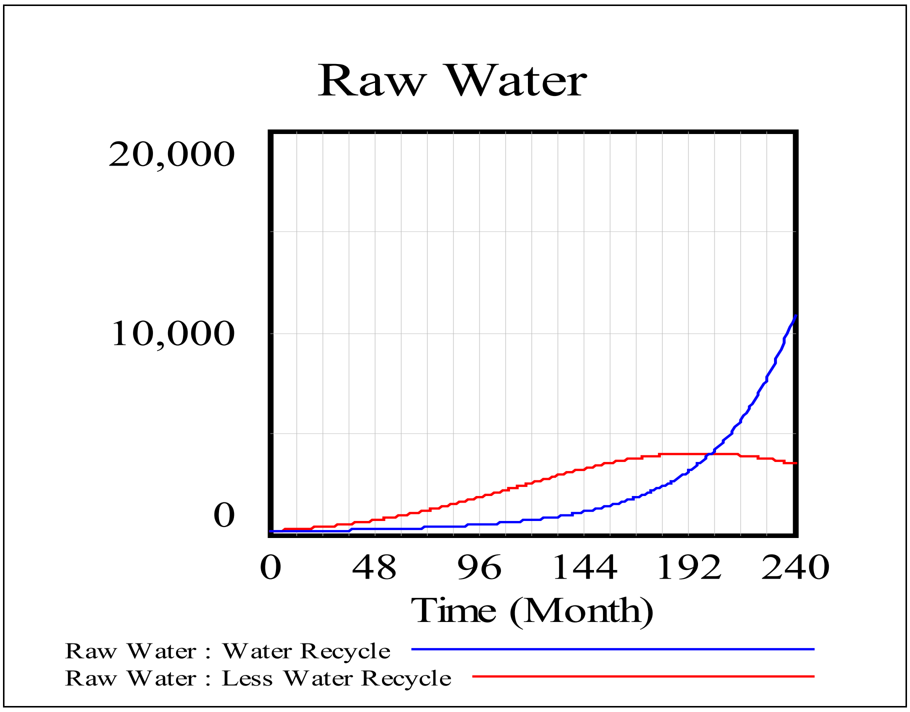

Figure 5: The Impact of Water Recycle and Less Water Recycle to the Raw Water.

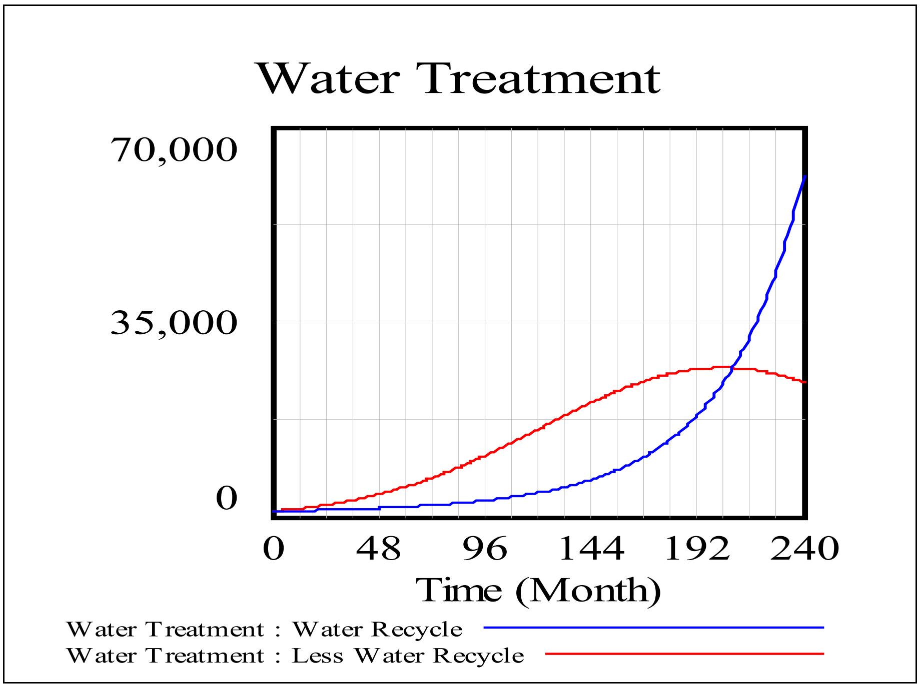

Figure 6: The Impact of Water Recycle and Less Water Recycle to the Water Treatment.

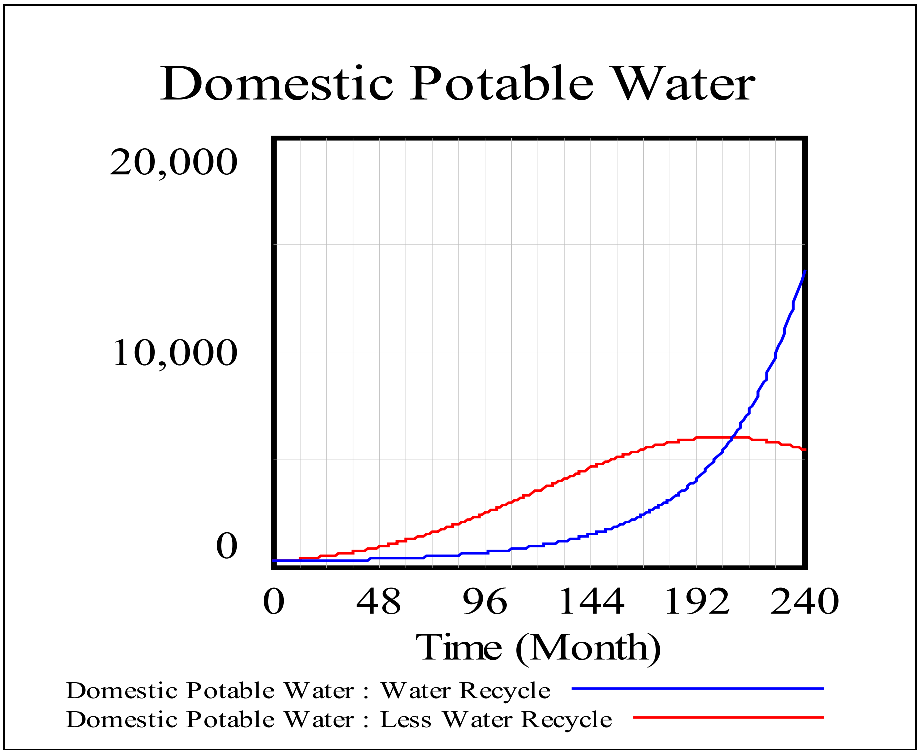

Figure 7: The Impact of Water Recycle and Less Water Recycle to the Domestic Portable Water.

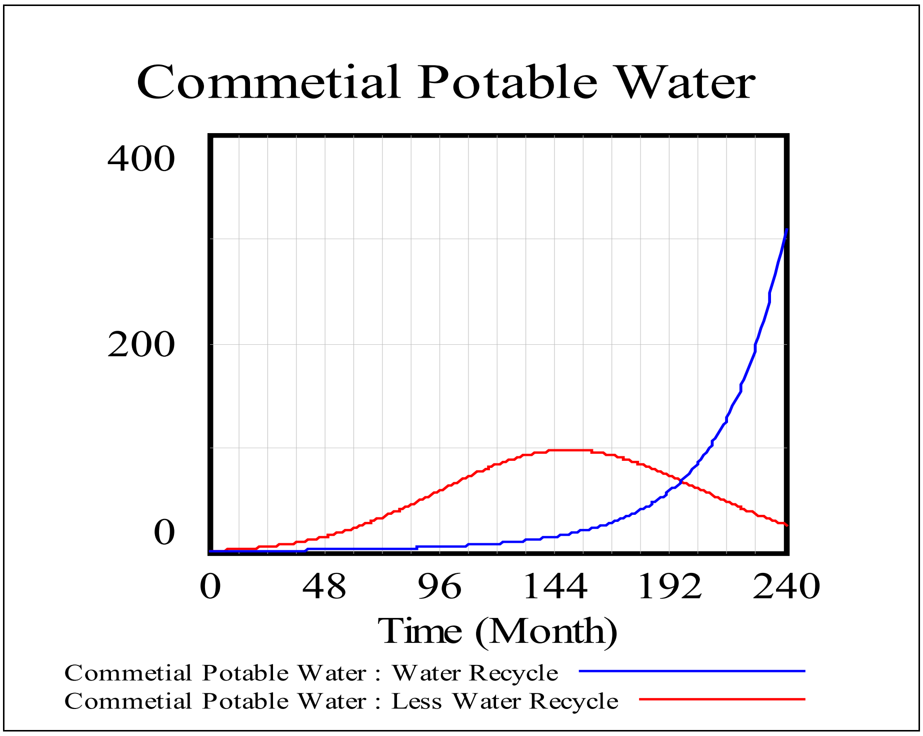

Figure 8: The Impact of Water Recycle and Less Water Recycle to the Commercial Potable Water.

5. Conclusion

In this study, the system dynamic model was developed to solve the challenges of water supply in Limpopo Province. The communities in the study areas get water from boreholes and rain in the season of rain. The system dynamic model for the current situation was developed, see Figure 1. Figure 2 shows that the communities will run short of water in the future should the problem of water not be addressed and solved. The system dynamic model helps with analyzing the problem and bringing suitable solution taking in considerations other challenges faced by the communities. The proposed solution for the water crisis in Limpopo is addressed in Figure 3. The recycling process is introduced to save water for the future and it can be seen in Figures 5 to 8 that the water cycle with the recycling process saves water, see the blue trend. The challenges affect the delivery of water services to the communities and need to be addressed with the purpose to improve the water delivery [11 - 12]. The health of the people is being considered, therefore, the abstracted water needs to be treated to meet the portable quality standards for drinkable water before it is distributed to the consumers. The infrastructures must be maintained regularly so that they can last for a longer period.

6. References

[1] J. P. Graham and L. M. Polizzotto, "Pit Latrines and Their Impacts on Groundwater Quality: A Systematic Review," *Environ Health Perspect,* pp. 521-530, 22 May 2013.

[2] M. E. Matlakala, D. V. V. Kallon, K. E. Mogapi, I. M. Mabelane and D. M. Magkgopa, "Influence of Impeller Diameter on the Performance of Centrifugal Pump,". *IOP Conference Series: Materials Science and Engineering.* 2019. Volume. 655 (1), pp. 009-012.

[3] D. V. V. Kallon and M. E. Matlakala. "Effect of Discharge Diameter on Centrifugal Pump Performance," S*AIIE NeXXXt*, 2019. Pp. 721-730.

[4] W. Randall and P. Whitesides, "Basic Pump Parameters and the affinity Laws," *PDHonline Course M125 (3 PDH),* p. 4, 2008.

[5] A. Mayher, T. Mukamba and A. Vermeulen, "Bushbuckridge Municipality," 2009. [Online]. Available: https://en.wikipedia.org/wiki/Bushbuckridge_Local_Municipality. [Accessed 30 04 2020].

[6] M. E. Matlakala, "A Computational Model for the Efficiency of Centrifugal Pumps. Dissertation Submitted to the University of Johannesburg," 2021.

[7] D. V. V. Kallon and M. E. Matlakala, "Influence of impeller Blade Count on the Performance of Centrifugal Pump," *SAIIE NeXXXt*, 2019. Pp. 603 - 612.

[8] S. Mpandeli, E. Nesamvuni and P. Maponya, "Adapting to the Impacts of Drought by Smallholder Farmers in Sekhukhune District in Limpopo Province, South Africa," vol. 7, no. 2, pp. 1-10, 15 January 2015.

[9] A. Niazi, S. O. Prasher, J. Adamowski and T. Gleeson, "A System Dynamics Model to Conserve Arid Region Water Resources through Aquifer Storage and Recovery in Conjunction with a Dam," *Water,* 7 August 2014.

[10] J. P. Guyer, "Introduction to Pumping Stations for Water Supply Systems," 2012.

[11] M. E. Matlakala, D. D. V. Kallon, S. P. Simelane and P. M. Mashinini, "Impact of Design Parameters on the Performance of Centrifugal Pumps," *Procedia Manufacturing*. 2019. Volume 35. Pp 197-306.

[12] D.V.V. Kallon, M.E. Matlakala, K.F. Nkoana, B.D. Mafu, S.B. Mkhwanazi. Efect of Suction Diameter Variation s on Performance of Centrifugal Pumps. *Proceedings of OIC*, 2019. Pp 170 - 173.

[13] L. Mafanya, D.V.V. Kallon, S.P. Simelane. Flow Properties Upon Treatment of Acid Mine Drainage using Pervious Concrete Slabs. *SAIIE NeXXXt*, 2019, Pp 399-403.

[14] L. Mafanya, D.V.V. Kallon. 2021. A Contribution to the Debate on the Problem of Acid Mine Drainage in South Africa. *SAIIE31. Pp* 718 – 729.

[15] L. Mafanya. Flow Model for the Treatment of Acid Mine Drainage Using Pervious Concrete. Dissertation submitted to the University of Johannesburg. 2021.

[16] S.K.Thisani, D.V.V. Kallon, P. Byrne. Geochemical Classification of Global Mine Water Drainage. *Sustaiability.* 2020. Vol 12, Issue 24. Pp 10244.

Biographies

Mr Motsi Ephrey Matlakala is a South African PhD candidate in Mechanical Engineering at the University of Johannesburg. Mr Matlakala has been working as a Mechanical Engineering Graduate at Rand Water Zuikerbourch Pumping Station since June 2017. During his Masters studies, He published five (5) papers and was also selected as a reviewer of paper in two (2) international conferences. Mr Matlakala is a member of South African Institute of Mechanical Engineering (SAIMechE) and Candidate Technologist with the Engineering Council of South Africa (ECSA). Mr Matlakala's primary research areas are System Analysis and Dynamics, Optimization, Computational Fluid Dynamics, Finate Element Analysis and Water Research.

Dr Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD degree obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT. At the start of 2014 Dr Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Dr Kallon transferred to the University of Johannesburg as a full-time Lecturer and later a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology (DMIET). Dr Kallon has more than twelve (12) years of experience in research and six (6) years of teaching at University level, with industry-based collaborations. He is widely published, has supervised from Masters to Postdoctoral and has graduated seven (7) Masters Candidates. Dr. Kallon's primary research areas are Acoustics Technologies, Mathematical Analysis and Optimization, Vibration Analysis, Water Research and Engineering Education.