PAPER • **OPEN ACCESS**

Determination of volume of wastewater generated in a university campus

To cite this article: D.O. Omole *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **655** 012086

Determination of volume of wastewater generated in a university campus

Omole D.O.[1], Chichezie, T.E.[1], Akpan V.E.[1]

[1]Department of Civil Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria.

*victor.akpan@stu.cu.edu.ng

Abstract. The development of wastewater reuse schemes has been greatly slowed down by the lack of adequate wastewater generation data. Most data sources on wastewater generation provided by international organizations are mere estimates ofa nation'swastewater generation pattern and can only go a long way in explaining the wastewater situation of that nation. Intensive wastewater reuse schemes for futuristic purposes would require collection and storage of wastewater data for effective planning. This study identifies and closes that gap in a University campus where there is a high demand of water for daily use. Flowrates of wastewater being discharged into the environment was determined over a period of time using a standard weir and a level measuring tool. From this, the volume of wastewater generated was calculated. The results show that about 1,529,288 liters of wastewater was generated daily in the University campus. From this value, the water consumption rate of the university community was estimated to be 1,911,610 liters of water daily. From these findings, the wastewater generated within the Covenant University campus could be sufficient for agricultural, urban and other municipal reuse schemes. The environmental, economic and public health benefits from wastewater recycling are enormous and thus more attention must be given to its generation, treatment, disposal and reuse.
Keywords: Wastewater, reuse, generation, recycling

1. Introduction

Wastewater, according to [1], [2], signifies any water that is not needed again as no extra advantages can be derived from it.Wastewater results from most human activities that require water. This implies that an increase in the overall water demand will lead to a corresponding increase in wastewater generation globally and thus an increase in environmental pollution loads, if not managed efficiently [3]. Wastewater generation has been directly linked to factors such as accelerated urbanization, economic developments and rapid population growth [4], [5].

Studies haveshownasignificant data gap on wastewater generation data globally [6], with only about 55 countries possessing data on wastewater generation, treatment and reuse. Of these 55 countries, only 37% can boast of current wastewater generation data [6].This dearthof data on wastewater generation shows that little attention is being paid to wastewater resources globally, most especially in low to middle income economies. Studies have revealed that more than 80% of wastewatergenerated globally receives any form of treatment or management process before final discharge or disposal [3], [4], [7], [8].In low to middle income economies, the problem is further heightened.Only 8% of wastewater (municipal and industrial) undergoes any form of treatment before any disposal[6], [9]. This means that 92% of wastewater discharged into the environment is unaccounted for.

This indiscriminate discharge of wastewater into the environment poses serious implications to the environment[10].Studies have shown that about 2 billion peoplesource drinking water from a river contaminated with faeces thus putting them at risk of getting diseases such as typhoid, cholera, polio and dysentery[11]. These challenges are common in African countries where wastewater management is below standards due to several factors such as poor data management systems, weak institutions, low technical expertise, funding challenges[12], [13]. [12] revealed that the leading cause of mortality in humans have been traced to water-related illnesseswhich has led to over half of hospital cases on the African continent. This study has shown that women and children suffer the greatest health implications from poor wastewater management.Other challenges such as liver diseases, kidney failures heart and pancreas problems have been traced to indiscriminate wastewater discharge especially from industrial effluents [14], [15].

Wastewater has been beneficial economically and environmentally as shown by several studies. An extensive study carried out by [1] on the economic evaluation of wastewater reuse on the Covenant University campus showed an annual return of approximately 42 million Naira when wastewater is reused. Other benefits from this study revealed that about 60,160 naira will be saved on pumping of water to meet university demands daily with the reuse of treated wastewater. Globally, thewastewater reuse market is currently valued at over $ 12 billion with expected growths to about $22 billion dollars by 2021[16]. These advantages traced to wastewater recycling has led to the development of sophisticated reuse schemes especially in high income economies. For example, some cities in the United states have developed a potable reuse scheme for its wastewater resource. For instance over 40% of Saint Petersburg’s(Florida) city supply comes from recycled wastewater[17]. In addition, over 200 wastewater reuse schemes have been linked to the European Union. With a vast majority of reuse projects going to agricultural production, industrial reuse and urban purposes[18].

2. Methodology

This study was conducted in 2016 on the constructed wetland with Covenant University, in Ota, Nigeria. The wastewater treatment facility is constructed on a site of about 10,417 m^2 in area. The coordinates of the study location are6^{o}40’22"N &3^{o}09’10"E.Topographic maps reveal that the treatment facility is located at the lowest points of the campus. This enables the easy flow of wastewater from the point of generation to the point of discharge. Figure 1 shows the area of the constructed wetland and point of discharge. Wastewater flowing out of the campus is conveyed in an open channel. Wastewater flowing to the constructed wetland is stored in underground storage tanks and then released slowly into the environment. Figures 1 and 2 give the map of the study location.

2.1 Data Collection

For the purpose of this research, a rectangular crested weir was fabricated. The weir is an obstruction that is built across a river or an open channel so as to measure the flowrate at any given point in time[19]. Figure 3 gives the diagram of a typical contracted rectangular weir

From figure 3, L is the length of the notch or crest while B is the length of the weir or the length of the channel.Therefore,fora contracted rectangular weir $L<B$.The water measurement manualrecommends the use of the Kindsvater-Carter method[20].

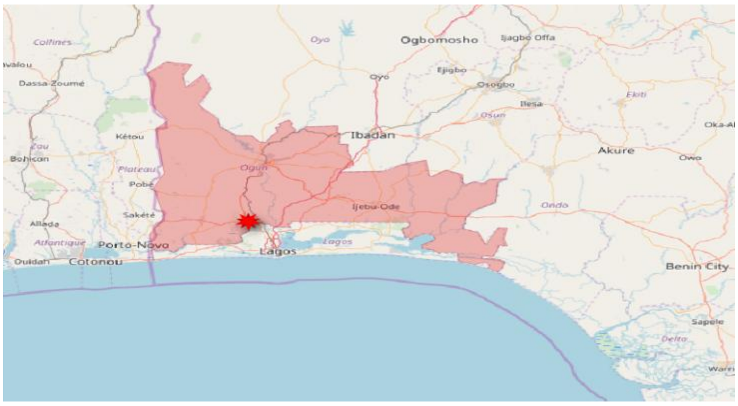

Figure 1: Map of Ogun State showing Study Location

Figure 2: Wastewater treatment facility (constructed wetland) in Covenant University

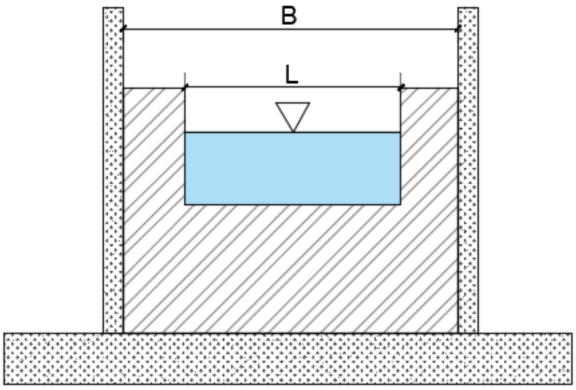

Figure 3: Weir Specifications

IOP Conf. Series: Earth and Environmental Science **655** (2021) 012086 doi:10.1088/1755-1315/655/1/012086

The Kindsvater-Carter equation for a rectangular, sharp-crested weir (suppressed or contracted) is given as:

$$\boldsymbol{Q = C_e L_e\, h_{le}^{3/2}} \quad (1)$$

Where:
Q = discharge, cubic feet per second (ft^3/s)
e = a subscript denoting "effective"
Ce = effective coefficient of discharge, $ft^{1/2}/s$

$$Le = L + kb \quad (2)$$
$$hle = h1 + kh \quad (3)$$

In these equations:
kb = a correction factor to obtain effective weir length
L = measured length of weir crest
B = average width of approach channel, ft
h1 = head measured above the weir crest, ft
kh = a correction factor with a value of 0.003 ft

The general Kindsvater-Carter equation was simplified for a fully contracted flow. The flowover the weir was designed to satisfy the following:

i. Weir must be fully contracted, i.e.: B – L > 4 Hmax and P > 2 Hmax
ii. H/L < 0.33

The flow was considered fully contracted and thefollowing equation was used:

$$\mathbf{Q = 3.33(L - 0.2\ H)\ (H3/2)} \quad (4)$$

Where, Q is in m^3/s and L and H are in meters (m).

2.2 Flowrate Determination

Volumetric flowrate measurement can be classified as a simple and also exactly accurate method forflow measurement[21]. This will involve the determination of wastewater that passes through a particular point over a period of time and thus determining the volume of wastewater generated in a day[21].
Table 1 gives the processes and steps followed inorder to determine the volume of wastewater generated within the university campus.

Figure 4 shows the open channel that conveys wastewater out of the university campus with a fabricated weir used to impound the flow of water.

For this study, the following data was collected during field investigations:
i. The average dailyflowrate for blackwater, greywater and their combined flowrates.
ii. The average weekly flowrate for blackwater, greywater and their combined flowrates.
iii. The total volume of wastewater generated within the covenant University campus daily.

iv. The volume of water withdrawn daily was estimated using the wastewater generation data. According to [22], 80% of water used is converted to wastewater.

Table 1: Methods adopted for wastewater volume measurement

S/n	Methods
1	The weir was installed perpendicular to the direction of flow. The spaces between the channel and the weir, was sealed using an impervious material.
2	The height (H) of the water above the crest of the weir was taken using a graduated staff
3	The reading for H together with the value for L was then imputed into equation (4) to determine the flow rate.
4	The readings were taken from 5am to 9pm every day for a week.

Figure 4: Wastewater Channel and Fabricated weir

3. Results and Discussion

From the field experiments carried out, the following results were obtained.

3.1. Blackwater Flowrate

Figure 5 gives a graphical representation of blackwater flowrates within the university campus. From figure 5, the flowrates show a fairly constant trend with some occasional changes. This fairly constant trend can be attributed to the fact that the blackwater is first collected in an undergroundstorage tank and then released at a regulated rate.

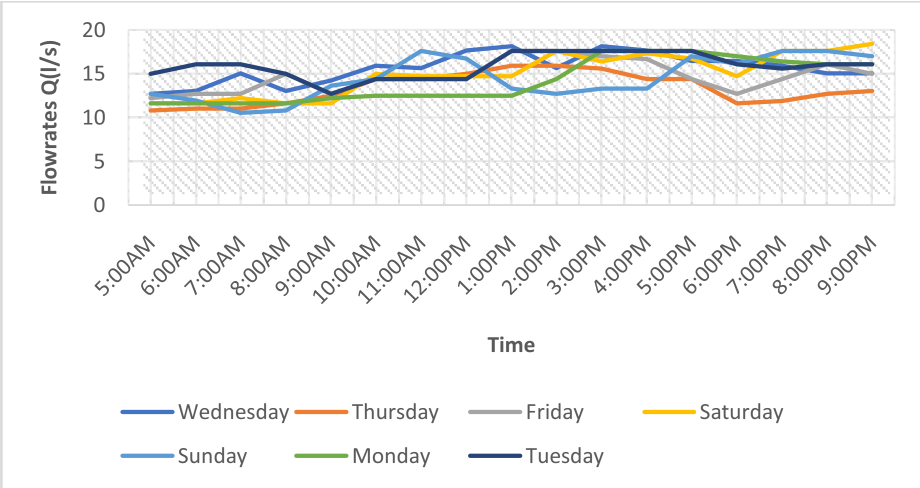

Figure 5: Blackwater Flowrates

3.2. Greywater Flowrates

From findings, it can be observed that there is a of variation in the flow of greywater on the campus with peak periods between 6:00 AMand 10:00 AM. These peak periods represent hours when there are lots of activities in the student's halls of residence and staff quarters at the same time. Also, there are no storage tanks which entails that there are rapid changes in greywater flowrates with respect to activities carried out on the campus. Figure 6 gives the graphical representation of greywater flowrates within the campus.

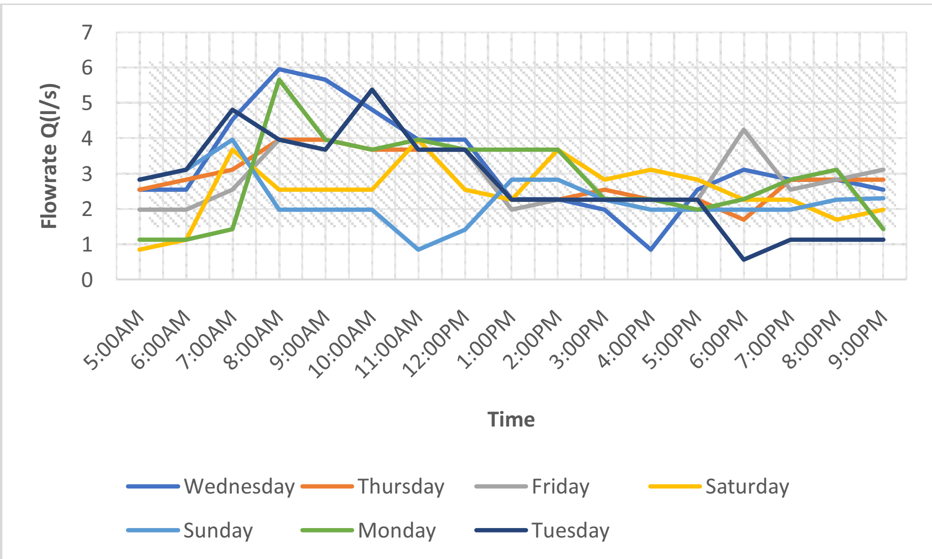

Figure 6: Greywater flowrates

A combined wastewater generation pattern is illustrated with figure 7. This shows a summation of blackwater and greywater flows on the campus.

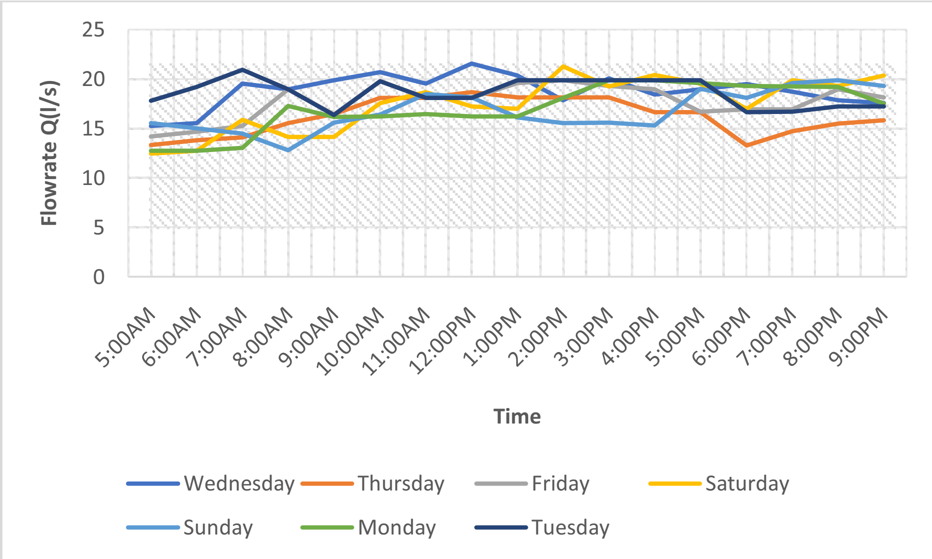

Figure 7: Combined Wastewater Flowrates

Table 2 gives a summary of the total flow computations for the University Campus

Table 2: Wastewater Flow Summary and Total Flow

Days	**Wednes**	**Thursd**	**Friday**	**Saturday**	**Sunday**	**Monday**	**Tuesday**	**Weekly Average**	**Volume**
Wastewater	Q(l/s)	Q(l/s)	Q(l/s)	Q(l/s)	Q(l/s)	Q(l/s)	Q(l/s)	Q(l/s)	liters
Blackwater	15.775	13.45625	14.8625	15.15	14.5875	14.3625	15.9375	14.87589	1285277
Greywater	3.29125	2.92	3.044375	2.619375	2.23125	2.9375	2.725625	2.824196	244010.6
Total	19.06625	16.37625	17.90688	17.76938	16.81875	17.3	18.66313	17.70009	**1529288**

From Table 2, the highest wastewater flow was recorded on a Wednesday at about 19.07 l/s with the lowest flows recorded on Thursday at about 16.38 l/s. The total volume of wastewater generated in a daywas recorded at 1,529,288 l/day. Figure 8 gives the wastewater flow pattern on the campus.

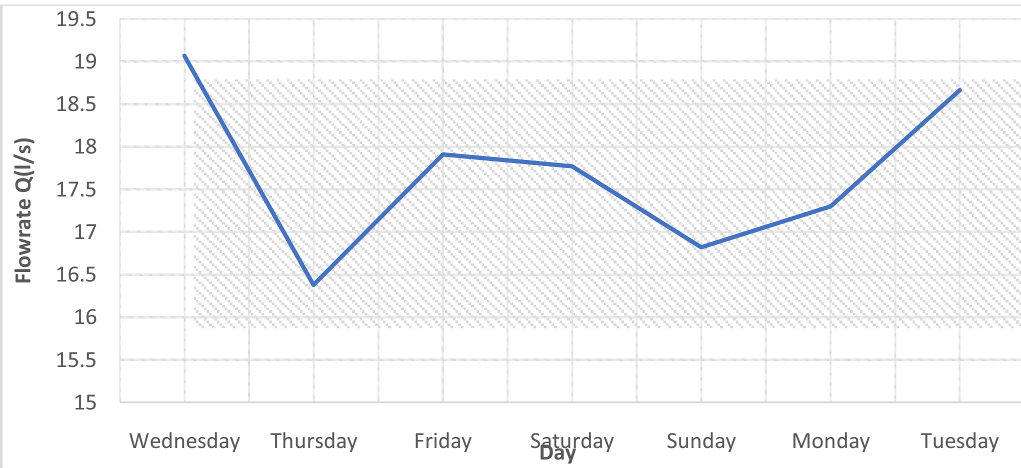

Figure 8: Daily Wastewater Flowrate

80% of used water is usually converted to wastewater[22]. From results obtained, total water consumptionis estimated to be:

$$\frac{100}{80} \, x \, 1529288$$

= 1,911,610liters

3.3 Discussion

The amount of water being produced averagely is 1,911,610 l with wastewater volumes recorded at about 1,529,288 l/day. Blackwater value was recorded at about 244,010.6 l/day and greywater at about 1,285,277 l/day. In comparison topast studies which revealed a wastewater generation rate of about 874,081 l/day[1], [23], [24]; this study shows that there has been a 74% increase in wastewater generated between 2013 and 2015. This can be attributed to rapid population growth, church activities and increase inproduction activities within the community.

4. Conclusion

Understanding wastewater generation patterns in Covenant University has closed up the gap in data needs and thus will aid in the development of wastewater reuse schemes for different purposes peculiar to the university community in the near future. Wastewater reuse must be considered as a core part of Integrated Water Resources Management (IWRM) in any society, so as to create an organized framework for wastewater management most especially in low to middle income economies.

From this study, the volume of wastewater generated within the Covenant University Campus has proven to be sufficient for any reuse scheme. Reuse schemes such as car wash, irrigation of farms and lawns and other reuse purposes could be potentially beneficial within the university community if wastewater reuse is considered.

Wastewater, after adequate and necessary treatment, can be reused in various ways in the environment without causing harm to it. Asides sensitizing the public on the dangers of water wastage and water resource management in terms of finding ways to manage freshwater, establishing an efficient system to harness and manage wastewater is also paramount as this would reduce the nuisance and harm it causes to the environment. But in order to choose a system suitable and effective enough, certain factors must be considered such as the volume of wastewater generated, climatic conditions, the availability of funds and the efficiency of such a system.

Acknowledgement

The authors appreciate the management of Covenant University for their enormous support and contribution to this research.

Conflicts of Interest

The Authors declare no conflicts of interest.

References

[1] Omole, T. Jim-George, and V. . Akpan, "Economic Analysis of Wastewater Reuse in Covenant University," *J. Phys. Conf. Ser.*, vol. 1299, no. 1, p. 012125, Aug. 2019.
[2] A. A. Badejo, D. O. Omole, J. M. Ndambuki, and W. K. Kupolati, "Municipal wastewater treatment using sequential activated sludge reactor and vegetated submerged bed constructed wetland planted with Vetiveria zizanioides," *Ecol. Eng.*, vol. 99, pp. 525–529, Feb. 2017.
[3] Wwap, *The United Nations World Water Development Report 2017*. 2017.
[4] United Nations, "Quality and Wastewater | UN-Water," 2020. [Online]. Available: https://www.unwater.org/water-facts/quality-and-wastewater/. [Accessed: 30-Jan-2020].
[5] D. O. Omole, S. A. Isiorho, and J. M. Ndambuki, "Waste management practices in Nigeria:

Impacts and mitigation," in *Geographical Society of America*, 2016, pp. 377–386.

[6] T. Sato, M. Qadir, S. Yamamoto, T. Endo, and A. Zahoor, "Global, regional, and country level need for data on wastewater generation, treatment, and use," *Agric. Water Manag.*, vol. 130, pp. 1–13, Dec. 2013.

[7] Aquatech, "Wastewater Treatment | Essential Guide | Aquatech," 2020. [Online]. Available: https://www.aquatechtrade.com/news/article/wastewater-essential-guide/. [Accessed: 30-Jan-2020].

[8] United Nations, "Wastewater Management - A UN-Water Analytical Brief | UN-Water," 2015. [Online]. Available: https://www.unwater.org/publications/wastewater-management-un-water-analytical-brief/. [Accessed: 10-Dec-2019].

[9] E. O. Longe and D. O. Omole, "Analysis of pollution status of River Illo, Ota, Nigeria," *Environmentalist*, vol. 28, no. 4, pp. 451–457, Dec. 2008.

[10] D. O. Omole and E. O. Longe, "Reaeration Coefficient Modeling: A Case Study of River Atuwara in Nigeria," *Res. J. Appl. Sci. Eng. Technol.*, vol. 4, no. 10, pp. 1237–1243, 2012.

[11] WHO, "Drinking-water," 2019. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/drinking-water. [Accessed: 30-Jan-2020].

[12] D. O. Omole and J. M. Ndambuki, "Sustainable living in Africa: Case of water, sanitation, air pollution and energy," *Sustain.*, vol. 6, no. 8, pp. 5187–5202, 2014.

[13] H. O. Nwankwoala, "An integrated approach to sustainable groundwater development and management in Nigeria," pp. 123–130, 2011.

[14] P. C. Emenike, D. O. Omole, B. U. Ngene, and I. T. Tenebe, "Assessment of KOH-activated unripe Musa paradisiaca peel for adsorption of copper from aqueous solution," *Cogent Eng.*, vol. 4, no. 1, Sep. 2017.

[15] D. O. Omole, J. M. Ndambuki, and K. Balogun, "Consumption of sachet water in nigeria: Quality, public health and economic perspectives," *African J. Sci. Technol. Innov. Dev.*, vol. 7, no. 1, pp. 45–51, 2015.

[16] Fluence, "Where Is the Most Water Reuse Taking Place? | Fluence," 2017. [Online]. Available: https://www.fluencecorp.com/where-is-the-most-water-reuse-taking-place/. [Accessed: 07-Nov-2019].

[17] NAS, "Types of Water Reuse – Water Reuse," 2019. [Online]. Available: http://nas-sites.org/waterreuse/what-is-water-reuse/types-of-water-reuse/. [Accessed: 07-Nov-2019].

[18] D. Bixio *et al.*, "Wastewater reuse in Europe," *Desalination*, vol. 187, no. 1–3, pp. 89–101, Feb. 2006.

[19] H. Jordan, S. Kailyn, and D. Jason, "Weir ," 2020. [Online]. Available: https://energyeducation.ca/encyclopedia/Weir. [Accessed: 29-Jan-2020].

[20] Bureau of Reclaimation, "kindsvater carter - Reclamation Search Results," 2020. [Online]. Available: https://search.usa.gov/search?affiliate=Reclamation&query=kindsvater+carter. [Accessed: 29-Jan-2020].

[21] USEPA, "Wastewater Flow Measurement," 2015.

[22] S. A. Isiorho and F. A. Oginni, "ASSESSMENT OF WASTE WATER TREATMENT IN CANAANLAND, OTA, OGUN STATE, N…," 2008. [Online]. Available: https://www.slideshare.net/felixss/assessment-of-waste-water-treatment-in-canaanland-ota-ogun-state-nigeriaoginni-isiorho-paper-1st-postgraduatepostcon2008iupdur. [Accessed: 29-Jan-2020].

[23] P. Emenike, I. Tenebe, D. Omole, J. Ndambuki, A. Ogbiye, and A. Sojobi, "Application of Water Recovery Option for Agricultural Use in Developing Countries: Case Study of a Nigerian Community," in *Tropentag*, 2015.

[24] Omole, O. O. Alade, P. C. Emenike, I. T. Tenebe, A. S. Ogbiye, and B. U. Ngene, "Quality assessment of a university campus wastewater resource," in *WIT Transactions on Ecology and the Environment*, 2017, vol. 216, pp. 193–201.