Impact of Coffee Processing on Wastewater Quality in Rwanda

KAYIGEMA Rita Gisele[1] and Christophe Mupenzi[1]
[1]University of lay Adventists of Kigali, P.O Box: 6392 Kigali-Rwanda

Correspondence: gkayirita@gmail.com

Abstract:

Coffee processing wastewater is acidic and rich in total suspended and dissolved solids which are biodegradable but pollute the receiving environment. The objective of this research was to analyze the impact of coffee processing on wastewater quality at Kayumbu coffee washing station located in Kamonyi district, Southern Rwanda from May 2019 to May 2021. The researcher visited the washing station to analyze the coffee washing routine, washing machines' transport mechanism of wastewater, receiving area of wastewater, and wastewater management measures in place. The authors evaluated the wastewater quality by considering Physico-chemical parameters, namely pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), and Oil and grease. These parameters were collected from the University of Rwanda, College of Science and Technology. Finally, a comparison of these parameters with the national and international standards was performed. The results show that between May 2019 and May 2021, the concentration of COD and BOD recorded an increasing trend surpassing the prefixed standards but until last year there was a decrease in concentrations. Although some measures are put in place to minimize wastewater pollution, more efforts are in practice to maintain the national and international standards mainly for COD and BOD to minimize the associated risks to the receiving environment. The authors believe that this study will advance the awareness of owners of coffee washing stations in terms of wastewater management and other possessors of coffee washing stations. And permanence evaluation of wastewater from coffee processing is suggested to identify its status and to ensure surrounding environmental components.

Keywords: Kayumbu Coffee washing station, Rwanda, Wastewater, coffee processing

1. Introduction

Coffee is a plant belonging to the family Rubiaceae, genus Coffea. Coffee seeds (beans) can be processed into drinks. Although coffee's lifetime may extend up to 100 years, its most productive years are from 5 to 20 according to the National Coffee Association (Eakin et al. 2012). In Rwanda, Coffee was introduced by German missionaries in 1904 and the largely cultivated coffee was consumed by colonial regimes. The most impressive and visible aspect of the transformation of the Rwandan coffee sector is the multiplication of coffee washing stations, which increased in number from 2 to 213 in the period 2002-2012. As a result, the average distance from the center-point of a sector to the closest station decreased from more than 50 km in 2002 to less than 10 km in 2012 (Guariso et al. 2011).

In many coffee processing countries, the wastewater starts its generation within the pulping process, through fermentation and washing processes of the coffee beans and presents series of challenges to its receiving environment especially on water bodies

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

(Kanu and Achi 2011). The associated coffee washing acidic wastewater is also rich in total suspended and dissolved solids and that this is biodegradable. However, in case such wastewaters are immediately loaded into the environment, much pollution on soil and water is largely recorded from upstream to downstream (Selvamurugan et al. 2010).

The organic compounds in coffee wastewater create high BOD and COD and the fermentation of sugars in fermentation tank also generates high acidity. Some of the constituents of the effluent can be varied toxic chemicals including the alkaloids (caffeine), tannins, nutrients like nitrates and phosphate along with the polyphenolic compounds (Takashina et al. 2018). Discharge of such kinds of untreated coffee washed effluent into open environment can generate numerous problems and may even lead to socio-economic consequences resulting from human health problems and loss of biodiversity (Villanueva-Rodríguez et al. 2014).

In Rwanda, coffee processing is at large extent wet method which uses large volume of water to separate the outer red coffee skin and pulp and also for the removal of the mucilage in fermentation tank. It reported that coffee processing by-product includes pulp with 43%, mucilage 12% and parchment 6.1%. This effluent is generally made of high concentration of organic matter and suspended solid and is highly acidic (Hakorimana and Akçaöz 2017; Ngabitsinze et al. 2011). Nevertheless, the generated wastewater is stored in the holes which in turn may release the wastewater in the near environment and/or through filtration the soil may be polluted (Kazoora 2011).

Although several studies on wastewater treatment have been conducted, there no studies on how wastewater from coffee processing units are handle sin order to minimize the harmful effects they may cause. This was recognized by the authors and then chose to carry out this study which can help to better understand the nature of coffee processing wastewater which is fundamental for the design and operation of appropriate and effective treatment technologies. The main objective of this study was to evaluate the impact of coffee processing on wastewater quality with the case of Kayumbu Coffee Washing Station located in Kamonyi district of the Southern Rwanda.

2.2 Methods and Materials

2.1 Description of the study area

This study was conducted by considering Kayumbu coffee washing station located in Kayumbu sector of Kamonyi district in the southern province of Rwanda.

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

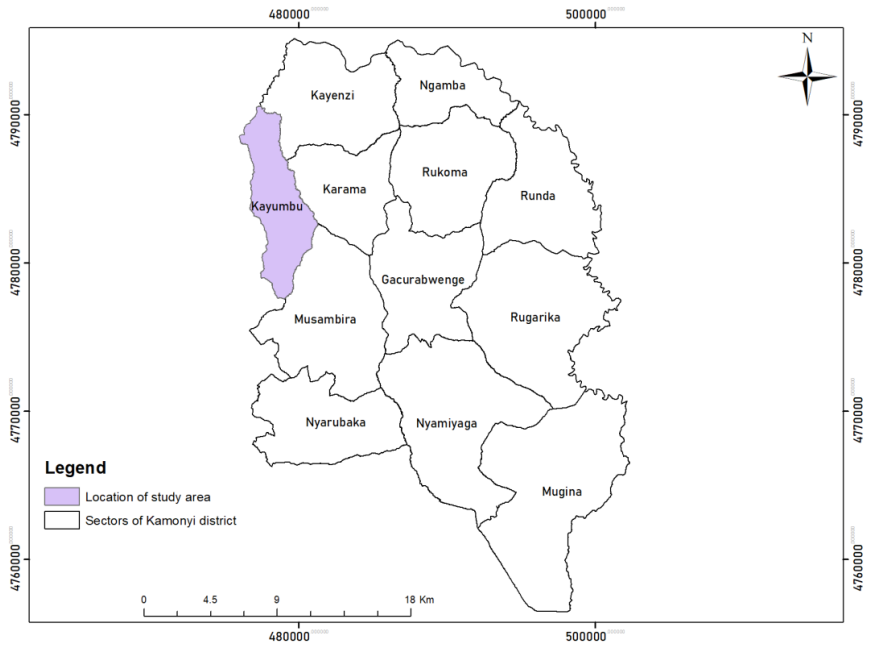


Figure 1: Location of Kayumbu coffee washing station in Kayumbu sector of Kamonyi district

As indicated in Figure 1, Kayumbu sector is one of twelve (12) sectors namely Gacurabwenge, Kayenzi, Karama, kayumbu, Mugina, Ngamba, Nyamiyaga, Musambira, Rugalika, Rukoma, Runda and Nyarubaka of Kamonyi district. As per the Fourth Population and Housing Census, Rwanda conducted by the National Institute of Statistics, Kayumbu sector is inhabited by 15,530 population with a population density of 467 inhabitant/Km^2 (NISR 2012). As of 2019, it was reported that Kayumbu coffee washing station supports 1,057 smallholder coffee producers from the surrounding hills that lie at 1,600 to 2,100 meter above sea level. The station produces naturals only at the beginning and end of the harvest season by only processing delicious coffee.

2.2 Data collection

Field data on sources of wastewater

In order to better detect the sources of wastewater generated by the coffee washing station, the authors undertook a field visit which helped to identify all possible sources of wastewater at the Kayumbu coffee washing station. These included the source and type of coffee washing water, types of coffee cherries and their washing routine, types of coffee washing machines and their tools/accessories like oil and grease, transport mechanism of wastewater after coffee washing, receiving area of wastewater, etc. The authors conducted a field visit in order to assess the current Kayumbu coffee washing routines and its wastewater management procedures. This exercise was completed by taking some field photos of the coffee washing wastewaters and their receiving bodies.

Wastewater physico-chemical parameters

For this phase, the study analyzed wwastewater physico-chemical parameters.

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

These parameters were the pH, Chemical Oxygen Demand, Biological Oxygen Demand, Total Suspended Solids and Oil and grease. The employed physicochemical parameters were collected from the Chemical Laboratory of the College of Science and Technology of the University of Rwanda. They ranged from May 2019 to May 2021.

The wastewater samples were collected from Kayumbu coffee washing station and then transported to the laboratory. The composite sampling method was utilized to collect all samples. Composite samples provide a more representative sampling of heterogeneous matrices in which the concentration of analytes of interest may vary over short periods of time and/or space (Talvitie et al. 2017). Composite samples were obtained by combining portions of multiple grab samples using specially designed extendable hand sampler. The collection of the above primary data facilitated the authors to avoid prejudices and pre-conceived ideas, highlight the precise and concise explanation of the problem under the study, and help to formulate corrective measures of the problem analysed.

2.3 Data analysis

This study analyzed the Chemical Oxygen Demand (COD) with International Organization for Standardization i.e. RS ISO 6060 as test method, Biological Oxygen Demand (BOD) with RS ISO 5815 as test method, Total Suspended Solid (TSS) with RS ISO 11923 as test method, the PH with RS ISO 10523 as test method, Graise and Oil with ISO 9377 as test method.

All samples were analysed with reference to the requirements of International Organization for Standardization (ISO). Finally, the obtained results were compared with Tolerance Limit fixed by the Rwanda Standard Board and the international Tolerance limits of the United States Environmental protection Agency in order to reveal the status quo of the wastewater at Kayumbu coffee washing station.

3. Results and Discussion

3.1 Coffee processing approaches

In order to better understand the coffee processing procedures undertaken by Kayumbu Coffee processing station, the authors conducted a field visit and the following schematic (Figure 2) was drawn by basing on how coffee is washed form cherries reception to wastewater discharge. The field visit indicated that after coffee cherries are received (1), they are washed and fermented (2 and 3) and then the washing processes. This process involves the use of much water is employed to make sure that coffee is washed at maximum level to remove all mucilage and that all other impurities are removed as well.

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

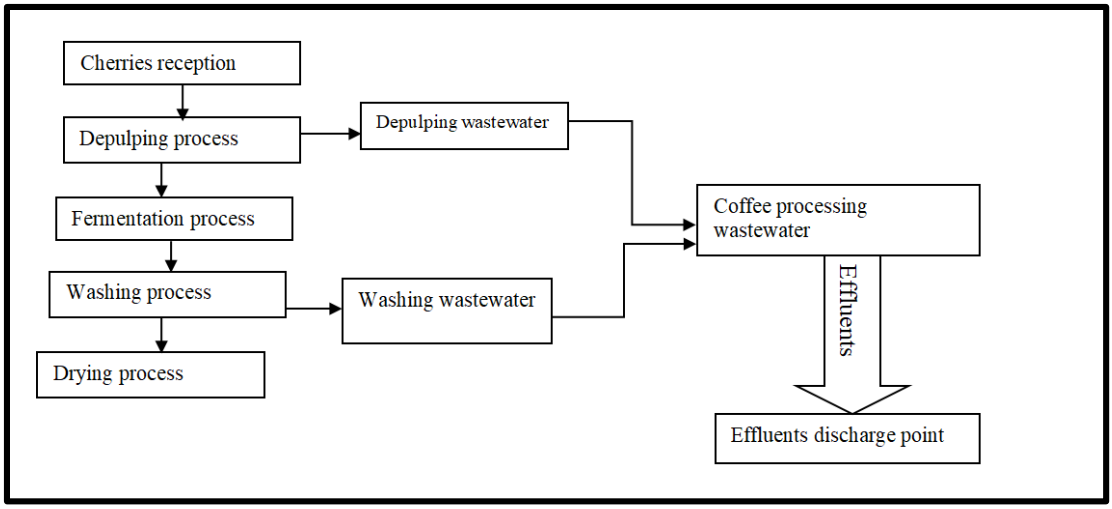


Figure 2: Schematic of Kayumbu coffee washing routines
Source: Authors, 2022

The above washing procedure can lead to increasing the concentration of wastewater and bad odor in the neighboring environment. It is form the above facts that the authors then interpreted the recently analyzed wastewater quality of Kayumbu coffee washing station.

3.2 Wastewater quality analysis

For this section, the authors performed wastewater quality analysis where field samples were utilized with reference to the report of annual wastewater quality assessment conducted by Kayumbu Coffee processing station. It was noticed that from May 2019 to May 2021, the considered physicochemical parameters recorded varying numbers. The results in Figure 3 showed that in 2019, the Chemical Exchange Demand recorded high value (643) compared to other parameters tested by this research.

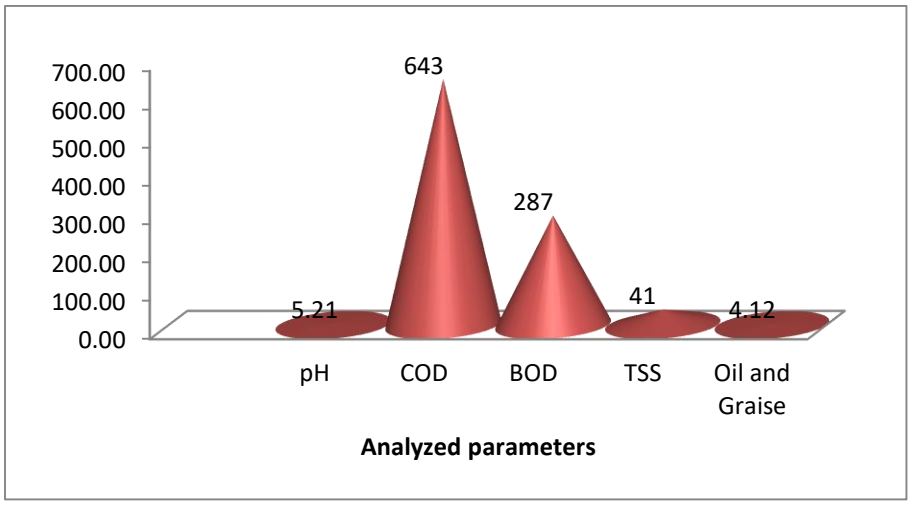


Figure 3: 2019 parameters analysis results
Source: Kayumbu wastewater quality, 2021

With regard to the analysis results of 2020, the research findings illustrated in Figure 4.4 show that in from May 2019 to May 2020, the Chemical Oxygen Demand (COD) and the Biochemical Oxygen Demand (BOD) value

kept on increasing compared to its value of 2019 (643,287) mg/l and reached (867,312) mg/l, in 2020. However, other parameters also registered increasing trend regales their slightness compared to the COD and BOD record therefore BOD and COD Concentration indicate pollution by their concentrations.

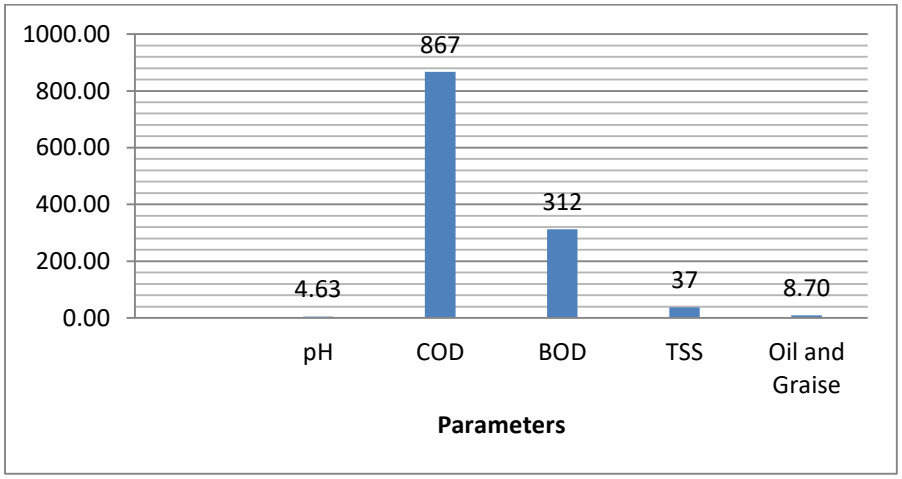


Figure 4: 2020 parameters analysis results

Source: Kayumbu wastewater quality, 2021

In May 2021, the results in Figure 5 reveal almost decreasing record compared to both wastewater quality of May 2019 and May 2020 (Figure 3 and 4). The results on wastewater quality analysis demonstrated in Figure 5 revealed that in May 2021, the concentration of the Chemical Oxygen Demand decreased up to 350 compared to that of May 2019 (643) and May 2020 (867), respectively. In addition, the record of the P^H increased up to 6.12 in May 2021 while with the Total Suspended Solids which also decreased to 37 in May 2021 (Figure 5) from 41 registered in May of 2020 (Figure 4).

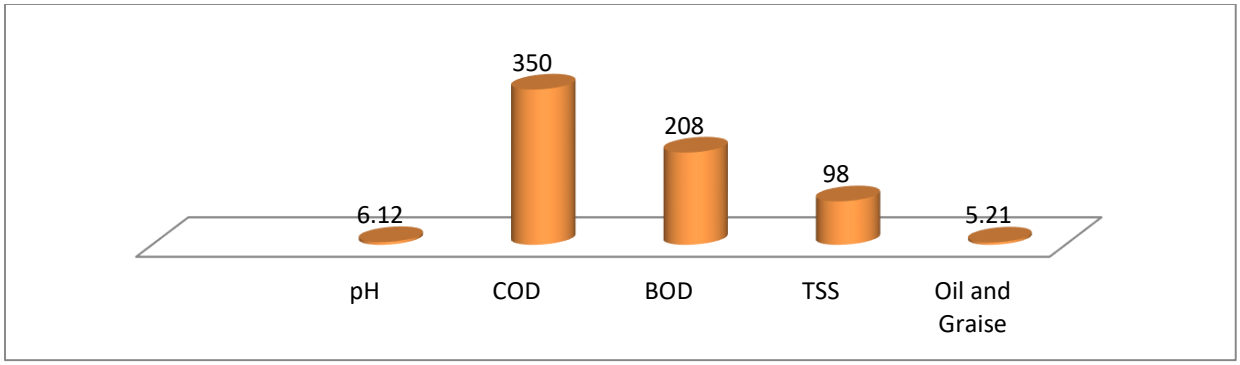
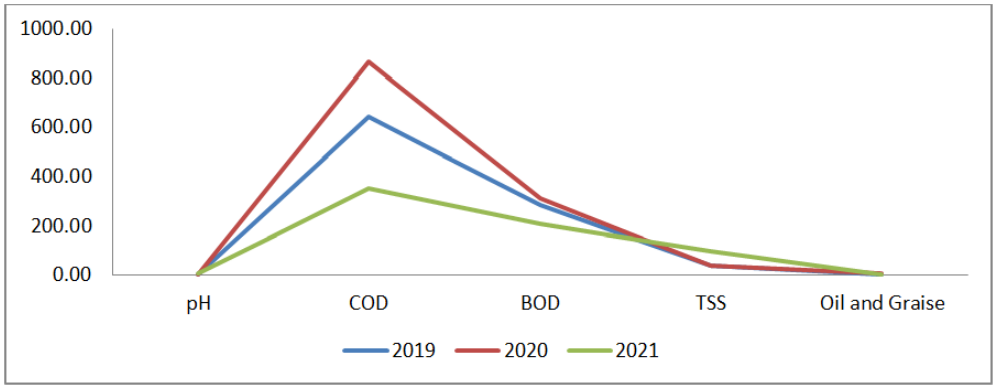


Figure 5: 2021 parameters analysis results
Source: Kayumbu wastewater quality, 2021

The sum of the total recorded physicochemical parameters from May 2019 to May 2021 (Figure 6) showed that the concentrations of some parameters reduced

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

while others increased. The Chemical Oxygen Demand registered an increasing concentration between May 2019 and May 2020 and then considerably dropped in May of 2021.



2019	5.21	643	287	41	4.12
2020	4.63	867	312	37	8.70
2021	6.12	350	208	98	5.21

Figure 6: Wastewater quality annual trend (2019-2021)
Source: Kayumbu wastewater quality, 2021

3.3 Impact of coffee processing on wastewater quality

As this study aimed to analyze the impact of coffee processing on wastewater quality, the researcher considered the fact that coffee processing is associated with wastewater from the processing but also that such wastewater should be handled in order to ensure that its quality is maintained at the acceptable/tolerable level. The results in Table 1 indicated that only Oil and Grease content did not go beyond the RS 109-2017 Tolerance Limit of Discharge Industrial Wastewater.

Table 1: Kayumbu wastewater quality compared to RS standards

	2019	**2020**	**2021**	Tolerance limit in Rwanda	International tolerance limit
pH	5.21	4.63	6.12	5 – 9	5 – 9
COD	643	867	350	< 250	120
BOD	287	312	208	< 50	45
TSS	41	37	98	< 50	45
Oil and Graise	4.12	8.7	5.21	10	5

Moreover, based on the obtained wastewater quality and their comparison to Tolerance Limit fixed by the Rwanda Standard Board and the international Tolerance limits of the United States Environmental protection Agency (US EPA), it is noted that wastewater at Kayumbu coffee washing station is unclean due to two parameters among five which present negative impact.

Regardless the fact that the generated wastewaters are discharged into the

http://eajournal.unilak.ac.rw/EAJST (online Version) ISSN: 2227-1902 Email: eajst_editor@unilak.ac.rw /eajscience@gmail.com

surrounding environment, the management of Kayumbu coffee washing station has put in place some annual measures which to minimize environmental impact of the generated wastewater such as biological and Chemical mechanisms.

These include planting more grasslands/ensuring vegetation cover within area (s) receiving the wastewater for infiltration, Biological wastewater treatment for the removal of BOD (Biological Oxygen Demand). The station also utilizes biofiltration system to remove pollutants from wastewater generated by coffee washing. In addition, as highlighted by the Kayumbu coffee washing station, every year, waste-water quality is tested to check on its concentration progress and keep on applying other environmentally friendly approaches.

The above is highlighted by previous studies (Chaudhary et al. 2003; Othuon et al. 2021) that coffee washing stations do generate much wastewater and that in case the wastewater are treated and prevented to enter the neighboring environment,, the risk can be kept low. This contributes mainly in reducing water, air and soil quality pollution. Hence, Kayumbu coffee washing station generate wastewater but its current wastewater treatment/management facilitate in impact reduction but as long as COD and BOD concentration are quite higher, more efforts are suggested to maintain the national and international standards shown in Table 1.

4. Conclusion

This study was conducted in order to determine the impact of coffee processing on wastewater quality with case of Kayumbu washing station located in Kamonyi district, Southern Rwanda. The considered wastewater quality parameters were pH, Chemical Oxygen Demand, Biological Oxygen Demand, Total Suspended Solids and Oil and grease. The annual (May 2019, May 2020 and May 2021) concentrations of these parameters were collected from the report of Kayumbu coffee washing station. It is noted that COD and BOD concentration surpass the national and international limits, but at low extent. However, some wastewater treatments are in practice such as the use biological and chemical process in the removal of organic pollutant in wastewater, ensuring vegetation cover in the area receiving wastewater for infiltration and reduction of rrunoff along with using Ecological Coffee Wet Mill that minimize water consumption. Further studies can carry out the test on same physicochemical parameters at the coffee washing station and their wastes receiving environment and compare the wastewater quality during the coffee washing station to that of non-coffee washing station and a permanence evaluation of wastewater from coffee processing is suggested to identify its status and to ensure surrounding environmental components

Acknowledgements

The author thanks the Chemistry Laboratory at the College of Science and Technology of the University of Rwanda for providing the utilized data on physicochemical parameters. The authors also thank the Kayumbu coffee washing station for sharing its report and allowing the authors to consider it as case study.

References

Chaudhary, D. S., S. Vigneswaran, H.-H. Ngo, W. G. Shim, and H. Moon. 2003. Biofilter in water and wastewater treatment. *Korean Journal of Chemical Engineering* 20 (6):1054-1065.

Eakin, H., K. Benessaiah, J. F. Barrera, G. M. Cruz-Bello, and H. Morales. 2012. Livelihoods and landscapes at the

threshold of change: disaster and resilience in a Chiapas coffee community. *Regional Environmental Change* 12 (3):475-488.

Guariso, A., C. Ngabitsinze, and M. Verpoorten. 2011. The Rwandan coffee sector: out of the ordinary. *L'Afrique des grands lacs: Annuaire* 2012:397-426.

Hakorimana, F., and H. Akçaöz. 2017. The Climate Change and Rwandan Coffee Sector. *Turkish Journal of Agriculture-Food Science and Technology* 5 (10):1206-1215.

Kanu, I., and O. Achi. 2011. Industrial effluents and their impact on water quality of receiving rivers in Nigeria. *Journal of applied technology in environmental sanitation* 1 (1):75-86.

Kazoora, C. 2011. Costs and benefits of addressing environmental impacts in the wet coffee processing in Rwanda. *PEI, Rwanda*.

Ngabitsinze, J., A. Mukashema, M. Ikirezi, and F. Niyitanga. 2011. Planning and costing adaptation of perennial crop farming systems to climate change: Coffee and banana in Rwanda. *International Institute for Environment and Development (IIED), London, UK*.

NISR. 2012. National Institute of Statistics of Rwanda. Population and Housing Survey. Kigali, Rwanda.

Othuon, D. O., K. K. Gatimbu, C. M. Musafiri, and F. K. Ngetich. 2021. Working capital management impacts on small-scale coffee wet mills' financial performance in eastern Kenya. *Heliyon* 7 (9):e07887.

Selvamurugan, M., P. Doraisamy, and M. Maheswari. 2010. An integrated treatment system for coffee processing wastewater using anaerobic and aerobic process. *Ecological Engineering* 36 (12):1686-1690.

Takashina, T. A., V. Leifeld, D. W. Zelinski, M. R. Mafra, and L. Igarashi-Mafra. 2018. Application of response surface methodology for coffee effluent treatment by ozone and combined ozone/UV. *Ozone: Science & Engineering* 40 (4):293-304.

Talvitie, J., A. Mikola, O. Setälä, M. Heinonen, and A. Koistinen. 2017. How well is microlitter purified from wastewater?–A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant. *Water research* 109:164-172.

Villanueva-Rodríguez, M., R. Bello-Mendoza, D. G. Wareham, E. Ruiz-Ruiz, and M. d. L. Maya-Treviño. 2014. Discoloration and organic matter removal from coffee wastewater by electrochemical advanced oxidation processes. *Water, Air, & Soil Pollution* 225 (12):1-11.