BUSITEMA UNIVERSITY
Pursuing Excellence

P.O. Box 236, Tororo, Uganda
Gen: +256 - 45 444 8838
Fax: +256 - 45 4436517
Email: info@adm.busitema.ac.ug
www.busitema.ac.ug

FACULTY OF ENGINEERING DEPARTMENT OF WATER RESOURCES AND MINING ENGINEERING

Investigating the effectiveness of using natural zeolite as an adsorbent for removing chromium from tannery wastewater.

(Case study: SkyFat tannery, Jinja)

BY REGINALD BUSULWA

BU/UP/2017/1480

busulwareginald20@gmail.com

SUPERVISOR: MR. WANGI MARIO

A final year research report submitted to the Directorate of Graduate Studies, Research and Innovations in partial fulfillment of the requirements for the award of a Bachelor of Science in water resources engineering of Busitema University.

DECLARATION:

I the undersigned, declare that this research is my original work, except where due acknowledgement has been made. I declare that this work has never been submitted to this University or to any other institution for funding for partial fulfillment for any award

Student Name: …………

Registration Number: …………...Signature: ……….

DEDICATION:

I hereby dedicate this thesis to my lovely family specifically my beloved parents. Thank you for never giving up on me and encouraging me towards my goals because your sincere sacrifice towards my education has exposed me to the world of Engineering. If it were not for your love, encouragement, support and sacrifices, I would have never made it this far. I love and appreciate you

ABSTRACT

During the tanning step, 30–40% of trivalent chromium remains in the solid and liquid wastes, generating highly polluted sewage. Chromium is a toxic heavy metals and once it is mobilized in the aquatic ecosystem greatly endangers the life of aquatic organisms that use water for survival and also to people who consume fish causing several irreversible damages such as genetic defects, impairment of pulmonary and kidney function. In this study, zeolite was used as a low-cost adsorbent to remove trivalent chromium from tanning effluent. Batch adsorption experiments on zeolite were performed. After samples were filtered, and the uptake of chromium was determined. A 3-level Box-Behnken Design was used to study the combined effect of contact time, pH values and adsorbent dose on the removal of trivalent chromium.

The study was done in skyfat tannery located in Jinja, Ugandass. The effects of pH (3–8), contact time (5–60 mins), and adsorbent dose (0.1-1g) and their interactions were investigated using response surface methodology following a box Behnken design. Optimum adsorption capacity (92.21%) was obtained at pH 4.41, contact time 31.667 minutes and adsorbent dose 0.6545g by response surface plots and response optimizer in Minitab 20.0 software

APPROVAL:

This research proposal is submitted as a partial fulfillment for the award of Bachelor of Water Resources Engineering at Busitema University, with my approval as the academic

supervisor

Name: …………………….

Academic Qualifications: ………………….   Rank: …

Department: …………… Faculty:
Signature: ……………

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

Contents

LIST OF ACRONYMS

NTU	Nephelometer Turbidity Unit
TSS	Total Suspended Solids
XRD	X-Ray Diffraction
XRF	X-ray Fluorescence

ACKNOWLEDGMENT

First and foremost, I thank the Almighty God for giving me good health and strength to work. I appreciate my parents for supporting and motivating me throughout the year.

I am greatly indebted to Mr. Wangi Mario, Mr.Tigalana Daniel, Mr. Bagoole Christopher, Mr. Gezaho Ronald, Mr. Nasasira Michael Bakamaa for advising and guiding during project research.

Special thanks goes to water quality managers Mr. Ssebulime stevephen of the Wandegeya analytical laboratory Environment, for giving me the opportunity to perform my research tests in laboratories under their supervision.

I also appreciate all my fellow classmates for guiding me during proposal and project research preparations.

1 CHAPTER ONE: INTRODUCTION:

1.1 BACKGROUND

In the tannery world, there are two basic types of tanning systems, vegetable tanning which is done using plant extracts such as tree backs, fruits and chrome tanning which is done using chemicals like chromium sulfate, acid dyes, salt, and other chemicals. However, chrome tanning is preferred mainly due to the high pollution load and low treatability associated with vegetable tanning (Tadesse & Guya, 2017).

About 60-70% of total chromium salts used in chrome tanning reacts with the hides and the rest of the 40-30% remain in the solid and liquid. The leather industry consumes more than 50 m^3 of water for processing 1 tonne of raw hides (Mottalib et al., 2015).One of the major emerging environmental problems in the tanning industry is the disposal of chromium contaminated sludge produced as a by-product of wastewater treatment. Tannery effluents severely affect the mitotic process and reduce seed germination in extensively cultivated pulse crops.

At high concentrations, chromium is toxic, mutagenic, carcinogenic, and teratogenic. Its toxicity may damage human organs including kidney and liver as well as can cause dermatitis and gastrointestinal ulcers. Chromium exists in the oxidation states of Cr (II), Cr (III) and Cr (VI) where the hexavalent form of Cr is 500 times more toxic than the trivalent one. In the presence of certain naturally minerals such as MnO_2, Cr (III) can easily be oxidized to Cr (VI) in the soil environment. Various treatment procedures such as adsorption, chemical precipitation, electrocoagulation, ion exchange, electrodialysis, and membrane separation are available for removal of Cr from wastewater (Covarrubias et al., 2005). Among these, chemical precipitation using calcium hydroxide is a technique commonly employed in many tanneries including skyfat tannery, but this method greatly associated with heavy sludge formation in which chromium is compounded and easily gets mobilized to the environment where it harms many species of organisms. Other advanced treatment techniques, such as ion exchange, reverse osmosis, electrocoagulation, membrane filtration, and electrodialysis are effective for removing Cr (VI), but these are expensive and produce concentrated wastes that require subsequent treatment and disposal.

RSM is a collection of mathematical and statistical techniques used for modelling and analysis of problems on which the response of interest is influence by several variables and the objective is to optimize the response. (Tadesse & Guya, 2017)

RSM has to two designs, central composite design (CCD) and box Behnken design (BBD).

In this study BBD was used which involves 3-level for each of the factors of contact time, zeolite dose and pH.

Zeolite was formed millions of years ago when the ash volcanoes reacts with alkaline water.Zeolites are aluminosilicate solid with honey-comb framework containing a negative charge that is counterbalanced by cations such as Na, Ca, Mg. It is these cations that are exchanged in preference to the cations in the aqueous solution. This cation exchange property has famed zeolite in the scientific community making it an indispensable tool for treating waste water mostly containing heavy metals, it was famously used decontamination of Chernobyl after nuclear power disaster (Rhodes, 2010).

The case study of this research will be Skyfat tannery Co Ltd which is a Chinese-owned tannery located in Nyanza close, around the shores of Lake Victoria, Jinja district Uganda. it processes around 1500 -2000 hides per day and process them into wet blue hides and skins for export (NAPE, 2009a).

1.2 PROBLEM STATEMENT

Tanneries that indulge in chrome tanning such in Uganda continue to dissipate chromium beyond the accepted the limit of 0.5 mg/L (Water, 2019) and given its close proximity to water bodies it becomes easier for the chromium to get into the aquatic eco system, compounding in the food chain causing many fatal illness like as kidney failure, damage of the central nervous system, reproductive failure and possibly even infertility to human.

1.3 PURPOSE OF THE STUDY

The purpose of the study is to investigate the effectiveness of using natural zeolite as an adsorbent for removing chromium from tannery waste

1.4 JUSTIFICATION OF THE STUDY

Chromium pollutions of the aquatic ecosystem will be reduced

It would attract a lot of investment in zeolite exploration around wanale hence benefiting the residents economically.

It would contribute to SDG six (clean water and sanitation).

Calcium oxide (CaO), known as lime or quicklime, which tannery industry heavily depends on for chromium removal in their effluent is an energy intensive product and coz the production of tone of lime of limestone involves emission of 1.2 tons of carbondioxide to the of which CO_2 among all greenhouses is the prime contributor of global warming, it solely contributes a staggering 76% to the global warming (Cui et al., 2019)CO_2 emissions from human activities is considered as the main driver for anthropogenic climate change. CO_2 among all greenhouses is the prime contributor of global warming, it solely contributes a staggering 76% to the global warming (Cui et al., 2019).

Zeolite is fronted as the best alternative because of its ion-exchange and sorption properties for heavy metals such chromium and capabilities of being thermally regenerated.

1.5 OBJECTIVES OF THE STUDY

1.5.1 Main objective

To investigate the effectiveness of natural zeolite as an adsorbent for removing chromium in the tannery wastewater

1.5.2 Specific objectives

1. To characterize the wastewater at Skyfat tannery.
2. To determine composition of the natural zeolite.
3. To design experiment in Minitab using RSM-BBD
4. To the determine adsorption capacity for chromium and optimize the process conditions for improving the adsorption capacity

1.6 SCOPE OF THE STUDY

1.6.1 Conceptual scope

This study is limited to investigating the effectiveness of using natural zeolite as an adsorbent for removing chromium from the tannery industrial water.

1.6.2 Geographical scope

Skyfat tannery, Jinja district.

1.6.3 Time scope

The research was be done for 6 months.

5.3 References

references[UIA]Uganda Investment Authority. (2008). *Leather Sector Profile 1. February 2008Uganda Investment Authority [UIA]. (2008). Leather Sector Profile 1.*, *(February 2008)*, *24*. *Retrieved from http://www.ugandainvest.go.ug/uia/images/Download_Center/SECTOR_PROFILE/Leather_Sector_Profile.pdf*, 24. http://www.ugandainvest.go.ug/uia/images/Download_Center/SECTOR_PROFILE/Leather_Sector_Profile.pdf

Aghel, B., Mohadesi, M., Gouran, A., & Razmegir, M. H. (2020). Use of modified Iranian clinoptilolite zeolite for cadmium and lead removal from oil refinery wastewater. *International Journal of Environmental Science and Technology*, *17*(3), 1239–1250. https://doi.org/10.1007/s13762-019-02466-5

Azom, M. R., Mahmud, K., Yahya, S. M., Sontu, A., & Himon, S. B. (2012). Environmental Impact Assessment of Tanneries: A Case Study of Hazaribag in Bangladesh. *International Journal of Environmental Science and Development*, *3*(2), 152–156. https://doi.org/10.7763/ijesd.2012.v3.206

Bakhtiari, A. R., Zakaria, M. P., Yaziz, M. I., Lajis, M. N. H. L., & Bi, X. (2014). E nvironment A sia. *EnvironmentAsia*, *7*(1), 104–111.

Boehme, C., & Malissa, H. (2017). *Electrically Detected Magnetic Resonance Spectroscopy*. *6*, 83–100. https://doi.org/10.1002/9780470034590.emrstm1525

Buchanan, J. R., & Ph, D. (n.d.). *Wastewater Basics 101 Wastewater Basics 101*.

Chowdhury, M., Mostafa, M. G., Biswas, T. K., Mandal, A., & Saha, A. K. (2015). Characterization of the Effluents from Leather Processing Industries. *Environmental Processes*, *2*(1), 173–187. https://doi.org/10.1007/s40710-015-0065-7

Christidis, G. E. (2018). *Zeolite formation and deposits*. *July*. https://doi.org/10.2174/97816080526151120101002 8

Covarrubias, C., Arriagada, R., Yáñez, J., García, R., Angélica, M., Barros, S. D., Arroyo, P., & Sousa-Aguiar, E. F. (2005). Removal of chromium(III) from tannery effluents, using a system of packed columns of zeolite and activated carbon. *Journal of Chemical Technology and Biotechnology*, *80*(8), 899–908. https://doi.org/10.1002/jctb.1259

Department of Earth Sciences. (n.d.). *12*(4).

Diale, P. P., Muzenda, E., & Zimba, J. (2021). *A Study of South African Natural Zeolites Properties and Applications*. *II*.

El-Azim, H., & Mourad, F. (2018). Removal of Heavy Metals Cd (II), Fe (III) and Ni (II), from

Aqueous Solutions by Natural (Clinoptilolite) Zeolites and Application to Industrial Wastewater. *Asian Journal of Environment & Ecology*, *7*(1), 1–13. https://doi.org/10.9734/ajee/2018/41004

EUC. (2009). *Integrated pollution prevention and control: draft reference document on best available techniques in the tanning of hides and skins*. *February*, 1–241.

GracePavithra, K., Jaikumar, V., Kumar, P. S., & SundarRajan, P. S. (2019). A review on cleaner strategies for chromium industrial wastewater: Present research and future perspective. *Journal of Cleaner Production*, *228*, 580–593. https://doi.org/10.1016/j.jclepro.2019.04.117

IFC. (2007). Environmental, Health, and Safety Guidelines - Tanning and Leather Finishing. *Technical Revision of World Bank Group Environmental, Health, and Safety Guidelines*, 1–22. http://www.ifc.org/wps/wcm/connect/de6c3d00488556f2bb14fb6a6515bb18/Final+-+Tanning+and+Leather+Finishing.pdf?MOD=AJPERES

Jayanthi, D., Victor, J. S., Chellan, R., & Chellappa, M. (2019). *Green processing : minimising harmful substances in leather making*.

Kokkinos, E., & Zouboulis, A. (2020). *A step by step investigation of Cr(III) recovery from tannery waste*. *Iii*, 6436. https://doi.org/10.3390/ecws-4-06436

Kumar, S., & Jain, S. (2013). *History , Introduction , and Kinetics of Ion Exchange Materials*. *2013*.

Losch, P. (2017). *Synthesis and characterisation of zeolites , their application in catalysis and subsequent rationalisation : methanol-to-olefins (MTO) process with designed ZSM-5 zeolites To cite this version : HAL Id : tel-01531844*.

Margeta, K., Zabukovec, N., Siljeg, M., & Farkas, A. (2013). Natural Zeolites in Water Treatment – How Effective is Their Use. *Water Treatment*. https://doi.org/10.5772/50738

Marzan, L. W., Hossain, M., Mina, S. A., Akter, Y., & Chowdhury, A. M. M. A. (2017). Isolation and biochemical characterization of heavy-metal resistant bacteria from tannery effluent in Chittagong city, Bangladesh: Bioremediation viewpoint. *Egyptian Journal of Aquatic Research*, *43*(1), 65–74. https://doi.org/10.1016/j.ejar.2016.11.002

Mottalib, A., Somoal, S. H., Islam, S., & Alam, M. N. (2015). *RESEARCH ARTICLE REMOVAL OF CHROMIUM FROM TANNERY WASTEWATER BY TANNERY LIME LIQUOR ; 3 MD . Nurul Abser*. *September 2016*.

NAPE. (2009a). *The Leather-Tannery Industry in Uganda. Risks to the Environment and to Human Health*. *December*, 1–28. http://nape.or.ug/index.php/publications/chemical-management/12-the-leather-tannery-industries-in-uganda/file

NAPE. (2009b). *The Leather-Tannery Industry in Uganda. Risks to the Environment and to Human Health*. *December*, 1–28.

Nur-E-Alam, M., Mia, M. A. S., Ahmad, F., & Rahman, M. M. (2020). An overview of chromium removal techniques from tannery effluent. *Applied Water Science*, *10*(9), 1–22. https://doi.org/10.1007/s13201-020-01286-0

Ozgunay, H., Colak, S., Mutlu, M. M., & Akyuz, F. (2007). Characterization of leather industry wastes. *Polish Journal of Environmental Studies*, *16*(6), 867–873.

Rahaman, A., Hosen, M. R., Hena, M. A., Naher, U. H. B., & Moniruzzaman, M. (2016). A Study on removal of chromium from tannery effluent treatment of chrome tanning waste water using tannery solid waste. *Int. J. Hum. Capital Urban Manage*, *1*(4), 237–242.

Rhodes, C. J. (2010). Properties and applications of zeolites. *Science Progress*, *93*(3), 223–284. https://doi.org/10.3184/003685010X12800828155007

Samadder, S. L. P. K. S. S. R. (2014). *Regeneration of adsorbents and recovery of heavy metals : a review*. https://doi.org/10.1007/s13762-014-0714-9

Song, Z., Williams, C. J., & Edyvean, R. G. J. (2004). Treatment of tannery wastewater by chemical coagulation. *Desalination*, *164*(3), 249–259. https://doi.org/10.1016/S0011-9164(04)00193-6

Stern, T. (2019). Production Processes. *The Cambridge Guide to the Worlds of Shakespeare*, 122–128. https://doi.org/10.1017/9781316137062.018

Table, P., Table, P., & Table, P. (n.d.). *no N t t E o R be T re pu bl is he d no N t t E o R be T re pu*. *3*, 291–306.

Tadesse, G. L., & Guya, T. K. (2017). Impacts of Tannery Effluent on Environments and Human Health: A Review Article. *Advances in Life Science and Technology*, *54*(Vi), 58–67. https://www.iiste.org/Journals/index.php/ALST/article/viewFile/35827/36822

Temsch, R., & Marchich, M. (2002). *UNIDO PROGRAMS FUNDED BY AUSTRIA TO STRENGTHEN THE LEATHER SECTOR IN UGANDA Joint In-Depth Evaluation Mission*. https://www.unido.org/fileadmin/import/42858_FINAL_EVAL_REPORT_20021028_UGA.pdf

Tripathi, A., & Dwivedi, A. K. (2012). Studies on Recovery of Chromium From Tannery. *Journal of Industrial Pollution Control*, *28*(1), 29–34.

Virta, B. R. L. (2001). *By Robert L. Virta*.

Water, M. O. F. (2019). *REPUBLIC OF UGANDA UGANDA ' S FIRST BIENNIAL UPDATE REPORT TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE*. *September*.

Wingenfelder, U., & Schulin, R. (2005). *Removal of Heavy Metals from Mine Waters by Natural Zeolites*. *39*(12), 4606–4613.

Year, F., Report, P., The, I., Of, E., Zeolite, N., Remediation, A. S. A., For, O., & Mine, A. (2016). *Department of Mining and Water Resources Investigating the Efficiency of Natural Zeolite*. *May*.

Zanin, E., Scapinello, J., de Oliveira, M., Rambo, C. L., Franscescon, F., Freitas, L., de Mello, J. M. M., Fiori, M. A., Oliveira, J. V., & Dal Magro, J. (2017). Adsorption of heavy metals from wastewater graphic industry using clinoptilolite zeolite as adsorbent. *Process Safety and Environmental Protection*, *105*, 194–200. https://doi.org/10.1016/j.psep.2016.11.008

Zong, J., Li, Y. C., & Hu, K. (2016). Simultaneously Recovering High-Purity Chromium and Removing Organic Pollutants from Tannery Effluent. *Journal of Chemistry*, *2016*. https://doi.org/10.1155/2016/8298090