BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF ENVIRONMENTAL SCIENCE

Suitability of malt distillery effluent for vegetable irrigation

By

Sean Panashe

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF A BACHELOR OF SCIENCE HONOURS DEGREE (BSc SHEM) IN SAFETY, HEALTH AND ENVIRONMENTAL MANAGEMENT

MAY 2024

DECLARATION

To be complied by the student

Registration number B201041B

I, Tadiwa Zimbizi, do hereby declare that this work is entirely the product of my own research and it was never used on any other academic work. All reference to previously published work has been clearly shown.

Student signature Date: 30/05/24

To be complied by supervisor

This dissertation is suitable for submission to the faculty and has been checked for conformity with the faculty guidelines.

Supervisor's signature: ……………… Date: 7/10/24…………………

Chairman's signature: ……………….. Date:………………….

Supervisor Acceptance Letter

The Chairman

Department of Environmental Science

Date: 19 September, 2023

I wish to inform you that I am accepting *Tadiwa Zimbizi (B201041B)* as my student to guide his research work leading to attainment of a BSc. (Hons) SHEM degree with Bindura University Science and Education. I will supervise him throughout the research process.

Proposed title:

Suitability of malt distillery effluent for vegetable (spinach) irrigation

Sincerely,

A. Kanda (PhD PH, MSc WREM, BSc Hons Chem, PostGrad Dip WSS, Dip Ed)

TURNITIN REPORT

DEDICATION

The research is dedicated to my family.

ACKNOWLEDGEMENTS

Firstly, the Lord Almighty deserves all praise for the gift of life and the grace to go through the research. I carry on thanking my family and friends for the numerous types of support they provided at this stage of my academic and social development. My academic supervisor Dr. Artwell Kanda deserves special recognition for the supervision and direction he provided in making this phase successful. Lastly, I would like to convey my gratitude to African Distillers Limited for giving me the chance to experience and learn about SHEQ systems at their company and also their unflinching support during my research.

ABSTRACT

Background: Wastewater reuse for crop irrigation can meet irrigation water quality and crop water requirements. However, its use may have potential adverse public and environmental health effects. Malt distillery effluent (MDE) is a potential source of irrigation water. *Objectives*: The suitability of MDE for vegetable irrigation was determined using international irrigation water quality requirements.

Methods and materials: The study employed a quantitative analytical design where effluent grab samples from a distillery effluent treatment from August 2023 to April, 2024 were measured for pH, Biological oxygen demand(BOD), electrical conductivity (EC), nutrients, total suspended solids (TSS) and total dissolved solids (TDS). The results were statistically compared with international irrigation water quality requirements for vegetables.

Key findings: The study revealed that MDE quality parameters exhibited variations with FAO guidelines. Measured mean MDE quality parameters were pH (Mean7.16±0.16),NO_3-N (2.30±0.89), BOD(48.40±14.46), K (20.98±3.47) and Na (156.47±28.87).Only values for pH and NO_3-N were within threshold limits ($p < 0.05$). *Conclusion*: Overall, MDE may be a potential candidate for vegetable irrigation. However, it has to be treated before reuse to meet irrigation water quality requirements for vegetables. Dilution with river water may need further research.

Key terms: *Biological oxygen demand, Electrical conductivity, Irrigation, malt, pH*

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List of Acronyms and Abbreviations

AFDIS	**African Distillers**
BOD	**Biological Oxygen Demand**
Cl	**Chloride**
COD	**Chemical Oxygen Demand**
EC	**Electrical Conductivity**
MDE	**Malt Distillery Effluent**
Na	**Sodium**
NO_3	**Nitrates**
P	**Phosphate**
Pb	**Lead**
TDS	**Total Dissolved Solids**
TSS	**Total Suspended Solids**

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CHAPTER 1: INTRODUCTION

1. Introduction

1.1Background of the study

Reuse of wastewater has emerged a viable solution to augment freshwater resources particularly in arid environments (Brar et al., 2022).Malt distillery effluent (MDE) is aby-product of the brewing and distilling industry. Itcan be a potential alternative irrigation source for agricultural crops because it is rich in organic matter, nutrients and trace elements required for crop growth (Hashem et al., 2021).Crop irrigation is crucial for food security andcontributes to global food supply (Ramya & Patel, 2019).

Wastewater contains nutrients that are crucial for plant growth and development (Du et al., 2022). However, some limitations of wastewater reuse have been reported. These included (i) accumulation of salts in the plant's root zone due to continuous use (Kumar &Kambe et al.,2022), (ii) various diseases in and consumers of wastewater irrigated crops(Ungureanu et al.,2020), and (iii) deterioration of soil quality and ground water (Ratna et al.,2021).Wastewater may need to be treated to meet irrigation water quality requirements. Wastewater that was reportedly used to irrigate various crops include stillage (Mikucka&Zielinska, 2020) and domestic sewage effluent (Mishra et al., 2021).

The key parameters that can be used judgethe suitability of an effluent for irrigation include pH, C), nutrient concentrations, trace elements and the sodium adsorption ratio (Parwin et al.,2020; Tampo et al.,2022). Distillery effluent may be a suitable to irrigate vegetables, particularly spinach (Hussain et al., 2019). The study aimedatassessing the suitability of malt distillery effluent for vegetable irrigation.

1.2 Problem Statement

Characterisation of malt showed that it contains organic matter, plant nutrients(NPK), inorganic micronutrients, organic carbon, suspended solids, and heavy metals (Ungureanu et al., 2020;Singh & Sharma, 2021;Gezahegn et al., 2024). This may present an opportunity for vegetable (e.g., spinach)irrigation to address irrigation water scarcity and promote sustainable agricultural practices (Brar et al., 2022). However, there is a lack of comprehensive understanding of its suitability (Obayomiet al., 2019; Bakari et al., 2022). **1.3.1 Aim**

To investigate the suitability of malt distillery effluent for vegetable (spinach) irrigation.

1.3.2 Objectives

- To characterise MDE using selected physiochemical characteristics required for vegetable (spinach) irrigation (BOD, nutrients, pH, EC, Ca, Na).
- To compare measured effluent quality parameters with FAO crop water quality requirements for unrestricted vegetable irrigation.

1.4 Significance of the study

Findings from the study may contribute to literature and the debate on wastewater reuse. They may be used as a basis for further research. The study may provide regulatory agencies with data to support the development of informed regulations for wastewater irrigation.

1.5 Hypotheses

H_0 = There is no significant difference in the means of the measured effluent parameters between the three replicates (μR1 =μR2=μR3)

H_1 = There is a significant difference in the means of the measured effluent parameters between the three replicates (μR1 =μR2=μR3)

H_0= The means of the measured effluent parameters is equal to the FAO guideline values (μ=μ0)

H_1= The means of the measured effluent parameters is not equal to the FAO guideline values (μ≠μ0)

1.6 Assumptions

- Distillery effluent contains plant nutrients
- Effluent application rates are the same for all treatments

1.7 Limitations

- Potentially harmful substances may be present in the effluent to cause adverse plant effects.
- Changes in the characteristics of malt distillery effluent may change which is beyond the control of the researcher
- Effects of effluent application may be due to other confounding factors (soil, plant, environmental conditions)

1.8 Delimitations

- The study focuses on malt distillery effluent from African Distillers for irrigation of spinach crops on site only.
- The findings of this research may not be applicable to other regions or time periods.

CHAPTER 2: LITERATURE REVIEW

2. Literature review

2.1 Introduction

This chapter reviews existing literature on the suitability of distillery effluent for vegetable irrigation. It also provides a review of the current knowledge on wastewater reuse for crop irrigation, and the characteristics of malt effluent, effluent quality requirements for crop irrigation. It gives a theoretical framework that guided the study and summarised the review identifying research gaps.

2.2 The importance of vegetables to human diet

Vegetables contain important vitamins, minerals and chemicals essential for human health (Patel et al., 2019). WHO (2019) recommends that the consumption of vegetables should be 400g per individual per day. Vegetables were reported to contain minerals(iron and calcium), vitamins (A and C), soluble fibre, and lower calories (Ulger et al., 2018; Ramya& Patel, 2019; Rejeki, Wedowati & Haryanta, 2023). These components are essential for the human diet to provide optimum health and necessary nutrients lacking in other food groups (Noopur et al., 2023). Vegetables, specifically spinach, protect against chronic diseases such as cancer, stroke and heart diseases (Ramya et al., 2019).

2.3 The importance of wastewater reuse in irrigated crop production

FAO (2018) asserts that irrigated crops account for 40% of the worlds' food production, a figure expected increase as food demand increases due to population growth. Table 2.1 summarises the reported importance of irrigated agriculture using wastewater, environmental protection due to vegetation cover and preserving soil moisture reserves in arid zones.

2.4. Water quality for unrestricted crop irrigation

Water quality plays a crucial role in agricultural practices, particularly in unrestricted crop irrigation. It directly affects soil fertility, crop productivity, crop quality and environmental protection (Qi et al., 2021). For unrestricted crop irrigation various parameters are commonly monitored to assess the quality of water for irrigation (Mutavdzic et al., 2022). Table 2.1 below shows FAO (2019) drainage paper on water quality guidelines for unrestricted crop irrigation reported critical parameters that are used to determine the suitability of water quality for crop irrigation (Table 2.2).

Table 2.1 The importance wastewater in crop irrigation

Importance	Reference
• environmental protection due to vegetation cover • preserves soil moisture reserves in arid zones	Komissarov et al. (2019)
• Provides needed nutrients, essential elements, etc	Brar et al. (2022)
• Improves soil health • Water conservation	Rejeki et al. (2023)
• Addresses issues of water scarcity • Addresses food security around the globe	Ungureanu et al. (2020)
• Ensure availability of water for all • Reduces fertilizer costs	Singh (2021)
• Enhances soil fertility • Enhances crop productivity • Reduces environmental pollution due to inadequate planning for disposal	Naveed et al. (2018)
• Additional nitrogen in waste water improves sustainability and food security	Mishra et al. (2023)

Table 2.2Water quality guidelines for unrestricted crop irrigation (FAO, 2019). In mg/l.

Parameter	FAO Guidelines
pH (no units)	6.50 - 8.50
TDS	2 000
BOD	<30
NO_3^-	0 - 10
PO_4^{3-}	0-2
K^+	0-2
Pb^{2+}	2.00
SAR (no units)	15
Cl^-	<4
EC (dS/m)	3.00
Na^+	72.0
TSS	-
Ca^{2+}	<1
Mg^{2+}	-
CO_3^{2-}	-
HCO_3^-	<1.5

2.5 Application of wastewater/effluent for crop production

Table 2.3 indicates various effluents that have reportedly been applied to crops to augment or replace fresh water. Literature suggests that the commonest wastewater used was municipal wastewater for the irrigation of vegetables.

Table 2.3 Use of various effluents in vegetable production

Reference /country	Type of wastewater/effluent	Crop irrigated
Brar et al. (2022) / India	Treated	Vegetables.
Gurel (2022) / Turkey	Kitchen	Spinach
Hussain et al. (2019) / India	Untreated	Spinach
Du et al. (2022) / China	Piggery reclaim and saline water	Cucumbers
Chojnacka et al. (2020) / Nigeria	Untreated	Cucumbers
Hussain et al. (2019) / India	Untreated	Carrots
Beltran et al. (2020) / India	Untreated / treated municipal	Radishes

Beltran et al. (2020) / India	Untreated / treated	Lettuce

Further, treated and untreated wastewater has been used to irrigate vegetables.

2.6 Characteristics of malt effluent.

Malt distillery effluent is a by-product of the brewing and distilling industry (Hashem et al., 2021). Table 2.4 shows various studies which characterised MDE. The review shows that malt distillery effluent is generally characterised by high COD, optimum pH,salinity,high Na concentration and elevated nutrient levels.

Table 2.4 Characteristics of various malt distillery effluents in different study areas

Reference (Study area)	Measured characteristics of malt effluent	
	Parameter	Value
Malaviya et al. (2011) (India)	pH	5.53
	BOD	793.2mg/l
	EC	2.2mS/cm
	Temperature	45.2^{o}C
	TDS	1408 mg/l
	Cl^-	799.7 mg/l
Getachew (2017) (Oromia Region, Ethiopia)	pH	6.16
	TSS	1883.33mg/l
	Turbidity	2.27NTU
	TDS	2133.33mg/l
	TS	441.67mg/l
	EC	0.1764 dS/m
Beckley et al., 2014 (Benin city, Nigeria)	pH	5.8
	EC	80uS/m
	Turbidity	5.1NTU
	TSS	18mg/l
	COD	61.0mg/l
	Na	20.9mg/l
	K	9.10mg/l
	Ca	1.59mg/l
	Mg	0.78mg/l

2.7 Perceived environmental/public health challenges of wastewater reuse for vegetable irrigation

Excessive nutrients in effluent may:

- cause plant damage and leach into groundwater or surface waters(Helmecke et al., 2020),
- delay ripening and maturity, and human diseases(Brar et al., 2022),
- deterioration of soils' physiochemical properties and increased soil microbial activity (Xue-Bin et al., 2021),
- decreased quality of agricultural crops due to tainted soil (Brar et al., 2022),
- human exposure to heavy metals(Pb and Ca) and pathogens (Ofori et al., 2021),
- soil hardening and shallow groundwater contamination (Khalid et al., 2018),
- build-up of toxic metals in kidneys and liver, causing disorders physic-biochemical processes (Khalid et al., 2018)

2.8 Theoretical framework

This study is grounded in the Cause-Effect Theory which suggests that the physiochemical characteristics of MDE (cause) will directly impact spinach growth and productivity (effect). The Water Quality Parameters Model (WQPM) is used to analyse the relationships between the specific physiochemical characteristics of MDE and their effects on spinach growth. This framework will provide valuable information on how MDE quality affects spinach growth and weather it meets FAO crop water quality for irrigation.

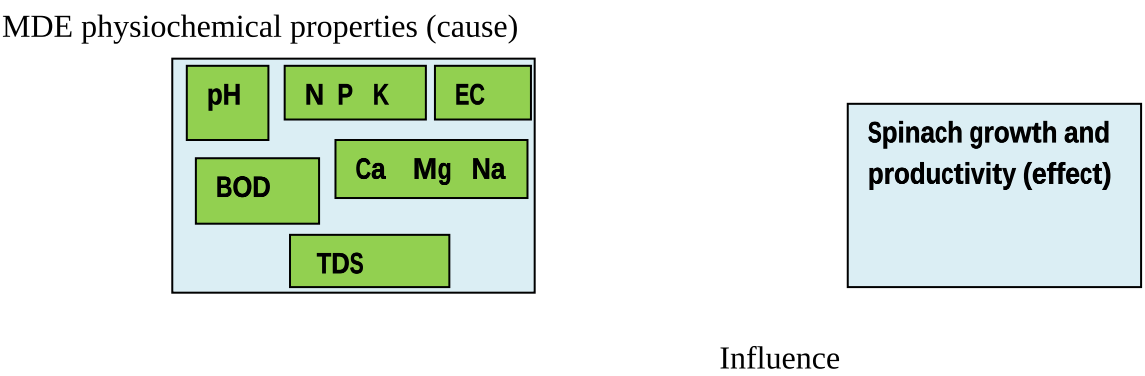

Fig2.1A conceptual model of MDE water quality parameters and spinach growth outcomes.

2.9 Summary

The literature review indicated that distillery effluent can be a valuable resource for agriculture. However, there is a need for its careful management and monitoring to ensure sustainability and safety. Further research is needed to fully understand the risks and benefits of this practice. It appears that to the best knowledge of the researcher no published work has been reported specifically for malt distillery effluent irrigation of spinach in Zimbabwe.

CHAPTER3: METHODS AND MATERIALS

3. Methods and materials

3.1 Description of study area

African Distillers is located along Lomagundi Road, Harare, Zimbabwe. Its core business is the manufacture, distribution and marketing of branded wines, spirits and ciders for the Zimbabwean market and export. The study area is the wastewater treatment plant (17.69134 S and 30.84814 E) (Fig. 3.1). The treatment plant consists of a train of nine ponds arranged in series (3A, 3F, 3M). Conventional water is from borehole water extraction on site.

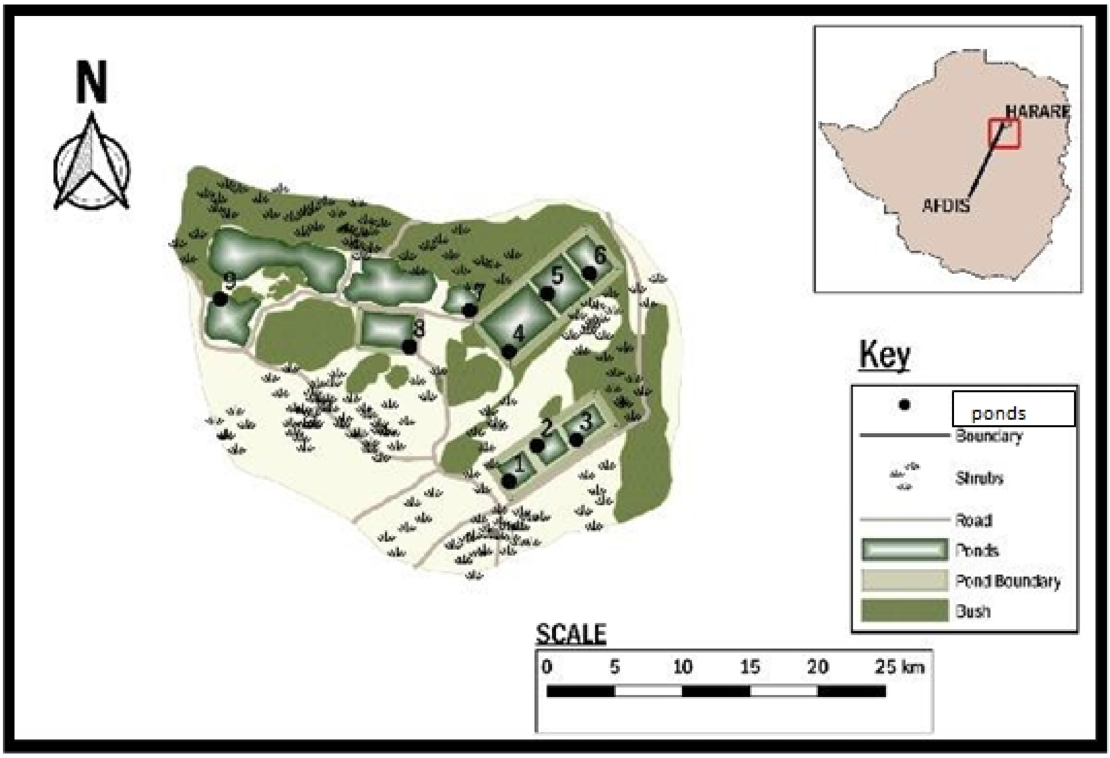

Fig3.1 Location AFDIS in Harare and the treatment ponds

3.2. Research design

The research employed a quantitative analytical design. MDE samples were collected and analysed in the laboratory, and statistically compared to established international crop irrigation water quality requirements. A similar design was reported by Bakari et al. (2022).

3.3. Sampling, sample preservation and pre-treatment

Wastewater samples were collected (grab method) in pre-cleaned 2L polyethylene bottles from three randomly selected sampling points, 3 samples per each sampling pointat discharge point after final treatment (SD4). Samples were collected per month in 9 months based on seasonal variations and similarity environmental conditions. Sampling was done from August 2023 to April 2024. The grab samples were mixed into 3 composites (3 replicates)9 months in order to capture temporal variations (Du et al., 2022). Sampling was uniform for all parameters in order to reduce bias. Standard water sampling methods (APHA, 2020) were used to collect samples from the sampling sites. pH and temperature were measured on site to minimize bias from rapid changes over time or during transportation.

3.4 Sample analysis

Sample parameters; pH and Temperature were measured on site by a calibrated micro 800 multi-parameter following standard procedures. Wastewater samples were filtered through acid treated Millipore filters within 24hrs of collection and stored under a refrigerator at $4C^0$ (Gezahen et al., 2024).Samples were analysed at EMA laboratories, KG (VI) Borrowdale, Harare. Analyses were done following standard analytical techniques (Table 3.1)

3.5 Data analysis

Analytical data were captured in Ms Excel 2013 spreadsheet and cleaned for completeness and correctness. The data were tested for normality using the Shapiro-Wilks test. Statistical comparison of measured wastewater quality parameters with FAO (2018) guidelines was done using a one sample t-test. The one-Way ANOVA was used to check on variability across months using means.

3.6 Quality control procedures

Measurements were run in triplicate and double checked to reduce random errors and increase precision (Agarwal et al., 2022). Instruments were calibrated and according to the manufacturer’s recommendations (Parmer, 2022) and some were regularly cleaned. Standard analytical procedures were used to analyse data.

Table3.1 Analytical methods and instruments used for water and effluent quality analysis(Neale et al., 2021)

Parameter	Analytical method	Equipment used (model, company of manufacture, country)	SOPs
Cl^-	Titrimetric	Standard titrimetric laboratory setup	SOP/CM07
Cd	Spectrophotometric	Spectrophotometer,(SP-AA4530)	SOP/M08
DO (saturation%)	Electrode	DO probe (KOG-202S), China	SOP/CM51
EC (Us/cm)	Electrode	EC METER (11A-CM001),Canfort Laboratory	SOP/CM12
Pb	FAAS	Atomic Absorption Spectrophotometer (SP-IAA320), China	SOP/CM22
NO_3^-	Spectrophotometric	Spectrophotometer (model 7100, Germany)	SOP/CM23
pH	Electrode	Portable pH meter (model CT-6021 A),India	SOP/CM27
PO_4^{3-}	Spectrophotometric	Spectrophotometer(SP-MV 5600,SP-MV5800), China	SOP/CM28
K	Flame photometric	Flame Photometer(FP-I640),China	SOP/CM31
Na	Flame photometric	Flame Photometer(FP-I640), China	SOP/CM31
TDS	Gravimetric	TDS meter (BOQU DDS-1702), China	SOP/CM11
TSS	Gravimetric	Digital balanceBP-2C Series(India)	SOP/CM35
Turbidity	Nephelometry	Nephelometer (BEP-TB 4000E)	SOP/CM39
Zn	FAAS	Atomic Absorption Spectrophotometer, (SP-AA4530)	SOP/CM22
BOD	Titrimetric	Magnetic stirrer (Remi 5 MLH plus, India)	SOP/CM25
COD	Titrimetric	Reflux Apparatus	APHA2020)
Fe	FAAS	AtomicAbsorption Spectrophotometer, (SP-AA4530	SOP/CM22

CHAPTER 4: RESULTS

4. Results

4.1 Wastewater characterization.

Table 4.1 shows the analytical results of characterising MDE.Results show that pH of MDE significantly varied with the sampling months category ($p < 0.05$). The values increased in the order: R1 (6.75±0.24) < R3 (7.13±0.28) < R2 (7.59±0.08). Effluent EC did not significantly vary with these categories, R1, R2 and R3 ($p > 0.05$). SO_4 values showed no significant difference between R1 and R2 but R3 showed a significant difference from the other two categories ($p<0.05$). K and TSS values significantly varied with the sampling months category ($p<0.05$). The values decreased in the order R3<R2<R1 for both parameters.

Na, BOD and TDS values were significantly higher in the first category (R1) and all did not significantly vary across all categories ($p>0.05$). BOD and Na values increased in the same order: R3<R2<R1. SO_4 values were only significantly different between R3 ($p<0.05$) and the other two categories R1 and R2 showed no significant difference ($p>0.05$).

Table 4.1 Characteristics of MDE and its variation with sampling month category (Values Are means of replicate month measurements)

MDE measured parameter	Mean parameter value (Mean±SE)		
	R1	R2	R3
pH (units)	6.75±0.24^{a}	7.59±0.08^{a}	7.13±0.28^{a}
EC (µS/cm)	1675.33±122.37^{a}	1233.67±309.57^{b}	1209±65.43^{c}
BOD (mg/l)	63.80±45.10^{a}	50.53±0.31^{b}	30.86±14.18^{c}

Na (mg/l)	138.22±59.31[a]	7.59±62.88[b]	7.13±18.61[c]
TDS (mg/l)	1054.66±177.18[a]	591.33±192.51[b]	820±137.57[c]
Fe (mg/l)	5.13±2.61[a]	0.73±0.54[b]	0.46±0.10[c]
K (mg/l)	27.88±6.44[a]	23.38±5.43[b]	11.68±1.77[c]
TSS (mg/l)	64±9.16[a]	40.66±25.62[b]	28.33±1.63[c]
SO_4 (mg/l)	2.66±0.33[a]	7.33±3.38[a]	11.66±10.17[b]
P (mg/l)	1.33±0.80[a]	2.00±1.71[b]	0.21±0.09[c]
N (mg/l)	1.89±1.20[a]	3.79±2.44[b]	1.21±0.41[c]

Different superscripts a, b, c along a given row for a given parameter denote significantly different ($p < 0.05$)
Similar superscripts aa, bb, cc along a given row for a given parameter denote not significantly different ($p > 0.05$)
R1, R2, R1 denote a category representing 3 months of the year
SE: Standard Error of the mean

4.2 Comparison of MDE characteristics means with FAO limits

Table 4.2 shows the comparison of the means of wastewater parameters across the 3 categories. The results indicate that Na values significantly varied ($p<0.05$) with FAO-TLV across all three categories and also the overall (9-months) value significantly varied with FAO-TLV. The values increased in the order R3 (121.6±18.61) <R1 (138.22±59.31) <Overall (156.47±28.87) <R2 (209.58±62.88). BOD was significantly higher ($p<0.05$) across all categories including the overall (9-months) than the FAO-TLV (<30). MDE TDS for overall (9-months) was significantly lower than the threshold value ($p<0.05$). No significant differences were observed between pH values across all categories when compared to FAO-TLV ($p>0.05$).TSS values across all replicates were significantly higher than the recommended FAO guidelines ($p<0.05$). All nitrogen values were within the FAO limits for irrigation water.

Table 4.2: Comparison of MDE parameters with FAO guidelines.

MDE parameter	R1		R2		R3		Overall (9-months)	
	Measured	FAO-TLV	Measured	FAO-TLV	Measured	FAO-TLV	Measured	FAO-TLV
pH (units)	6.75 ± 0.24^{a}	$6.50\text{-}8.50^{a}$	7.59 ± 0.08^{a}	$6.50\text{-}8.50^{a}$	7.13 ± 0.28^{a}	$6.50\text{-}8.50^{a}$	7.16 ± 0.16^{a}	$6.50\text{-}8.50^{a}$
BOD (mg/l)	63.8 ± 45.10^{b}	$<30^{b}$	50.53 ± 0.31^{b}	$<30^{b}$	30.86 ± 14.18^{b}	$<30^{b}$	48.40 ± 14.46^{b}	$<30^{b}$
Na (mg/l)	138.22 ± 59.31^{c}	72^{c}	209.58 ± 62.88^{c}	72^{c}	121.6 ± 18.61^{c}	72^{c}	156.47 ± 28.87^{c}	72^{c}
TDS (mg/l)	1054.66 ± 177.18^{d}	2000^{d}	591.33 ± 192.51^{d}	2000^{d}	820 ± 137.57^{d}	2000^{d}	822 ± 108.42^{d}	2000^{d}
EC (uS/cm)	1675.33 ± 122.37^{e}	3000^{e}	1233.67 ± 309.57^{e}	3000^{e}	1209 ± 65.43^{e}	3000^{e}	1372.67 ± 123.81^{e}	3000^{e}
K (mg/l)	27.88 ± 6.44^{f}	$0\text{-}2^{f}$	23.38 ± 5.43^{f}	$0\text{-}2^{f}$	11.68 ± 1.77^{f}	$0\text{-}2^{f}$	20.98 ± 3.47^{f}	$0\text{-}2^{f}$
TSS (mg/l)	64 ± 9.16^{g}	$<30^{g}$	40.66 ± 25.62^{g}	$<30^{g}$	28.33 ± 1.63^{g}	$<30^{g}$	44.33 ± 10.02^{g}	$<30^{g}$
N (mg/l)	1.89 ± 1.20^{h}	$0\text{-}10^{h}$	3.79 ± 2.44^{h}	$0\text{-}10^{h}$	1.21 ± 0.41^{h}	$0\text{-}10^{h}$	2.30 ± 0.89^{h}	$0\text{-}10^{h}$

Different superscripts (ab, ac, bc…) for a category (R1, R2, R3, Overall) down a column denote significant differences ($p < 0.05$)
Similar superscripts aa, bb, cc…) for a category (R1, R2, R3, Overall) down a column denote not significantly different ($p > 0.05$)

CHAPTER 5: DISCUSSION

5. Discussion

5.1 Introduction

This chapter discusses the findings of the analyses conducted on MDE samples collected for measurement of different parameters including pH, BOD, TDS, EC and nutrients. Evaluation of these characteristics allows analysing the suitability of MDE for vegetable irrigation, particularly spinach.

5.2Malt distillery effluent characterization

The MDE analysed across three categories (R1, R2, R3) showed a slightly acidic to a neutral pH (6.75-7.59) and high EC values (1675.33-1209) indicating a high concentration of dissolved solids (Gezahegn et al., 2024). Moderate to high BOD values (63.80-30.86) observed suggested a significant amount of contamination by organic matter and high TDS values (Gezahegn et al., 2024). In addition, high BOD values recorded were due to use of molasses in the sweetening process which often produce high amounts of BOD and COD wastewater per litre of alcohol produced (Saxena et al., 2024).

MDE exhibits varying concentrations of K, N, SO_4 and Na across the three categories (R1, R2, and R3). The results show a decreasing trend in K and N while SO_4 and Na increase. The difference in concentrations across the categories is explained by the differences in the water quality used in the malting process. Variability in P across the three categories is due to the addition of phosphate in the biological treatment process as a nutrient (Campana et al., 2014).

5.3Malt distillery effluent characteristics comparison with FAO guidelines for unrestricted crop irrigation.

The MDE characteristics showed several issues compared to the FAO guidelines. The pH values are within the acceptable limit, but the BOD values in R1 and R2 surpass the limit, indicating high contamination by organic matter (Gezahegn et al., 2024). Na values in all three categories exceed the FAO guidelines, suggesting excessive salinity and a slightly higher TDS mean value (Ikhajiagbe et al, .2014).

The overall (9-months) means of the parameters show that BOD value (48.40) exceeds the FAO limit, indicating high organic pollution of the MDE (Gezahegn et al., 2024). Na value (156.47) is more than twice the FAO limit suggesting excessive salinity in the MDE.

Additionally, the K value (20.98) is significantly higher than the FAO recommended range, which may hinder crop growth or delay ripening and maturity (Helmecke et al., 2020). Whilst the pH, TDS and EC are within FAO recommended limits, the excessive BOD, Na and K levels are the key issues that need to be addressed to ensure the environmental sustainability.

5.4 Summary

The discussion highlights the controversial issue of using treated wastewater for irrigation, a practice debated globally, mainly in water-scarce regions. Main arguments are that it can provide with essential nutrients to crops and enhance soil fertility, while some raise concerns about heavy metal contamination and salinization of soil. Current research interests appear to be focused on finding ways to treat wastewater in order to remove harmful contaminants and ensure safe water for irrigation.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6. Conclusion and recommendations

6.1 Conclusion

The study revealed characteristics and variations in MDE quality parameters compared to FAO guidelines for unrestricted crop irrigation water quality. Remarkably, pH and N values were within acceptable ranges, while EC and TDS values were below the recommended limits, indicating potential for pollution. This study is useful and different from others in its comprehensive analysis of multiple categories (R1, R2, and R3) and parameters hence providing with a clear and more detailed understanding of MDE quality parameters. The intended stakeholders to benefit from this study include environmental regulators and agricultural practitioners. Future studies can explore effective treatment technologies to mitigate pollution and ensure sustainable use of water.

6.2 Recommendations

- Upgrading or modifying existing wastewater treatment plants to reduce BOD, K and Na levels in the effluent.
- Regular monitoring of effluent quality by environmental regulatory agencies and agricultural practitioners through regular sampling and analysis of wastewater and use of automated monitoring systems and sensors to ensure compliance with FAO guidelines.

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FAO irrigation water quality, drainage paper No. 29

APPENDICES

Appendix 1: Data Collection permission later from Bindura University

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE
DEPARTMENT OF ENVIRONMENTAL SCIENCE

Bindura University of Science Education

P. Bag 1020
Bindura, Zimbabwe
Tel: 263 - 71 – 6505
Cell : 0778371588
Email : tnyamugure@buse.ac.zw

BINDURA UNIVERSITY OF SCIENCE EDUCATION

4 April 2024

Dear Sir/Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

This letter serves to inform you that...Tadiwa Zimbizi (B201041B)........................ is a fourth year student at Bindura University of Science Education, in the Department of Environmental Science. During his/her fourth year of study he/she is supposed to do a research project in his/her area of specialisation.

Please assist in any possible way. Data collected will be used for academic purposes only and will not be published without your prior consent.

Thank you for your assistance.

Yours faithfully.

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science

Yours faithfully.

Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020, BINDURA
ZIMBABWE
OFFICIAL

Mr .T .Nyamugure
Chairperson - Department of Environmental Science

Appendix 2:Letter granted by organisation

Permission to conduct Research on our Effluent Treatment Processes Inbox

Laudworth Chinyama 24 May
to me, Tadiwa, akanda@buse.ac.zw

Good day.

We acknowledge receipt of your request for permission to conduct your research study on our Effluent Treatment Processs.

We grant you permission for the research and we are willing to support you -within our means; particularly access to the Effluent Treatment Plant and our routine effluent quality analytical results.

@Tadiwa Nagashe; kindly assist Tadiwa with effluent quality analytical results and access to the treatment plant.

Regards

Laudworth Chinyama
SHEQ Specialist
22 Km Peg Lomagundi Road
Stapleford,, Harare
Email: laudworthc@afdis.co.zw
Tel: +26324233780Ext: 33861
Cell: +263777887733
Web: www.africandistillers.co.zw

afdis sig.jpg

Appendix 3:SOP for determining pH of effluent using electrode method (SOP/CM27)

A calibrated pH electrode is immersed into the wastewater sample. A small voltage signal is generated by the electrode that varies depending on the hydrogen ion concentration of the wastewater. The measured voltage is then converted by pH meter into a standard pH unit value, providing a direct result of the sample's acidity or alkalinity. The electrode is properly calibrated using standard solutions with known pH values before measurement, for accurate results

Appendix 4: Procedure for determining EC

A calibrated conductivity probe is dipped into the sample. The probe measures electric current flowing through the water due to dissolved ions. The meter converts the current to a specific conductivity unit (uS/cm). The probe is calibrated for accurate readings using solutions with known conductivity values before taking measurements.The probe is rinsed with distilled water before measurement to prevent contamination and ensure accurate results.

Appendix 5: Procedure for determining Sodium (Na) and Potassium (K) using flame photometric method.

To determine sodium concentration in wastewater, flame photometry uses unique light emissions of Na and K. Diluted samples are introduced to an intense flame, causing the elements to emit specific light wavelength. The intensity of the light is then measured by a detector at the characteristic wavelength of Na and K. The concentration of these elements can then be determined by comparing the light intensity of the two to a pre-established calibration curve.

Appendix 6: FAO Irrigation water quality guidelines

470 Water Wells and Boreholes

Table A3.1 *(Continued)*

		Degree of restriction on use		
Potential irrigation problems	Units	None	Slight to moderate	Severe
Miscellaneous effects (on susceptible crops)				
Nitrate ($NO_3 - N$)[d]	$mg\,l^{-1}$	<5	5–30	>30
Bicarbonate (HCO_3^-) (overhead sprinkling only)	$meq\,l^{-1}$	<1.5	1.5–8.5	>8.5
pH		Normal range 6.5–8.4		

Adapted from Ayers and Westcot (1985). Reproduced by permission of the Food and Agriculture Organization of the United Nations.
[a]EC_w, electrical conductivity of water, recorded at 25° C; TDS, total dissolved solids content.
[b]SAR, sodium adsorption ratio (see Chapter 2, Section 2.7.4).
[c]See Ayers and Wescot (1985) for further information on sodium and chloride tolerances of sensitive crops, and also for information concerning trace elements other than boron.
[d]Ammonia and organic nitrogen should be included when wastewater is used for irrigation.

470 Water Wells and Boreholes

Table A3.1 *(Continued)*

		Degree of restriction on use		
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