STUDY ON CARBON CREDITING MODEL FOR SCHOOLS AND ITS POTENTIAL SOCIAL IMPACT: INNOVATIVE MODEL TO FINANCE SCHOOLS SAFE DRINKING WATER SUPPLY

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ABSTRACT

This study investigated the dual benefits of water purification systems in schools: reducing carbon emissions through the use of UV water purification systems and improving health and educational outcomes via increased access to safe drinking water. Employing a rigorous methodology that integrates carbon credit frameworks and social impact analysis, the research is framed within the context of Sustainable Development Goals (SDGs). The carbon credit methodology, grounded in the Gold Standard and Verified Carbon Standard (VCS), quantified emissions avoided by transitioning from boiling water with biomass to UV water purification. Longitudinal data, collected via randomized controlled trials (RCTs), evaluated the intervention's impact on water consumption, health outcomes, absenteeism rates, and academic performance across 60 schools divided into treatment and control groups.

Key findings demonstrate significant reductions in carbon emissions, with treatment schools purifying 1,033 litres of water daily, generating annual carbon credits equivalent to 56.84 tCO_2e and revenues of $852.66 per school annually. Despite increased water availability, daily consumption in treatment schools remained low at 1.01 litres per student, indicating the need for strategies like classroom-level water access through innovations such as water backpacks. Health outcomes improved markedly, with waterborne illnesses reduced to an average of 1.5 cases in treatment schools compared to 8.9 in control schools ($p = .011$). Similarly, absenteeism decreased from 53.37 to 30 cases ($p < .001$), highlighting the intervention's positive impact on student attendance. The findings highlight the necessity of robust monitoring systems for waterborne illnesses and longitudinal studies to capture the long-term effects of safe drinking water access on student performance. This research provides a scalable model for leveraging carbon credit financing to address water, health, and education challenges in underserved regions.

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ACRONYMS AND ABBREVIATIONS

ACR	American Carbon Registry
GHG	Greenhouse Gases
GPS	Global Positioning System
GS	Gold Standard
IPCC	Intergovernmental Panel on Climate Change
KWh	Kilowatt hours
L	Litres
MEMD	Ministry of Energy and Mineral Development
MoES	Ministry of Education and Sports
MRV	Monitoring, Reporting and Verification
MWE	Ministry of Water and Environment
NDC	Nationally Determined Contribution
RCTs	Randomized Control Trials
SDG	Sustainable Development Goals
tCO2e	Tonnes of carbon dioxide equivalent
UGX	Ugandan Shilling
UN	United Nations
WHO	World Health Organization

1.1 Introduction

The study set out to investigate the contribution of water purification systems in saving carbon emissions and the intersection between access to safe drinking water, health outcomes, and educational performance, particularly in low-resource settings like Uganda. With inadequate access to safe drinking water linked to health issues and increased school absenteeism, this research aimed to understand the potential impact of a water quality intervention on schools and students. By employing a randomized controlled trial (RCT) and longitudinal design, the study sought to evaluate the contribution of water purification systems on saving carbon emissions and the causal relationship between the water intervention and various outcomes, including health, absenteeism rates, and academic performance. The study is framed within the broader context of Sustainable Development Goals (SDGs), the research aims to inform evidence-based policies and interventions to address water-related challenges in schools, contributing to global efforts to advance health and education for vulnerable populations. The baseline findings, drawn from a diverse sample of 30 schools across rural and urban areas, provides essential insights into key indicators such as access to clean water, prevalence of waterborne diseases, and school profiles, laying the groundwork for further investigation into the multifaceted impacts of the water quality intervention.

1.2 Study Background

Access to safe water is a fundamental requirement for health and well-being, and it plays a crucial role in educational outcomes, particularly in developing regions. Despite progress in global water accessibility, many schools, especially in low-resource settings, face water quality and availability challenges. The intersection of water, health, and education creates a compelling context for investigating the potential impact of a water intervention on both the physical well-being of school children and their academic performance.

According to UNICEF[1], thousands of children face health risks due to poor sanitation, hygiene, and unequal access to safe drinking water in schools. Diarrhoea alone, one of three major childhood killers in Uganda, kills 33 children every day. In most cases, children get the disease by drinking unsafe water or coming into contact with contaminated hands, theirs or parents or caregivers that have not been washed with soap.

This research was thus framed within the broader context of achieving Sustainable Development Goals (SDGs), specifically SDG 3 (Good Health and Well-Being) and SDG 4 (Quality Education). The outcomes of this study have the potential to inform evidence-based policies and interventions aimed at addressing water-related challenges in schools, contributing to the global effort to advance health and education for vulnerable populations.

The study addresses a critical gap in the existing literature by systematically examining the carbon emission and impact of a water quality intervention on the health and education of school children. Through a combination of randomized controlled trials and longitudinal observations, the research aims to provide insights that can guide future initiatives and interventions in the pursuit of sustainable improvements in health and education outcomes.

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[1] *UNICEF Water, sanitation and hygiene (WASH) Increasing access to safe drinking water, improved sanitation and hygiene practices.* https://www.unicef.org/uganda/what-we-do/wash

In Uganda, 83% of the population, equivalent to 38 million people, lack access to a reliable and safely managed source of water, and 7 million, or 17% do not have access to improved sanitation solutions. This situation leads to long journeys for water collection, especially in rural areas where residents spend more than 30 minutes on average to fetch water, detracting time from education and income generating activities. Educational institutions, schools in particular, are no exception and they face the same challenges. A staggering 90% of the protected underground water sources in Kampala are contaminated, mainly due to poor sanitation (Ministry of Water and Environment, 2022)

The Ugandan population faces significant challenges in accessing clean and safe water, compounded by inadequate sanitation infrastructure. Despite two decades of economic growth, rapid urbanization and population growth, have overstressed the existing water and sanitation services. Urban poverty compounds the issue, with some families spending up to 22% of their income to access water. The lack of clean water and proper sanitation facilities in schools is particularly concerning, as it not only affects the health of the children but also their attendance and performance. This situation is a barrier to national growth and development, representing a critical challenge that requires immediate and concerted action.

Waterborne diseases are a significant concern in Ugandan schools, posing health risks to students. The prevalence of such diseases is linked to contaminated water and poor sanitation practices. Reports indicate a connection between waterborne illnesses like cholera, diarrhea, dysentery, and hepatitis A, emphasizing the need for access to safe drinking water and proper hygiene measures in schools[2]. A study by Sente et al. (2023) highlights water-related diseases in remote villages of greater Bushenyi districts in Uganda, emphasizing the broader impact of unsafe water on public health. Additionally, waterborne parasites, including free-living amoeba, helminths, Cryptosporidium, and Giardia, have been identified in water sources in Uganda, further highlighting the need for vigilance and preventive measures[3]. Efforts to enhance access to safe drinking water can significantly improve students' health outcomes, reducing the incidence of waterborne diseases in Ugandan schools.

According to the United Nations 2020 Voluntary National Review, Uganda has a minor increase in the proportion of urban population using an upgraded drinking water source from 71% in 2016 to 79% in 2019, while in rural areas this grew from 65% to 69% over the same period. The same report also claimed that the proportion of communities with a safe water supply increased from 64% in 2017 to 66% in 2019.

Uganda requires substantial financing to implement its climate action plan, estimated at a total cost of US $28.1 billion by 2030. This includes supporting climate-smart agriculture, clean energy, and climate resilient infrastructure. The country is exploring various green financing mechanisms, which can potentially include leveraging carbon credit markets to direct private financing towards climate action projects, including water-related interventions (Norton Rose Fulbright, 2023).

Looking at a successful model in Northern Kenya, the DRIP FUNDI initiative demonstrates how sustainable funding through carbon credits can be achieved. Partnerships between organizations like the Millennium Water Alliance, Virridy, and the University of Colorado Boulder, funded primarily by USAID’s Bureau for Humanitarian Assistance, have shown that carbon credit financing can ensure long-

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[2] *Global Giving (2020) Curbing the Prevalence of Waterborne Diseases-6/20*

[3] *Sente, C., Onyuth, H., Tamale, A., Mali, B., Namara, B. G., Mugoya, J. G., & Omara, A. R. (2023). Waterborne parasites in Uganda: A survey in Queen Elizabeth Protected Area. Public Health Challenges, 2(4), e142. https://doi.org/10.1002/puh2.142*

term maintenance and improved water access for large populations. This model involves generating financing through the sale of carbon credits, and such a system could potentially be adapted for Uganda's context to support UV water purification systems. (mwater.org, Pioneering sustainable water solutions with carbon credits in drought stricken Northern Kenya).

Innovative and collaborative financing models are crucial for Africa to finance climate resilience projects, as highlighted during a roundtable at the 55th Conference of African Ministers of Finance, Planning and Economic Development. Investing in nature-based carbon credits is seen as a potential revenue for generating substantial funds, which can be channelled towards water sector improvements, among other climate action initiatives (UNECA, 2023) In summary, while there are challenges in financing UV water purification systems in Uganda, carbon crediting offers a promising avenue to attract the necessary investments. By taking clues from successful models like the one in Northern Kenya, Uganda could develop frameworks to generate and sell carbon credits, thus securing sustainable financing for its water purification initiatives.

1.2.1 Research Objectives

i. To establish the contribution of UV Water Purification Systems in Saving Carbon Emissions.
ii. To find out the contribution of Water quality intervention in improving health, reducing school absenteeism, as well as enhancing school performance.

1.2.2 Research Questions

I. To what extent could a carbon credit finance model achieve reduced carbon emissions, reasonable impact on climate mitigation, steady service provision and financial sustainability?
II. What is the contribution of safe drinking water to improving health, reducing school absenteeism, as well as enhancing school performance?

2.0 Methodology

2.1 Carbon Credit Methodologies for quantifying emission reduction

The Gold Standard (GS) for the Global Goals and the Verified Carbon Standard (VCS) have developed methodologies that quantify the avoided emissions from low greenhouse gas emissions. These standards and methodologies provide detailed calculations for emission reductions in different projects, including from water purification projects. These methodologies accounted for the baseline scenario often boiling water using firewood or kerosene and the project scenario where schools use energy efficient UV water purification systems. Conducting a baseline study is essential for measuring the impact of carbon-funded water projects, both in real time and in simulations. This data provides a point of comparison for post-intervention evaluations, helping to quantify the benefits of a carbon credit project.

The baseline emission calculation formula is adapted from the Gold Standard methodology for safe water supply Version 1.0. The baseline emission factor is calculated as follows;

$EF_b = SE_{w,b,y} * \sum(x_f * (EF_{b},f,\mathrm{CO_2} * f_{NRB,f,y} + EF_{b,f,non\mathrm{CO2}}))\, f \div 10^9$ Equation 1

Where:

EF_b = Emission factor for the use of fuel to obtain safe water in the baseline (tCO_2e/L)
$SE_{w,,}$ = Specific energy required to boil water (kJ/L), to be calculated as per the paragraph below
x_f = Proportion of fuel f used in the baseline (fraction determined based on an energy basis)
$EF_{b,,2}$ = CO_2 emission factor from use of fuel f (tCO_2/TJ)

$EF_{b,,2}$ = Non-CO$_2$ emission factor arising from use of fuel f, when the baseline fuel f is biomass or charcoal (tCO$_2$e/TJ). This parameter is omitted when f is a fossil fuel.

$f_{NRB,,}$ = Fractional non-renewability status of woody biomass fuel during year y (fraction). For biomass, it is the fraction of woody biomass that can be established as non-renewable. This parameter is omitted when f is a fossil fuel.

f = Index for baseline fuel types

The specific energy required to boil water using the baseline technology ($SE_{w,,}$) is determined as follows, by calculating the energy input required to obtain 1 L of boiling water, including boiling and vaporization losses[4], taking into account default or measured stove efficiency.

$SE_{w,,} = 360.83/\eta wb$ Equation 2

Where:

360.83 = Default amount of energy required to obtain 1 L of water after 5 minutes of boiling from first principles approach kJ/l

ηwb = Efficiency of the stoves for baseline water boiling (%). Weighted average of baseline stove types.

The baseline emissions shall be calculated as follows:

$BEy = EFb \times (1 - Cb - Xcleanboil,) \times Qy \times Mq,$ Equation 3

Where:

BEy = Baseline emissions from the use of fuel to obtain safe water in the baseline (tCO2e)

Cb = Proportion of project end-users who in the baseline were already using a safe water supply that did not require boiling (%)

$Xcleanboil,$ = Proportion of project end-users that boil safe water in the project year y (%)

Qy = Quantity of safe drinking water provided by the project in year y (L)

$Mq,$ = Modifier for the water quality in year y

In the case of HWT and IWT, the quantity of safe drinking water provided by the project Qy is determined as follows:

$Q_y = \sum N_{p,} \times U_{p,} \times QPW_{hh,,} \times DP_{p,y,p}$ Equation 4

Where:

$N_{p,}$ = Number of premises type p with at least one project technology in year y

$U_{p,}$ = Usage rate of the project technology by premises type p during year y (%)

$QPW_{hh,,}$ = Volume of drinking water per premises p per day in year y (L)

$DP_{p,}$ = Days the project technology is present for end-users in the premises p in year y

The volume of drinking water per premises per day is determined by considering whether the capacity of the project device is sufficient to provide at least the default amount of drinking water, as follows:

$QPW_{hh,,} = \min ((q_i \times t_{p,y} \times DN_{p,y}), (QPW_p \times HN_{p,y}))$ Equation 5

Where:

q_i = Capacity of the HWT or IWT individual project technology (L/h)

$t_{p,}$ = Usage time of the project technology by premises type p in year y (h/day)

$DN_{p,}$ = Average number of individual project technologies in each project premises type p in year y

$HN_{p,}$ = Number of individuals per premises type p (e.g. household, school) in year y

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[4] *The previous version of TPDDTEC Annex 3 assumed that purifying water by boiling would require boiling water for 10 minutes. This assumption is revised to 5 minutes, following WHO technical information that less than 5 minutes of boiling is sufficient for inactivation of enteric bacteria (Technical Brief WHO/FWC/WSH/15.02, 2015).*

$QPWp$ = Volume of drinking water per person per day for premises type p (L). Apply the default value or monitored value through water consumption field tests in the project scenario, capped at 5.5 L per person per day.

The study's second objective employed a longitudinal design, specifically using Randomized Controlled Trials (RCTs) to collect baseline data prior to the intervention and evaluation data afterward. The research focused on academic and health outcomes in 60 schools, equally divided into a control group of 30 schools and a treatment group of 30 schools, located in both rural and urban areas of Uganda. The study investigated the causal relationship between water quality and various health and educational parameters, including water consumption, health statistics, absenteeism rates, and academic performance.

3.0 STUDY FINDINGS

The findings of this study were based on data collected during two separate periods. Baseline data was collected in February 2024, at the beginning of the first school term, from 60 schools. During the second term, 30 schools were placed in the treatment group, which involved the installation of UV water purification systems with smart metering to monitor water consumption. The second phase of data collection occurred in October 2024, during the third term, to evaluate the changes brought about by the intervention. To minimize data bias, Semi-structured questionnaires were administered to school administrators and in some instances the class teachers were called to assist with classroom data such as absenteeism and academic performance of students with cross-reference to available records. It should be noted that in most schools, clear record of waterborne illnesses was missing, and we relied on scanty records such as student pass-out records. While the researcher endeavored to monitor these cases in the second term consequently, the results compare baseline and evaluation findings across both treatment and control schools, providing insights into the impact of the intervention.

3.1 School Demographic profile

The study schools were chosen from both rural and urban settings, encompassing primary and secondary schools, including both day and boarding sections. This diverse selection enabled comparisons across various social and health indicators, such as academic performance, absenteeism rates, prevalence of waterborne diseases, access to clean and safe drinking water, and levels of consumption.

Table 1: Showing Student Population

Student Population

Groups	N	Mean	Mean at Baseline
Control	30	539.40	518
Treatment	30	850.57	

Source: Primary data (2024)

The study, comprised of 60 schools evenly split between rural and urban settings, with 30 schools assigned UV water purifiers as the treatment group and 30 schools remaining in the control group. The

careful selection process ensured that schools in both groups shared similar baseline characteristics, strengthening the validity of comparisons across key health, environmental, and academic metrics.
At the evaluation phase, the average student population in the control group was 539, while treatment schools had a significantly higher average of 851 students. These figures show a marked shift from the baseline average of 518 students per school.

3.2 BASELINE CARBON FOOTPRINT ASSESSMENT

3.2.1 Calculation of stove efficiency

As per the methodology, traditional cookstoves have a default thermal efficiency of 10%, other convention stoves 20% and improved cookstoves 30%. The weighted average of these types of cookstoves is 40% and is within the limitation of the methodology and is presented in the table below.

Table 2: Showing calculation of stove efficiency

Stove type	Fuel Type	Schools		Default efficiency used
		Number	%	
Traditional stoves	Firewood	4	13.3	10%
Other convention stoves	Firewood	7	23,3%	20%
Improved stoves	Firewood	14	46.7	30%
Other convention stoves	Charcoal	3	10	20%
Improved stoves	Charcoal	2	6.7	30%
Weighted Average		30	100%	12

Source: Primary data (2024)

3.2.2 Baseline Emission Reduction

The baseline emission factors were calculated as

$$EF_b = SE_{w,b,y} * \left(\sum x_f * \left(EF_{b,f,CO2} * f_{NRB,f,y} + EF_{b,f,nonCO2}\right)\right) \div 10^9$$

$$SE_{w,b,y} = 360.83/\eta_{wb}$$

Table 3: Showing stove type

Stove type	**$SE_{w,b,y}$**
Traditional stove, firewood	3,608.30
Other convention stove, firewood	1804.15
Improved stove, firewood	1,202.77
Traditional stove, charcoal	3,608.30
Other convention stove, charcoal	1804.15
Improved stove, charcoal	1,202.77

Source: Primary data (2024)

$$EF_b = \{3608.30 * [13\% (112*87\%+9.46)\} + \{1804.15* [23\%*(112*87\%+9.46)\} + \{1202.77 * [47\%*(112*87\%+9.46)\} + \{1804.15 * [10\% (165.2*87\%+44.83)\} + \{1202.77* [7\%*(165.2*87\%+44.83)\} \div 10^9$$

$$= 0.000206$$

3.2.3 Quantity of drinking water purified by schools using traditional methods

The quantity of safe drinking water is determined as follows:

$$QPW_{ss,p,y} = \min((q_i \times t_{p,y} \times DN_{p,y}), (QPW_p \times HN_{p,y}))$$

$$= \min((60*2*1), (344*1))$$

$$= 120$$

$$Q_y = \sum_p N_{p,y} \times U_{p,y} \times QPW_{ss,p,y} \times DP_{p,y}$$

$$= 1*100\%*120*200$$

$$= 24{,}000 \text{ litres}$$

The baseline emission shall be calculated as

$$BE_y = EF_b * (1 - C_b - X_{cleanboil,y}) \times Q_y \times M_{q,y}$$

$$= 0.000206 * (1-0-0) * 24{,}000*1$$

$$= 4.944 \text{ tCO}_2\text{e/y/school}$$

The above results arise from the assumption that if a school boils 120 litres of water daily for 200 school days in a year totaling to 24,000 litres of drinking water, the average baseline emission is 4.944 tCO_2e/y. This means that for the 30 schools considered in the baseline, the total carbon emissions are 148.32 tCO_2e or 148,320 tCO_2e.

3.2.4 Assessment of CO2 savings when schools are equipped with ultraviolet-based water purification systems

Daily emission in schools that had UV water purification systems

Table 4: Showing Daily emissions in school that had UV water purification systems

	N	Mean	SD	p	t
Purification using previous method	30	0.001854	0.0049	0.942	-0.073
Purification using UV	30	0	0		

Source: Primary data (2024)

By purifying water using the previous method of purification, the mean carbon emissions of these schools are 0.00185tCO2e and the standard deviation is 0.049. Schools that purify all their water using UV water purification systems have zero carbon emissions, so the mean and standard deviation is zero. The p-value of 0.942 and the t-test value of -0.073 signifies that carbon emissions arising from UV water purification though negligible is a reason for concern. This means that these schools are still emitting carbon emissions during the UV water purification process, though they have UV water purifiers which should make their emissions from UV water purification zero.

3.2.5 Preliminary extent to which carbon credit financing can facilitate the installation of more water purification systems in schools.

Table 5: Reduction in carbon emissions in schools

Category	N	Average quantity of water purified daily	Daily emissions per litre (tCO_2e)	Total emissions (tCO_2e)	Price per carbon credit	Daily Carbon credits
Control schools	30	343.966	0.000206	0.0708	0	0
Treatment schools	30	1,033.33	0.000206	0.2129	$15	3.1935

Source: Primary data (2024)

At an emission rate of 0.000206 tCO2e per litre of water purified, control schools emitted 0.0708tCO2e daily, while treatment schools emit zero emissions. This means that treatment schools; by purifying 1,033.3 litres of water daily they generated carbon credits which translate to a revenue of $47.9 daily.

3.2.6 Comparison of the annual quantity of water purified and the annual carbon credit revenue

Table 6: Showing annual quantity of water purified and annual carbon credit revenue

Description	Quantity of water purified daily (litres)	Quantity of daily emissions (tCO2e)[5]	Number of school days in a term (days)[6]	Quantity of annual emissions (tCO2e)	Price per carbon credit	Annual carbon credit revenue
Treatment schools	1,033.33	0.2129	267	56.8443	$15	$852.66

Source: Primary data (2024)

By purifying 1,033.33 litres of water daily, an average school using UV water purification system generates 56.8443 tCO2e annually, corresponding to a carbon credit revenue of $852.66. This implies that carbon financed ultraviolet (UV) water purification is sustainable.

3.3 SOCIAL AND ACADEMIC IMPACT IN SCHOOLS

3.3.1 Water Consumption Level in the School

Table 7: Showing Level of water consumption in schools

Water Consumption in School

	N	Mean	Std. Deviation	p	t	Mean/student	Baseline
Control	30	238.10 L	253.059	.001	-3.418	0.44 L	0.5 L
Treatment	30	866.73 L	975.086			1.01 L	

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[5] *The Quantity of emissions offset is equal to the number of carbon credits. The carbon emission offset per litre is 0.000206 as per the baseline study.*

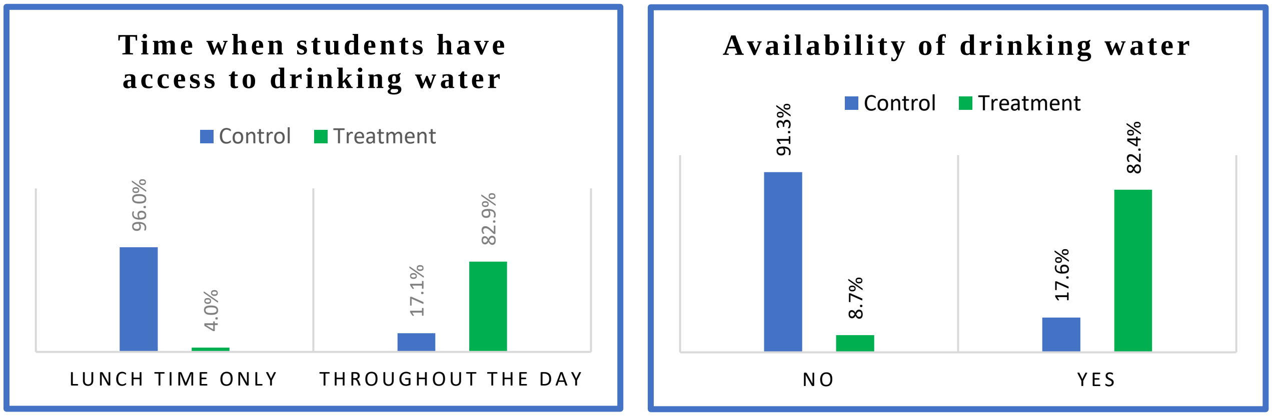
[6] *According to Uganda's Ministry of Education and Sports, an average school term has 89 days. www.education.go.ug/wp-contet/uploads/2023/11/SCHOOL-CALENDAR.pdf*

Source: Primary data (2024)

The study highlighted a significant variation in water consumption rates between control and treatment schools, with baseline data providing an important reference point. At baseline, the average water consumption rate across schools was 0.5 litres per student per day. During the evaluation phase, students in control schools consumed an average of 238.1 litres per day (0.44 litres per student), while those in treatment schools consumed 866.73 litres per day (1.01 litres per student). An independent sample test revealed a statistically significant difference in water consumption between the groups, with a p-value of .001 and a t-value of -3.418.

3.3.1.2 Availability and Access to Safe Drinking Water.

Figure 1: Showing availability and access to safe drinking water in schools



Source: Primary data (2024)

The timing of students' access to drinking water significantly differed between control and treatment schools, with important implications for water consumption. In control schools, 96% reported that students could only access drinking water at lunchtime, while only 4% of treatment schools followed this restricted schedule. Conversely, 82.9% of treatment schools reported providing students with access to drinking water throughout the day, compared to just 17.1% of control schools.

This disparity highlights a critical factor contributing to the significant difference in water consumption between the two groups. Treatment schools, equipped with UV water purification systems, could produce sufficient safe drinking water to meet students’ needs throughout the day. In contrast, control schools relied on boiling water, a process that limited their capacity to provide adequate quantities for continuous access. Therefore, the findings highlight the importance of sustainable water purification systems in enhancing drinking water accessibility, fostering better hydration, and supporting overall student well-being.

The availability of safe drinking water throughout the school term revealed a stark contrast between control and treatment schools. Among control schools, 91.3% (n=21) reported that safe drinking water was not available to students every day of the term, with only 17.6% (n=9) noting consistent availability. In contrast, 82.4% (n=28) of treatment schools reported that safe drinking water was available every day, and just 8.7% (n=2) indicated any interruptions.

In control schools, the lack of consistent access to safe drinking water was primarily attributed to financial constraints limiting the daily treatment of water. For treatment schools, the minimal cases of unavailability were due to occasional machine breakdowns of the UV water purification systems. These findings highlight the advantages of UV water purification systems in ensuring a reliable supply of safe drinking water, while also stressing the need for maintenance support to prevent disruptions.

3.4 Academic Performance

Table 8: Showing Academic performance of students

Independent sample test for academic performance

		N	Mean	Std. Dev	p	t	Cohen's d
No of students who complete final exam (UPE, UCE & UACE)	Control	30	77.17	80.55	.064	-1.911	-.493
	Treatment	30	176.43	272.84			
No of students who repeat class or dropout	Control	30	6.63	25.60	.900	-.126	-.033
	Treatment	30	7.50	27.59			

Source: Primary data (2024)

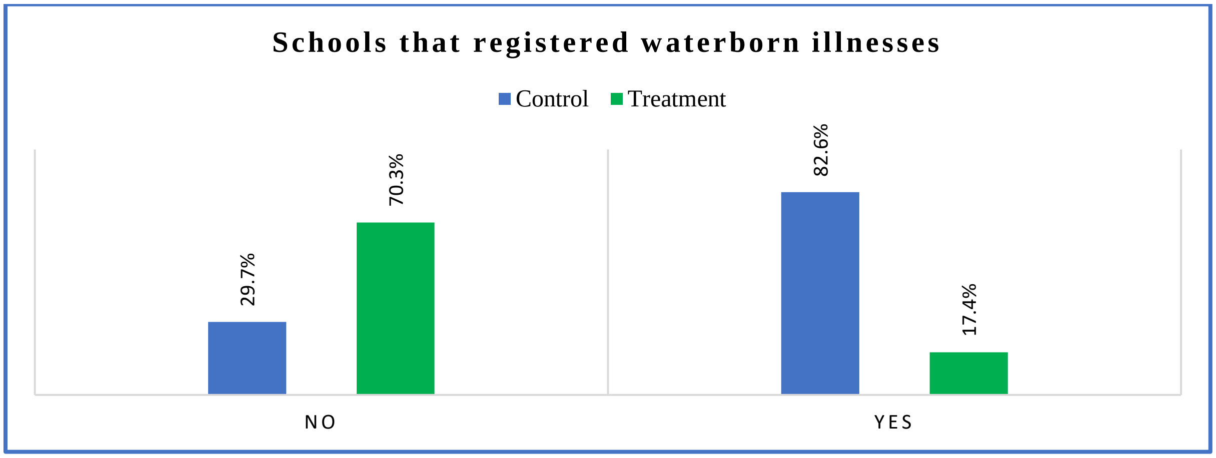
The study examined academic performance by focusing on candidate and semi-candidate classes: P.6 and P.7 at the primary level, S.3 and S.4 for ordinary level, and S.5 and S.6 for advanced level. Performance was assessed based on students meeting the pass mark criteria set by the Uganda National Examinations Board (UNEB). Additionally, the study tracked students who failed to meet the pass mark in the classes preceding the candidate level.

Findings showed that, on average, 77 students in control schools registered and completed the final national exams, compared to 176 students in treatment schools. While treatment schools demonstrated a higher number of students completing the exams, the p-value of .064 indicated that this difference was not statistically significant. The effect size, as measured by Cohen's d (-.493), suggested a small difference in academic performance, although with a slightly lower mean in control schools. Similarly, the average number of students failing to meet the pass mark or dropping out was 7 in control schools and 8 in treatment schools. This difference was also statistically insignificant, as evidenced by a p-value of .900. The Cohen's d value of -.033 further highlighted the negligible effect size.

3.5 Waterborne Diseases and levels of absenteeism

3.5.1 Schools that Registered Waterborne Illnesses

Figure 2: Showing schools that reported waterborne illnesses



Source: Primary data (2024)

The prevalence of waterborne illnesses differed significantly between control and treatment schools, emphasizing the impact of the intervention. Among schools reporting cases of waterborne illnesses, 82.6% (n=19) were control schools, while only 17.4% (n=4) were treatment schools. Conversely, of the schools that did not report any waterborne illnesses during the evaluation period, 70.3% (n=26) were treatment schools, compared to just 29.7% (n=11) of control schools.

These findings emphasize the critical role played by UV water purification systems in reducing the incidence of waterborne diseases in treatment schools. By providing students with consistent access to safe drinking water, these systems effectively mitigated health risks associated with contaminated water. In contrast, the high prevalence of illnesses in control schools highlights the continued challenges of relying on less efficient water treatment methods, such as boiling, which are often constrained by financial and operational limitations.

3.5.2 Relationship between waterborne illness and student absenteeism

Table 9: Showing Comparison between waterborne diseases and student absenteeism

Independent sample test for association between Waterborne diseases and student absenteeism

		N	Mean	Baseline	p	t	Cohen's d
Cases of Waterborne diseases	Control	19	8.95	12.6	.011	2.77	1.52
	Treatment	4	1.50				
Student Absenteeism	Control	30	75.60	53.37	<.001	3.70	.956
	Treatment	30	30.13				

Source: Primary data (2024)

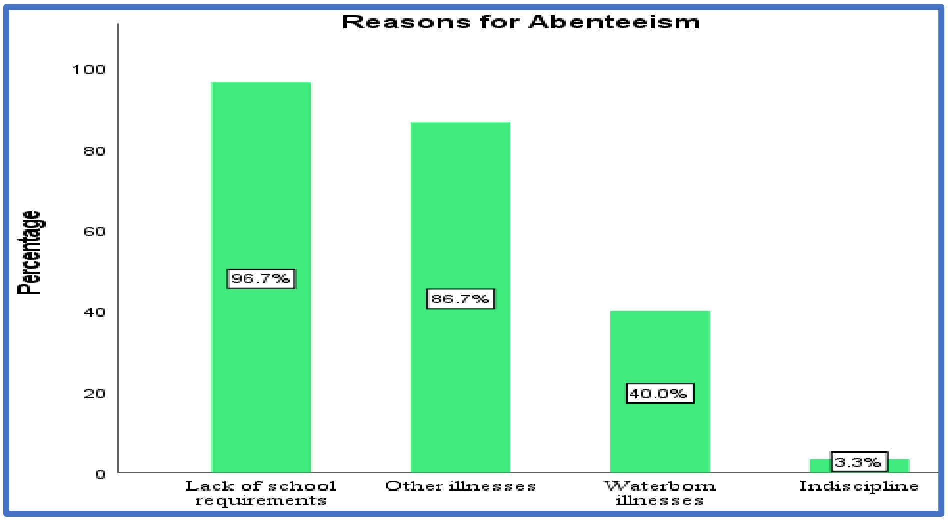
The study findings highlighted significant differences in the prevalence of waterborne diseases and student absenteeism between control and treatment schools during the evaluation phase, with notable improvements in treatment schools compared to baseline data.

On average, control schools reported 8.9 cases of waterborne diseases, compared to just 1.5 cases in treatment schools, marking a substantial decline from the baseline average of 12.6 cases across all schools. An independent sample test revealed a statistically significant difference between the two groups, with a p-value of .011. The effect size, measured by Cohen's d (1.52), indicated a large and meaningful impact of the intervention on reducing waterborne diseases.

Absenteeism rates, however, revealed a different trend. In control schools, the rate of absenteeism increased from a baseline mean of 53.37 cases to 75.6 cases during the evaluation time. In contrast, treatment schools experienced a decline to 30 cases of absenteeism during the same period. This difference was statistically significant, with a p-value of <.001, and Cohen's d value of .956 confirmed a large effect size, further emphasizing the positive impact of the intervention in reducing absenteeism.

3.5.3 Reason for Absenteeism

Figure 3: Showing reasons advanced for student absenteeism



Source: Primary data (2024)

Among schools reporting absenteeism, 96.7% (n=58) cited the lack of school requirements as the leading cause of absences, followed by 86.7% (n=52) schools attributing absenteeism to other illnesses, 40% (n=24) linked absenteeism to waterborne illnesses, and 3.3% (n=2) associating it with indiscipline cases among students.

These findings highlight the complex and intertwined factors driving absenteeism, with economic barriers, such as inadequate access to school requirements, emerging as the most significant challenge. Health-related issues, including both general and waterborne illnesses, are also major contributors, reflecting the critical need for improved health interventions in schools.

4.1 DISCUSSION OF FINDINGS

4.1.1 Carbon Emission and Carbon Credit Financing

The findings highlight the fundamental role of carbon credit financing in supporting water purification projects in schools, aligning with the global agenda to mitigate carbon emissions through sustainable interventions (Goldstein et al., 2021). By transitioning from traditional methods of water purification, such as boiling with firewood, to UV water purification systems, schools not only reduce their environmental footprint but also unlock financial benefits through carbon credits. The baseline emission assessment revealed that boiling 120 litres of water daily over 200 school days produces an average of 4.944 tCO2e annually per school. With the implementation of UV water purification systems, these emissions drop to zero, highlighting the transformative impact of this intervention.

Carbon credit methodologies, including those developed by the Gold Standard and Verified Carbon Standard (VCS), provide robust frameworks for quantifying emissions avoided through institutional water treatment projects. These methodologies emphasize establishing accurate baselines and conducting rigorous monitoring, reporting, and verification (MRV) processes to ensure the credibility of carbon savings (Diaz et al., 2022). For example, a study analyzing water purification projects across East Africa noted that schools with robust MRV systems generated 30% more carbon credits, demonstrating the critical importance of precise tracking and reporting mechanisms.

The financial viability of UV water purification systems is evident in their ability to generate carbon credits based on avoided emissions. For instance, a school purifying 1,033 litres of water daily using a UV water purification system can generate 56.84 tCO2e annually, corresponding to a revenue of $852.66 at a carbon credit price of $15. This revenue can offset operational costs, fund maintenance, and expand access to safe drinking water, making carbon credit financing a sustainable solution for schools.

The health and educational benefits of such interventions are equally compelling. The provision of safe drinking water reduces reliance on biomass combustion, which not only mitigates carbon emissions but also minimizes deforestation and air pollution, aligning with global climate goals (Hepburn et al., 2021). Additionally, the installation of UV water purification systems in schools addresses the persistent challenge of waterborne diseases, thereby reducing absenteeism and improving student well-being and academic performance (Hunter et al., 2014).

Case studies such as the LifeStraw Carbon for Water project in Kenya further validate the potential of carbon credit-funded water initiatives. By replacing biomass-based water purification methods with energy-efficient solutions, this project achieved significant carbon savings and improved community health outcomes, serving as a model for similar interventions in school settings (World Bank Group, 2023). Schools offer a unique opportunity for carbon credit projects due to their centralized infrastructure and multiplier effect, benefiting not only students but also their families and communities.

4.2 Water Consumption Level in Schools

The study results demonstrated that the introduction of UV water purifiers in treatment schools significantly improved access to safe drinking water and led to a remarkable increase in water consumption, surpassing baseline levels by over 100% (p = .001). Students in control schools consumed an average of 0.44 litres per day, compared to 1.01 litres per day in treatment schools. In contrast, control schools experienced a decline in consumption from baseline levels, likely due to ongoing challenges in water availability, as safe drinking water was not consistently available throughout the school term. These findings highlight the effectiveness of UV water purifier interventions in addressing barriers to drinking water access and improving hydration among students.

However, the observed water consumption levels in both groups fall significantly below the recommended daily intake of 5.3 litres per individual for optimal hydration in warmer climates, as suggested by Guy et al. (2020). Similarly, Franse et al. (2020) noted that while water interventions in school settings can increase water consumption among children, the effect may still be modest[7]. These gaps suggest that additional efforts are required to further enhance drinking water access and encourage adequate hydration among students[8].

Innovative strategies to address these gaps have been explored in various studies. Kirira, Oyatsi, Waudo, and Mbugua (2023) highlighted the use of water backpacks as a promising intervention to increase access to safe drinking water in schools. The backpacks reduced congestion around safe drinking water points by providing more decentralized access, facilitating transport, storage, and dispensing of water within the school environment[9]. Another study by Kenney et al. (2015) suggested that providing simple and inexpensive interventions, such as cups or bottles, to improve the convenience of drinking water can significantly enhance student water consumption[10].

Therefore, while interventions like UV water purifiers are instrumental in improving access to safe drinking water, additional measures to decentralize water access at the classroom level can amplify their impact. Combining infrastructure improvements with educational initiatives to promote optimal water intake among students is essential for achieving sustainable and meaningful outcomes in hydration and health.

4.3 Academic Performance and Water Intervention in Schools

The study results indicated that while the water intervention positively influenced several outcomes, its direct impact on academic performance metrics such as exam completion and failure rates was minimal, with p-values of .064 and .900, respectively. This suggests that factors beyond drinking water access significantly influence academic outcomes, including instructional quality, socioeconomic status, and broader school environment conditions. Similarly, a study by Ahiatrogah (2020) found that only 28% of students reported improved end-of-term exam performance following a water intervention, highlighting the limited direct effect of water access on academic achievement[11].

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[7] *Guy Howard, Jamie Bartram, Ashley Williams, Alycia Overbo, David Fuente, Jo-Anne Geere, (2020) Domestic water quantity, service level and health, second edition. World Health Organization.*

[8] *Franse, C. B., Boelens, M., Fries, L. R., Constant, F., van Grieken, A., & Raat, H. (2020). Interventions to increase the consumption of water among children: A systematic review and meta-analysis. Obesity Reviews, 21(7), e13015.*

[9] *Kirira, P., Oyatsi, F., Waudo, A., & Mbugua, S. (2023). Improving Access to Safe Water in Rural Schools of Kenya: Qualitative Multisectoral Insights. Cureus, 15(11), e49174. https://doi.org/10.7759/cureus.49174*

[10] *Kenney, E. L., Gortmaker, S. L., Carter, J. E., Howe, M. C. W., Reiner, J. F., & Cradock, A. L. (2015). Grab a cup, fill it up! An intervention to promote the convenience of drinking water and increase student water consumption during school lunch. American journal of public health, 105(9), 1777-1783.*

[11] *Ahiatrogah, M. D. (2020). Effects of water, sanitation and hygiene facilities on academic performance of basic school pupils in the Ketu North Municipality (Doctoral dissertation, University of Cape Coast).*

A pilot study in rural Mali explored the impact of supplementary drinking water on hydration and cognitive performance in water-scarce schools. Although there was a trend of improved cognitive test performance under the water intervention, the results were not statistically significant.[12]. The study by Almalki (2022) suggested that encouraging children to consume approximately 250 ml of water 20–60 minutes before engaging in challenging academic tasks may enhance performance[13].

Conversely, a study conducted in Ghana, Sierra Leone, and South Africa demonstrated a significant positive correlation between access to safe drinking water and academic achievements. Students with consistent access to safe drinking water outperformed their peers, emphasizing the critical role of hydration in improving educational outcomes[14]. SANG (2023) also observed that access to safe drinking water, sanitation facilities alongside hygiene education were all positively associated with improved academic outcomes[15].

Therefore, consistency in drinking water consumption is essential to realize the full benefits of hydration on academic outcomes. Regular access to safe drinking water ensures that students remain adequately hydrated throughout the school day, which can positively impact cognitive functions such as memory, attention, and concentration. Intermittent or insufficient access to safe drinking water may limit these potential benefits, highlighting the importance of sustained interventions that prioritize both access and consistent consumption habits among students.

4.4 Waterborne Diseases and level of absenteeism

The study findings highlighted the significant impact of safe drinking water on reducing waterborne illnesses and absenteeism among students, emphasizing the effectiveness of the intervention in treatment schools. Among schools reporting cases of waterborne illnesses, 82.6% (n=19) were control schools, compared to just 17.4% (n=4) in treatment schools. On average, control schools reported 8.9 cases of waterborne diseases, whereas treatment schools reported only 1.5 cases, marking a significant decline from the baseline average of 12.6 cases across all schools. An independent sample test confirmed this difference as statistically significant ($p = .011$). Globally, unsafe water is a leading cause of mortality, claiming 1.2 million lives annually, with children being the most vulnerable[16]. These findings underscore the critical role of safe drinking water in reducing waterborne illnesses, which can lead to missed learning opportunities and, in severe cases, death.

Absenteeism rates followed a similar trend, with control schools experiencing an increase from a baseline mean of 53.37 cases to 75.6 cases during the evaluation period. In contrast, treatment schools saw a significant decline to 30 cases over the same period, a difference that was statistically significant ($p < .001$). Previous research supports these findings, with Ochien'g (2013) reporting that treating

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[12] *Chard, A. N., Trinies, V., Edmonds, C. J., Sogore, A., & Freeman, M. C. (2019). The impact of water consumption on hydration and cognition among schoolchildren: Methods and results from a crossover trial in rural Mali. PLOS ONE, 14(1), e0210568. https://doi.org/10.1371/journal.pone.0210568*

[13] *Almalki, J. A., Knight, S. N., Poulos, S. P., Stanfield, D. L., Killen, L. G., Waldman, H. S., & O'Neal, E. K. (2022). Hydration and Cognitive Task Performance in Children: A Systematic Review. Journal of Cognitive Enhancement, 6(4), 519-530.*

[14] *Wadan, C. M. (2012). What knowledge exists about drinking water and academic achievements in schools in Ghana, Sierra Leone and South Africa? International Journal of Social Science and Humanity.*

[15] *SANG, E. J. (2023). EFFECT OF SANITATION AND HYGIENE PRACTICES ON STUDENTS'ACADEMIC PERFORMANCE IN PUBLIC SECONDARY SCHOOLS IN MUHORONI SUB-COUNTY, KENYA (Doctoral dissertation, University of Eldoret).*

[16] *Berggreen, S., & Mattisson, L. (2023). Waterborne diseases and children's learning.*

drinking water at school can reduce absenteeism by 30%, using clean latrines by 42%, and practicing handwashing by 41%. These hygiene interventions also have a strong positive relationship with academic performance, further emphasizing their importance[17].

Among schools reporting absenteeism, 96.7% (n=58) attributed it to the lack of school requirements, 86.7% (n=52) to other illnesses, and 40% (n=24) specifically to waterborne illnesses. This highlights the contribution of waterborne diseases to absenteeism, aligning with Dube and January's (2012) observation that pupils in developing countries often miss school or experience ineffective learning due to diseases linked to unsafe drinking water and inadequate sanitation[18].

Hunter, Risebro, Yen, and Lefebvre (2014) also found that providing safe drinking water significantly reduces absenteeism, as evidenced by their study in Cambodia, where schools with access to safe drinking water reported lower absenteeism rates than those without. This study reinforces the conclusion that the provision of safe drinking water not only decreases cases of waterborne diseases but also enhances school attendance, contributing to improved educational outcomes[19]. These findings stress the necessity of sustained investments in water, sanitation, and hygiene (WASH) initiatives to foster healthier, more conducive learning environments in schools.

5.1 CONCLUSION

In conclusion, the integration of carbon credit financing into UV water purification projects for schools presents a dual benefit: environmental sustainability and enhanced access to safe drinking water. By leveraging established carbon credit standards and methodologies, schools can effectively reduce their carbon footprint, generate financial resources, and contribute to broader health and educational outcomes. This approach provides a scalable and replicable model for addressing the intertwined challenges of climate change and access to clean water in underserved regions.

The study highlights the effectiveness of UV water purification systems in providing an adequate supply of safe drinking water in treatment schools but highlights the low water consumption levels among students as a pressing concern. Despite sufficient availability, daily water intake falls below recommended levels for optimal hydration, necessitating targeted efforts to encourage consumption. Decentralizing water access to the classroom level through innovations such as water backpacks as well as provision of cups or bottles could address this issue by improving convenience and promoting regular hydration. Such measures would maximize the health and cognitive benefits of safe drinking water, enhancing student well-being and academic performance.

Additionally, the study emphasizes the need for robust monitoring mechanisms and capacity-building in schools to accurately report waterborne illnesses. Reliable data is essential for understanding their linkage to absenteeism and for designing effective interventions. Furthermore, longitudinal studies are needed to observe the sustained impact of safe drinking water on student performance over time. These

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[17] *OCHIEN'G, W. D. (2013). INFLUENCE OF SCHOOL WATER, SANITATION & HYGIENE PROGRAMS ON PUPILS'PERFORMANCE AMONG RURAL PUBLIC PRIMARY SCHOOLS IN MASENO DIVISION, KISUMU COUNTY, KENYA (Doctoral dissertation, Msc. Dissertation, University of Nairobi).*

[18] *Dube, B., & January, J. (2012). Factors leading to poor water sanitation hygiene among primary school going children in Chitungwiza. Journal of public health in Africa, 3(1).*

[19] *Hunter PR, Risebro H, Yen M, Lefebvre H, Lo C, et al. (2014) Impact of the Provision of Safe Drinking Water on School Absence Rates in Cambodia: A Quasi-Experimental Study. PLoS ONE 9(3): e91847. doi: 10.1371/journal.pone.0091847*

initiatives would provide deeper insights into how clean water access shapes health and academic outcomes, ensuring evidence-based strategies for scaling up water interventions in schools.

6.1 NEXT STEPS

Carbon Credit Feasibility Study: Undertaking a comprehensive carbon credit feasibility study shall strategically position WaterQuip to explore the development of a carbon credit project. This initiative would evaluate the potential for monetizing the environmental benefits derived from improved water access and usage, specifically through the reduction of emissions. Such a study would identify actionable pathways to integrate water-focused interventions into carbon credit frameworks, unlocking new revenue streams and reinforcing the environmental sustainability of WaterQuip's operations.

Hydration Awareness and Intervention Project: A targeted project addressing the importance of hydration in schools is crucial for fostering a culture of consistent water intake. This initiative could combine educational campaigns with practical interventions such as decentralized water access points, reusable cups, or innovative storage solutions like classroom water packs. By improving access and awareness, the intervention could aim to ensure students consume adequate water, enhancing their health, cognitive function, and academic performance. The project design could involve 60 schools, with 30 in a control group and 30 in an intervention group, all equipped with UV water purification systems. The intervention/treatment group would additionally receive educational and infrastructure enhancements, and its impact on hydration, health, and potential carbon credit generation would be assessed at the project's conclusion.

Expanding UV Purification System Installations: Given the proven effectiveness of UV water purification systems in reducing waterborne illnesses, improving attendance, and moderately enhancing academic performance, expanding their installation is imperative. However, the high costs of installation and maintenance remain a major barrier, especially for rural schools with limited budgets. To address this challenge, we are focusing on our subscription model, which enables schools to access safe drinking water through affordable monthly payments instead of a large upfront investment. The subscription covers installation, regular maintenance, and prompt repairs, ensuring uninterrupted service. By shifting from ownership to a service-based model, schools can provide safe drinking water sustainably while focusing their resources on education.