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Determinants and Evaluation of Onsite Water Loss Due to Leakages in a Selected Institution in South Africa

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Abstract: Water loss due to onsite leakage is a problem in the effective management of potable water mostly in semi-arid and arid countries of the world whose quantity of freshwater is depleted, and recharge is highly variable. This study assessed the quality and quantity of water loss in an academic institution due to onsite leakage resulting from various drivers such as leaks, corrosion, pressure, ageing infrastructure, and student attitude. An observational approach was used for water loss analysis. Samples were collected from each point from which water is lost and analyzed for physicochemical parameters, indicator microbes, and trace metals using standard procedures. It was observed that a high amount of water is lost in the study area which was partly influenced by high water pressure, the corrosion of taps and faucets, tap faults, and leaks. A total water loss of 9013.56 L/day in three selected residences of the institution was recorded. The wasted water was found to be of good quality with no harmful contamination. The Metal Pollution Index (MPI) showed that the water poses no threat from trace metals with a maximum MPI value of 7.76. The sampled water quality complied to the South African National Standard and World Health Organization standards for drinking water. The hazard quotient and hazard index both showed a level less than one, implying no possible non-carcinogenic risk associated with the consumption of the water. The wasted water from the institution's residences is therefore of a very high quality and needs to be conserved for better usage.

Keywords: economic valuation; pollution index; health risk; water quality; water loss; water tariffs

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1. Introduction

South Africa is a semi-arid country which is water scarce and receives unpredictable precipitation which is not sufficient and often unreliable. The annual rainfall (497 mm/year) recorded in South Africa is about 50% less than the global average (860 mm/year) and water is not equitably distributed across the country [1,2].

As of 2010, the South African government loses about R 7 billion annually because of water that is lost through the supply and distribution systems amounting to an annual loss greater than 1500 million cubic meters in a country that is already water stressed. One of the major reasons for water loss in the country includes aging infrastructure and a reduced budget for the maintenance of the functional water infrastructure [3].

With ageing infrastructure, water loss cannot be prevented as the plumbing means need to be changed after their shelf lives and when this is not done it leads to water leakages and loss [1–4]. A document from the Water Research Commission of South Africa reported that about 40% of municipal treated water is lost before it reaches the end users. Such an amount of water loss is alarming owing to the limited water resources in the country and the financial investment made on water treatment such as energy cost and the payment of the sector employees, etc. [4,5].

To add to the woes of water loss is the reported cases of onsite water leakages which often is not given much attention, but it is critical to reducing global water security. Onsite water leakages have been reported globally and varies across countries. Water leakage in residential property contributes to water shortage across a community. Several factors have been reported to contribute to residential water losses such as old plumbing networks which are often not properly monitored or replaced, the erratic supply of water which often makes the residents forget to close faucets or their taps, the attitudes of people living in the residential building, faulty pipes and taps, the age of water appliances used, and the lack of leak detection devices, amongst others [5–8].

Onsite water leakages have been reported in various regions of South Africa in the range of 20–38% of total water supplied to those residences [5,9–11]. This is high as South Africa is a semi-arid country which is water stressed and has almost all its surface water allocated. Hence there is need to effectively manage the limited water resources available in the country. There have been several protests due to the unavailability of portable water across the country and all effort must be put in place to limit water loss within water supply and distribution networks. Onsite water leakage is usually not the responsibility of the municipality that supplies such water, but is that of the residents, hence there is no incentive provided to quickly address issues of water leakages [12,13]. The need to conserve the scarce water resources in South Africa requires a holistic measure to reduce such water losses for the good of everyone.

Though issues of water losses have been globally reported, only a few reports have been published on onsite water leakage in an organization setting such as a tertiary institution [13,14]. Water security is essential for any thriving economy and water leakage and losses is a threat that needs to be given urgent attention as it is important to conserve the limited potable water which is often treated with huge financial investment. This study was carried out to investigate the quantity of water loss and its quality in a rural based University in South Africa and the possible reasons associated with it.

Study Area

The research area is in Limpopo Province, which is situated between 22°58′ S latitude and 30°26′ E longitude. Thohoyandou (Figure 1) is characterised by elevated temperature variations depending on the season.

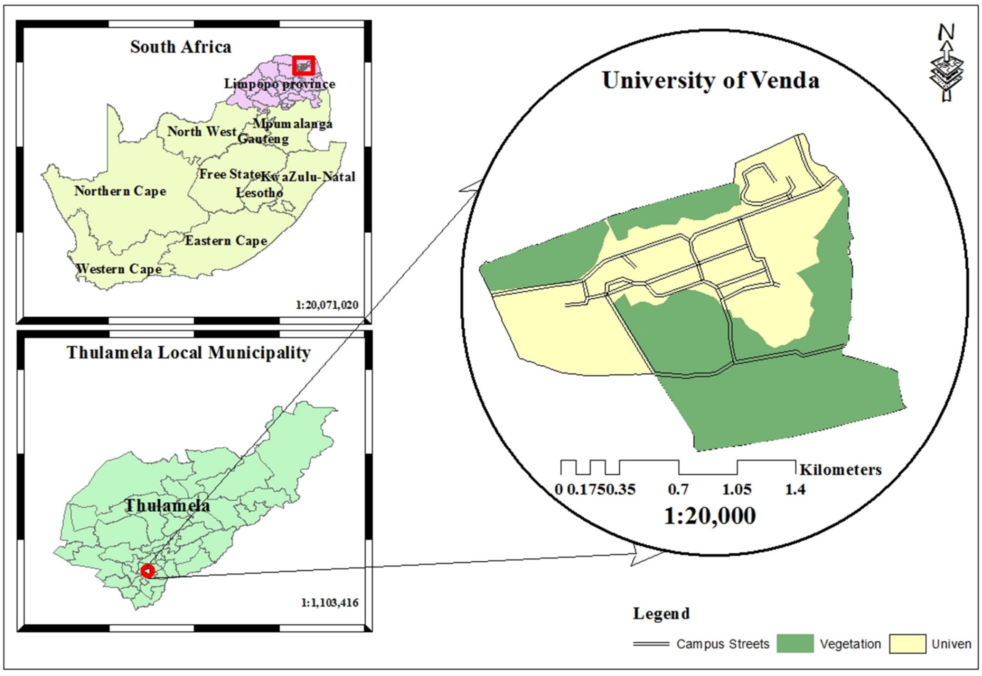

Figure 1. A map showing the study area.

The monthly distribution of the average daily maximum temperature ranges from 22.9 to 30 °C in summer and 17 to 22 °C in winter [15]. The region experiences its coldest nights in July, when the average temperature falls to 7.5 °C. The average annual rainfall in Thohoyandou is 752 mm, with the majority falling between January and March. Rainfall ranges from 4 mm in June to 154 mm in January (Figure 2) [16].

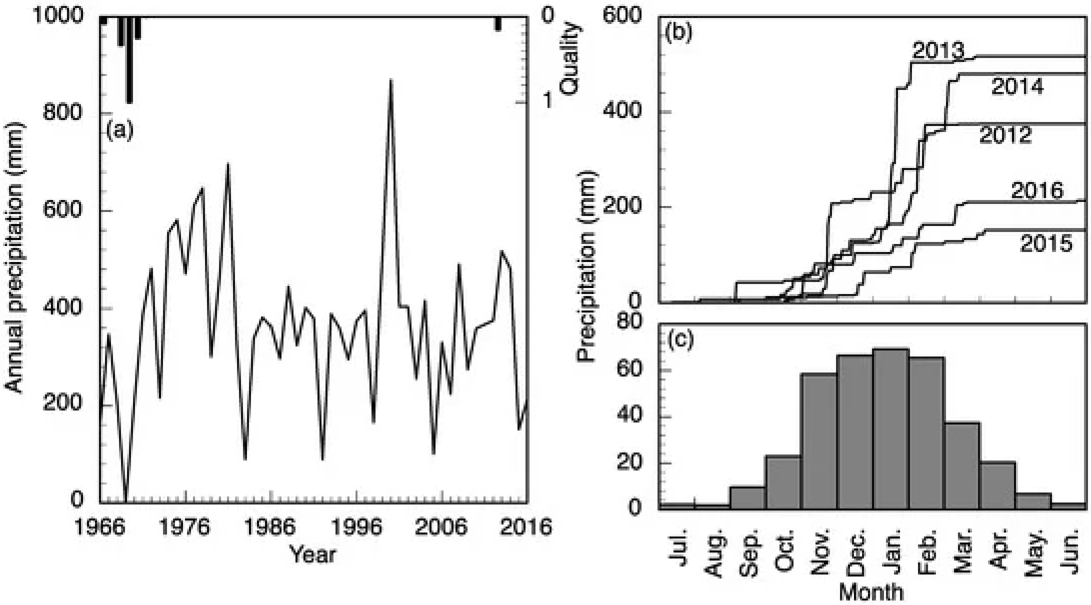

Figure 2. Precipitation trend in the study area. (**a**) annual precipitation by hydrologic year; (**b**) cumulative precipitation between 2012–2016; (**c**) mean monthly precipitation computed for years with >90% reliable data [16].

Rainfall is seasonal and about 20% of it falls in the winter months (April–September). The academic institution is supplied with treated water from Nandoni Dam (for domestic and other purposes) through a conduit to the reservoir tanks of the institution [17,18]. From the reservoir tanks, water is supplied to the faculty buildings and other residences. The water supplied is used mostly by the approximately 16,000 registered students of the university, 973 staff members, and other visitors for domestic purposes. Leakages are often seen around the hostels, caused by high water pressure, pipe bursts, students' mismanagement, and aging infrastructure, which leads to inefficient water utilisation.

2. Materials & Methods

2.1. Sampling

Water samples are from randomly selected residences located on the campus of the academic institution. Using Slovin's formula Equation (1), which is based on the number of residences on campus, a 10% decision for the random selection was made.

$$Sz = \frac{N}{1 + Ne^2} \quad (1)$$

where: Sz = Required number of the total residences. N = Total residences and e = Margin of error set at 95% confidence level as 0.05.

Observation was used to account for causes and sources of water loss. Water loss in each of the randomly selected residences was accounted for at any point of loss. A 15 mL funnel tube and 500 mL bucket were used to account for loss. A stopwatch was used to measure the loss rate. After which the records obtained were further used for economic evaluation of water lost using Equation (2).

$$P = A(L/d) \times T(R) \quad (2)$$

where: P—Wasted Water Price. $A(L/d)$—Amount of Wasted Water in litres per day and T—Proposed Water Tariff in rands.

For quality assessment all sample bottles used were sterilized before sample collection. A total of twenty-six water samples were collected at the points where water losses occurred. For metal analysis, 50 mL of each sample was acidified with a drop of concentrated nitric acid on site retaining the consistency of the trace metals. Samples for microbial analysis were collected using sterile containers in duplicate and were transported on ice to the laboratory. The samples were analysed within 24 h of collection [18].

2.2. Sample Analysis

An Extech EC400 Exstik® multi-meter was used in field, to measure the following parameters: temperature, pH, electrical conductivity (EC), salinity, and total dissolved solids (TDS) (EC 400, Extech Instruments, Nashua, NH, USA). Before use, the equipment was calibrated following the manufacturer's guidelines.

Trace metals were analyzed using an inductively coupled plasma optical atomic spectrophotometer (ICP-OES) (Agilent 5800, Agilent Technologies, Mulgrave, Victoria Australia). The National Institute of Standards and Technology traceable standards (NIST, Gaithersburg, MD, USA) were used to calibrate the instrument before sample analysis. Analytical precision was routinely verified by NIST-traceable quality control standards. Microbial analysis was done using the membrane filtration technique for estimation of faecal coliform and total heterotrophic bacteria (nutrient agar). Media were sterilized in the autoclave at 121 °C for 15 min. Sterilized media were dispensed in sterile petri dishes and allowed to cool. The pore size used for filtering was 0.2 microns for each water sample. Filter papers with a diameter of 47 mm were used, and the filter sheets were set on sterile agar surfaces. For 24 h, plates were incubated at 37 °C [19,20].

2.3. Trace Metals Pollution Indexing

Each metal weight was used to calculate the metal variety's pollution index (HPI) (Equation (3)). The ranking, which runs from 0 to 1, indicates how important each quality factor is in relation to the others [21]. The maximum permissible value for drinking water (Si) and the maximum desired value (Ii) for each parameter were used to establish the concentration limits [15]. Equation (4) is used to determine the parameter's sub index (Qi).

$$\text{HPI} = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \quad (3)$$

where Qi is the subindex of the ith parameter. Wi is the unit weight of the ith parameter, and n is the total number of parameters considered.

$$Qi = \sum_{i=1}^{n} \frac{|Mi - Ii|}{Si - Ii} \times 100 \quad (4)$$

where Mi denotes the value under observation for the trace metal parameter. The ith parameter's ideal value is Ii, while the ith parameter's average value is Si in ppb. Usually, 100 is the critical pollution index value.

2.4. Health Risk Assessment

The risk to human health associated with drinking water was calculated making use of the daily human exposure assessment. The ingestion method was used to evaluate this risk, as stated by the USEPA [22]. Each potentially harmful heavy metal's daily human exposure was assessed based on the level of risk evaluation in terms of a non-carcinogenic health concern. The hazard quotient (HQ) index and the chronic daily intake (CDI) were used to compute the chronic risk in accordance with Equation (5).

$$CDI = \frac{C \times DI}{BW} \quad (5)$$

where *BW* represents for body weight, *C* for the quantity of heavy metals in water (reported in mg L^{-1}), *DI* for average daily intake (2 L per day/person), and *CDI* for the risk of human exposure through the drinking water (evaluated in mg/kg/day) (Child weight is 15 kg, and adult weight is 72 kg.) [23]. The *HQ* evaluated the non-carcinogenic risk using Equation (6) [24].

$$HQ = \frac{CDI}{RfD} \tag{6}$$

For each heavy metal to which humans are sensitive, *RfD* stands for the maximum permissible daily oral exposure dose (mg/kg). USEPA [25] provided the data used for this investigation [26].

The *HQ* of each metal separately and the total of all metals' *HQ* were used to calculate the risk of non-carcinogens, also known as the hazard index (*HI*) [27]. Humans are regarded to be safe when the value of *HQ* is less than 1, but if the value is greater than 1, there is an unacceptable risk of adverse non-carcinogenic consequences on human health [25]. By integrating the risk evaluations of each of the separate *HQ*s for a heavy metals combination, the hazard index was produced (*HI*). The risk of non-carcinogenic health impacts is unfavourable if HI is greater than 1 [28].

3. Results and Discussion

3.1. Water Loss and Valuation

3.1.1. Water Loss Causes

From the observation of this study, several factors can be regarded as contributing to water loss in the institution. Firstly, cases of higher water pressure were noticed. High water pressure is known to have an adverse impact on pipes thus leading to water loss [29]. High water pressure exerts an excessive amount of strain on the plumbing system, particularly the pipes, seals, and water-using appliances. Such pressures cause pipes to deteriorate and reduces their capacity to retain water leading to tiny leaks that steadily increases into more profound leaks.

Similarly high-water pressure causes the seals surrounding pipe's ends to deteriorate quickly and these broken seals usually lead to pipes bursting and water spills [30,31]. Water-using appliances such as geysers are made to operate with a specific water pressure. The appliances' hoses and internal parts are subject to conditions that are causing excessive wear of or are a complete failure due to high pressure thus violating the warranty by raising the possibility of an early appliance failure [32]. A step closer to the sustainability of water resources can be through the fixing of the high-water pressure which helps in extending the lifespan of plumbing systems and appliances and preventing other significant plumbing problems brought on by water leaks or pipes bursting [33].

Another cause of water leakage determined in this study is the age of the plumbing system and water distribution network. When a plumbing system is old and has passed its shelf life, water leakage may result. Hence there is a need for the proper maintenance and replacement of the water distribution system to prevent any likelihood of water leakage. It was also observed that sometimes the taps are left to run unattended, and this usually occurs when there is a water cut from the university campus. The students could have opened the taps and forgot to close them leading to water loss when water is restored. Faulty taps, wash hand basins, and showers also contributed to the amount of water loss in the institution (Figure 3).

When a faulty system is not reported on time, there can be water loss which can run from days into weeks [34]. The attitude of some students also contributed to water loss in the institution. Some students sometimes leave the tap running while attending to other chores. A similar study by Bhagat [35] shows most water losses were due to several components of the distribution system including pipe-joint failure, relatively older pipes, the poor maintenance of water taps, pipe joints, and shower taps, the negligence of the consumer, and an unreliable water supply. Figure 4 shows the various places where water loss was observed in the current study.

Figure 3. Water loss from the academic institution from different sources.

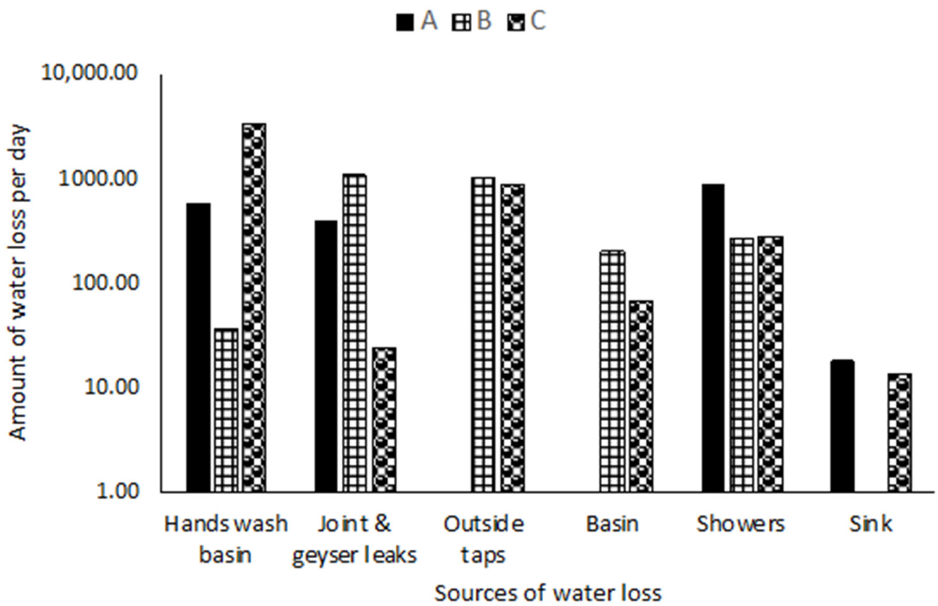

Figure 4. Sources of water loss in the academic institution.

Hand wash basins from the Lost city girls' residence of the academic institution recorded the highest amount (>3000 L) of water lost during a day, which is considerably high, followed by outside taps and joint geyser leaks with >1000 L/day, respectively (Figure 4). A high amount of water loss from hand wash basins and taps can be caused by the frequent opening and closing of taps which reduces the life span of such taps.

There is therefore a need for the proper management of pressure within the Institution's water distribution system. Low water pressures increase the time a consumer spends in acquiring enough water but too much pressure is a threat to the water pipeline network, leading to high failure rates, a reduced pipeline shelf life, and water leakages, amongst others. The pressure in the system should be kept within an acceptable range [36,37]. Plumbing replacement initiatives could also help in reducing water loss within the institution as ageing infrastructures tend to fail mostly when they have exceeded their shelf lives [4]. The university should therefore establish an active leakage control mechanism as this will aid in the continuous detection and fixing of all leakage-related issues within the water distribution system. Furthermore, the use of leak detection devices is highly recommended as it has been proven to greatly reduce water loss due to leakage. Most of these devices are automated and report any occurrence of leaks and the point where the leaks are occurring in the water distribution system for quick response [38].

3.1.2. Water Loss Analysis

High water loss is recorded within each analysed residence recording more than 1000 L/day (Table 1). Water loss and misuse in the institution residence may, therefore, affect the availability and supply of water to the institution and nearby communities that share water resources from the same source. The treatment of water is cost intensive with a high amount allocated to energy and the distribution system; hence, the loss of such water should be prevented [39].

Table 1. Estimated water loss values, prices, and causes of loss from selected residences.

Residence	Amount of Water per Day	
	Litres/day	Rands/day
A (n = 210)	1845.37	39.90 ($2.20)
B (n = 180)	2602.88	52.06 ($2.87)
C (n = 180)	4565.31	91.31 ($5.03)
Total:	9013.56	180.27 ($9.93)

NB: (A-River side, B-Lost city boys, C-Lost city girls and n-No of students residing). (Exchange rate: USD $1.00 = R18.15 South African Rand).

The adequate maintenance of institutional infrastructures plays a major role in reducing water loss. The quantity of water loss can be prevented or reduced greatly through constant monitoring and maintenance. There is a need to educate students during orientation programs on the proper use of water and the handling of water-related infrastructure. The students should also be notified to report all cases of water loss they cannot handle, such as major leaks, to the appropriate authorities, while they can simply close a shower or a tap if left unattended.

3.1.3. Comparisons of Reported Cases of Onsite Water Loss

Some previous studies have reported on onsite water loss in various countries. In Colorado, DeOreo et al. [40] reported a 20% onsite water loss from the 16 households investigated. In other parts of the United States of America, Mayer et al. [41] reported that, of 1188 households studied, 67% of them recorded onsite water loss below 1.6 L/h while 5.5% of the households recorded 15.5 L/h. In Namibia, Fourie [42] reported an onsite leakage (20% and 9%) in two residential buildings with average leakage rates of 20.3 and 9.0 L/h, respectively. In South Africa, Mckenzie [10] and Alliance to Save Energy [9] reported onsite water loss due to leakage from various household faucets in the range of 20–38% in the Kagiso, Tembisa, Hernanus, and Mogale regions of South Africa. In Spain, the rate of onsite leakages up to 100 L/h was reported by Arregui et al. [43]. In Ethiopia, Bhagat et al. [35] reported a daily onsite water loss in the range of 0.01–1.77 L/h. In this study, onsite water leakage ranged between 76.89–109.22 L/h, which is higher than most of the cases reported. The various reasons given for the onsite water loss include: bursted pipe and joints; high water pressure; aged materials; corrosion of pipes; broken faucets; broken valves; damaged shower fixtures; unreliable pressure fluctuations; and the poor management of water fixtures, etc. [10,11,35–40].

3.1.4. Economics of The Water Loss Due to Onsite Leakage

For businesses such as universities, Further Education and Training colleges, schools, clinics, hospitals, parks, health centers, and churches, the planned water tariff from the Vhembe district municipality is R 21.00 ($1.18) per 1000 litres of treated water, while the water price for 1 litre is projected at R 0.02 ($0.0011) [44]. Water pricing ensures that the expenses associated with achieving and sustaining the resource quality objectives are adequately collected through the water use charges which facilitates the financial sustainability of water management and encourages water use efficiency. With the accompanying costs and services, the institution loses about R 65, 798.55 ($3624.93) (Figure 5) annually from the three selected hostels due to water loss.

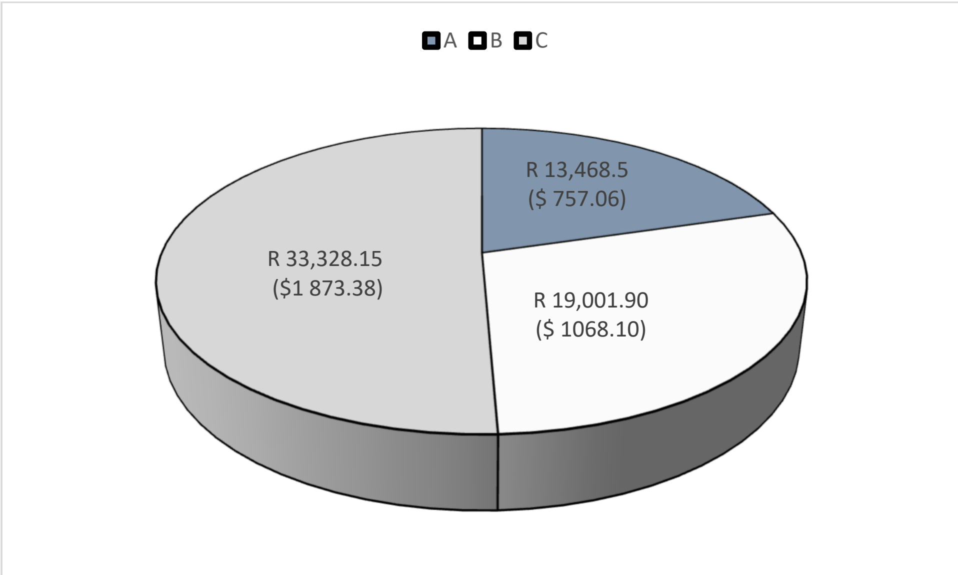

Figure 5. Cost analysis of water loss due to onsite leakage in three residences of the study area. NB: Exchange rate: USD $1.00 = R18.15 South African Rand).

The amount of money lost due to water leakage is high and adequate efforts should be channeled towards eradicating water leakage in the institution. As stated earlier, the installation of a leak detection mechanisms is essential for the university to minimize funds spent on the purchase of potable water.

3.2. Quality of Water Loss

3.2.1. Physiochemical Parameters

The physiochemical parameters from the study were measured to check the quality of water that is being lost by comparing their levels with the South African drinking water National standards (SANS) and those of the World Health Organisation. The temperature measured in all sampling points ranged between 27 and 30.3 °C and complied with the recommended guideline set by SANS [23] and WHO [45]. The pH values for the samples ranged from 7.45 to 9.04 which complied with the pH standard for the South African National Standard for human consumption [23] and WHO [45] standard. A similar study conducted at Jigjiga city, Ethiopia by Adhena et al. [46] showed the pH value of tap water which was in the range of WHO standards. The total dissolved solids fluctuate from 116.6 to 646 mg/L (Table 2). The maximum value (646 mg/L) was recorded at residence B and was within the SANS guideline value (1200 mg/L) for domestic use [47]. The salinity of the study ranged from 77 to 85.4 ppm. The highest salinity was recorded in residence C (85.4 ppm). The EC values varied from 145.83 to 247.6 µS/cm. Since the quality of water from the academic institution is of good quality, as prescribed by the SANS and WHO drinking water standards, the institution is spending more money paying for treated water that is lost without serving its purpose. Water loss saving strategies need to be implemented to reduce the amount of funds being spent on water by the institution.

Table 2. Physio chemical parameters of water recorded from the area.

Residence	Parameters	Min	Max	Average	Stdev	SANS 241 (2015)	WHO (2015)
A (*n* = 7)	Temperature (°C)	28.0	30.3	29.08	0.90	-	-
	pH	7.45	8.35	7.83	0.31	≥5 to ≤9.7	6.5 to 9.7
	TDS (mg/L)	160.0	630	460	219.43	≤1200	500
	Salinity (ppm)	74.5	85	79.6	3.52	-	-
	EC (μS/cm)	145.83	247.6	216.58	35.45	≤1700	600
B (*n* = 8)	Temperature (°C)	27.0	27.6	27.28	0.22	-	-
	pH	7.7	8.47	8	0.24	≥5 to ≤9.7	6.5 to 9.7
	TDS (mg/L)	116.6	646	432.94	269.1	≤1200	500
	Salinity (ppm)	75.7	85	80.05	3.42	-	-
	EC (μS/cm)	167.5	180.8	172.73	4.36	≤1700	600
C (*n* = 11)	Temperature (°C)	28.2	29	28.52	0.24	-	-
	pH	8.08	9.04	8.5	0.31	≥5 to ≤9.7	6.5 to 9.7
	TDS (mg/L)	117.1	126	120.6	2.72	≤1200	500
	Salinity (ppm)	77.7	85.4	81.01	2.52	-	-
	EC (μS/cm)	167.2	181.4	172.54	4.79	≤1700	600

3.2.2. Microbial Analysis

Wasted water samples collected from the various residences were safe for drinking as no faecal contamination were recorded in all the water samples analysed during the course of this study. This implies that there is no health risk linked to the consumption of the water due to the absence of pathogenic microorganisms. Heterotrophic bacteria were however recorded in some of the water samples and ranged from 0 to 134 cfu/100 mL (Figure 6). An overall average of 18.67 cfu/100 mL were recorded for all the residences during the course of this study.

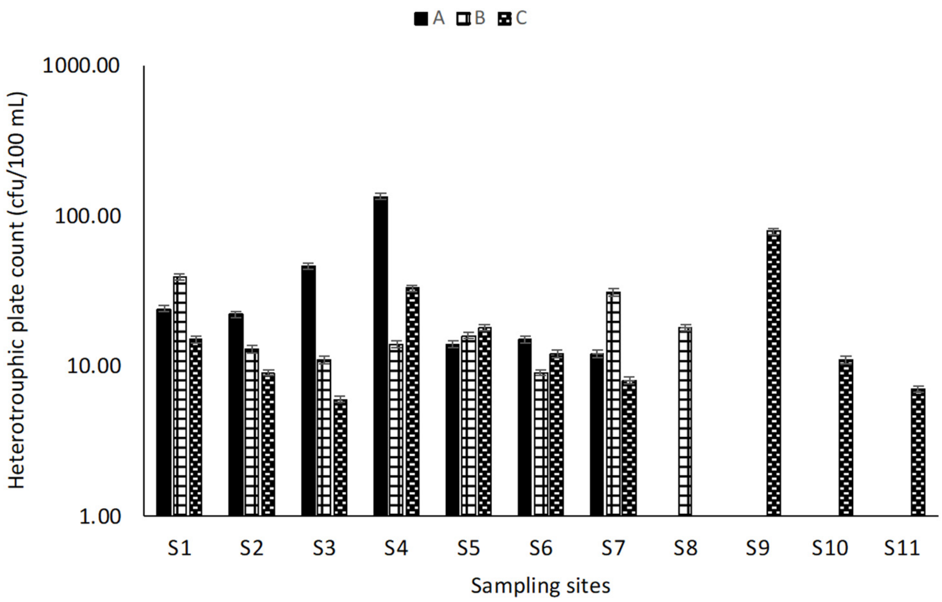

Figure 6. Heterotroph bacteria recorded within the institution residence.

Only one sample from the riverside residence recorded a >100 cfu/mL of heterotrophic bacteria. These heterotrophs could cause digestive related problems [48]. A very low concentration of heterotrophic bacteria in the water indicates no health risk to people, but a high concentration (>100 cfu/mL) is a sign of favourable conditions for bacterial growth [49]. This could serve as a breeding environment for more harmful bacteria such as Legionella or *E. coli*, which produce water with a bad taste and cause corrosion or the creation of slime in pipes [50].

3.2.3. Trace Metals

Seven common metals namely Cobalt (Co), Chromium (Cr), Copper (Cu), Manganese (Mn), Mercury (Hg), Nickel (Ni), and Zinc (Zn) were analyzed in the sampled water. Heavy metals recorded from the study fell within the SANS [23] and WHO [51] drinking water standards as expected (Table 3). This showed that the water being lost due to onsite leakage possessed a good quality and satisfied the requirements for human consumption.

Table 3. Trace metals results of wasted water from selected UNIVEN residences.

Residence	Trace Metal (μg/L)	Min	Max	Avrage	Stdev	SANS 241 (μg/L) (2015)	WHO (μg/L) (2015)
A (*n* = 7)	Mn	7.36	9.73	8.30	0.95	≤50	50
	Co	0.07	0.1	0.08	0.01	≤500	-
	Ni	1.6	2.9	2.06	0.46	≤2000	2000
	Zn	16.1	21.74	18.55	2.02	≤6	1
	Hg	0.07	0.45	0.22	0.17	≤400	100
	Cu	2.13	43.97	15.17	14.35	≤70	50,000
	Cr	2.16	4.71	2.94	0.9	≤5	3000
B (*n* = 8)	Mn	7.62	12.42	9.57	1.84	≤50	50
	Co	0.06	0.1	0.08	0.01	≤500	-
	Ni	1.45	2.98	2.03	0.48	≤2000	2000
	Zn	15.16	28.53	19.72	4.22	≤6	1
	Hg	0.05	0.48	0.2	0.14	≤400	100
	Cu	8.17	95.38	33.08	29.95	≤70	50,000
	Cr	1.42	3.13	2.39	0.61	≤5	3000
C (*n* = 10)	Mn	1.55	10.66	7.76	2.98	≤50	50
	Co	0.03	0.13	0.08	0.03	≤500	-
	Ni	0.18	3.7	1.98	1.01	≤2000	2000
	Zn	8.3	44.68	21.25	9.82	≤6	1
	Hg	0.05	1.66	0.39	0.49	≤400	100
	Cu	0.34	97.66	39.49	40.77	≤70	50,000
	Cr	0.14	5.96	2.75	1.64	≤5	3000

3.2.4. Trace Metals Pollution Index

The summation from the Trace Metals Pollution Index analysis was 7.76, which is under the threshold value of 100 (Appendix A). This shows that the water is generally safe to drink in terms of the trace metals levels recorded. Each chosen residence's Trace Metal Pollution Index was determined independently (Table 4). All the water's HPI values fell below the threshold limit of 100. This is not surprising as the wasted water is treated water supplied for human consumption. Boateng et al. [52] have reported HPI values > 100 from water supplied by Ejisu-Juaben Municipality, Ghana. Other authors have reported HPI values < 100 for water from various sources used for human consumption [53,54]. Hence, no health risk is anticipated due to trace metals because of the consumption of this water on a continuous basis.

Table 4. HPI of water at selected residences.

Residence	Trace Metals (μg/L)	Unit Weightage (*Wi*)	Sub-index (*Qi*)	*Wi* × *Qi*
A (*n* = 7)	Cr	0.002	24.383	0.049
	Co	0.001	99.985	0.1
	Cu	0.001	97.198	0.049

Table 4. *Cont.*

Residence	Trace Metals (µg/L)	Unit Weightage (*Wi*)	Sub-index (*Qi*)	*Wi* × *Qi*
	Hg	0.2	18.25	3.65
	Mn	0.001	10.181	0.010
	Ni	0.003	74.04	0.212
	Zn	0.1	285.3	28.53
		HPI = 2.92		
B (n = 8)	Cr	0.002	24.363	0.049
	Co	0.001	99.983	0.1
	Cu	0.001	95.352	0.048
	Hg	0.2	22.625	4.525
	Mn	0.001	10.186	0.010
	Ni	0.003	73.79	0.211
	Zn	0.1	232.4	23.24
		HPI = 2.38		
C (n = 10)	Cr	0.002	24.52	0.049
	Co	0.001	99.987	0.1
	Cu	0.001	94.41	0.047
	Hg	0.2	3.6	0.72
	Mn	0.001	10.413	0.010
	Ni	0.003	74.338	0.212
	Zn	0.1	242.1	24.21
		HPI = 2.47		
		Total: HPI = 7.77		

3.2.5. Human Health Risk Assessment

A summary of the Hazard Quotient (HQ) values for metals (Cr, Co, Cu, Hg, Mn, Ni, and Zn) in drinking water through an ingestion route was computed for adults (Table 5). Trace metals can pose potential adverse health effects when the HQ value of a metal is greater than 1 [55]. In this study, the HQ exposure for adult groups did not exceed 1 (Table 5). Hence there is no non-carcinogenic risk associated with the levels of trace metals determined. The Hazard Index (HI) which is a summation of the HQs was below the maximum limit of 1 from all the residents, this further implies that the consumption of the water does not pose non-carcinogenic risk to the consumers. A similar study by Mohammadi et al. [56] estimated the total potential non-carcinogenic impacts induced by more than one metal, the HQ computed for each metal was summed and expressed as a Hazard Index (HI). The mean values of the HI through ingestion and dermal adsorption as well as the total HI recorded were 3.31×10^{-3}, 2.15×10^{-6}, and 3.32×10^{-3}, respectively [57].

Table 5. Hazard Quotient (HQ) of studied metals.

Residence	RfD	Trace Metals	Min	Max	Average	Stdev
A (n = 7)	24	Mn	0.01	0.01	0.01	0.00
	0.3	Co	0.01	0.01	0.01	0.00
	20	Ni	0.00	0.00	0.00	0.00
	300	Zn	0.00	0.00	0.00	0.00
	0.3	Hg	0.01	0.05	0.02	0.01
	40	Cu	0.00	0.03	0.01	0.01
	3	Cr	0.02	0.05	0.03	0.01
		HI (Total)	0.05	0.15	0.08	0.03
B (n = 8)	24	Mn	0.01	0.02	0.01	0.00
	0.3	Co	0.01	0.01	0.01	0.00
	20	Ni	0.00	0.00	0.00	0.00
	300	Zn	0.00	0.00	0.00	0.00
	0.3	Hg	0.01	0.05	0.02	0.01
	40	Cu	0.01	0.07	0.03	0.02

Table 5. *Cont.*

Residence	RfD	Trace Metals	Min	Max	AVRG	STDEV
	3	Cr	0.01	0.03	0.03	0.01
		HI (Total)	0.05	0.18	0.10	0.04
C (n = 10)	24	Mn	0.00	0.01	0.01	0.00
	0.3	Co	0.00	0.01	0.01	0.00
	20	Ni	0.00	0.01	0.00	0.00
	300	Zn	0.00	0.00	0.00	0.00
	0.3	Hg	0.01	0.17	0.04	0.05
	40	Cu	0.00	0.08	0.03	0.03
	3	Cr	0.00	0.06	0.03	0.02
		HI (Total)	0.01	0.34	0.12	0.10

4. Limitation of The Study

This study was restricted to one institution of higher learning in a peri-urban setting and three residences were chosen to establish the need for a more comprehensive water resource management in the institution. Data obtained from this study can aid in understanding onsite water loss in tertiary institution which are not often reported.

5. Conclusions

South Africa is a water scarce country and there should be increased efforts towards reducing water losses both onsite and during water distribution and supply. An estimated 9013.56 L of water is lost daily from three residences in the institution from this study. The quality of the water loss is good as it complies with both the South African National Standards and the WHO standards for drinking water. The consumption of the water poses no health risk to the consumers as the hazard quotient and hazard index values were below unity. There are a lot of resources that go into water treatment and supply thus losing water in a semi-arid country with various water challenges is uncalled for. The use of water leaks detection systems is therefore also recommended. This study further recommends a more comprehensive study in other institutions of higher learning to ascertain the extent of this problem in the country for a necessary solution.

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Appendix A

Table A1. Calculations of Trace metal Pollution Index.

Heavy Metals (µg/L)	Mean Concentration (Mi)	Highest Permitted Value of Drinking Water (Si)	Desirable Maximum Value (Ii)	Unit Weightage (Wi)	Sub-Index (Qi)	$Wi \times Qi$
Residence A						
Cr	2.47	500	100	0.002	24.383	0.049
Co	0.08	1000	500	0.001	99.985	0.1

Table A1. *Cont.*

Heavy Metals (µg/L)	Mean Concentration (*Mi*)	Highest Permitted Value of Drinking Water (*Si*)	Desirable Maximum Value (*Ii*)	Unit Weightage (*Wi*)	Sub-Index (*Qi*)	$Wi \times Qi$
Cu	28.025	2000	1000	0.001	97.198	0.049
Hg	0.27	5	1	0.2	18.25	3.65
Mn	8.37	1000	100	0.001	10.181	0.010
Ni	1.92	350	150	0.003	74.04	0.212
Zn	19.265	10	5	0.1	285.3	28.53
$\sum Wi = 0.102$	$\sum WiQi = 28.578$	HPI = 2.92				
Residence B						
Cr	2.55	500	100	0.002	24.363	0.049
Co	0.085	1000	500	0.001	99.983	0.1
Cu	46.48	2000	1000	0.001	95.352	0.048
Hg	0.095	5	1	0.2	22.625	4.525
Mn	8.325	1000	100	0.001	10.186	0.010
Ni	2.42	350	150	0.003	73.79	0.211
Zn	16.62	10	5	0.1	232.4	23.24
$\sum Wi = 0.102$	$\sum WiQi = 23.289$	HPI = 2.38				
Residence C						
Cr	1.92	500	100	0.002	24.52	0.049
Co	0.065	1000	500	0.001	99.987	0.1
Cu	55.9	2000	1000	0.001	94.41	0.047
Hg	0.856	5	1	0.2	3.6	0.72
Mn	6.285	1000	100	0.001	10.413	0.010
Ni	1.325	350	150	0.003	74.338	0.212
Zn	17.105	10	5	0.1	242.1	24.21
$\sum Wi = 0.10$	$\sum WiQi = 24.26$	HPI = 2.47				
TOTAL:	HPI = 7.77					

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