Rapid Identification and Evaluation of Interventions for Improved Water Performance at South Africa Schools

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Abstract. Many areas of South Africa experience water shortages and unreliable water supplies. Water and sanitation costs at South African municipalities have been steadily rising in the last 5 years and are particularly high in water-stressed areas such as Cape Town. At the same time, public funding for schools is reducing. Schools, therefore, need to understand their water consumption and be able to rapidly identify and evaluate options to reduce water usage, thereby decreasing costs and improving environmental performance. In order to identify the smartest options for reducing water consumption, a rapid identification and evaluation methodology is proposed. Characteristics of existing infrastructure and usage are modelled in a School Water Use Model (SWUM). Results from this modelling are used to identify potential interventions for improved performance. These are evaluated and compared using the SWUM and ranked in terms of impact and applicability. The SWUM-based methodology is tested by applying this to school in Pretoria, South Africa. The application and results of the SWUM-based methodology show promise as a rapid way of identifying, and evaluating, interventions to improve the sustainability performance of water systems in schools in South Africa. Recommendations for further development of the approach are made.

Keywords: Sustainable school sanitation, sustainable school water systems

1 Introduction

South Africa is classified as a water-scarce country [1]. In many areas, there are water shortages and water supplies are unreliable [2]. Water shortages can cause significant problems for schools and may lead to their temporary closure because of health concerns. This can have devastating knock-on effects as learning time is lost and exam results drop [3].

Schools that rely on flush toilets also have to pay significant costs for water. Water shortages in many areas of South Africa have resulted in these costs increasing rapidly as municipal tariffs rise. At the same time, public funding for schools has been reducing making it increasingly difficult for schools to absorb additional costs.

It is therefore increasingly important to understand water systems and waterborne sanitation at schools and identify ways that water consumption can be reduced. Reducing water consumption at schools helps to reduce school operational costs, it preserves limited water resources and helps ensure that children (and their parents) become more aware of the water scarcity and how water consumption can be reduced.

This paper presents work carried out to investigate water consumption in schools. It provides background to the need to address water in schools in South Africa and provides a methodology for the study. Results from the study are presented and discussed to develop conclusions and recommendations. It aims to address the following questions a) How is water used in the case study school?, b) Can this water use be modelled to identify options for improvement?, c) Which options appear to be the smartest and most sustainable solutions? and, d) What recommendations can be made?

2 Water in South Africa

Many countries in Africa face very high levels of water scarcity [1]. Studies indicate that 98% of available water supplies in South Africa are already exploited [2]. Major South Africa cities, such as Cape Town and Johannesburg, are vulnerable to water shortages [3]. For instance, in December 2017, water shortages in Cape Town were of an extent that, without rain, water for the city was predicted to run out in May 2018 [4].

Climate change will result in the severity and frequency of droughts in many areas increasing, making water supplies unpredictable [5]. Conservation of water resources and water efficiency has, therefore, become a key issue [6, 7]. Schools can make a significant contribution to reducing water consumption by being more efficient on their premises and by influencing learners and parents [8, 9].

3 Methodology

A mixed-method research methodology was applied to the study and included the following methods. Analysis of quantitative data was used to understand current water consumption data at the school and develop this as input for a modelling tool. Qualitative data was gathered in interviews and interpreted to understand how the school operated and used water. A process of synthesis and conjecture was used to develop a model of water consumption at the school and identify potential interventions that could be used to reduce water consumption. Finally, quantitative analysis was applied to understand, compare results and draw conclusions and recommendations.

The study applies the School Water Use Model (SWUM) to school to identify and evaluate options for reducing water consumption. The SWUM was developed by the author as a way of identifying, and testing options to reduce school water consumption. The SWUM and the methodology of applying this have been deliberately designed to be simple and non-technical. This is to ensure that 'non-professional' users, such as school principals, teachers, staff and pupils can use the methodology to identify valuable opportunities to reduce water consumption and school operating costs. This makes the approach different from conventional water audits and water consumption monitoring using water loggers. A diagram of the tool is provided in figure 1.

SCHOOL WATER USE MODEL (SWUM 1.01)

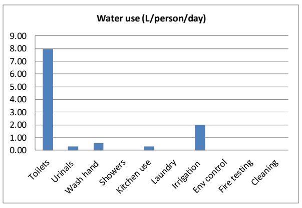
SWUM HEADLINE INDICATORS

Modelled litres per person per day	11.15	Target litres per person per day	80.00	Over/under	-68.85 L
Modelled litres per m2 per day	1.95	Target litres per m2 per day		Over/under	1.95 L

Normalized performance and benchmarks

Water use in the building

Water Use	Monthly use (kL)	Annual use (kL)	Use L/m2/day	Use L/person/day	Percentage
Toilets	252.52	3 030.21	1.39	7.95	71.35
Urinals	9.35	112.23	0.05	0.29	2.64
Wash hand basins	18.71	224.46	0.10	0.59	5.28
Showers	0.00	0.00	0.00	0.00	0.00
Kitchen use	9.35	112.23	0.05	0.29	2.64
Laundry	0.00	0.00	0.00	0.00	0.00
Irrigation	64.00	768.00	0.35	2.02	18.08
Env control	0.00	0.00	0.00	0.00	0.00
Fire testing	0.00	0.00	0.00	0.00	0.00
Cleaning	0.00	0.00	0.00	0.00	0.00
Total	**353.93**	**4 247.13**	**1.95**	**11.15**	**100.00**



Performance in a table and graph

Building details

Name of building		Address		Number of weeks occupied	43
Gross Internal Area (m2)	5970	Site area (m2)		Occupancy (hours per week)	32.5

Occupants

Number of full time occupants	1044	Number of part-time occupants	1070
Full time equivalent occupants	1044.00	Occupancy (0.1 to 0.9)	0

School inputs including school day and year schedules, building areas and learner and staff numbers

Assessment

Assessment by		Date		Validation by		Date	

Toilets

	Number of users	Full flush rates (L/flush)	Half flush rates (L/flush)	Uses per day	Days per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Female	0.00	6.00	3.00	2.00	5.00	43.00	0.00	0		
Male	0.00	6.00	3.00	1.00	5.00	43.00	0.00	0		
		Full flush rates only (L/flush)								
Female	522.00	9.00		2.00	5.00	43.00	168.35	2020.14	0.93	5.30
Male	522.00	9.00		1.00	5.00	43.00	84.17	1010.07	0.46	2.65
							252.52	3030.21	1.39	7.95

Urinals

	Number of users	Flush rates (L/flush)	Uses per day	Days per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Male	522.00	1.00	1.00	5.00	43.00	9.35	112.23	0.05	0.29

Wash hand basins

	Number of users	Flow rates (L/minute)	Duration (minutes)	Uses per day	Days per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
	1 044.00	5.00	0.10	2.00	5.00	43.00	18.71	224.46	0.10	0.59

Equipment inputs including quantities, flow rates and flush volumes and operating schedules

Showers

	Number of users	Flow rates (L/min)	Duration (minutes)	Times per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Users	0.00	14.00	4.00	7.00	43.00	0.00	0.00	0.00	0.00

Kitchen use

	Number of users	Water used per activity (L)	Times per day	Days per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Drinking	1 044.00	0.50	1.00	5.00	43.00	9.35	112.23	0.05	0.29
Washing		10.00	3.00	5.00	43.00	0.00	0.00	0.00	0.00
						9.35	112.23	0.05	0.29

Laundry

	Number of users	Water use per wash (L)	Times per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Washing	0.00	70.00	1.00	43.00	0.00	0.00	0.00	0.00

Irrigation

	Area	Duration of flows (Min)	Times per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Sports	50.00	60.00	3.00	20.00	56.00	672	0.31	1.76
Decorative	20.00	60.00	3.00	43.00	8.00	96	0.04	0.25
					64.00	768.00	0.35	2.02

Env control

	Flow of water to equipment (L/min)	Duration of flows (Min)	Times per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Equipment	0.00	0.00	0.00	43.00	0.00	0.00	0.00	0.00

Fire testing

	Flow of water to equipment (L/min)	Duration of flows (Min)	Times per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cleaning

	Flow of water (L/min)	Duration (Min)	Times per week	Weeks per year	Use per month (KL)	Use per year (KL)	Use L/m2/day	Use L/person/day
Equipment 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equipment 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					0.00	0.00	0.00	0.00

Fig. 1. School Water Use Model (by Author)

Data on all equipment and fittings that use water, such as flow rates and water consumption volumes, is entered under Equipment Inputs. Operational data such as learner, educator and staff numbers, school building areas and the school day and school year schedule is then entered under School Inputs. This data generates water performance information for the school in the form of a table and graph. Data is finally summarized in key water performance indicators which are compared to targets and benchmarks under Normalized Performance and Benchmarks. The SWUM is applied within a structured methodology which consists of the following steps.

Firstly, a case study school was identified and analyzed. The school selected is located in Pretoria, South Africa (25° S, 28° E) as it has waterborne sanitation, grounds with irrigation, is in an urban area, has about 1,000 learners and is fairly typical of a large school in a middle-class South African neighbourhood.

Secondly, data on the school, including learner and staff populations were obtained from the school. School plans and Google maps were used to acquire school and site areas and other data on school infrastructure. A walkthrough of school facilities was used to obtain data on equipment and fittings that used water. Data gathered in this way is shown in table 1 and 2. A review of literature and green building rating tools was used for the norms and assumptions indicated in table 3.

Thirdly, an analysis of municipal utility bills for 12 consecutive months during 2017 and 2018 was used to ascertain water consumption and sewage figures for the school. Data gathered in this way is shown in table 2 and was used to cross-check figures generated by the SWUM.

Fourthly, a range of options was identified that could be used to reduce water consumption. These were entered into the SWUM to ascertain their potential impacts. These options were:

A. Eliminating irrigated recreational lawns and replacing grass with a surface that did not require irrigation.
B. Eliminating all lawns, including sports field laws that required irrigation and replacing with surfaces that do not need irrigation.
C. Replacing all WCs with dual flush WCs with a flush rate of 3l (half flush) and 6l (full flush).
D. Installing a rainwater harvesting system and using water from this to flush toilets.
E. Installing composting toilets and waterless urinals.

3.1 Input data used in the School Water Use Model.

Infrastructure and operational data entered into the SWUM are shown in tables 1 and 2. Table 3 shows the assumptions and norms used in the model.

Table 1. Infrastructure data.

Aspect	Data

Site area	3.33ha
Building area	5,970m2
Irrigated sports grounds	7,000m2
Irrigated recreational lawn	2,000m2
Wash hand basin flow rates	10l/minute
Urinal flush rates	1ll/flush
WC flush rates	9l/flush

Table 2. Operational data.

Aspect	Data
Learner numbers	980
Staff numbers	64
School operational schedule	07:30 -14:00 weekdays (32.5 hours per week, 100% school population), sports (14:00 – 16:00, weekdays (10 hours per week, 10% school population)
School year	43 weeks
Water tariff	R24.37/kl
Sanitation tariff	R3.84kl
Combined tariff	R28/kl [10]

Table 3. Assumptions and norms.

Aspect	Data
Sex	There are equal numbers of male and female learners and staff.
WC usage	Female learners will use the WC three times a day, males will use WC once a day and use urinals twice a day.
Wash hand basins	Users wash their hands every time they visit the toilet and will open the tap for 6 seconds.
Drinking water	An average of 500ml of water per day will be consumed by all occupants.

4 Results

The analysis of municipal utility bills indicated that water consumption at the school for a full calendar year was 4,167kl. This is an average of 347kl per month. Sewage flows on utility bills are indicated as the same as water flows.

Entering the data listed in tables 1, 2 and 3 into the School Water Use Model provided the following figures. Annual water consumption was 4,247kl. This was within 2% of the actual water consumption figures. A report from the SWUM in figure 2 indicates that this equals 11.15 litres per person per day and 1.95 litres per m2/day. It shows that most water (71%) is used by toilets, followed by irrigation (18%), and wash-hand basins (5%).

Water Use	Monthly use (kL)	Annual use (kL)	Use L/m2/day	Use L/person/day	Percentage
Toilets	252.52	3 030.21	1.39	7.95	71.35
Urinals	9.35	112.23	0.05	0.29	2.64
Wash hand basins	18.71	224.46	0.10	0.59	5.28
Showers	0.00	0.00	0.00	0.00	0.00
Kitchen use	9.35	112.23	0.05	0.29	2.64
Laundry	0.00	0.00	0.00	0.00	0.00
Irrigation	64.00	768.00	0.35	2.02	18.08
Env control	0.00	0.00	0.00	0.00	0.00
Fire testing	0.00	0.00	0.00	0.00	0.00
Cleaning	0.00	0.00	0.00	0.00	0.00
Total	**353.93**	**4 247.13**	**1.95**	**11.15**	**100.00**

Fig. 2. Consumption analysis report from the School Water Use Model (SWUM)

4.1 Interventions

Water consumption impacts of proposed interventions as modelled in the SWUM are described below.

4.2 A. Eliminating irrigated recreational lawns

Eliminating irrigated recreational lawns at the school can be achieved by replacing this with ground cover that does not irrigation. This intervention reduces overall water consumption from 4,247 to 4,151kl per year, a 2.36% reduction in water consumption.

4.3 B. Eliminating all irrigated lawns

Eliminating all irrigated lawns, including sports fields, at the school can be achieved by replacing these surfaces with an alternative that does not require irrigation. Possible alternatives are planted xeriscape ground covers or an 'AstroTurf' type surface that does not require irrigation. This intervention results in water consumption dropping from 4,247 to 3,479kl per year, an 18% reduction.

4.4 C. Replacing all WCs with dual flush WC

Replacing conventional toilets with dual flush toilets reduces water consumption from 4,247 to 2,378 kl per year. This reduces water consumption in the school by 44%.

4.5 D. Installing dual flush WC and a rainwater harvesting system

Annual average rainfall at the school location is about 600mm. This amount of rain (0.6m) combined with the roof area (approx. 5,000 m2) indicates that sufficient rainwater (approx. 3,000kl) could be harvested to meet the water volume requirements (1,161kl) to flush the toilets throughout the year. Monthly water volumes required to flush toilets (dual flush toilets) are 96kl/month. Given that the longest period without rain is 3 - 4 months, the volume of water harvested and stored would have to be 4 x 96kl, which is approximately 384kl. This intervention would reduce mains water consumption by 3,031kl from 4,247 kl to 1,216 kl, a 71% reduction in consumption.

4.6 E. Installing composting toilets and waterless urinals

Installing composting toilets privies and waterless urinals could be used to reduce water consumption associated with toilets. This intervention would reduce mains water consumption by 3,031kl from 4,247 kl to 1,216 kl, a 71% reduction in consumption.

5 Discussion

A review of the interventions indicates that Intervention A (eliminating recreational lawns) has a relatively small impact and only reduces water consumption by about 2%. Eliminating all irrigation (Intervention B) has a greater impact and leads to savings in water consumption of about 18%. Converting inefficient WCs to more efficient dual flush WCs (Intervention C) has a significant impact and reduces water consumption by 44%. Intervention D, which includes using harvesting rainwater to flush toilets results in a saving of water of 71%. Intervention E, replacing existing water-based sanitation with a composting toilet system also achieves water savings of about 71%.

The SWUM provides water consumption data in a form that can be used to compare performance with other schools and to set targets for the management of the school [10]. For instance, water consumption at this school (4kl/person/year) can be compared to schools in Taiwan where consumption 12.83kl/person [11]. An annual measure, however, does not reflect differences that may occur in the length of the school year and therefore comparing consumption in terms of litres/person/day may be more accurate. Comparing the school's performance (11l/person/day) with Italian schools performance (18-56l/person/day) indicates consumption is far lower in the case study school [10].

While the methodology is rapid and cost-effective it may not be highly accurate as it based on school facilities audits, field observations and assumptions and not on actual water consumption data within the different areas of the school. Highly accurate data of this nature could be achieved by logging water consumption in the different areas and recording this for a year. This, however, would be expensive as it would require metering and would take some time to undertake. The methodology also does not take into account behaviour-based approaches which aim to reduce water consumption through actions which aim to conserve water, such as turning wash-hand basin taps on for shorter periods. This approach has been successfully integrated into school curricula [9].

It could, however, be argued that the primary purpose of the SWUM-based methodology is not to be highly accurate but to provide a simple and rapid way of *identifying and evaluating possible ways of reducing water consumption* in schools [12]. By basing the model on readily available data, the approach can be used by non-professionals, including school principals, school staff and school governing bodies (SGBs) who can use it to rapidly identify possible ways of improving their water consumption. In this way, it provides valuable early guidance to schools on ways water consumption may be reduced so that they can engage and instruct external parties such as water engineers, landscaping firms, and plumbing contractors appropriately. A recommendation, therefore, would be the further development and testing of the SWUM at more schools to refine the approach. This should include a representative sample of the type of schools that exist in South Africa including rural schools.

6 Conclusion

The application of the School Water Use Model methodology to the case study school is used to identify and evaluate interventions to reduce water consumption. The methodology proves effective at enabling possible interventions to be identified and tested to identify the most promising options. A critical review indicates that the approach is suitable as an early-stage, feasibility and decision-support tool rather than a precise modelling, diagnostic or predictive tool.

Application of the methodology as an early stage decision-support tool shows significant promise. By being simple to use and only requiring readily available data the tool is highly suitable for 'non-professional' users, such as school principals and staff who can use this to identify valuable opportunities to reduce water consumption and school operating costs.

It is recommended that the methodology is refined further and tested at a range of schools. This could be supported by converting the current Excel-based tool to an online tool which schools could pilot. Feedback from this process could be used to develop a final online tool which could be used by schools to reduce water consumption.

Acknowledgements

The author would like to thank Gauge for providing access to the tool, the school for data and the reviewers for their feedback on the paper.

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