Document number: W361-FOR-001

Final Operational Report:

NEWgenerator™ Off-grid Treatment System - Khanyisani Primary School

Rev	Date	Description	Author
0	17/06/2024	Submission to client	Aphiwe Mapetere

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Table of Contents

List of Tables 3

List of Figures 3

A. Evaluation period 5

B. Introduction 5

C. Process overview and operational philosophy 5

D. Plant performance 7

D.2. Treated water quality 7

D.2.1. Chemical oxygen demand (COD) 9

D.2.2. Total suspended solids (TSS) 10

D.2.3. Nutrient (nitrogen and phosphorus) removal 11

D.2.4. pH 13

D.2.5. E. coli 14

D.3. Treated water production and water balance 15

E. Operational overview and challenges 17

E.1. Overview of operations 17

E.2. Operational challenges 18

F. Conclusions 20

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

List of Tables

Table 1: Measures and resources utilised in the operation and maintenance of the Khanyisani Primary School NEWgenerator™ system..... 6

Table 2: NEWgenerator™ laboratory analysis results from raw and product (treated) water sample results taken from October 2023 to April 2024..... 8

Table 3: Comparison of treated water sample results taken from October 2023 to April 2024 to SANS 30500 standards for reuse..... 9

Table 4: NEWgenerator™ water meter readings for every month and calculated average supply rate. 16

Table 5: Summary of operational incidents and responses from October 2023 to April 2024 18

List of Figures

Figure 1: COD concentrations and percentage removal achieved for treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit for COD 10

Figure 2: Total suspended solids (TSS) concentrations achieved for treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit for TSS. 11

Figure 3. Left: Photograph of raw (left) and treated (right) water samples taken on 17 April 2024. Right: Zoomed-in image of treated water sample showing tiny particles of undissolved granular chlorine. 11

Figure 4: Percentage total nitrogen (TN) removal achieved from October 2023 to April 2024. Dashed line represents SANS 30500 minimum percentage removal requirement..... 12

Figure 5: Percentage total phosphorus (TP) removal achieved from October 2023 to April 2024. Dashed line represents SANS 30500 minimum removal percentage requirement..... 13

Figure 6: pH of treated water achieved from October 2023 to April 2024 compared to upper and lower SANS 30500 limits for pH (dashed lines). 14

Figure 7: E.coli concentration observed in treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit. 14

Figure 8: Valve (encircled in red) used to transfer rainwater supply to flushing water storage tank..... 15

Figure 9: Water balance comparing the average daily flowrate of toilet flushing water supplied by rainwater versus NEWgenerator™. The percentage of water that is ultimately recycled once flushed (regardless of original source) is also shown. 17

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Figure 10: Leaking permeate pump replaced in January 2024 19
Figure 11: Original (left) and new (right) permeate pump and motor control valve arrangement with backwash flow direction. 20

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

A. Evaluation period

Report	Date
W361-QOR-001	01 April 2023
W361-QOR-002	30 September 2023
W361-FOR-001	**01 October 2023 – 31 April 2024**

B. Introduction

Many South African schools located in rural areas lack adequate sanitation. These schools are mainly found in villages where pit toilets are mostly used. The pit toilet system is unhygienic and has thus caused the widespread transfer of infections such as diarrhoea, cholera, and intestinal worms. Furthermore, many rural schools are in water-scarce areas where water conservation is paramount.

One such school is Khanyisani Primary School located in the low-rainfall area of Bizana in the Eastern Cape. Prior to the installation of the NEWgenerator™ system in 2022, the learners and teachers at the school were dependent on pit toilets. This document serves as the final operational report to the Water Research Commission (WRC), focussing on the operational performance and efficiency of the system during the final project months of October 2023 to April 2024.

C. Process overview and operational philosophy

The NEWgenerator™ is a modular, off-grid sewage treatment system developed by the University of South Florida (USF). It treats sewage through using an anaerobic membrane bioreactor, nutrient capture system and electro-chlorination to produce treated water, biogas, and liquid fertiliser. Treated water can be recycled for toilet flushing to reduce the external water demands. It is equipped with a solar system to provide all power required for off-grid operation.

The operational and maintenance measures implemented for the Khanyisani NEWgenerator™ system are outlined in Table 1. These measures were applied based on the philosophy of providing a sanitation system that is not only off-grid (with no reliance on municipal supply of water and electricity), but also robust, i.e., with minimal downtime of the treatment system.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Table 1: Measures and resources utilised in the operation and maintenance of the Khanyisani Primary School NEWgenerator™ system

No.	Measure implemented	Description	Function(s)
1.1	Ewon and eCatcher installation	Modules and programmes installed to provide internet connection to the plant.	Remote monitoring - allows data from site to be observed from anywhere in South Africa
1.2	Onsite caretaker	Local community member employed to oversee the operation of the back-end system and housekeeping of front-end toilet block	- Fulfil housekeeping and minor maintenance tasks daily - Monitor the system for abnormalities - Notify WEC technical support of any abnormalities or breakdowns
1.3	WEC operational checklists	Recording of tasks, observations and measurements by caretaker.	Outlines clear objectives for daily tasks around the system that ensures adequate maintenance and provides useful site information
1.4	Monthly site visits and sampling	WEC support visits the site monthly	This monthly visit includes site inspection, sampling of the plant for laboratory analysis, supply of consumables and spares and to resolve any mechanical or technical issues that are reported.
1.5	WEC maintenance technicians	WEC personnel that can respond to installation, maintenance, and repair requirements.	Utilised for cases when additional installations/replacements are needed, when planned maintenance tasks need to be performed, or when there is a breakdown of the plant that needs resolution

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

D. Plant performance

The performance of the system is evaluated in terms of:

(i) the quality of water recycled by the NEWgenerator™ based on laboratory analyses, and

(ii) the water balance of the system which provides average volumes of water treated and recycled daily.

D.2. Treated water quality

The laboratory results for the months of October 2023 to April 2024 are shown in Table 2. The results of February 2024 have been excluded due to the incorrect sampling procedures followed. Hence, sampling was extended to April 2024 to ensure that 6 months of representative sampling results could be presented.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Table 2: NEWgenerator™ laboratory analysis results from raw and product (treated) water sample results taken from October 2023 to April 2024

Parameters	Units	October 2023		November 2023		December 2023		January 2024		March 2024		April 2024	
		Raw	Product	Raw	Product	Raw	Product	Raw	Product	Raw	Product	Raw	Product
Faecal coliforms	MPN/100 mL	46000	81	>100000	<1	>2420	<1	>2420	<1	>2420	<1	>2420	<1
COD	mg/L	1158	213	9139	101	870	85	3882	25	12296	28	1882	25
Free and saline ammonia as N	mg/L	279	291	376	266	360	459	119	4.11	355	41	277	48
Nitrate as N	mg/L	<0.1	0.1	<0.1	3.8	<0.25	<0.25	0.73	<0.25	0.25	0.93	0.25	0.25
Free chlorine	mg/L	<0.1	<0.1	<0.1	32	-	-	<0.1	<0.1	-	0.1	-	0.1
TSS	mg/L	517	40	3865	146	194	51	1865	18	7665	18	1080	18
Electrical conductivity	mS/m	392	430	504	426	597	585	207	11,9	451	257	588	192
Total phosphorus	mg/l	28	28	102	33	47	22	51	2,34	57	0.63	21	1.54
E. coli	CFU/100mL	34000	60	>100000	<1	>2420	<1	>2420	<1	2420	<1	>2420	<1
Turbidity	NTU	394	23	>4000	113	350	79	>1000	2.3	>1000	3	>1000	12
Colour	Pt-Co	310	66	600	12	1510	358	8020	23	301	10	159	<10
BOD	mg/L	546	96	7200	<10	32	7	-	-	1573	2	-	-
TKN	mg/L	325	311	711	266	448	476	218	26	833	48	388	63
pH		7.2	7.6	-	-	7.7	7.8	6.5	7.1	6.9	7.2	7.8	7.5

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

From these laboratory results, the quality of treated water has been compared to the SANS 30500 standards for reuse (Table 3) and discussed in the following sections.

Table 3: Comparison of treated water sample results taken from October 2023 to April 2024 to SANS 30500 standards for reuse

Determinant	SANS 30500 Limit	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Mar 2024	Apr 2024
COD	≤ 50 mg/L (reuse)	213	101	85	25	28	25
TSS	≤ 50 mg/L (reuse)	40	146	51	18	18	18
Total N	≥ 70% reduction	39	62	-6.25	88	94	84
Total P	≥ 80% reduction	0	68	78	95	99	93
pH	6-9	7.6	-	7.8	7.1	7.2	7.5
E. coli	100 CFU/L	600	1	1	1	1	1

D.2.1. Chemical oxygen demand (COD)

At 213 mg/L, the COD concentration was well above the SANS 30500 limit of 50 mg/L in October 2023, even though a reduction of 82% had been achieved from an influent concentration of 1158 mg/L (Figure 1, Table 2). In November and December 2023, the removal rates improved to 99% and 90%, respectively, however these excellent rates were not sufficient to achieve the SANS 30500 limit.

In the NEWgenerator™, COD is removed in the anaerobic baffled reactor (ABR) as well as the granular activated carbon (GAC) media in the final nutrient capture tank. Therefore, to further improve the COD removal, the GAC media was replaced in January 2024. This resulted in consistently low treated water COD concentrations of 25, 28 and 25 mg/L in January, March and April 2024, respectively. As such, the COD in the treated water has remained compliant since the GAC media replacement.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

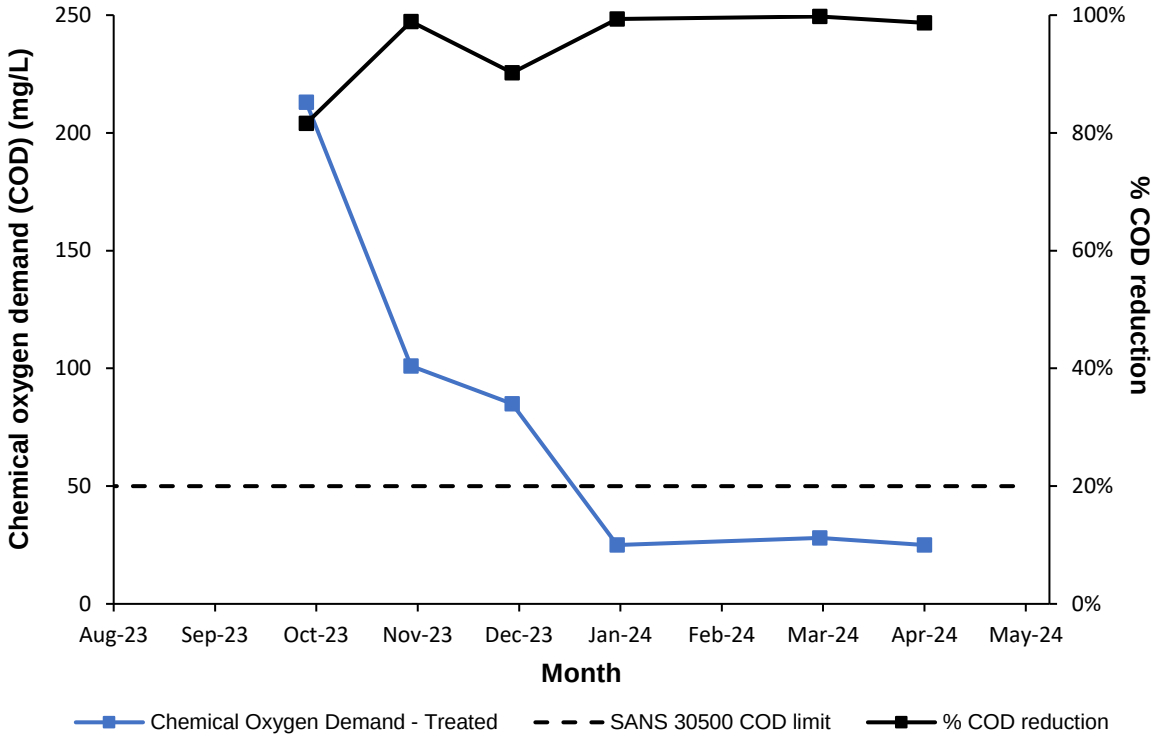

Figure 1: COD concentrations and percentage removal achieved for treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit for COD

D.2.2. Total suspended solids (TSS)

Unfortunately, TSS concentration in the treated water remained above the limit of 10 mg/L for the period considered (Figure 2). In the NEWgenerator™, the ultrafiltration (UF) membrane is responsible for TSS removal. However, it is unlikely that the observed TSS in the treated water is due to membrane breakthrough. Instead, visual inspection of the samples shows that it is more likely due to the granular chlorine (HTH) used in the process which has not fully dissolved in the treated water (Figure 3).

This is further substantiated by the peak TSS of 146 mg/L coinciding with high levels of free chlorine (32 mg/L, Table 2) in the product water in November 2023. Hence, the relatively high TSS concentrations observed are not indicative of poor effluent quality. Nevertheless, an alternative granular chlorine product has since been applied to the process to reduce the concentration of undissolved particles as shown in the consistent TSS product concentration from January to April 2024.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

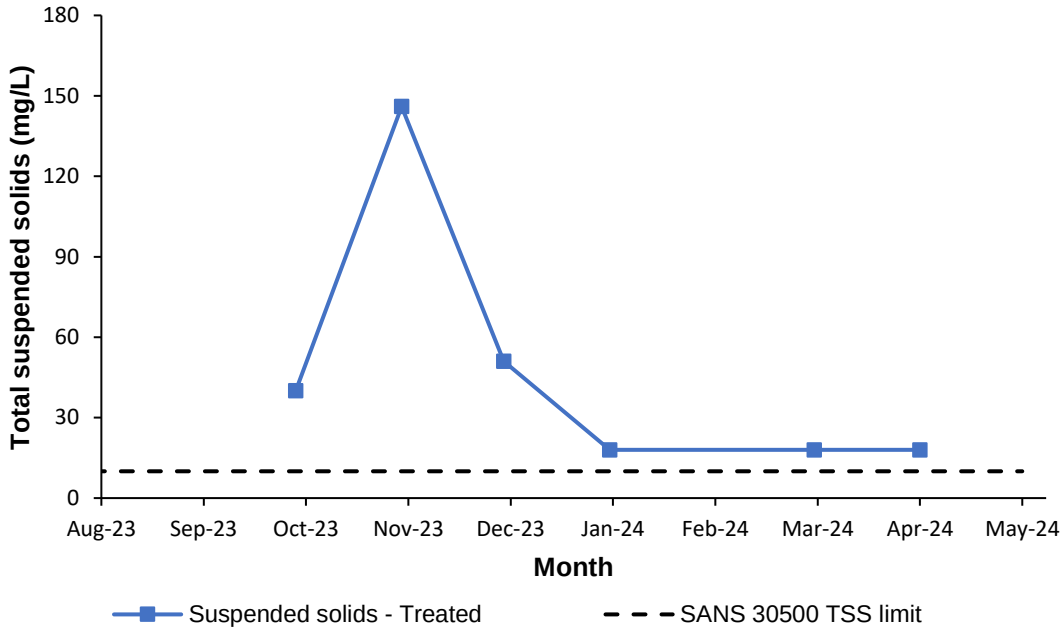

Figure 2: Total suspended solids (TSS) concentrations achieved for treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit for TSS.

Figure 3. Left: Photograph of raw (left) and treated (right) water samples taken on 17 April 2024. Right: Zoomed-in image of treated water sample showing tiny particles of undissolved granular chlorine.

D.2.3. Nutrient (nitrogen and phosphorus) removal

After TSS removal in the UF module, the wastewater passes through two nutrient capture tanks filled with zeolite media for the removal of nitrogen and phosphorus compounds. During the period of October 2023 to April 2024, the trends observed for total nitrogen (TN) and

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

phosphorus (TP) removal were similar in that the percentage reductions achieved in the first three months were the below the SANS requirements of 70 and 80%, respectively (Figure 4 and Figure 5). This was followed by removal percentages above the respective limits from January to April 2024 as a result of the remedial action of zeolite media regeneration completed in January 2024. The negative TN removal percentage of -6.25% in December 2023 indicates that the media was saturated with nitrogen and therefore adding to nitrogen to the wastewater instead of removing it.

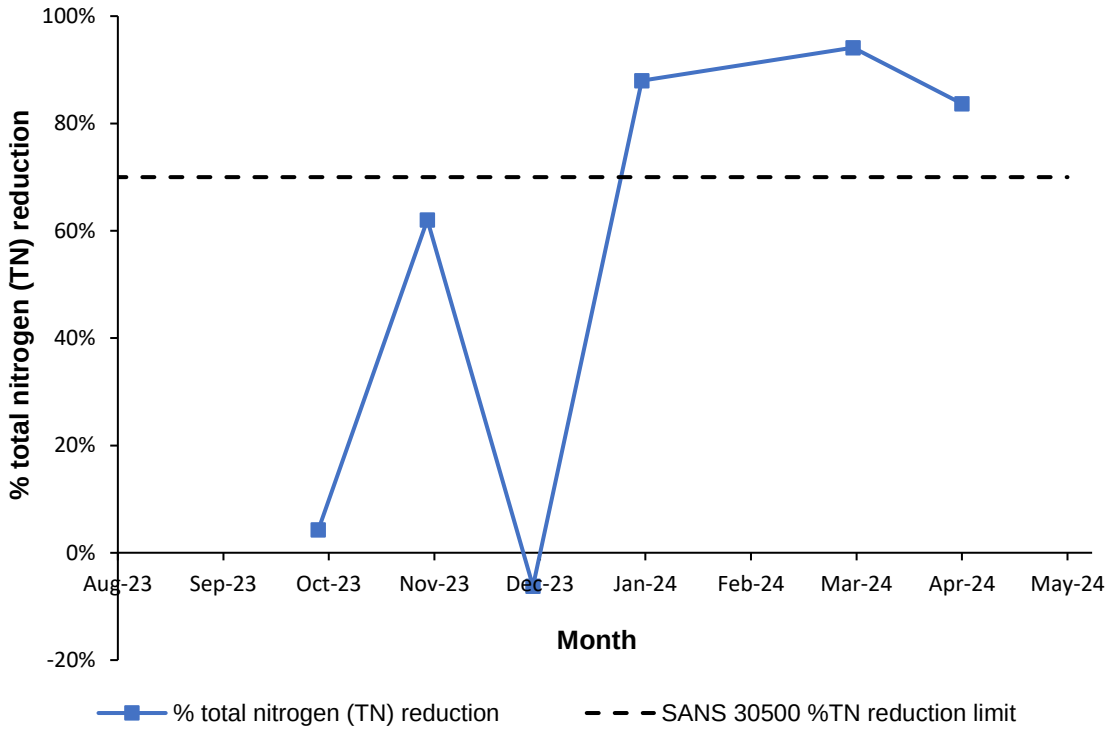

Figure 4: Percentage total nitrogen (TN) removal achieved from October 2023 to April 2024. Dashed line represents SANS 30500 minimum percentage removal requirement.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

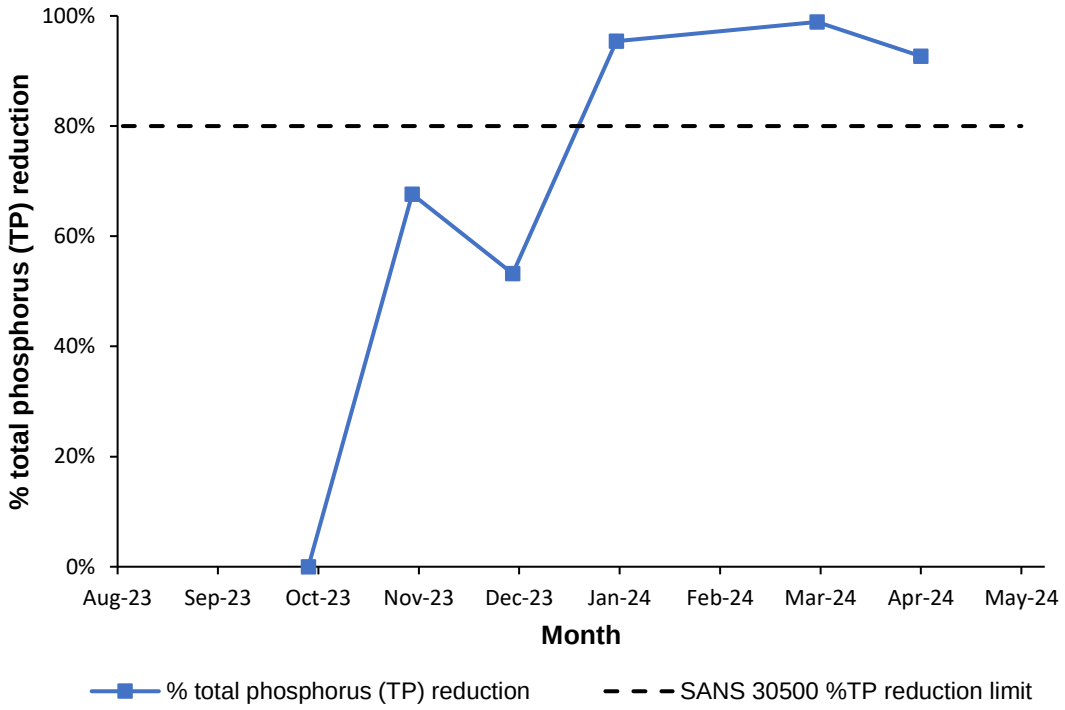

Figure 5: Percentage total phosphorus (TP) removal achieved from October 2023 to April 2024. Dashed line represents SANS 30500 minimum removal percentage requirement.

The maximum TN removal of 94% was achieved in March 2024. Similarly, the TP removal reached a maximum of 99% in the same month. These percentages have since reduced to 84% for TN and 93% for TP in April 2024, indicating a progressive reduction in nutrient removal efficiency. Hence, the system is likely to require another media regeneration cycle within the next three months to prevent the removal percentages dropping below the respective SANS 30500 requirements.

D.2.4. pH

The pH of the treated water remained between the upper and lower SANS 30500 limits, ranging between 7.1 and 7.8 for the period of October 2023 to April 2024 (Figure 6).

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

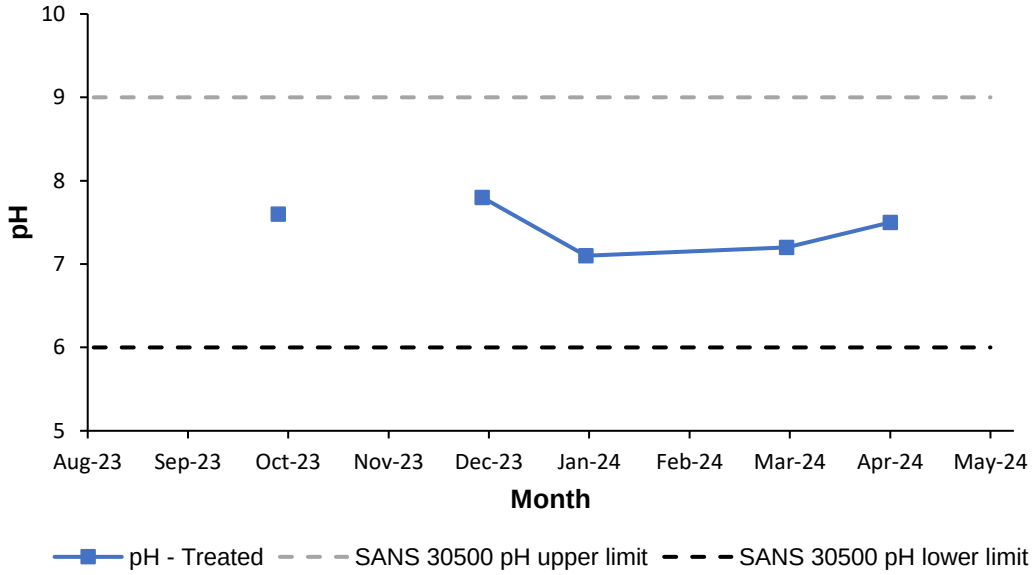

Figure 6: pH of treated water achieved from October 2023 to April 2024 compared to upper and lower SANS 30500 limits for pH (dashed lines).

D.2.5. E. coli

Apart from a spike in October 2023, the system was compliant with regard to bacterial pathogens (as indicated by concentration of E. coli) for the period considered (Figure 7). This spike also explains that the high concentration of free chlorine and resultant high TSS observed in November 2023 (Figure 2) was likely due to the overcompensation from the previous month.

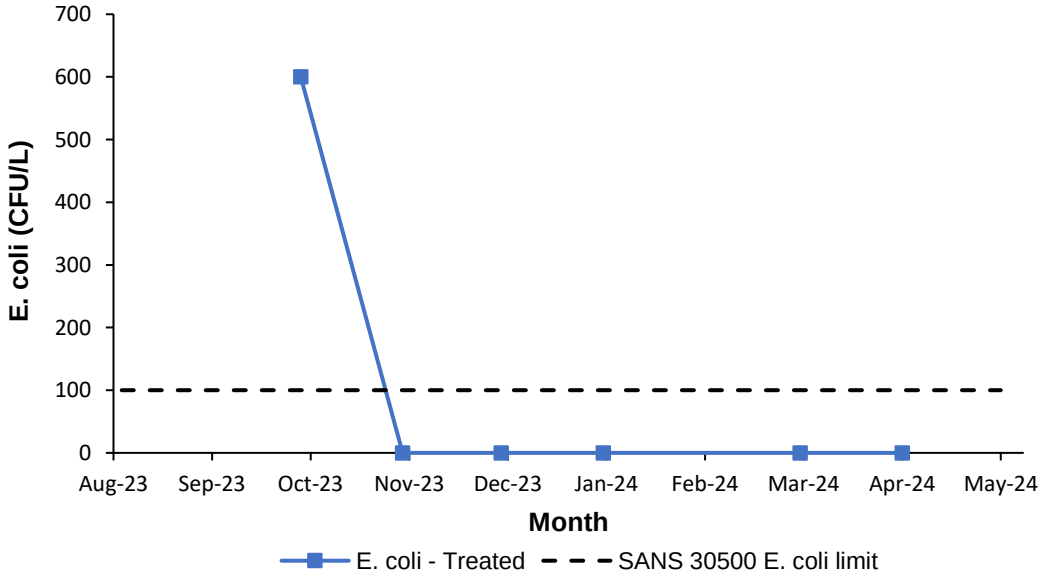

Figure 7: E.coli concentration observed in treated water from October 2023 to April 2024. Dashed line shows SANS 30500 reuse limit.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

D.3. Treated water production and water balance

To evaluate the amount of water treated by the NEWgenerator™ system, water meter readings from the rainwater supply line (FG001) and the treated water to storage tank line (FG002) were recorded and the average rate of supply from each line was determined.

Table 4 shows the meter readings that were recorded as well as the calculated supply rate of rainwater and production rate of treated water for flushing. Due to the arrangement of the rainwater storage tank (used to fill handwash basins) and the treated water storage tank (used to fill toilet cisterns), water only flows into the tank when toilet systems are in use and water is being drawn from the tanks. If no water is being flushed, treated water will not be drawn from the storage tanks and no water is sent to the NEWgenerator™ for treatment. Thus, only the days when the school was active, i.e., weekdays the during term, were considered as working days for more representative analysis.

In the case of plant breakdown or maintenance, the valve shown in Figure 8 is used to divert rainwater supply into the flush water tank.

Figure 8: Valve (encircled in red) used to transfer rainwater supply to flushing water storage tank

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Table 4: NEWgenerator™ water meter readings for every month and calculated average supply rate.

Date	Total number of days	Actual working days	Incoming water from rainwater tank to NEWgen™ (FG001)	Treated water from NEWgen™ to toilets (FG002)	FG001 - total volume (m^3)	FG002 - total volume (m^3)	Average treated water flow (m^3/day)	Average rainwater flow (m^3/day)
18-Oct	31	15	29	50	8	7	0.47	0.53
18-Nov	30	20	39	59	10	9	0.45	0.50
07-Dec	19	14	39	64	0	5	0.36	0.00
29-Jan	54	17	50	68	11	4	0.24	0.65
22-Feb	24	19	55	70.5	5	2.5	0.13	0.26
20-Mar	29	19	56	72.5	1	2	0.11	0.05
19-Apr	30	13	61	77	5	4.5	0.35	0.38

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

When presented graphically (Figure 9), it is clear that the treated water available for flushing decreased from 0.47 m^3/day in October 2023, reaching the lowest point of 0.11 m^3/day March 2024. This decline in treated water production can be attributed to the operational challenges discussed in Section E.2. Positively, however, the fraction of water recycled remained high, at an average of 90% throughout the period considered. This means that on average, 90% of the water introduced into the system was treated for use as flush water.

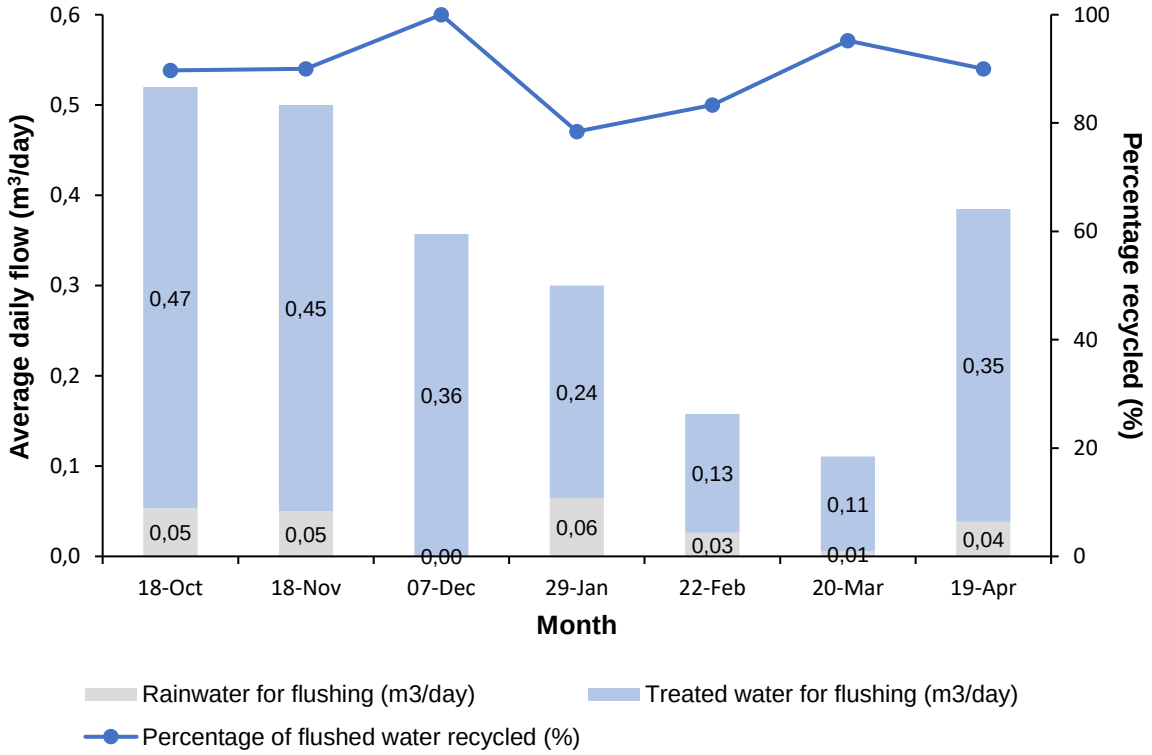

Figure 9: Water balance comparing the average daily flowrate of toilet flushing water supplied by rainwater versus NEWgenerator™. The percentage of water that is ultimately recycled once flushed (regardless of original source) is also shown.

E. Operational overview and challenges

E.1. Overview of operations

The NEWgenerator™ at Khanyisani Primary School is staffed by one local caretaker to overlook the daily and weekly tasks. Major maintenance tasks and equipment breakdowns were tended to by WEC technical personnel. Examples of operational tasks include the following:

Daily tasks

- Cleaning and disposal of solid objects of the bar screen
- Recording of water meter readings

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

- Residual free chlorine measurement
- Storage tank level measurement
- Recording of system pressures and flows from instruments

Weekly tasks

- Topping up of disinfection chemicals
- Observation of plant sequences such as backwashing
- General housekeeping around plant
- Inspections of leaks and equipment abnormalities

Monthly tasks

- Site inspections
- Mechanical and electrical inspections
- Water sampling
- Restocking of janitorial supplies

Major maintenance tasks

- Chemical enhanced membrane clean (CIP) – performed annually
- Salt regeneration of nutrient capture media – performed every 6 – 12 months

E.2. Operational challenges

A summary of the operational issues experience from October 2023 to April 2024 and how they were resolved is shown in Table 5.

Table 5: Summary of operational incidents and responses from October 2023 to April 2024

Month	Incident	Resolution
Oct 2023	Overflow on NCS tank	WEC technician sent out to rectify problem
Oct 2023	Overflow on ABR tank	WEC technician sent out to rectify problem
Nov 2023	Leak from permeate pump	Area cleaned up and pump fittings were tightened
Jan 2024	Membrane CIP	WEC personnel performed CIP
Jan 2024	Nutrient capture tank regeneration required	WEC personnel performed regeneration tasks
Jan 2024	Leak from permeate pump – damaged diaphragm	Pump replaced with available spare
Feb 2024	Feed pump tripping the plant	WEC technician sent out to rectify problem

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

Month	Incident	Resolution
Mar 2024	Spare permeate pump failure – no recycle water production	WEC technicians sent out to rectify problem – permeate pump and motor valve swapped changed to locally sourced pump
April 2024	Feed pump failure due to suction line blockage	Pump replaced – operator trained on how to inspect suction line ensure and ensure it remains clear by clearing any blockages

The most recurring issue during this period was the permeate pump failure (Figure 10). This is a critical component of the system because it is responsible for the transfer of filtered water to the NCS system and into the product tank. This was the primary reason for reduced production of treated water between January and March 2024. After the pump failed in January 2024, it was replaced with an identical spare pump which WEC had available in stock.

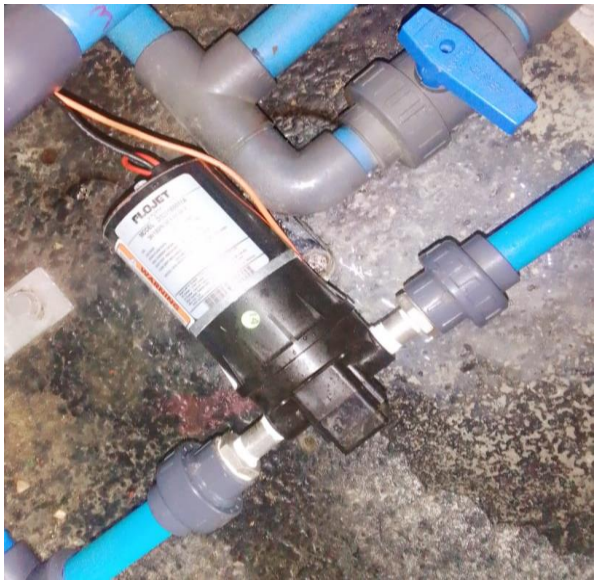

Figure 10: Leaking permeate pump replaced in January 2024

Once the spare pump failed again March 2024, further interrogation of the system revealed a flaw in the permeate piping arrangement (Figure 11, left). It became evident that the permeate pump was not able to withstand back pressures produced from other pumps in the system. When the backwash sequence occurred, the backwash pump would push water into the permeate pump and therefore rupture the diaphragm inside, hence the continuous breakdowns of this pump.

To rectify this problem, the permeate pump and the motor control valve were swapped (Figure 11, right). By doing this, the motor control valve can close and protect the pump from the pressures supplied by the backwash pump. The backwash pump and its corresponding valve

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed

are arranged in this way which is why it has not failed since. This discovery will be implemented in future NEWgenerator™ designs to prolong pump lifespans.

Furthermore, the decision was made to replace the pump with a more robust, locally-sourced alternative. Since WEC did not have this pump available in stock for an immediate replacement, the longer lead time led to the low production rates observed in March 2024.

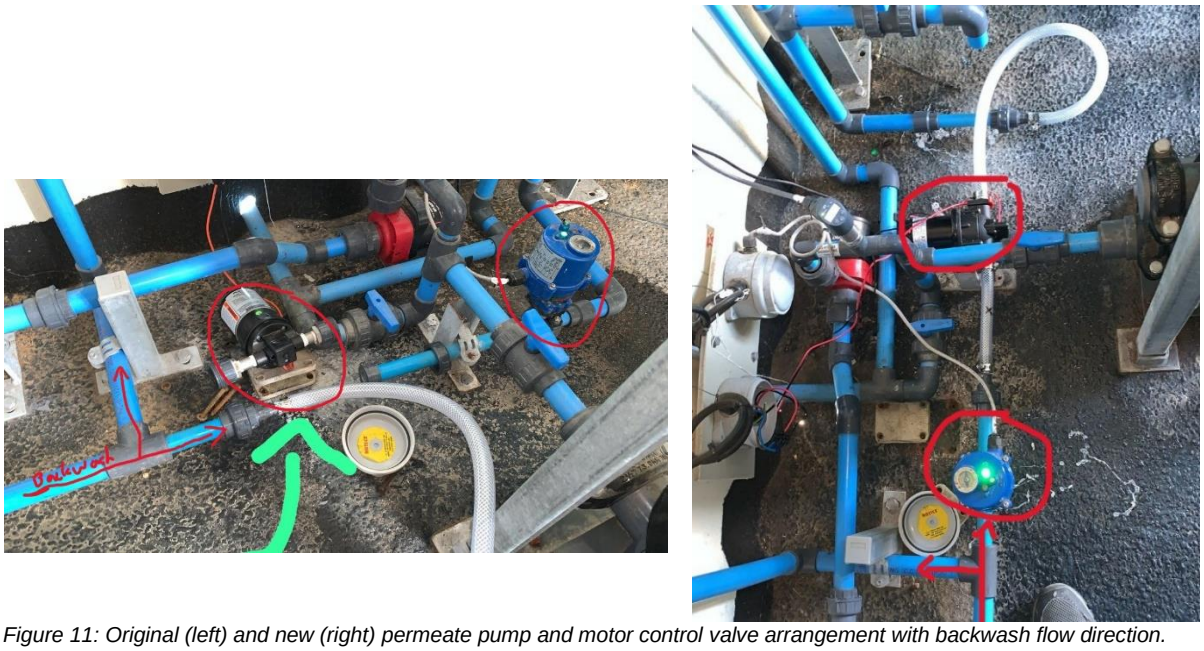

Figure 11: Original (left) and new (right) permeate pump and motor control valve arrangement with backwash flow direction.

F. Conclusions

Since its commissioning in November 2022, the NEWgenerator™ system has continued to provide the learners and staff at Khanyisani Primary School with high-quality, dignified sanitation. While the system has not been without its operational issues, these issues have served as lessons learnt for the improvement of this current system and implementation in future NEWgenerator™ systems.

As the operational responsibility of the Khanyisani NEWgenerator™ system will now be handed over from the WRC to the Department of Basic Education (DBE), it is hoped that a new partnership between WEC Projects and DBE can be formed in order to ensure that the operations and maintenance requirements of the system are met, and Khanyisani Primary School continues to benefit from it.

This document and the details contained herein are confidential and intended for the individual to whom it has been addressed. This document in its entirety (or in parts) may not be circulated or distributed