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Effects of operational strategies on drinking water quality in intermittent water supply systems

The case of Moamba, Mozambique

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Master of Science Thesis
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Abstract

The prevalence of intermittent water supply (IWS) is a global challenge, and IWS has been often associated with poor drinking water quality. The mechanisms which contribute to water quality deterioration and the perceptions of consumers under intermittent supply have been studied in recent years, but there are still unknowns both in terms of fundamental research and applied research. Regarding the latter, water operators still need to fully understand how operation of IWS systems can affect water quality, and consequently develop strategies for improving water quality within the distribution system until reaching the consumers' taps.

This study is aimed at assessing and improving operational strategies in an IWS system of a small town of southern Mozambique. In this context, different chlorine dosages and chlorine dosing strategies were tested to understand their effect on water quality. Moreover, the effect of first flush and duration of supply were investigated. Water quality was monitored in different points along one line in the distribution from the outlet of the water tower, through 4 consumers' taps up to a distance of 2.2 km from the water treatment plant. Under the different operational strategies, physico-chemical parameters (free and total chlorine, turbidity, pH, conductivity and temperature) and faecal indicators (*E.coli* and total coliforms) were monitored.

In the baseline assessment, 10 out of 34 samples from the taps had free residual chlorine concentration lower than 0.2 mg/L and none of the 34 samples had a residual chlorine concentration greater than 0.4 mg/L. 68% of the collected samples from both neighbourhoods revealed to have the presence of indicator bacteria. The mean value of *E.coli* present was 2 CFU/100mL.

An average free residual chlorine of 0.46 mg/L was observed during the chlorine dosage and dosing strategy optimization experiment and this resulted in a reduction in the number of samples positive to faecal contamination in the distribution system. The average turbidity reading at the consumer taps were 7.8 NTU with a standard deviation of 5.4.

The first flush effect on water quality was monitored for the first 60 minutes in the morning and 60 minutes during the afternoon first flush event. The maximum turbidity level of 9.6 NTU was recorded and decreased after 30 minutes during the first flush event at the sampling point 2.2 km away from the WTP. *E.coli* was identified in the first flush sample collected having the mean value count of 4 CFU/100mL. Free chlorine concentration in Cimento during both the morning and afternoon first flush events were 0.5 mg/L, which is higher relative to that of Matadouro's 0.3 mg/L. However pressure reading at Matadouro was 1.8 bar high when compared to the pressure reading in Cimento of 1.2 bar during the first flush events. Observation of turbidity levels showed a variation of turbidity with distance, with the farthest points of the selected neighbourhoods having the highest average turbidity reading of 8.2 NTU with a standard deviation of 4.2

Using the modified dosage and dosing strategy resulted in the improvement of water quality at consumer taps. However, comparing the free residual chlorine concentration at the

consumer taps before the supply stops and when it resumes after a period of no supply, there is always a reduction in concentration.

The residual chlorine results showed that, the duration of supply of water (CWS for 10 hours or 12 hours) does not influence the concentration of the free residual chlorine at the consumer taps, but conditions such as the internal pipe characteristics and operational conditions prior to the supply has an effect on residual chlorine. The results of the microbiological analysis shows that, the mean value of *E.coli* during the 12 hours of supply was higher than that of the mean *E.coli* identified during the 10 hours of supply.

First flush water quality at the beginning of each supply cycle sees free residual chlorine exhibiting a gradual increments at consumer taps within the first hour of supply start-up. From 0.2 mg/L to 0.3 mg/L at Matadouro and at Cimento 0.49 mg/L to 0.59 mg/L.

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Abbreviations

CFU	Colony-forming unit
CWS	Continuous Water Supply
DC	Distribution Centre
EPA	Environmental Protection Agency
IBNET	International Benchmarking Network
IWS	Intermittent Water Supply
NTU	Nephelometric Turbidity Units
PAHO	Pan African Health Organisation
PSI	Pounds per Square Inch
PVC	Polyvinyl Chloride
SDG	Sustainable Development Goal
TSS	Total Suspended Solids
UN	United Nations
UNICEF	United Nation Children's Fund
WHO	World Health Organisation
WSP	Water and Sanitation Program
WTP	Water Treatment Plant

1

INTRODUCTION

1.1 Background

Provision of safe drinking water is an essential activity that must not be compromised. The Sustainable Development Goal (SDG) 6, target 6.1 affirms this notion, as it aims to achieve "by 2030, a universal and equitable access to safe and affordable drinking water for all". This target will be tracked by using indicator 6.1.1 which looks at the "proportion of population using 'safely' managed drinking water" (UN, 2016). This indicator is a measure of the proportion of people that are having access to improved drinking water sources located on premises, available when required (> 12 hours per day) and free of faecal contamination and other hazardous substances. The direct correlation of safely managed drinking water to improved health and to the economies of nations cannot be overestimated. As 71% of the world's population uses safely managed drinking water (water service is located on the compound, it is available in time of need and is free from contamination) (WHO/UNICEF JMP, 2015).

Nevertheless, over 300 million people globally are provided with water through pipes lasting for limited durations (Kumpel and Nelson, 2016), a phenomenon known as intermittent water supply (IWS). In IWS systems, water supply companies are not able to supply water continuously and sustain a positive operating pressure within the distribution network (Agathokleous and Christodoulou, 2016, Galaitsi, et al., 2016). Many countries in Africa, Asia and Latin America practice IWS as a normal operational strategy due to the enormous levels of leakage in the distribution network, making it virtually impossible to operate a continuous supply system (Charalambous and Laspidou, 2017). The Pan African Health Organisation (PAHO) and World Health Organisation (WHO) in 2001 estimated that Latin America and the Caribbean had 60% of its population having household water connections experiencing IWS. However this situation has improved drastically with 93% coverage within this sub-region now having access to drinking water(WHO/UNICEF JMP, 2015) . Houses having access to piped water on their compound is considered as improved water source (WHO/UNICEF JMP, 2015), however this phenomenon alone is not sufficient, since there is a need to consider the main factors that constitute "improved water source": reliability, safe water and adequacy (houses that have the capacity to access sufficient amount of water when needed and free from faecal contamination (Heitzinger, et al., 2015, Shaheed, et al., 2014, WHO/UNICEF JMP, 2015). In Africa coverage is estimated to be 76 %, but it is not necessarily related to safely managed drinking water; that implies that IWS is very rampant in Sub-Saharan Africa (WHO/UNICEF JMP, 2015). In Central & Southern Asia coverage is approximately 40% and this sub-region is also experiencing widespread IWS (WHO/UNICEF JMP, 2015). The situation in India is dire, with the Water and Sanitation Program (WSP) of the World Bank reporting that continuous water supply is absent in most of the major cities in India (WSP, 2001). The situation is very

appalling since for a supply duration of 2-3 hours per day is considered acceptable, and on certain days it can be as low as 1 hour a day (Charalambous and Laspidou, 2017).

Reweta and Sampath (2000) noted that the demand for safe water supplies has increased in the last 10 years due to the improvement of per-capita income, population and the increase in standards of living. This phenomenon has inevitably put stress on the existing water infrastructure and development in these countries, but the financial muscles to match these demands are restricted. Various studies noted that IWS is multi-faceted and it is co-produced by lack of water resources, infrastructure deficit and the ever increasing high non-revenue water (Charalambous and Laspidou, 2017). The repercussions normally associated with IWS vary, and range from a) stagnation periods which lead to microbial regrowth, b) detachment of biofilms as a results of surges in pressure and velocity, c) ingress of contaminants during non-pressurised periods of the distribution system (Coelho, et al., 2003). Another major challenge of IWS systems is to maintain good water quality throughout the water distribution network (Elala, et al., 2011, Kumpel and Nelson, 2013). The difference in water quality has been proven to be directly proportional to the water age (Momba, et al., 2000). To overcome the practical challenges associated to IWS, consumers often rely on household storage containers that enable them having readily available water (Ayoub and Malaeb, 2006).

At the same time, small towns in low and medium income countries are experiencing an increase in population, but the development and appropriate management of the water infrastructure and services is lagging behind (Matsinhe, et al., 2008). The majority of population of Mozambique lives in small towns where water and sanitation might be a challenge (Gumbo, et al., 2003). WHO/UNICEF (2014) reported that access to sufficient potable drinking water stands at 49% of the country's total population, out of which 80% are in urban areas, leaving 35% as rural settlers. 18% of the urban dwellers have piped water on premises, versus 2% in the rural areas.

1.2 Problem Statement

One of the issues often associated to IWS is poor water quality. Kumpel and Nelson (2013) concluded that water supplied continuously showed lower contamination at consumers' taps if compared to IWS. A study conducted in Panama also revealed that supply areas connected to IWS systems risked having intrusion and backflow, since continuous pressure monitoring revealed the occurrence of negative pressures (Erickson, et al., 2017). Another study conducted on the effect of IWS on water quality in Lebanon concluded that changes in pressure, water stagnation and difference in chlorine residuals are a result of IWS and its consequence is the deterioration of water quality at consumers' taps (Ayoub and Malaeb, 2006). Faecal contamination in IWS is the evidence of intrusion during times of low or negative pressure (Coelho, et al., 2003).

The presence of *E.coli* or other faecal indicator bacteria is normally associated with IWS systems, when residual chlorine concentrations at the taps are below 0.2 mg/L, the guideline value recommended by WHO (2011). This is reported in the research conducted in Hubli and Dharwan, India, which revealed samples being positive for *E.coli* when the residual chlorine was below 0.2 mg/L (Kumpel and Nelson, 2013). In Kathmandu, Nepal, low concentration of

free chlorine in the piped water system and the rather high concentration of combined chlorine suggested the reaction of free chlorine and contaminants which intrude the pipe during low pressure periods (Guragai, et al., 2017). Kumpel and Nelson (2014) noted that the percentage of tap water samples in continuous water supply that met the guidelines for chlorine residual was higher than the percentage of samples from IWS network. This confirms the challenge of inadequate residual chlorine concentrations in IWS systems and thus the need to investigate residual chlorine profiles and optimise dosing strategies to improve water quality in IWS distribution networks.

The intermittent operation of water supply systems is also of great concern in Mozambique, where this has generally led to question the quality of drinking water (Matsinhe, et al., 2008). Improving the water distribution systems and coverage also requires both extending the existing network and having an effective monitoring of the operation and management of water quality in the pipelines (Matsinhe, et al., 2014). In order to improve water supply services, a vast amount of investments is required in the advancement of infrastructure or expansion of current ones (Matsinhe, et al., 2014). This solution won't be feasible in most places in Mozambique due to financial constraints, and particularly in small towns. This is because, utilities and investors are more likely to invest in areas where they can recuperate their investment in a short time (Matsinhe, et al., 2008).

Moreover, a large number of Mozambican towns and villages experience IWS with an average time of supply being less than 12 hours per day (Gumbo, et al., 2003). Continuous water supply is done in only 4 out of the 23 cities in Mozambique provided by private operators. This translates to 83% of the country's water supply service is intermittent supply (Matsinhe, et al., 2008). If this situation will persist, it will mean that the great majority of people in Mozambique will certainly not be classified as using 'safely' managed drinking water, according to indicator 6.1.1 of the SDGs. Guragai et al (2017) found evidence that consumers' perception of the level of service in terms of water quality in rural Nepal worsens as the duration of supply decrease. But there is no evidence that correlates the duration of supply cycles to water quality. Research on the effects of IWS systems on water quality has mainly looked at the mechanisms, impacts and technical causes of intermittent water supply.

1.3 Research Goal and Objectives

The goal of this study is to evaluate operational strategies for improving drinking water quality in IWS systems.

The specific objectives are:

i. To determine the optimal strategy for chlorine dosage.
ii. To assess how the typology and duration of supply cycles affect water quality at the point of delivery.
iii. To evaluate the first flush water quality at the beginning of each supply cycle.

The study focuses on the case of a small town of Mozambique, Moamba.

1.4 Research Questions

The research questions are:

1. What is the optimum dose that is required to curtail the levels of bacterial contamination?
2. Does the typology and duration of supply cycles have an impact on water quality?
3. To which extent can the first flush contribute to water quality improvement?

2

LITERATURE REVIEW

2.1 Prevalence of intermittent water supply

The amount of research done on the optimization of distribution systems vary largely, but the literature is skewed towards the management and operation of the distribution system with continuous supply.

When it comes to developing countries, intermittent water supply is one research topic that has been covered to a large extent. Studies conducted in IWS systems range from the prevalence to mechanisms by which IWS systems affect the water quality. Low pressure in pipes contributing to the contamination in the distribution system is one of the mechanism associated with deterioration of water quality in IWS systems (Kumpel and Nelson, 2014). The major evidence established by the research of Kumpel and Nelson (2014) was that, the main mechanism involved in potentially contaminating the distribution system are intrusion, backflow, resuspension of particulate matter or sloughing of biofilms from pipe walls. The effects of IWS system on water quality has been researched by (Klingel, 2012). Urban piped water systems which were originally designed to have continuous supply are used in most cases to supply water intermittently (Charalambous and Laspidou, 2017). It can be stated that, no distribution system was designed to operate as an IWS system (Kumpel and Nelson, 2016). This view is also shared by other researchers (Galaitsi, et al., 2016, Yepes, et al., 2000), with the view that IWS systems are as a result of numerous reasons such as lack of infrastructure to meet demand, limited water resources and increasing leakage in the distribution networks. In an article by Kumpel and Nelson (2016), the estimated number of person relying on intermittent supplies was over 309 million people worldwide. South Asian countries are said to have more than 90% of their population supplied with water for less than 24 hours per day (Totsuka, et al., 2004). Data from IBNET database as reported the variation in supply durations: East Asia and the Pacific have an average supply duration of 16.7 hours being the longest supply duration in an IWS system, and South Asia has an average supply duration of 7.2 hours being the shortest supply duration in an IWS system; Sub-saharan Africa has an average supply of 12.8 hours (Kumpel and Nelson, 2016). The issue of water shortage is commonly resolved by using IWS to ration the limited water resource. This measure is widely used not only in developing countries (Hardoy, et al., 2013, McIntosh, 2003) but also in first class countries also suffers similar measures in solving short-term challenges with water scarcity (Cubillo Gonzales and Ibanez Carranza, 2003). IWS is also quiet rampant in countries in the Mediterranean (Fontanazza, et al., 2007)

It is estimated that the Kathmandu valley in Nepal will need more than 200 MLD (million litres per day) to meet the demand and IWS in this region will continue at least until 2028 (Guragai, et al., 2017).

Major cities in India estimated to have above one third of the population lacking access to safe drinking water, since the level of IWS and the hydraulic challenge of low pressure in the distribution system is a great problem (Charalambous and Laspidou, 2017).
These literature presented shows that IWS is a phenomenon which can no longer go unnoticed. Its prevalence of 309 million people globally (Kumpel and Nelson, 2016) is quiet alarming and with the supply patterns in IWS systems from studies carried out being very different, a number of authors reveal the effect of IWS systems on the quality of water.

2.2 Drivers of intermittent water supply

The main understanding given to why intermittent supply occurs has been attributed to the inability of the water available to meet the demands of consumers. Research however has revealed that, in places such as the Eastern part of India and Bangladesh, even though they have water and have it in abundance, they still do not have continuous supply of water. This is one of the reason why water scarcity cannot be said to the only cause of IWS but many different factors (Charalambous and Laspidou, 2017). It can therefore be said that there are different reasons and factors that bring about IWS. Rampant increases in the population of people in developing and middle income countries, water scarcity, the migration of people from the rural to urban areas which brings about the need for the provision of more water and lack of adequate planning (Charalambous, 2012) are factors that contribute to IWS systems. Each of these causes are further explained in the sub-chapters.

2.2.1 Fast growing population

The everyday increase in the number of people living in the third and second world countries makes the provision of water difficult due to the inadequacy of water infrastructure. (Vairavamoorthy, et al., 2008). The population of the world is expected to increase generally with Africa and certain areas of Southern Asia being the worst culprits (McIntosh, 2003). This is invariably going to affect the water resources as they are already scanty. (Gardner-Outlaw and Engelman, 1997). Reports from (UN DESA, 2011) on population, indicates that, the increase in the population is expected by means of projection to be around 33% spanning from 2011 to 2050.

2.2.2 Water Scarcity

Water scarcity is defined as the “inversely proportional relationship between water resource availability and population on a national scale” (Gleick, 1996). Water scarce area is a classification given to an area which has a large population and having inadequate water for a significant period of time (Rijsberman, 2006). Projections by the Organisation for Economic Cooperation and Development (OECD) 2012 report on water scarcity, predicts that by 2050, 2.3 billion people are projected to live in areas having inadequate water (Connor, 2015). Thus an estimation of water supply in low and middle income countries which reveals that 663 million people still require “improved sources” of drinking water supply (WHO/UNICEF JMP, 2017) gives credence to the establishment of IWS system. This is however an improvement with three quarters of the population of the world having piped water to their premises which indicates an increase of 2.3 billion to 4.2 billion people. With the SDG target 6.1 which unequivocally states that by “2030, achieve universal and equitable access to safe and affordable drinking water for all” reflects the need to work to curb water scarcity.

2.2.3 Urbanization leading to increase in water demand

The rural urban migration phenomenon is in existence in many countries. The number of people expected to move from rural areas to end up living in the urban areas is projected to increase from 3.6 billion to 6.3 billion from 2011 to 2050 respectively this is according to (United Nations, 2013). Reports from the world population policy available data, reveals 80% of governments from 185 countries have put in measures to curb this phenomenon (UN DESA, 2014). These happenings often leads to these now populated cities having to struggle for basic social requirements including potable water. The strain of these amenities often translates to the intermittent water supply becoming even more prevalent (Kumpel and Nelson, 2016). The need to have one of the basic needs (water) which is required for good health and an improved life thus becomes very essential (Charalambous and Laspidou, 2017). This rural urban migration inevitably leads to the need for expansion of the distribution network and a more regularized attitude in the maintenance of the network (McIntosh, 2003). Water supply services is then reduced due to the compromise of policy makers (government) to prioritize expansion of facilities to satisfy the majority (Galaitsi, et al., 2016)

2.2.4 Lack of planning

The relationship between water scarcity and water available but not judiciously used was assessed to evaluate if the scarcity was indeed a case of “physical scarcity” or it was a matter of “demand scarcity” (Rijsberman, 2006). With this assessment, knowing the results of proper planning is very necessary, as it will go a long way in preventing the implementation of IWS schemes (Vairavamoorthy, et al., 2007). In the bid to satisfy everyone’s water needs with limited resources, the need of planning is necessary (Charalambous and Laspidou, 2017). Wasteful use of current water supplies are as a result of lack planning (Rosegrant, et al., 2002). Putting in place proper and well-structured ways to manage the inadequate amount of water in water scarce areas is one of the major challenges (Collier and Venables, 2012). Intermittent water supply is a feature which is real and there is a need to adopt a proactive measure in the planning and design of IWS system to ensure satisfactory results (Khroda, 1996).

2.3 Drinking water quality monitoring

The quality of water from source to consumer taps is dependent on the different treatment and distribution processes undertaken by the water providers. Thus the need to have detailed and accurate assessment of water quality trends. This routine monitoring will help give reliable data for current challenges to be resolved and provide a basis for the future limitations to be acted upon. The International Organization for Standardization (ISO) defines monitoring as “the programmed process of sampling measurement and subsequent recording or signalling or both, of various water characteristics, often with the aim of assessing conformity to specified objectives”. (Bartram and Ballance, 1996). Water quality monitoring gives an indication on the changes water undergoes from its source through treatment, through the distribution network to the consumer. With the different types of monitoring ranging from, source water monitoring, operational monitoring and compliance monitoring (surveillance), the water quality trends can be monitored and always improved for consumer satisfaction. Firstly we can focus on source water quality monitoring. From the definition, one can deduce that, data collection to know the raw water quality is paramount in water quality monitoring. The source water quality monitoring will give an indication on whether the design of the

treatment plant can efficiently treat the raw water. The monitoring data also gives management of water companies an idea on policy directions to take (Bartram and Ballance, 1996).

Secondly the other means of ensuring water quality is the operational monitoring. In operational monitoring, the objective is to verify whether all standards instituted are operating normally as is required and most importantly undertake actions as soon as possible to get it working efficiently. This means of monitoring is undertaken through simply observing and running quick tests for verification of the process. Checking of turbidity, residual chlorine, pH and indicator organisms are all included in operational monitoring. The frequency of operational monitoring is dependent on the control measure being monitored. Thus operational monitoring differs in general. The quality of water supplied to the consumer is the most important objective for monitoring. The data gotten, must be assessed and conclusions drawn to enable recommendations identified and proposed for the efficient and safe supply of water (World Health Organization, 2006).

Thirdly compliance monitoring which is another type of monitoring required in water quality assessment. This type of monitoring seeks to evaluate if water supply companies are strictly complying with the standards and regulations of the water quality required. This type of monitoring is mandatory and is carried out by water services board or authorities backed by legislature. The compliance monitoring assessment is normally done at the start of the monitoring year (Environmental Protection Agency 2010). Water quality control refers to the process of having access to data, comparing data and controlling operations to help reduce or eliminate factors contributing to the pollution of the water by providing means to correct the causal factors (Alley, 2007). This is achieved by two means: Surveillance and Monitoring.
Surveillance as defined by WHO (2011) guidelines “is an investigative activity undertaken to identify and evaluate potential health risks associated with drinking water and a review of the safety and acceptability of drinking water supplies”. With surveillance, the complete drinking water system is covered. This includes the source, treatment plant infrastructure and the distribution system. It further includes the insistence of good storage facilities and appropriate collection mechanisms in the various households (WHO, 2011).

2.4 Factors affecting water quality in intermittent water supply

Different factors have been noted as being the causes of the effects of water quality deterioration in an IWS system. These factors ranges from season variation, transient pressure, turbidity, residual disinfectant, microbial contamination.

2.4.1 Season Variation

The variation in seasons over the course of the year has effects on IWS systems (McIntosh, 2003). The dry season is the period in which the effect of the IWS system is mostly felt, as there is a high demand for water by consumers but due to the season, the rivers are often dried up leading to a more stringent means to distribute the meagre water available (Charalambous, 2012). In the wet seasons, increase in the water table can cause intrusion of contaminants into the distribution lines by means of the backpressure which develops when the surrounding soil becomes saturated (Kumpel and Nelson, 2013). The incidence of high

bacteria contamination, which is invariably inversely proportional to free chlorine concentration has been shown to have a positive relation to temperature (Francisque, et al., 2009).
In Hubli-Dharward, India, the levels of turbidity were high and the levels of free chlorine concentration reduced in samples taken during the wet seasons from both continuous and IWS taps (Kumpel & Nelson, 2013). The same study also noted that in IWS areas, during winter periods, the concentration of bacterial indicators decreased and increased again at the beginning of the wet season.
The quality of water tends to get worse during the rainy season, which may be due to transport of water in the soil through breaks or loosened joints. Contaminants easily getting into the distribution system is made more likely by the intermittent supply nature of the distribution system (Elala, et al., 2011). With the current climate change, the implication of the seasonal variation is likely to lead to even worse effects on IWS and if care is not taken, and distribution systems are left unattended, IWS will be the only option left for utilities to implement all year long (Charalambous and Laspidou, 2017).

2.4.2 Transient pressure

The water quality of distribution systems can be highly impacted upon by factors that can best be described as hydraulic factors. These hydraulic factors comprise of flow characteristics, pressure and water age (Klingel, 2012). Although the provision of stand pipes on the compound of households is considered as an indication of "improved water source", this assumption cannot further suggest that the quality of water is adequate for consumption (Heitzinger, et al., 2015). The intermittency nature of supply established in many developing countries encourages contamination of the water. This intermittency brings about changes in the flow of water. The "no supply" period in IWS systems bring about stagnation, a suitable situation for growth of microorganisms. The other cause of degradation of water quality as a result of changes in flow, is the detachment of biomass from pipes and its resultant release of microbes into the water (Lee and Schwab, 2005).
Pressure within the distribution system is another major hydraulic factor which influences the water quality. The level of pressure in the system is dependent on factors such as; topography of the area, the diameters of the pipes, the head of the pump to overcome the different elevations and lastly, the volume of the water being supplied. When the pressure within the distribution system is not adequately maintained a phenomenon known as "backpressure" arises often leading to contamination of the water in the distribution system (Trussell, 1998). Pipes lose pressure whether in continuous supply or in IWS systems, but the pressure loss in IWS is rather very much a frequent feature. The severity of IWS systems vary from city to city and are often because of the varying characteristic of the consumers. This varying characteristics can lead to the complete emptying of the distribution system and thereby causing contaminants to gain access by means of backflow when there is cross connections (Kumpel and Nelson, 2016). The sudden change in the velocity of water is what causes the phenomenon known as transient pressure (Besner, et al., 2011). This phenomenon is associated with IWS system. The backflow has been classified into two categories. The occurrence of drop in pressure resulting in the creation of a vacuum in pipes is known as back-siphonage. This phenomenon draws contaminants through leaks in the pipelines (Kelkar, et al., 2001, Mermin, et al., 1999). However prevention of hydraulic surges is very difficult even when there is enough water in distribution system which causes it to pressurized, especially when the size of waves are high. This creates a negative pressure (Karim, et al., 2003). The many factors that give rise to pressure transients are abrupt changes in demand, power

outages, fire hydrants opening and closing and the indiscriminate pump starting and stopping. Many authors (Besner, et al., 2011, Funk, et al., 1992, Karim, et al., 2003, LeChevallier, et al., 2003) suggested that contamination of the distribution system is by means of intrusion through leaks or faulty joints and the nature of the transient pressure. The second category of backflow known as the back-pressure, occurs when there is differential pressure within the system (Herrick, 1997). This occurs especially when the water surrounding the pipeline is of higher pressure than the internal pressure within the pipe. This notwithstanding, intrusion under different scenarios can be attributed to low pressure not necessarily negative pressures only (LeChevallier, et al., 2003).

The study conducted in Hubli-Dharward, India, reported low and negative pressures over the cause of sampling. With the shutting and opening of valves being rampant in IWS systems, transient pressure was expected. Sampling days saw pressure going below 0 psi for a minimum period of 2 seconds and a maximum period of 39 minutes. Observation of the low pressure and contamination was evident by the high level of bacteria indicator concentrations (Kumpel and Nelson, 2014).

Pressure within the distribution system may often times start at an initial high level and drop off quickly. This results in zones at the end of the distribution lines often experiencing low pressure and no supply (Chowdhury, et al., 1999).

The time water takes to flow from the treatment plant to the consumer is termed the water age (WHO, 2011). The age of water is influenced by operational mode of the distribution system. When water stays in the distribution network over a period of time before getting to consumers, water is said to be stagnant. This water is termed “old”(Gadgil, 1998). Suggestions from studies conducted is that water quality deteriorates when the stagnation period is long, as there are issues of pipe lining leaching, corrosion effects and decay of residual chlorine (Douglas, et al., 1996, Gadgil, 1998)

2.4.3 pH

The level of acidity or otherwise of drinking water is determined by its pH level. pH which means “potential of hydrogen” represents the number of hydrogen ions (H^+) in a particular solution (water). The environmental protection agency of US recommends a pH range of 6.5 - 8.5 as the standard for drinking water. Water having a low pH below 7 is considered acidic and can be corrosive and causes corrosion in pipe materials. Issues of tastes and laundry staining are also linked with acidic drinking water. Water which has pH > 8.5 is normally considered as hard water. Such water causes problems such as scale formation within the interior of pipes reducing the diameter of these pipes, difficulty in getting soap to lather and reducing the effectiveness of water heaters. Low pH is preferable in order to have effective disinfection. This is because when chlorine is placed in water, hypochlorous acid (HOCL) is formed as a result. An equilibrium state is achieved. The HOCL further dissociates into hydrogen (H^+) ions and hypochlorite ions (OCL^-). pH decreases after dissolution. The chemical reactions are as shown below:

$$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$$

$$HOCl \longleftrightarrow OCl^- + H^+$$

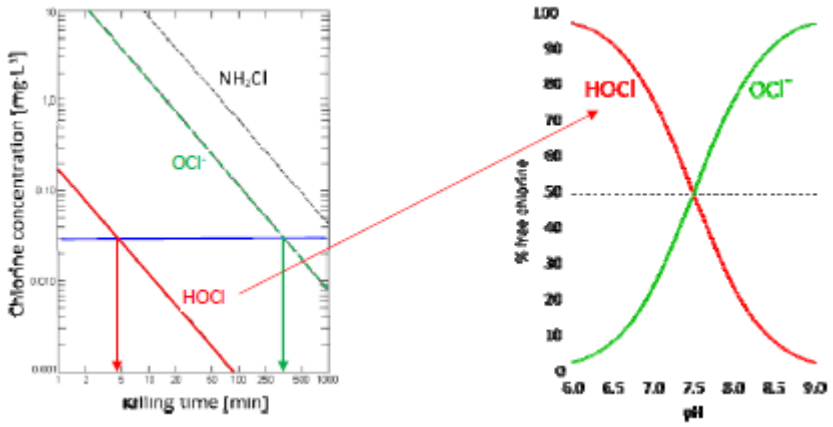

Figure 2-1 pH and chlorine relationship (Credit: IHE Chemistry Lecture note)

From the equation above. It is seen that at low pH, the equation shifts to the left of the equilibrium, due to the increase in the H^+ ions, this thus produces more HOCL and thereby producing more HOCL (strong disinfectant) and invariably increasing the effectiveness of disinfection. At a high pH, ie. Alkaline water, the H^+ ions are reduced, thus the HOCL dissociates leading to the equation shifting to the right producing more OCl^- which is a weak disinfectant thus a reduction in the effectiveness of disinfection.

2.4.4 Turbidity

The measure of cloudiness of water as a result of suspended particles is termed turbidity. The measure of turbidity, is an important parameter and a proven indicator of the presence of pathogens or absence of pathogens when the quality of water is being analysed (World Health Organization, 2017). The units for the measuring of turbidity is Nephelometric turbidity units (NTU).

The turbid water is caused as a result of colloidal and small particles being present. This turbid water results in challenges affecting the water quality. Some of these challenges associated with turbidity is (i) aesthetic acceptability, (ii) ineffective disinfection as a result of the shielding effect of the colloidal particles (Prof. J.C. Schippers, et al., 2017) and (iii)the attachment of microorganisms (bacteria, protozoa and viruses) to particulates makes the removal of turbidity significantly important in reducing microbial contamination in treated water (WHO, 2011). Thus in order to ensure the proper disinfection, turbidity level of water should be 1 NTU or less. Turbidity levels more than 1-2 NTU causes shielding effect for microorganism, thus the effectiveness of the disinfectant is reduced which invariably increases the chlorine demand (Keegan, et al., 2012). However, in small utilities, reducing the turbidity to less than 1 NTU possess a great challenge to their already limited resources, thus the WHO (2011) drinking water guidelines recommends that they should aim to produce water that has turbidity of at least 5 NTU or less.

Monitoring of turbidity levels shows that increase in turbidity has a direct relation with disease outbreaks (Mann, et al., 2007). In making investment decisions regarding the choice of water source and treatment process, turbidity is an essential parameter that must be considered (WHO, 2011). This is essential to reduce the amount of chemical that will be needed to treat the water. According to the US National Interim Primary Drinking Water regulation, 1975, a turbidity level of 1 NTU is highly recommended and 5 NTU is acceptable if the amount of residual chlorine is adequate in the distribution system and does not influence microbiological

analysis (Environmental Protection Agency, 1975). It is worth noting that, the recommended level of turbidity of 1 NTU applies to water at the treatment plant and not within the distribution system. Requirements of the National Interim Primary Drinking Water regulations insists that, turbidity levels be checked daily from the outlet of the treatment plant before it is transported to the distribution system. In case turbidity level is over 1 NTU, the measurement must be repeated within the hour. Studies undertaken by (LeChevallier, et al., 1981), shows the relationship between residual chlorine and turbidity , which revealed that , in waters with high turbidity levels of 13 NTU a reduction in number of coliforms by 20% only of the initial count is achieved. In low-turbid waters of 1.5 NTU, coliforms were undetectable. Maintaining a free chlorine residual in the distribution systems are essential since this is impacted upon due to the positive relationship between chlorine demand and turbidity. High levels of turbidity are also linked to the inability to detect coliforms (LeChevallier, et al., 1981). The effects of turbidity has been greatly emphasized and are believed to (i) have an influence in micro bacterial activities by acting as carriers of nutrients which results in the reduction of water quality (Prof. J.C. Schippers, et al., 2017), ii) influence the efficiency of disinfection (G. Ferrero, 2017). The resultant effects of ineffective treatment at the treatment plant, scheduled or non-scheduled repair of pipes and the removals of components of the pipe lining itself may cause the turbidity to increase in the distribution systems. (Hoff, 1978). After the water is transported from the WTP to the consumers, the water quality in terms of turbidity and particle count is reduced as reported by (Elala, et al., 2011)

Continuous monitoring of turbidity in the IWS system in Panama suggested that, turbidity increase was frequent after resumption of supply with peak turbidity readings of 22 NTU (Erickson, et al., 2017). Samples collected from consumer taps and storage tanks from the research conducted in Beirut, Lebanon, showed an increase in coliform counts with increase in turbidity (Ayoub and Malaeb, 2006).

Research conducted by (Kotlarz, et al., 2009), revealed three clarification mechanisms that could be used to reduce the level of turbidity in water. The three clarification mechanisms used were namely: cloth filtration, settling/decanting and sand filtration. The studies showed that, sand filtration was the best mechanism that could be used in reducing turbidity levels, having a reduction of 57.0% to 98.5% of the turbidity which had initial values of 10 NTU and 300 NTU respectively. Settling/decanting showed a consistent reduction in the level of turbidity with cloth filtration being the least effective means of reducing turbidity with a removal percentage of -0.8% to 59.8% at initial turbidity levels of 10 NTU and 300 NTU. Another studies conducted on reduction of turbidity levels also suggested that, although settling and decanting alone gives consistent reduction of turbidity levels, this mechanism is not enough for effective water treatment. The research reported alum flocculation as showing a very high level of turbidity reduction from a minimum of 23.0% to 91.4% having initial turbidity levels of 10 NTU and 300 NTU respectively (Preston, et al., 2010). To this end Preston, et al. (2010) stated that, the level of efficiency of removal by coagulant is increased by increase in turbidity.

High turbidity levels have been also linked to cases of gastrointestinal (GI) diseases (Mann, et al., 2007). This finding was further emphasised when studies carried out in Milwaukee reported high levels of turbidity of drinking water were associated with increase in gastroenteritis (Morris, et al., 1996)

2.4.5 Residual disinfectant

The final treatment process before the water is distributed is disinfection. The most commonly used disinfectant is chlorine due to its persistent in water. This is done so as to maintain

chlorine residual in the quest to prevent any microbial recontamination in the distribution system (Lu, et al., 1999). Using chlorine is nothing new, as many countries prefer it due to the ease of monitoring, application and its effectiveness in killing bacteria (Chambers, et al., 1995, Hua, et al., 1999, Kiene, et al., 1998).

Hypochlorous acid (HOCl) and Hypochlorite ions (OCl^-) are formed when chlorine is added to water. Hypochlorous acid (HOCl) when formed further dissociates to form hypochlorite (OCl^-) ions when chlorine is added to water.

$$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$$
$$HOCl \longleftrightarrow OCl^- + H^+$$

Free chlorine which is the sum of HOCl and OCl^-. This amount of chlorine shows the available chlorine to inactivate/kill microorganisms. When chlorine is in a huge volume of water, the reactions with certain compounds such as ammonia, (not in drinking water), iron and organic compound generally consumes this chlorine (Vasconcelos and Boulos, 1996). The chlorine that is dosed at the WTP gets used up to an extent due to its interactions with sediments, the corrosiveness within the pipe and biomass in the pipe, with chlorine decay kinetics largely dependent on the pipe materials and other conditions like pipe age, the size of the pipe and how the rate at which the water is flowing (Kiéné and Lévi, 1996). This phenomenon of chlorine concentration decreasing throughout its time in the distribution system is known as chlorine decay. In order to describe the chlorine consumption after different times the chlorine has been in contact with water in the network, the first order decay equation is used generally (Characklis, 1988, Hart, 1991).In order to account for both the chlorine used up, and the available chlorine (residual chlorine), the total chlorine which is the sum of free chlorine and combined chlorine is estimated. All these are expressed as mg Cl_2/L.

Having the right amount of residual chlorine is very essential, this is because it will provide the requisite conditions in the distribution system to curtail microorganism recontamination. The dilemma is that, a low dosage will results in no residual chlorine in the system as all will be used up. A high dosage of chlorine will also cause issues to do with tastes and inevitably customer dissatisfaction, the high nature of the chlorine will cause the pipe materials to corrode and by-product formation such as trihalomethanes (Gibbs, et al., 2006). At a water treatment plant, determination of how much chlorine to dose and how effective that dosage will be is very much dependent on the knowledge and experience of the operator and what previous results of monitoring of the residual chlorine and level of contaminations with the distribution network (Gibbs, et al., 2006) and also “static test” is used to determine the minimum concentration of chlorine required in the distribution network (LeChevallier, et al., 1988). Throughout the distribution system, the vulnerable points must be known to make room for improvements when the level of residual chlorine is inadequate, not reaching the minimum required 0.2 mg/L, as this will give the options of either increasing the dosage at the WTP or providing an in-line injection point to remedy the situation (Biswas, et al., 1993).

Prediction of how chlorine behaves has been one of the many researches that has been undertaken by numerous researchers. The variations in daily activities has its effect on how much dosing of chlorine is done and this results in the different concentrations of residual chlorine at sampling points (Gibbs, et al., 2006). To this end, Gibbs, et al., (2006) noted that, in times when the amount of water usage differs from the normal volume of consumption, chlorine dosing rate varied may result in sections of the water having either very high concentration in spikes or low concentrations in other spikes moving through the system.

Microorganism such as *Escherichia coli* has been shown to have cellular damage as a result of the dosing of chlorine into water that they may be present in, and this invariably causes a reduction in the numbers or concentration of these indicator bacteria (Bissonnette, et al., 1975, Camper and McFETERS, 1979). However, with some of the indicator organisms suffering cellular damage, other chlorine resistance microorganisms such as *Staphylococcus aureus*, *Micrococcus varians* and *Aeromonas hydrophila* (Al-Berfkani[1], et al., 2014) also tend to develop by means of these suggested mechanisms: evolution of cell surface structures with the possibility of increasing "collective or clumping of cells in situ" (Dennis, et al., 1979), finding a way to be bonded with the surfaces of pipes or any suspended particulate matter (Stagg, et al., 1977), the removal of "protective extracellular capsular or slime layers" (Seyfried and Fraser, 1980) and the development of resistant spores (Ridgway and Olson, 1982).

With IWS system, the possibility of recontamination which leads to the quality reduction in drinking water makes the level of residual chlorine of great importance for any research on quality of drinking water. Results in the research conducted by Elala et al., (2011) on the deterioration in water quality from supply chain to household and appropriate storage in the context of intermittent water supplies shows that, when enough or adequate chlorine is not added at the designated point of injections, the water that is collected and stored in the houses, do feel the effect of the chlorine dosed. In Hubli-Dhawad, samples collected in both continuous and IWS showed reduced count of indicator bacteria when chlorine residual were high with grabbed samples showing lower total coliform concentration in samples having more than 0.1 mg/L of free chlorine residual (Kumpel and Nelson, 2013).

2.4.6 Microbial contamination

The national drinking water regulation has recognised the coliform group of bacteria as the main criterion used by numerous industry players in the water sector for operational strategies (World Health Organization, 2015). The (WHO/UNICEF JMP, 2017) classifies drinking water as "basic" and "safely managed" if the water is said to be free from faecal contamination, thus microbial contamination analysis is vital to water quality. Using coliform bacteria as a means for indicating water quality has had its fair share of criticism, with many publications stating the shortfalls (Dutka, 1973). This suggestion is emphasised when findings in cities that experienced outbreaks of waterborne diseases showed no presence of coliforms (BORING III, et al., 1971). Notwithstanding these drawbacks, coliforms are still used as important indicators of water quality (Committee and Council, 1977, Environmental Protection Agency, 1975, World Health Organization, 2015).

Findings from a research conducted on injured coliforms in drinking water revealed that, water samples from normal distribution system, water collected from broken and repaired pipes and chlorinated water leaving the treatment plants having coliforms are often not detected by the normal counting methods (McFeters, et al., 1986).

The verification for microbial water quality is done when the analyses of indicator bacteria is performed. This involves the testing for *Escherichia Coli* an indicator for faecal contamination (Environmental Protection Agency 2010). A group of "gram- negative", "rod shaped bacteria" with several characteristics together are known as total coliforms. These groups which make up the total coliform are "thermotolerant coliforms", "faecal based bacteria" and bacteria from environmental related conditions. It is worth noting that, total coliform being present is thus not entirely indicative of faecal contamination as it may or may not be (Bartram and Ballance, 1996). In analysing these indicator bacteria, two methods were first proposed; the multi-tube fermentation (MTF) and the membrane filtration method (MF) (American Public Health Association , et al., 1985). The multi-tube fermentation method can be used for very

turbid water and the results are normally reported as the most probable number (MPN) index. This means of reporting the results does not give the count of the exact number of indicator bacteria present. With the many limitations suffered from the enumeration processes of coliform, the third method which is the presence- absence technique of enumeration was adopted by the EPA. The second method of analysing microbial water quality which is the membrane filtration method, unlike the multi-tube fermentation gives an exact count of total coliforms and faecal coliforms that are present in the collected water sample. Under many circumstances the thermotolerant coliform bacteria testing is an alternative (World Health Organization, 2006).

The presence or absence of indicator microorganisms is a means to identify drinking water which is safe to drink or free from any pathogenic organism (G. Ferrero, 2017). To this end, total coliform and *E.coli* out of the many indicator bacteria is used as a common indicator in research. Indicator organisms are purposeful for reasons, such as being indicators of

- Integrity and cleanliness of distribution systems in operational monitoring
- Faecal pollution in verification and surveillance monitoring
- The effectiveness of processes such as filtration or disinfection in validation (G. Ferrero, 2017).

The presence of total coliform in samples (depending on where the samples are taken) are indicative of inefficiency in the treatment process, loss of disinfectants and ingress of contaminants due to backflow (McFeters, et al., 1986, Rompré, et al., 2002) or problems related to regrowth (LeChevallier, et al., 1988). *Escherichia coli* is used as an indicator for faecal contamination and an indicator of the presence of pathogenic bacteria such as C*ampylobacter, Salmonella and Shigella etc. (G. Ferrero, 2017).* The standard guideline for amount of E.coli in drinking water is 0 in 100 mL. A study conducted by Karim et al (2003), showed more than 50% of the samples collected had indicator microorganisms and enteric viruses in the soil and water samples close to drinking water pipelines. This study suggested that, the source of most contamination was detected to be from the soil which may be contaminated because of the water in the ground which may be contaminated by the sewers which were identified as leaking. With many developing countries, where IWS is common are found to have piped sewage network. Thus sewerage are often seen flowing in open drains or flowing on the ground close to drinking water lines. This risks an intrusion into IWS through opened orifices of the pipes or loosened joints in valves (Kumpel and Nelson, 2016).

2.5 First-flush effect on water quality

A common feature which is quiet regular in IWS system is flushing. Its effect on water quality can be regarded as both positive and negative based on factors such as; situation of supply, pressure in the IWS system and frequency (Kumpel and Nelson, 2016). The level of water quality deterioration has been seen to occur in many IWS system when supply cycle begins (Cerrato, et al., 2006).

Intrusion of contaminants which resulted in the presence of *E.coli* in samples collected from first flush in IWS systems having a short duration of supply corroborates the effect of first flush in water quality. The water quality is reduced very much when flushing of the system is done due to the changing of the water's steady state (Barbeau, et al., 2005). In a research conducted by Barbeau, et al., (2005), in Montreal revealed the increase of total suspended solids (TSS) to

12.3 mg l^{-1} in the initial 5 minutes when the supply began and decreased gradually in the next 15 minutes to a level of 2 mg l^{-1}.
In Hubli-Dhaward, when the supply began, and sampling began, it was observed that turbidity was very high but steadily reduced after a period of time, with the overall average of 242 NTU during the initial 30 seconds of supply to 24 NTU (Kumpel and Nelson, 2014). For the first flush sampling in Panama, after 120 minutes of sampling, it was observed that more than one sample was positive for total coliform (Erickson, et al., 2017).
With CWS, consumers the luxury of constant flow of water can be afforded, thus are informed not to use water as soon as flushing is completed or water supply begins, but rather open to waste and this is the major difference between CWS and IWS systems. IWS consumers cannot afford to open their taps to waste due to the limited supply duration and therefore would rather collect water which is likely to be highly contaminated (Charalambous and Laspidou, 2017)

2.6 Public health implications

The potential risks of contamination is high when intermittent water supply system is being operated, and this obviously poses a great challenge to public health (Charalambous and Laspidou, 2017). With distribution systems being partially the cause of gastro-intestinal illness as suggested in studies conducted by (Payment, et al., 1991). The studies showed that, the evaluation of people who drank from tap water and comparing it to individuals who received water treated by reverse osmosis, gastro-intestinal illness was more prevalent with the people who drank from tap water. Reports from Canada and the United States suggests that an estimated half of people inflicted with waterborne related disease occur in small non-community drinking water systems (SDWS) with 44% and 62% respectively (Pons, et al., 2015). Out of the fifty-one states in the United States, fourteen states which were under surveillance had 28 waterborne –disease outbreaks (WBDOs) within a year (2005-2006). 20 of these outbreaks were as a result of the drinking water supplied. The 20 reported (WBDOs) had 10 of the reported 20 outbreaks ended up resulting in acute respiratory illness, 45% resulting in acute gastrointestinal illness and 5% were infected with hepatitis (Yoder, et al., 2008).
Sweden, a country known for its long culture of having systems in place for surveillance and reporting of waterborne diseases in a study shows that, the outbreaks incidence and "aetiological agents" in the past years are disparate (Andersson and Bohan, 2001). The study conducted by Andersson and Bohan (2001), reports that typhoid fever and shigellosis has been the most prevalent reported disease (water related) in Sweden at the turn of the twentieth century.
Amongst the many causes of waterborne diseases, one of the major causes of waterborne disease outbreaks has been identified to be *Campylobacter spp.* This is said to be the main causative agent of water related disease in Scandinavian countries, England and Wales (Clark, et al., 2003, Duke, et al., 1996).
The outbreak of the disease caused by C. *jejuni* or C.*coli* affected over 7 million people annually had an estimated cost of $1.2 - $6 billion (Buzby and Roberts, 1997).
In most developing countries, the inability to provide adequate, reliable and safe drinking water & sanitation is responsible for sickness and deaths (Liew and Lepesteur, 2006). A 250 million infection rate of waterborne related pathogens and the corresponding 10 – 20 million deaths in developing countries globally annually is reported by (Dzwairo, et al., 2006). These

numbers are very alarming and the global effect of waterborne disease and public health is dire especially in developing countries which are as a result of poor water quality (Ryan, et al., 2004). The way to combat these diseases caused is to putting in stringent methods to force the adherence to water quality standards and supply schemes (Hunter, et al., 2009).

With studies previously mentioned, stating that intrusion through loose joints and opened orifices in pipes are the means by which contamination of water in distribution system occurs (Kirmeyer and Martel, 2001). The situation is exacerbated especially when the sanitary conditions in the areas where IWS is being operated is very appalling, with wastewater flowing indiscriminately or drains which are not closed are closely situated by the distribution network (Charalambous and Laspidou, 2017).

A study which was conducted by (Wright, et al., 2004), explains the difference in microbiological contamination in the distribution system from water treatment plant (WTP) to the point-of-use of consumers. Lastly, in a research conducted in Melbourne, to ascertain if drinking water is a cause for gastroenteritis by (Hellard, et al., 2001), showed that the distribution system had samples which were positive for *Aeromonas spp*, *Campylobacter* and *Giardia*. This is proof that drinking water quality has an effect on public health and with pressure transient being a constant feature in IWS system, it can safely be said that IWS systems does have an effect on Public Health.

Table 2-1 Studies of water quality in intermittent and continuous supplies and the summaries and objectives

Title of Paper	Author	Date	Summary of Paper	Objective
Comparing microbial water quality in intermittent and continuous piped water supply	E. Kumpel, K.L. Nelson	2013	Comparison of CWS and IWS based on how different water parameters were affected due to the kind of flow. More contamination in IWS during first flush, More contamination was reported during rainy periods in IWS due to intrusion from the environment.	Comparing water quality at Reservoir, taps, and drinking water in homes with IWS & CWS for the upgrading IWS to CWS
Dead end flushing of distribution system: Short and long term effects on water quality	B. Barbeau, V. Gauthier, K. Julienne, A. Carriere	2005	the effectiveness of routine spot flushing with its effect on water quality by checking heterotrophic plate counts and residual chlorine concentrations	to document the benefits of periodically spot flushing dead-end locations in the distribution system
Impact of intermittent water supply on water quality in Lebanon	G.M. Ayoub, L. Malaeb	2006	They looked at mainly the relationship between water parameters such as pH, Residual Chlorine, Temp, turbidity vs faecal Coliform(Bacteria)	To present findings of intermittent water supply & highlighting the key aspects of intermittent supply systems. Influences of other parameter on water quality in respect to distance was also studied
Mechanisms affecting water quality in an Intermittent piped water supply	E. Kumpel, K.L. Nelson	2015	The different processes by which the water quality in intermittent piped water system is affected. With pressure monitored, chlorine residual checked and compared with microbiological parameters presence.	To measure the temporal variability in water quality in an IWS and identify the predominant mechanisms causing contamination
Assessing the public health risk of microbial intrusion events in distribution systems: Conceptual model, available data, and challenges	M.C. Besner, M. Prevost, S. Regli	2010	Various review of different papers on microbial intrusion events, their characterization of causes, magnitudes and durations of pressures, characterization of pathways for contaminants entry	To review and discuss the available information within the context of conceptual model, developed by author, for estimation of public health risk resulting from intrusion events
Water quality effects of intermittent water supply in Arraijan, Panama	J.J. Erickson, C.D. Smith, A. Goodridge, K.L. Nelson	2017	The water quality was compared when the flow was CWS and also IWS and the. The pressures within each system analysed and its effects on water quality	The objective of this research is to analyse different supply conditions, with the goal of better understanding the relationships between intermittent supply and water quality.
Intermittent water supply: Prevalence, Practice and Microbial Water Quality	E. Kumpel, K.L. Nelson		Examines the status and nature of IWS practices throughout the world, and how the typical contexts in which IWS systems often exist	Examines the status and nature of IWS practices throughout the world, and how the typical contexts in which IWS systems often exist. How inadequate sanitation infrastructure can exacerbate mechanisms causing contamination
Controlling water quality in intermittent systems	S.T. Coelho, S. James, N. Sunna	2003	Numerous countries were sampled. The influence of household storage on quality. The results confirmed that the deterioration of water quality in domestic tanks is by far the greatest challenge to an extent that improvement obtained during treatment is negated	understanding the factors controlling bacterial concentrations in IWS and present an overview of the most important aspects of water quality control in IWS
Technical Causes and impacts of intermittent water distribution	P. Klingel	2012	The research focus on two aspects, technical causes of IWS eg. Water resources, system knowledge, infrastructure management and water loss reduction. Also the technical impacts of IWS was investigated it was found out that hydraulic issues are imparted (piping systems are not designed for IWS, thus effects are felt on the pipes, financial burden on consumers)	To discuss the possible causes and consequences and their interactions. The technical side of water distribution and are mainly based on the technical literature
Multi-criteria optimization of supply schedule in intermittent water supply systems	A.E. Ilaya-Ayza, J. Benitez, J. Izquirdo, R.l. Perez-Garcia	2016	modelling of how the intermittent water system can be managed well using a multi-criteria analysis	to propose a tool to aid technical management of IWS systems built on a methodology to manage supply schedules for every sector of the network to improve the conditions of service based on multi-criteria optimization
The potential for health risks from intrusion of contaminants into the distribution system from pressure transients	M. Lechavellier, R.W. Gullick, M.R. Karim, M. Friedman and J.E. Funk	2003	Transient pressures events occur in distribution systems, that during negative pressure events, pipeline leaks provide a potential portal for entry of groundwater into treated drinking water. To date all observed negative pressure events have been related to power outages or pump shut downs, more research is needed to better characterize the type of systems most prone to these events	insufficient data to indicate whether pressure transient are substantial source of risk to water quality
Water quality problems associated with Intermittent water supply	S. Tokajian , F. Hashwa	2003	Various parameters were checked to ascertain how they affect water quality. Also the paper was used to confirm or explain anomalies that may have occurred and does not correspond to previous findings.	Determining factors that may contribute to the deterioration of the water quality in networks operating with an intermittent supply strategy
Deterioration in water quality from supply chain to household and appropriate storage in the context of intermittent water supplies	D. Elala, P. Labhasetwar, S. Tyrrel	2011	The common risks and possible alternative solutions are investigated in this research in Nagpur municipal using quantitative and qualitative data collection. Testing of grabbed samples from taps and point of use was done.	the objective was to investigate factors leading to post-source contamination in an intermittent water supply combining microbiological analysis and qualitative survey approaches
Water quality and health - review of turbidity: information for regulators and water suppliers	WHO	2017	information on the uses and significance of turbidity in drinking water and is intended from regulators and operators of drinking water supplies	
Chlorine demand of biofilms in water distribution systems	W. Lu, L. Kiene, Y. Levi	1998	Chlorine demand produced from 3 test waters is studies and the effects of biofilms chlorine demand methods are shown	The purpose of the work was to determine whether the biofilm has an observable chlorine demand; if it is possible to characterize the biofilm growth in various environments by means of their chlorine consumptions
Potential for pathogen intrusion during pressure transients	M.R. Karim, M. Abbaszadegan, M. Lechevallier	2003	Soil and water samples were collected at sites immediately exterior to drinking water pipelines at eight locations and tested for occurrence of total and faecal coliforms. Monitoring of pressure transients was done	the objective of this study was to determine the occurrence of indicator microorganism and pathogens in the vicinity of potable water pipeline and assess the potential for intrusion attributable to transient distribution system pressure changes

3

MATERIALS & METHODS

3.1 Study area

Moamba district is located in Mozambique, in the southern part of the Maputo province; it has an area of 4,628 square kilometres (Figure 3.1). The district consists of 4 towns namely, Maomba town, Ressana Garcia, Pessene and Sabie. The population as of 2007 was 56,335 inhabitants.

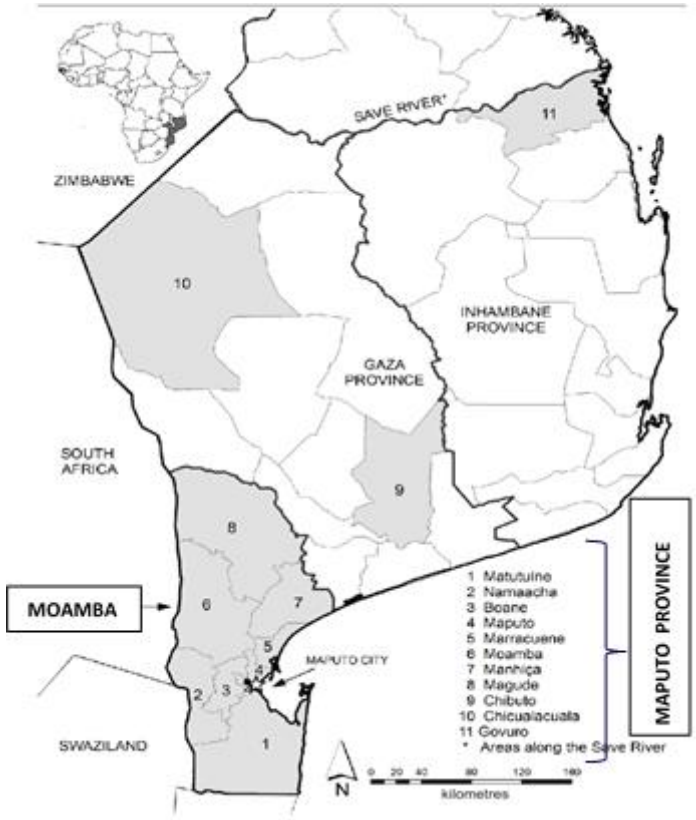

Figure 3-1 Map of Mozambique showing location of districts (Source: ephotopix)

The population of Moamba is distributed in ten neighbourhoods, namely: Bairro de Cimento, Bairro Central, Bairro Sul, Bairro do Matadouro, Bairro 7 de Abril, Bairro Madingine, Bairro 25 de Junho, Bairro Livivine, Bairro Josina Machel, Bairro Luziveve .

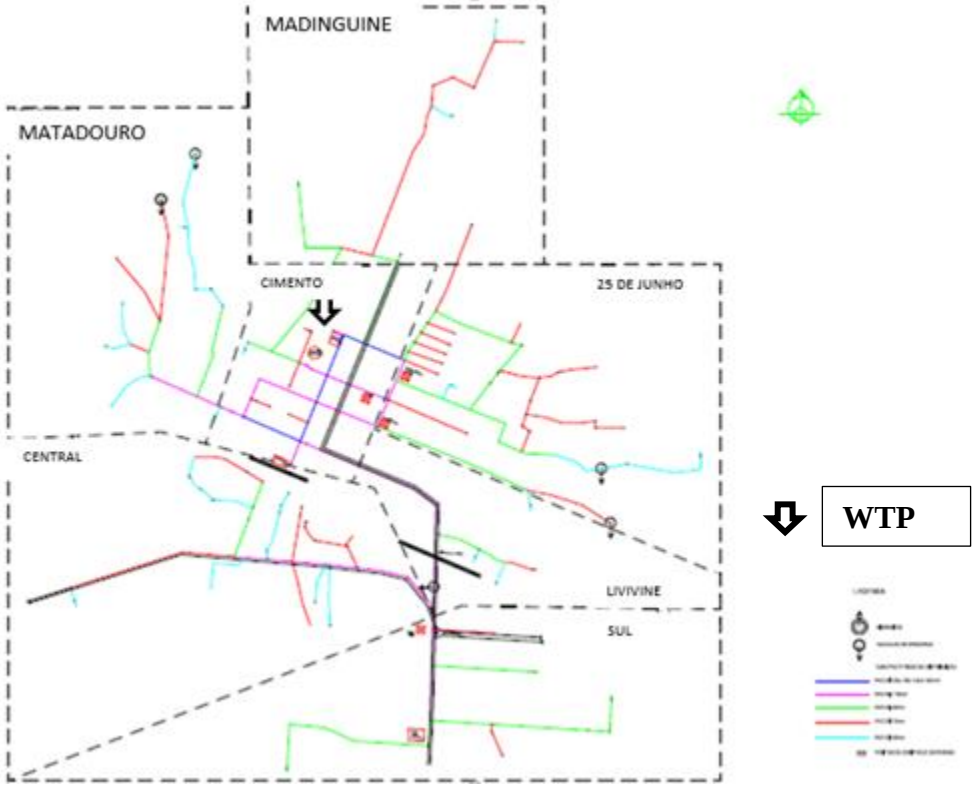

Figure 3-2 Schematic of Moamba's neighboorhoods (Source: Collins)

The water supply system of Vila de Moamba covers the areas of the District of Moamba and the Administrative Post of Pessene (14 km from Moamba), and was inaugurated in June 2013. The Moamba system, consists of the intake, pipelines, water treatment plant (WTP), distribution center (DC), distribution network and connection to Pessene.

3.1.1 Abstraction / Intake

The intake structure (Figure 3-3) is located on the river Incomáti and it consists of an infiltration chamber and a suction chamber with two submersible elevation pumps, which work alternately pumping the water to a buffer tank with a capacity of 80 m³, located between the Intake and the WTP. Two pumps located in a secondary pump house pump the water from the buffer tank to the WTP.

The piping system that connects the intake station and the WTP has an extension of about 3.5 km and counts on a polyvinyl chloride (PVC) pipe with a diameter of 250 mm (PN9). At the WTP treated water is stored and then distributed for consumption.

Figure 3-3 A: location of intake structure on the river Incomáti; B: buffer tank; C: Pump house; D: pumps (Credit; Collins)

3.1.2 Water Treatment Plant

The WTP consists of a processing line with a capacity of 3000 m³/day, for a distribution of 250 m^3 /h for up to 12 h/day. The treatment sequence consists of coagulation-flocculation, rapid sand filtration and disinfection with chlorine.

Coagulation - flocculation

At the WTP, the dosing of Aluminium Sulphate $Al_2(SO4)_3$. $18H_2O$ of concentration 20 mg/L is done concurrently as the raw water is fed into the two contact tanks of combined volume 200 m^3. Dosing is first done at the intake of the WTP and at the WTP. Coagulation- flocculation takes place within the tank and in the pipes which is connected to sand filters

Rapid sand filtration

The six pressure filters, each has a capacity of 40 m³/h and each of the three existing filter pumps has a maximum flow rate of 80 m³/h. The filtration rate of six pressure filters is $40m^3/h/0.92m^2$ (per filter) which is 44 $m^3/h/m^2$. Backwashing of the filters vary with respect to the raw water quality. The breakthrough time vary with the raw water turbidity conditions. In the dry seasons, the filters takes 2-3 weeks before breakthrough is reached. In the rainy season, due to the high turbidity of the raw water being close to 100 NTU, the breakthrough time is between 5 days to 1 week. In addition to this, the backwash time is also determined by readings of the pressure gauge fitted to the filter manifold. The normal pressure of the filtration process when is in operation is 8 bar, when this rises to 9 bar, the backwash operation is commenced to protect the equipment since the manifolds and fibre-glass filters are class 9. The backwash water is then drained out to spoil in the yard of the WTP.

Chlorination

After this filtration, the filtered water is then dosed with HTH granular chlorine with 65% active chlorine. The 10kg $Ca(OCl)_2$ is measured by means of a graduated measuring bucket. It is then poured gently into the empty 200 L tank and then filtered water is used to fill the tank to the 200 L mark on the tank to have a solution of concentration 32500 ppm of chlorine. The tank is fitted with a stirrer (which currently does not work) and Grundfos DMX 14-10 B-PVC/ V/GX- G1B1B1F pump having a pumping rate of 14 L/h. Each 200 L batch of chlorine solution is used for two days. In the determination of the dosing rate, 3 bottles of 5 litres each was filled in 1 hour. The third bottle was filled up to 4 litres. This confirmed the dosing rate of the chlorine injector was indeed 14 L/h.

Chlorine dosing at the WTP starts as soon as the treatment process is started, normally at 6:00 am, and stops at 12:00 pm. Between the period when supply in Moamba is stopped at 10:00 am, treatment and dosing continues until the CWR and the water tower is filled completely. Treatment and dosing is then stopped completely at 12:00 pm. Treatment and chlorine dosing resumes when water supplied to Moamba begins again at 3:00 pm and continues till 7:00 pm when treatment for the day is ended.

Storage reservoir

The treated water goes to the clear water reservoir having a volume of 500 m³. From the 500 m³ tank the water is lifted through two sets of electric pumps for the 150 m³ pressure tower. From the pressure towers the water goes to the Moamba distribution network and another part follows by gravitational supply to a supported reservoir of 80 m³ in Pessene. The two tanks shown with the blue colour are currently not in use. They are, the 150 m^3 and the 80 m^3 water tower.

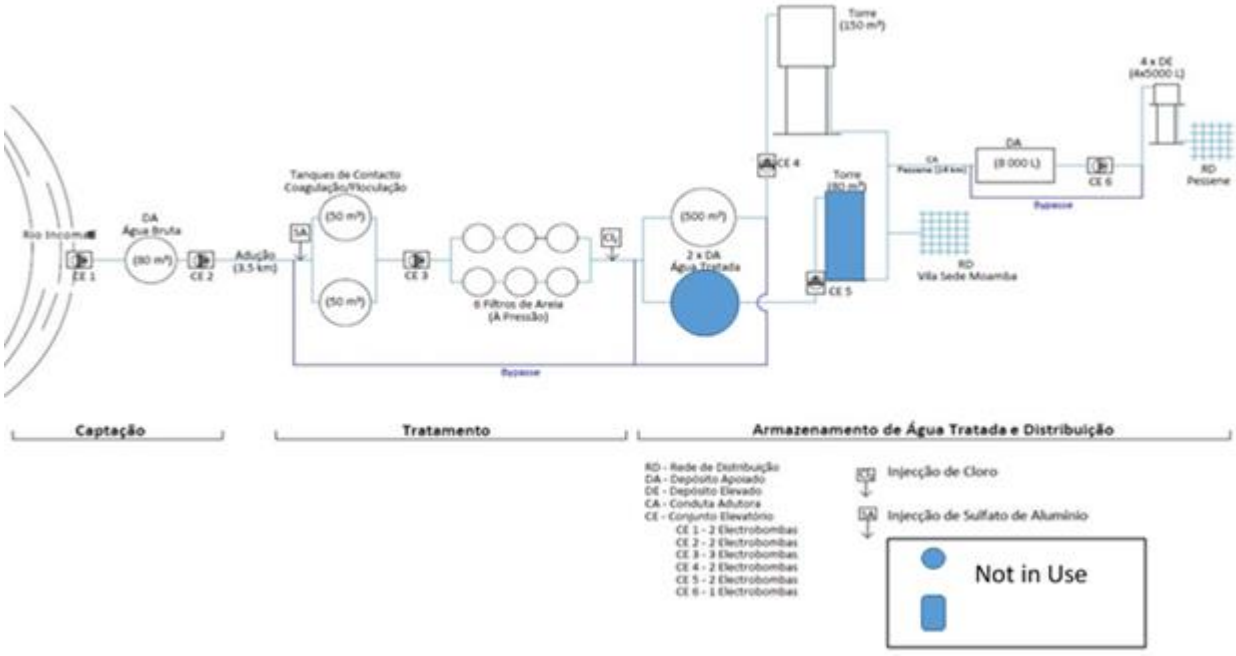

Figure 3-4 Flow diagram of the water supply system of Moamba and Pessene (source: Collins).

3.1.3 Water distribution

The distribution network has a total length of 36 km and the ducts are made of class 9 PVC with diameters ranging from 50 mm to 250 mm. Currently, the number of connections is about 2,453 and the network operates for 4 to 7 hours per day in Moamba and 6 h per day in Pessene. The connection to Pessene is made by a 14 km long pipeline and operates alternately for reasons of pressure stabilization in Moamba's distribution network. In the pumping / gravity supply system in Moamba, the nominal pressure of 1.5 bar to 2 bar at the consumer taps fluctuates very often during the times of supply. Thus the storage reservoirs at both treatment plants in Moamba and Pessene aid to maintain the pressure in the system. The distribution in Moamba starts at 6:00 am in the morning and water is treated and supplied to all the 7 neighbourhoods in Moamba, however the neighbourhood of Central receives the water (low pressures) after a two hours lag period, which is due to its high elevation with respect to the WTP. Supply to Moamba is stopped at 10:00 am with all the valves on the distribution pipelines to Moamba closed except the valves on the pipeline to Bairro Central which are opened for pressure to build up in the lines to supply water. The valves to Pessene are opened and water is supplied from 10:00 am to 3:00 pm. At 3:00 pm the valves to Pessene are closed and those of Maomba are re-opened for supply of water to resume in Moamba. The supply to Moamba finally come to a stop at 6:00 pm when the valves are closed for the day. The valves to Pessene are opened and water is transported to Pessene to fill the 80 m^3 tanks situated there.

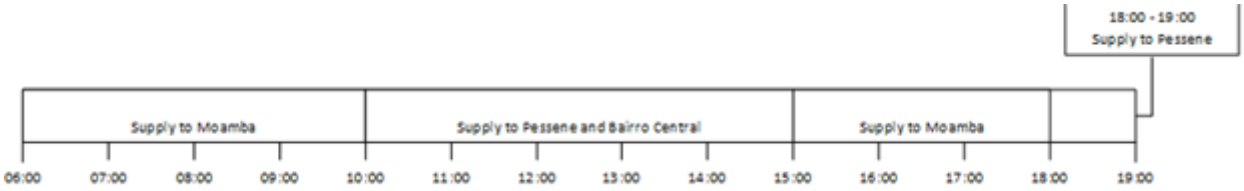

Figure 3-5 Supply cycle in Moamba

Figure 3-6 Overhead CWR on the Moamba DC (left) and elevated tanks in Pessene (right). (Source; Collins)

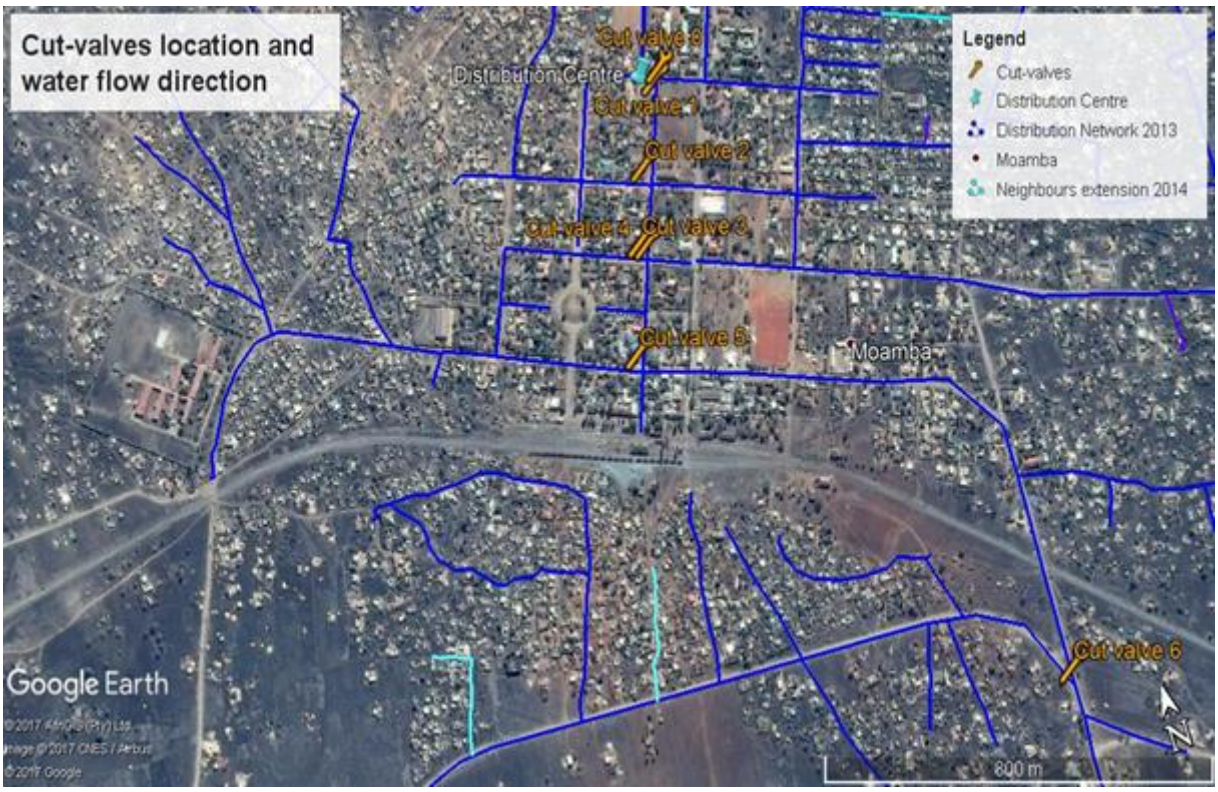

Figure 3-7 Distribution system in Moamba (Source: Luis Miguel Silva-Novoa Sanchez)

3.2 Methods

3.2.1 Selection of neighbourhoods

For carrying out this study, two neighbourhoods were selected based on the following criteria:

i. Distance from the DC (close proximity and further away)
ii. Spatial patterns of the neighbourhoods (scattered and well defined)

It should be noted that not all of these neighbourhoods are connected to the existing distribution network. Bairro 7 de Abril, Bairro Josina Machel and Bairro Luziveve do not receive water from the water supply system.

Based on the above criteria, two neighbourhoods were selected: Bairro Cimento and Bairro Matadouro. The distance from the distribution centre was taken into consideration: Matadouro is at a distance of approximately 2200 m from the WTP, whilst Cimento is about 800 metres away from it. The spatial patterns of Matadouro and Bairro Cimento are of contrasting nature: on one hand, Matadouro is a neighbourhood densely populated and with lack of formal spatial planning, and on the other hand, Bairro Cimento is a less dense and planned neighbourhood.

3.2.2 Sampling points

In each of the selected neighbourhoods (Cimento and Matadouro) two sampling points were selected, with the houses having standing pipes located on the compounds. Households were selected in each neighbourhood based on the distance from the WTP and availability to

participate in this study. Samples were also taken at the WTP. The different sampling points were at the following distances from the WTP:

- C1 - 50 meters
- C2 - 800 meters
- M1 - 1000 meters
- M2 - 2200 meters

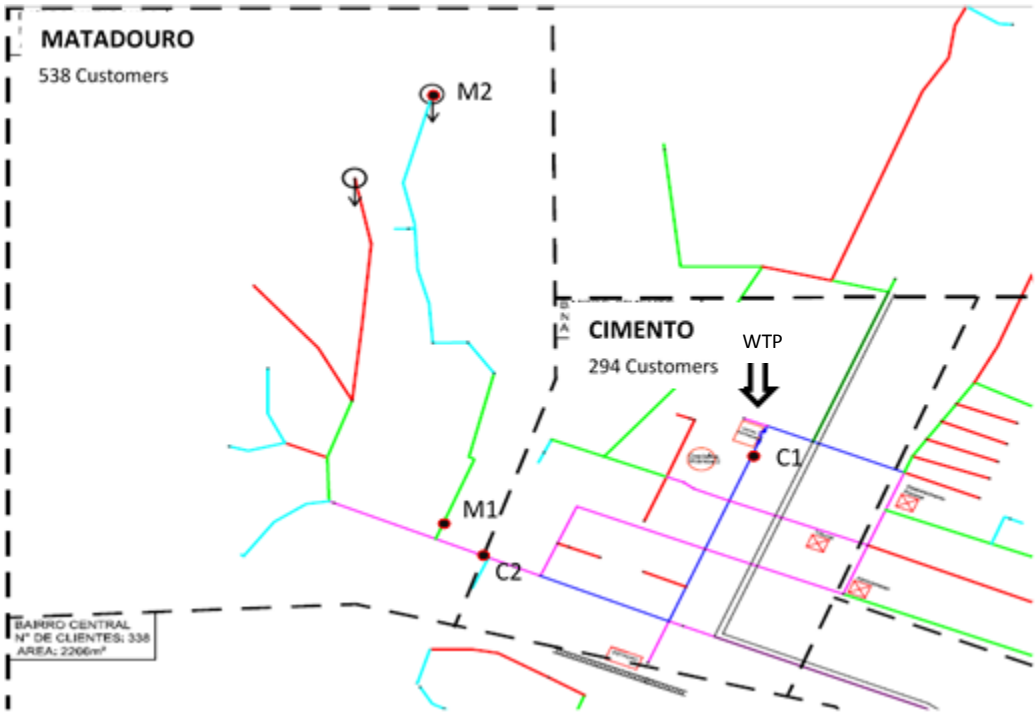

Figure 3-8 Schematic view of the sampling points (source; Collins)

3.2.3 Sampling

Sampling was done over a three month period between (November 2017 and January 2018).

Method

Samples for microbiological analyses were collected in 100 mL sterile whirl-pak thio-bags® containing 3 tablets of sodium thiosulfate for quenching residual chlorine.
Samples for physico-chemical analyses were collected in 75 mL plastic cups

Each sample collected in the whirl-pak thio-bags® was well labelled with information that are distinct namely:

- Project name
- Sampling location
- Name of person collecting sample
- Test to be performed
- Unique ID number

In order to prevent self-contamination, the consumer taps was sterilized by cleaning the taps with a clean tissue soaked with ethanol 70% before samples are grabbed.

Storage

Samples collected for microbiological analysis was placed on ice in an insulated container and transported for testing and samples were analysed within 24 hours after collection. All physico-chemical parameters were analysed immediately on site.

Strategy

Samples were collected according to the following strategy. Sampling at the households started at the beginning of the supply cycle, recorded as time zero, then every 10 minutes during the first hour. For the next hours, samples were taken hourly until 10:00 am. The supply to Moamba was then interrupted from 10:00 am to 3:00 pm. Sampling continued when the supply to Moamba was resumed at 3:00 p.m. and samples were taken at a 10 minutes interval for the first hour. Finally, 2 samples are taken at 4:00 p.m. and 5:00 p.m. During each sampling day, one sample was collected from the outlet of the water tower at the WTP. The sample from the treatment plant was done at 10:30 am. On the first day, samples were collected from C2 and M2 and on the second day samples were collected from C1 and M1. On each day of sampling, a sample was first collected from the outlet of the water tower at the WTP.

During this study, sampling was carried out under a range of weather conditions: long period of rainfall, clear days or periods after interruption supply due electrical faults or reduction in the water level in the Incomati river. A summary of the weather conditions is shown in APPENDIX

3.2.4 Analytical Methods

Physico-chemical parameters

The analysis of pH was done directly using Palintest pH pocket sensor PT155 according to the manufacturer's handbook. The calibration of the pH meter was done monthly using a buffer 7 solution to always keep the pH meter calibrated. The same pH meter was used to measure the temperature. Conductivity of the sample taken was measured using the Palintest conductivity pocket sensor PT157.

Turbidity was measured using the Palintest Turbimeter Plus PTH092 according to the handbook from the manufacturer. In the analysis of turbidity levels of samples, only clean sample tubes provided in the test kit was used. The water sample was poured into the sample tube to the 10mL mark on the tube. By cleaning the outside of the tube, it was ensured that all marks and fingerprints were removed. Sample tube was placed into the instrument for reading the level of turbidity. The Turbimeter Plus PTH092 was calibrated using samples of known turbidity supplied together with the equipment.

Free and total chlorine were measured with the Palintest Photometer 7100 PTH7100. A DPD 1 (diethyl-p-pheneylene diamine) tablet was put into a vial of sample water. This vial then had a change in colour to pink according to the level of residual chlorine in the water. The colorimeter was used to read the intensity of the colour change and automatically determined the free residual digitally. In order to determine the total residual chlorine, the DPD 3 (diethyl-p-pheneylene diamine) tablet was put into the same vial containing the sample tested for free residual chlorine. The vial was then put into a colorimeter which in tend read the intensity of the colour change and provided the results digitally. The necessary blanks were used to zero the equipment before readings were taken. HACH DR890 photometer was used when more than one household was sampled simultaneously.

Pressure meters were installed at the taps midway into the duration of the study and the pressure recorded manually every time that a sample was taken.
Pressure was measured with the RDPG digital pressure gauge. This was fixed to the consumer tap on the compound. The function for the gauge was set on bar. The pressure reading were taken when the samples was collected.

Microbiological parameters
For the microbiological analysis, the Wagtech Potatech was used. Total coliforms and *Escherichia coli* were tested using the membrane filtration method. All samples were tested in duplicate.
Chromocult agar Nutrient Pad Sets (Sartorius) were used to culture the bacteria. Labelling of the chromocult agar was done with sample identification number. A flamed forceps was used to place the membrane filter of 47 mm diameter and 0.45 µm pore size with the grid-side up on the filtration device. 100 mL sample was filtered, then the membrane filters were placed on chromocult agar and incubated for a period of 24 hour at a constant temperature of 37^{o}C in an Aquagenx Portable Incubator.
In Enumerating E.coli, the resultant colonies on the chromocult agar having dark blue to violet colour which is different from the salmon red of other coliform bacteria colonies.

Statistical analysis
The SPSS software was used in some of the statistical analysis. The average (mean) used in this report, is the value gotten as a result of adding all the different values of concentrations and dividing it by the total number of different concentrations. The median on the other hand is the value of the middle point in a sorted number set. Thus the average or mean used in this report refers to the value that is "representative" of all the different results under consideration. Anytime the median is referred to, then the middle number of the different results arranged in ascending order under consideration is being analysed. The boxplot and error bar plots used in this report, gives a visual depiction of the quantitative data from the results. The median shown in the boxplot is the measure of the central tendency and the middle value of the data under review. The second quartile represent by 2Q box and the third quartile 3Q box gives an indication of the 25th and 75th percentile respectively. The 75th percentile gives an indication of the lowest value of concentration (residual chlorine) that is greater than 75% of the results. The whiskers in the box plot shows the lowest value of the data and the highest value of the data that are not outliers. The range is also defined in the box plot. The boxplot also gives information on the skew/ shape of the distribution of the results.
The error bars used in this document gives indication on the similarity or difference of the data analysed between two sets of data. In the analyses, the data from one set is said to be different from the other data if the error bars do not overlap. However if the error bars overlap between the two sets of data, the data sets are said to be similar and the results are said to be conclusive. The Kruskal Wallis test for non-parametric test was performed.

3.2.5 Experimental methods
For this research, three sets of experiments was designed: a) Optimization of chlorine dosing strategy, b) Effect of supply duration on water quality, c) Effect of first flush. It was however imperative to know the existing conditions at the consumer taps and operational conditions at the WTP. Thus before starting with the experiments, a baseline assessment was carried out.

Verification of actual chlorine dosage

In measuring the amount of chlorine dose, the already calibrated 10 kg bucket was verified, by using the 250 g cup that accompanied the $Ca(OCl)_2$ bucket from the suppliers. Thus the 250 g was filled 40 times to make up the 10kg of $Ca(OCl)_2$. This was the measure used to verify the already marked gauge on the arbitrary bucket. Thus in order to 11 kg, 4 more of the 250 g cups was added to the measuring bucket that was filled to the 10 kg marked gauge. Similarly, to measure 12 kg, 8 of the 250 g cups was added to the gauge on the bucket. The dosage of chlorine used will be expressed as mg Cl_2/L.

3.2.5.1 Baseline assessment

The baseline assessment consisted of monitoring microbial and physico-chemical water quality at the outlet of the WTP and at two consumer taps, the farthest sampling point in each of the neighbourhoods (point M2& C2). The existing dosage of (1.76 mg/L) (see Appendix for Calculations) was used and was performed according to the times described in section 3.1.2. The baseline assessment was done in four consecutive days. Due to the fact that one batch (200 L) of chlorine solution was prepared and used for two days, the baseline was conducted for two consecutive days in each sampling point. At the WTP, samples were taken from the outlet of the water tower at the WTP on the first day with the new batch of chlorine solution. The parameters monitored were free and total residual chlorine, turbidity, pH, temperature, conductivity, *E.coli* and total coliform.

Sampling was undertaken as described in section 3.2.3. During the baseline assessment, the sample for residual chlorine at the outlet of water tower was taken simultaneously as the sample of the consumer taps at C2 on the first two days of the new chlorine solution.

The baseline was undertaken for a period of 4 days. The first two days had samples taken from C2 and the samples at M2 were taken after a new chlorine solution was mixed and dosed on the third and fourth day within the same week.

Table 3.1 shows a summary of water quality parameters monitored, by sample location and the various monitoring parameters. For each sampling point, the number of samples that were tested for the above-listed

Sample Location	Number of samples
Outlet of WTP	18
Tap Matadouro (M2)	18
Tap Cimento (C2)	18
Total	**54**

3.2.5.2 Chlorine dosage optimization

Chlorine dosage optimization experiments were undertaken for a period of 6 weeks. In the chlorine dosage optimization, identifying the optimal chlorine dosage and dosing strategy was the focus of this experiment. The “injector chlorinator” which is used at the WTP enable the chlorine dosage and dosing rate to be kept constant throughout the dosing period.

Two different strategies was applied during this process: (i) increasing the chlorine dosage (but using the same operation) termed “Constant” and (ii) varying the chlorine dosage termed “Variable chlorine dosage”

Table 3-2 Summary of experiments for chlorine dosage optimization

Experiment	Dosage[1] (mg Cl_2/L)	Sample Location	Monitored parameters
Constant chlorine dosage	**1.76**	WTP, C1, C2, M1, M2	Physico-chemical & pressure
Constant chlorine dosage	**2.00**		
Constant chlorine dosage constant	**2.18**		
Variable chlorine dosage with flow at different times	**1.76 – 1.06**		
Variable chlorine dosage with flow at different times	**2.18 – 1.31**		
Validation of optimized chlorine dosage	**2.18 – 1.31**	WTP, C2, M2	Physico-chemical, Microbiological & Pressure

3 different dosages namely 1.76 mgCl_2/L, 2.00 mgCl_2/L, and 2.18 mgCl_2/L were experimented on and the dosing rate kept constant. This was done with the hypothesis that, in order to make sure there is adequate free residual chlorine in the distribution system and at the consumer taps, a constant chlorine dosing rate be maintained.

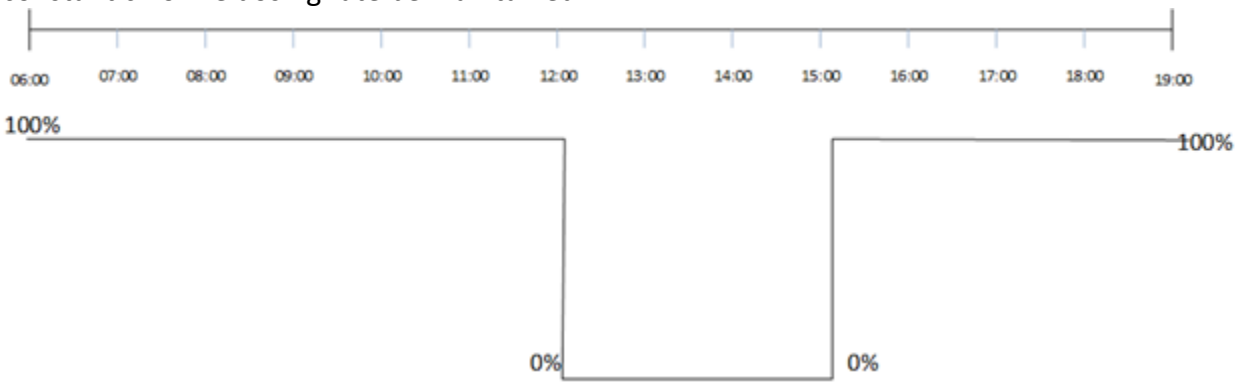

Figure 3-11 Constant dosing rate

The different dosages with constant dosing rates (14 L/h) applied was done bearing in mind the characteristics of water and the chlorine demand. It was plausible that water at the consumer taps will have very low residual chlorine or very high residual chlorine depending on factors such as seasonal changes which more often affects the water characteristics and chlorine demand in the distribution system.

Additionally 1.76 mgCl_2/L and 2.18 mgCl_2/L dosages were dosed into the treated water at a varied dosing rate (14 L/h, 11.2 L/h, 8.4 L/h) as a second strategy, the decision was taken to vary the chlorine dosage but maintaining the same maximum concentrations, by now applying the range 1.76 – 1.06 mg/L and 2.18 – 1.31 mg/L. A study conducted by (Heber, 1985) indicating that, the

[1] Dosage added to the treated water at a rate of 14 L/h

rate of dosing should be proportional to the amount of water used, which is normally dependent on the consumption pattern. Figures 3.9 and 3.10 show the consumption pattern in Moamba and the variation in the dosing rate that was utilised during this research, respectively. The consumption profile shows the daily Moamba consumption pattern. Thus the dosing pattern was designed to have the highest dosing rate at the peak consumption period. In the afternoon, the highest dosing rate was determined to be during the late afternoon when the water treated will be transported to Pessene over a long distance.

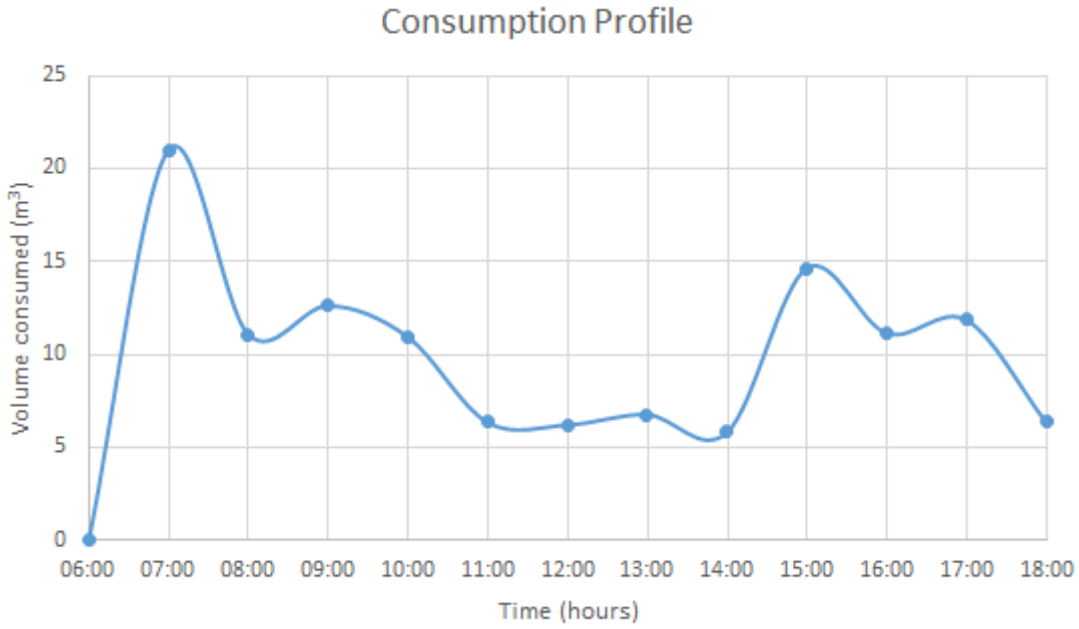

Figure 3-9 Consumption pattern in Moamba, calculated over14 days

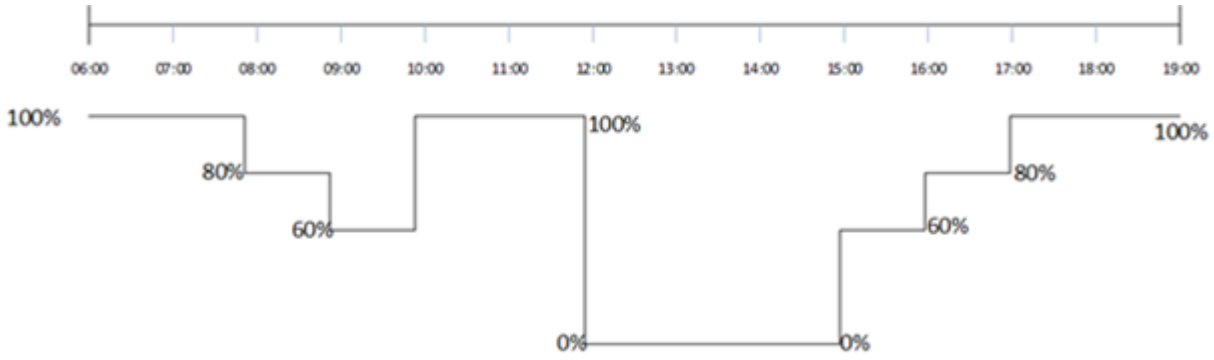

Figure 3-10 Varied dosing rates strategy at different times

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Samples were taken as described in the sampling methods. Only physico-chemical parameters were analysed for the samples in this experiment. Pressure readings were monitored using pressure gauges at the taps of the sampling points in each of the selected neighbourhood and recorded every time a sample is taken.

After all the chlorine dosage optimization was done, the dosing strategy which resulted in the "best" (residual chlorine that was consistently above 0.2 mg/L and less than 1.5 mg/L and had the highest mean residual chlorine) residual chlorine and within the guidelines of the WHO was

chosen and used for the validation of the optimal chlorine dosage and dosing strategy. After the optimization experiment, the need to validate the results from the experiments was imperative. Validation is defined as whether there is an improvement in the concentrations of indicator bacteria, which was evident in the baseline phase. This validation phase is determined using the Kruskal Wallis test with 95 per cent confidence level by comparing *E.coli* and total coliform concentrations during the baseline results and the validation phase. With different research papers suggesting that, the presence of chlorine residual alone is not enough to verify the quality of water but a further analysis of microbial contamination must be investigated to ascertain to a large extent the quality if drinking water. Studies conducted in India by Kumpel & Nelson, suggested that conductivity, temperature and pH gave a minimal understanding of how contamination occurs. It further revealed that residual chlorine was more indicative on the probability of contamination in IWS. However indicator bacteria analysis are useful in detecting contamination. The samples were taken at the farthest point in each of the selected neighbourhoods (C2 and M2) using a similar fashion as described in the sampling methods. Both physico-chemical and microbiological parameters were analysed for the grab samples in this experiment. Pressure readings were monitored using pressure gauges at the taps of the sampling points in each of the selected neighbourhood and recorded every time a sample is taken.
The experiment was repeated to enable standard deviation, variance and reproducible results.
Table 3.3 shows a summary of water quality grab samples, by sample location and the experiments undertaken. For each experiment, the number of samples that will be tested for the above-listed experiment are given.

Table 3-3 Summary of water quantity grab sample for chlorine dosage optimization

Sample Location	EXPERIMENTS					
	Constant Cl_2 dosage 1.76 mg/L	Constant Cl_2 dosage 2.00 mg/L	Constant Cl_2 dosage 2.18 mg/L	Variable Cl_2 dosage 1.76 – 1.06 mg/L according to water flow	Variable Cl_2 dosage 2.18 – 1.31 mg/L according to water flow	Validation of optimized Cl_2 dosage
Outlet of water tower at WTP	2	2	2	2	2	2
Tap Matadouro (M1)	36	36	36	36	36	-
Tap Matadouro (M2)	36	36	36	36	36	36
Tap Cimento (C1)	36	36	36	36	36	-
Tap Cimento (C2)	36	36	36	36	36	36
Total number of samples	146	146	146	146	146	74

3.2.5.3 Effect of supply cycles duration

For the variation of supply duration, permission from the utility company was sought to enable the variation of the typology and the duration of the supply cycle. With supply duration in the study area averaging 8 hours supplied in two daily cycles, the utility company was asked to supply for a continuous 10 hours and 12 hours to test the influence of this supply cycle strategy on water quality. Using indicator 6.1.1 which looks at the "proportion of population using 'safely' managed drinking water" (UN, 2016). This indicator which is a measure of the proportion of people that are having access to improved drinking water sources located on premises, available when required (> 12 hours per day) and free of faecal contamination and other hazardous substances.

To this end, supply was done for a continuous period of 10 hours and 12 continuous hours. The perceptions of consumers that in an intermittent water supply system, the duration of supply affects the water quality (Guragai, et al., 2017).This hypothesis influenced the objective of this experiment.

The chorine dosage of 1.76 mg/L was dosed at a constant dosing rate of 14 L/h. The dosing rate was kept constant and samples were collected at the yard taps of the M2 and C2. Pressure within the distribution lines was monitored and recorded at the consumer taps were the samples was being taken and this was done using pressure gauges. Samples were collected as soon as I got to the chosen household at 6:00 am and that sample is recorded as time zero. Samples were collected every hour afterwards until 4:00 pm. In total 10 samples were collected and analysed for physico-chemical parameters and 21 samples for microbiological analysis for *E. coli* and total coliform. The chlorine mixed batch was used for only one day in this experiment. The next experiment had the period of continuous supply extended to 12 continuous hours. The chlorine dosage of 1.76 mg/L was newly mixed again and dosed at a constant dosing rate of 14 L/h. Samples were similarly collected at the households designated C2 and M2. Sampling started at 6:00 am as soon as I got to the yards of the selected households and ended at 6:00 pm. Samples were taken hourly during the continuous 12 hours of supply. In total 12 samples were analysed for physico-chemical parameters and 25 samples were analysed for microbiological parameters (*E.coli* and total coliforms). Pressure within the distribution lines was monitored and recorded at the consumer taps were the samples was being taken and this was done using pressure gauges. Table 3.4 shows a summary of water samples during the experiment to determine the effects of supply cycle duration.

Table 3-4 Summary of grab samples for effects of supply cycles duration

EXPERIMENTS	Chlorine Dosage 1.76 mg/L	Supply Characteristic	Sampling Points	Parameters Monitored	Sampling Frequency	Total number of samples
Effects of supply cycles duration	10	10 Continuous hours	Outlet of water tower at WTP, C2, M2	Physico-chemical and microbiological	Every hour at taps but only 1 sample taken at WTP	21
	10	12 Continuous hours	Outlet of water tower at WTP, C2, M2	Physico-chemical and microbiological	Every hour at taps but only 1 sample taken at WTP	25

3.2.5.4 First-flush

All previous experiments were used to understand the effect of first flush. First flush is defined as the water that comes out at the consumer taps after a period of no flow. The first flush is normally used to gauge the level of deterioration of water quality in the distribution system when there was no supply. Samples were taken at 10 minutes interval in the first hour and then the next sample was taken after an hour when supply started in the morning. At the resumption of

flow of water in the afternoon after the period of no supply in Moamba, samples were taken again in 10 minute interval for the first hour. The turbidity and residual chlorine parameters were recorded to ascertain how long it took before water quality improved.

3.3 Materials

The materials that were used for the research are listed below:

- Wagtech Potatech (Palintest)
- Chromocult agar (Sartorius Nutri pads)
- Wagtech Microbiological Incubator
- 0.45µm membrane filters (Sartorius, 11406)
- Whirl-pak Thio-bags of 100mL volume
- Sampling bottles
- Forceps
- Sodium hypochlorite
- Nalgene filtration unit (Filters for distilled water sterilization)
- Cooling box
- 70% Ethanol

4

RESULTS

4.1 Baseline assessment

The baseline assessment revealed the existing conditions of the water supplied to consumers. Results showed that water quality deteriorates after the treated water leaves the outlet of the WTP to consumers' taps. Specifically, 50% of samples collected at both sampling points (C2 and M2) were below the recommended value for residual chlorine at the taps (> 0.2 mg/L). The water samples collected at WTP however showed 67% of the samples had residual chlorine above the recommended 0.5 mg/L at the treatment plant with an average residual chlorine of the water leaving the outlet of the WTP being 0.8 mg/L.

At the consumer taps, the data of free residual chlorine showed a variation with respect to chlorine levels at different distances from the WTP. Out of the 34 samples taken in the baseline assessment, Matadouro (the further away neighbourhood) had 10 of the samples recording values lower than 0.2 mg/L as compared to 7 of the samples taken in Cimento. 7 samples collected in Cimento had chlorine levels higher than 0.4 mg/L but in Matadouro there was none. Figure 4.1 shows distribution of free chlorine measurements by sampling point. The samples with free residual concentration of 0.1-0.2 mg/L had the highest frequency in the case of Matadouro, but in the case of Cimento the results were more spread out.

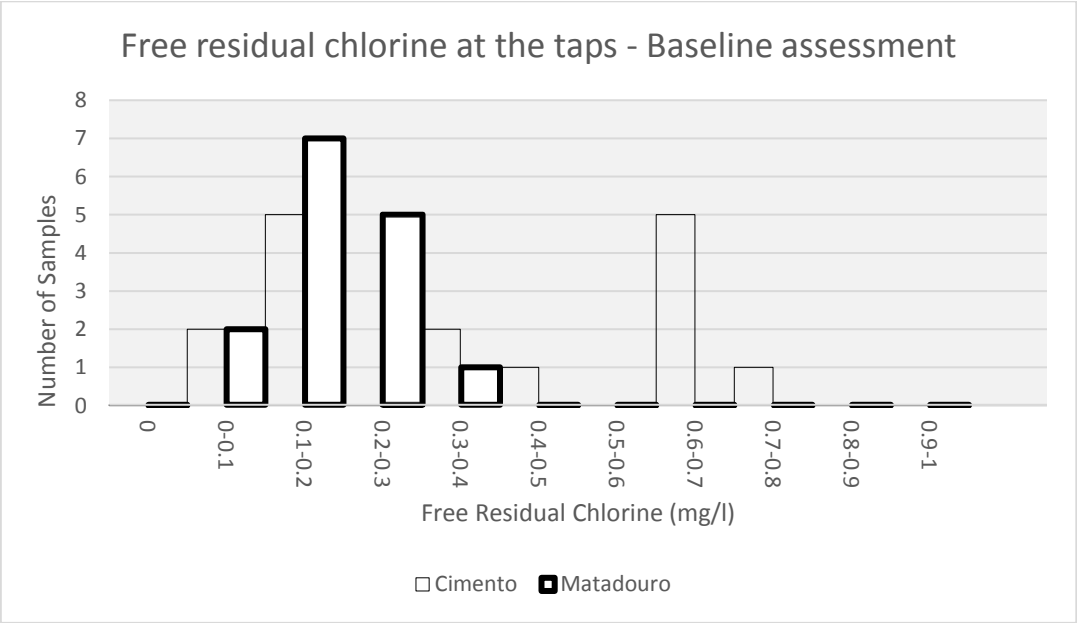


Figure 4-1 Distribution of free residual chlorine in the two neighbourhoods during the baseline

The benchmark for the turbidity levels for the water collected at the consumers' taps was set at 5 NTU according to the technical brief on review of turbidity for regulators and water supplies(World Health Organization, 2017). 74% of the water collected at consumer taps were below 5 NTU, with an average turbidity level record being 3.8 NTU. 26% representing 9 out of

the 34 samples had turbidity levels greater than 5 NTU with an average turbidity reading of 6.8 NTU. The total mean turbidity was thus 4.5 NTU during the baseline assessment.
The relatively low turbidity reading at the consumers' taps however did not have a positive correlation with level of contamination. 68% of the collected samples from both neighbourhoods revealed to have the presence of indicator bacteria. The mean value of *E.coli* present was 2 CFU/100mL. Table 4-1 shows the number of collected samples that satisfied the WHO guideline on *E.coli*. See Appendix B1 for the statistics on the physico-chemical parameters.

Table 4-1 E.coli statistics of the baseline assessment

	Number	Percent
Met WHO guideline	11	32.4
Did not Meet WHO guideline	23	67.6
Total	34	

4.2 Determination of the optimal strategy for chlorine dosage

Based on the results from the baseline assessment, there was the need to conduct different experiments to determine the optimal strategy for chlorine dosing. In order to assess the optimised chlorine dose and verify which operational strategy was optimal, there was the need to breakdown the experiment into two sub-groups. The chlorine dosages experimentation and the validation of the optimal chlorine dosage.

4.2.1 Residual Chlorine

A total of 613 samples were taken and analysed for free residual chlorine and total chlorine during the sampling period. Majority of the samples tested showed residual chlorine levels in the network and at the outlet of the WTP above the WHO guidance value and Mozambican regulation of 0.2 mg/L. The standard for Mozambican water supply (MISAU, 2004) as stipulated by Ministerio da Saude recommends a range between 0.2 mg/L – 1.5 mg/L at the water works.
Table 4.1 shows the results of all the samples collected from the outlet of the water tower.

Table 4-2 free residual chlorine in all samples taken at the outlet of the WTP

	Number of samples	Percentage
Within guideline value (0.2 mg/L)	**63**	**76**
Below minimum guideline value (0.2 mg/L)	**9**	**11**
Above maximum guideline value (1.5 mg/L)	**11**	**13**

Out of the 83 samples collected at the outlet of the WTP, the test for free residual chlorine showed that, 76% of the samples were within the recommended range by the standards of WHO and the MISAU (2004). However, in 11% of the samples, free residual chlorine did not meet the

recommended guideline value; 13% of samples had higher level of residual chlorine which was above the Mozambican guideline.
In the chlorine dosage optimisation experiments, the data of the residual chlorine at the different sampling locations at the taps revealed that the total residual chlorine levels are above 0.2 mg/L with all the different chlorine dosages. The minimum recorded free residual chlorine was 0.02 mg/L, which is below the limit of detection (LoD) which was 0.03.

Constant chlorine dosage 1.76 mg Cl_2/L

The water samples for this chlorine dosing strategy were analysed only for physico-chemical parameters with the emphasis on the free residual chlorine at the different consumer taps at the selected neighbourhoods. Out of the 99 samples collected, 73 (representing 74%) had free residual chlorine higher than 0.2 mg/L. A breakdown of this percentage however showed that 41% of the samples that had free residual chlorine concentration above 0.2 mg/L was from Cimento and 33% was from Matadouro.
The mean value of free residual chlorine using the above dosing strategy was 0.35 mg/L, with a mean turbidity level of 10.4 NTU. Table 4-3 shows the descriptive statistics for the physico-chemical parameters.

Table 4-3 Descriptive Statistics for free residual chlorine, total chlorine and turbidity

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	99	1.36	0.02	1.38	0.35	0.28	0.08
Total_Residual_Chlorine	99	1.30	0.14	1.44	0.45	0.28	0.08
Turbidity	99	28.46	2.24	30.70	10.40	6.99	48.91

Constant chlorine dosage 2.00 mg Cl_2/L

It was found that 85% of the total samples collected had residual chlorine above 0.2 mg/L. This figure is represented by 116 out of 136 samples collected during this experimentation. 15% of the samples collected did not have the required residual chlorine at the taps of consumers as recommended by the WHO. The minimum free residual chlorine concentration recorded using this chlorine dosing strategy was 0.06 mg/L with the maximum concentration of free residual chlorine being 1.16 mg/L. Both neighbourhoods had 68 samples collected each from the taps of the selected houses. Only 1 of the 68 samples in Cimento had free residual chlorine less than 0.2 mg/L with the average being 0.48 mg/L. However 20 out of the 68 samples in Matadouro had residual chlorine less than 0.2 mg/L with the average free residual chlorine in Matadouro being 0.32 mg/L. In general the average free residual chlorine was 0.4 mg/L with the mean turbidity during this period was 7.8 NTU. Table 4-4 gives a summary of the parameters analysed.

Table 4-4 Descriptive statistics for the 2.0 mg/L chlorine dosing strategy

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	136	1.10	0.06	1.16	0.40	0.23	0.05
Total_Residual_Chlorine	136	1.20	0.14	1.34	0.51	0.23	0.05
Turbidity	136	24.96	3.15	28.11	7.75	3.43	11.74

Constant chlorine dosage 2.18 mg Cl_2/L

119 samples were taken out of which 87 had residual chlorine between 0.2 mg/L – 1.5 mg/L. 17 of the samples had residual chlorine which was less than 0.2 mg/L and 15 samples had residual chlorine being above the Mozambican guideline of 1.5 mg/L. The mean free residual chlorine at the consumer taps was 0.63 mg/L. This is comprised of 73% of the samples above 0.2 mg/L, 14% of the samples below 0.2 mg/L and 13% of all the collected samples were above 1.5 mg/L. The average turbidity recorded was 7.5 NTU. The average free residual chlorine in both Cimento and Matadouro was 0.63 mg/L. Below is the figure showing the distribution of the residual chlorine in the neighbourhoods

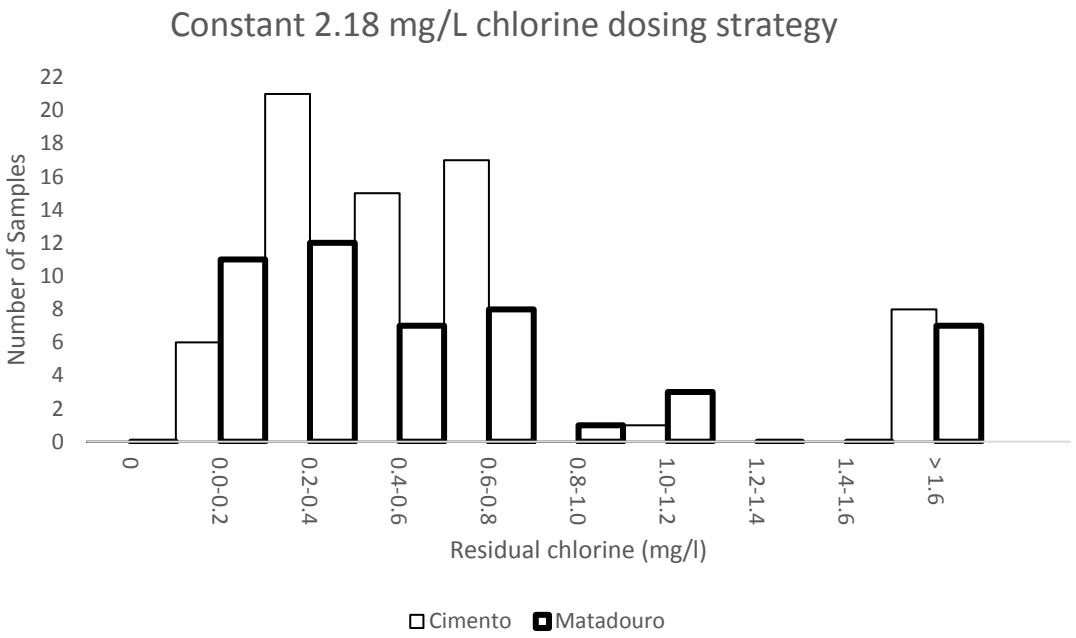


Figure 4-2 Distribution of the free residual chlorine at the consumer taps from the sampling points in Cimento and Matadouro

Variable chlorine dosage with flow at different time (1.76 mg/L – 1.06 mg/L)

During the variable chlorine dosing strategy using a dosage range of 1.76 mg/L – 1.06 mg/L, 70 samples were analysed. None of the samples collected and analysed had residual chlorine above 1.5 mg/L. However 67% of the samples had residual chlorine above 0.2 mg/L which was satisfactory according to the guidelines of WHO. 33% of the samples on the other hand had residual chlorine being less than 0.2 mg/L. 65% of the samples collected in Matadouro had residual chlorine being less than the recommended guideline for water at consumer taps. This compared to 0% of the samples in Cimento was recorded with residual chlorine less than 0.2 mg/L. The general mean of all the 70 samples collected was 0.39 mg/L. the turbidity recorded during this period of sampling was 4.8 NTU. Table 4-5 shows a summary of the general statistics of the collected sample when the variable chlorine dosing strategy was undertaken.

Table 4-5 Summary of descriptive statistics in both Cimento and Matadouro when the 1.76 mg/L - 1.06 mg/L varied dosing strategy

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	70	1.18	0.08	1.26	0.39	0.28	0.08
Total_Residual_Chlorine	70	1.21	0.19	1.40	0.49	0.27	0.07
Turbidity	70	12.66	1.74	14.40	4.77	2.27	5.15

Variable chlorine dosage with flow at different time (2.18 mg/L – 1.31 mg/L)

The analysis of residual chlorine at the consumer taps when the chlorine dosage of range (2.18 mg/L – 1.31 mg/L) was varied at different times during the supply period was done for 68 samples. 90% of these samples had residual chlorine above 0.2 mg/L. The mean free residual chlorine at the consumer taps was 0.6 mg/L. With the minimum recorded free residual chlorine at the sampling points being 0.12 mg/L and the maximum free residual chlorine recorded was 1.36 mg/L. The breakdown of the results at the different locations showed that 81% of the samples in Matadouro had free residual chlorine greater than 0.2 mg/L as against 100% of the samples collected in Cimento having residual chlorine greater than 0.2 mg/L. The results shows most of the free residual chlorine was in the range of 0.2 mg/L – 0.4 mg/L is both neighbourhoods. Figure 4-3 shows the distribution of the free residual chlorine in Matadouro and Cimento

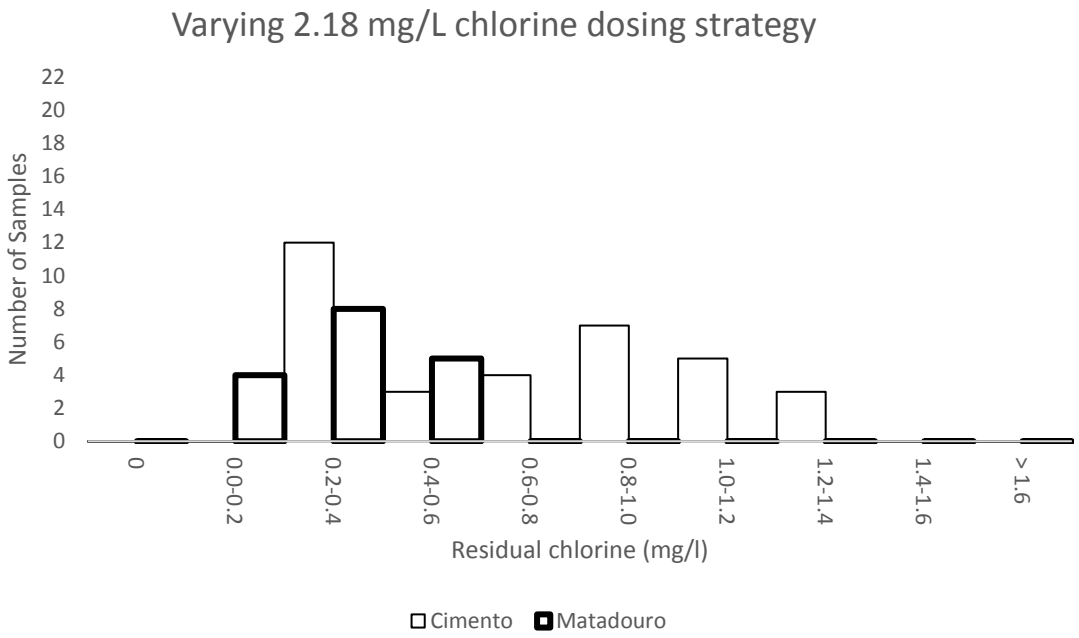


Figure 4-3 Distribution of chlorine profile at the consumer taps in both Cimento and Matadouro

Summary of the optimal chlorine dosage strategy

475 samples were collected and analysed, out of which 91 representing 19% were below the minimum recommended value for free chlorine residual, while 78% were complying. 3% were above the Mozambican guideline of 1.5 mg/L. Table 4.3, gives a general outlook of the free chlorine residual for all the different dosing strategies analysed.

The average combined chlorine detected was 0.2 mg/l which is an indication of the amount of chlorine that forms a reaction with ammonium in the water. The mean free residual chlorine was 0.46 mg/l with the total residual chlorine having a mean of 0.66 mg/l. At the start of flow in some cases, the data showed lower chlorine residuals persistently throughout the morning and this could be as a result of water age. During the period of lower chlorine residuals, the results showed that an average of 0.2 mg/L in Cimento and 0.14 mg/L in Matadouro.

The free residual chlorine with different chlorine dosages and dosing strategies showed high residual at consumer taps when 2.18 $mgCl_2/L$ constant dosing was done in Fig 4-4. The table 4-6 gives a detailed statistics on all the different chlorine dosing strategies.

In appendix C, the plot showing the variation of temperature and free chlorine shows no distinct correlation between temperature and free chlorine.

The figure 4-4 shows the 2Q box representing the second quartile or 50th percentile, which indicates the lowest value of concentration of residual chlorine which is greater than 50% of the data. The 3Q box also shows the third quartile or 75th percentile which indicates the lowest value of the data under review that is greater than 75% of the results. The median and the range of the data is also represented.

Table 4-6 General outlook of free chlorine of different dosages

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Variable dosage of 1.76 $mgCl_2/L$ – 1.06 $mgCl_2/L$	70	0.39	0.28	0.03	0.32	0.46	0.08	1.26
Variable dosage of 2.18 $mgCl_2/L$ – 1.31 $mgCl_2/L$	51	0.58	0.34	0.05	0.48	0.67	0.12	1.36
Constant dosage of 1.76 $mgCl_2/L$	99	0.35	0.28	0.03	0.29	0.41	0.02	1.38
Constant dosage of 2.0 $mgCl_2/L$	136	0.40	0.23	0.02	0.36	0.44	0.06	1.16
Constant dosage of 2.18 $mgCl_2/L$	119	0.63	0.55	0.05	0.53	0.73	0.06	2.30
Total	475	0.46	0.38	0.02	0.43	0.50	0.02	2.30

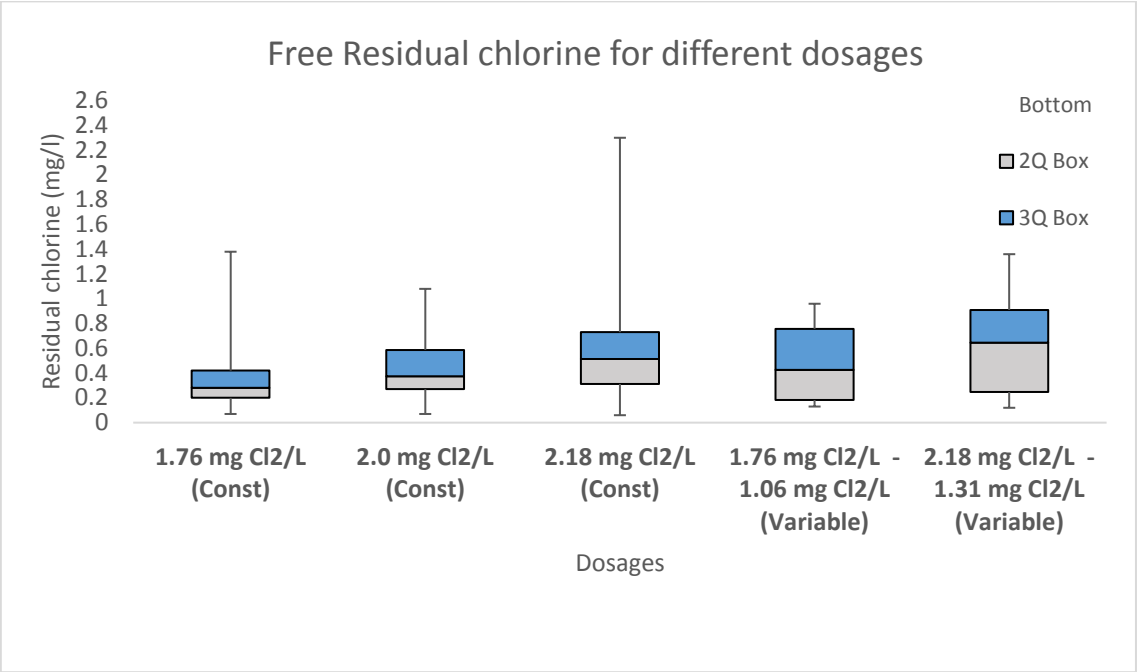


Figure 4-4 Free Residual chlorine at the taps with "constant" chlorine dosage and "variable" chlorine dosage

Validation of optimized chlorine dosage

In the validation section of the experiments undertaken, the 2.18 $mgCl_2$ /L – 1.31 mgCl2/L (12kg of $Ca(OCl)_2$)dosage with varying the chlorine dosing rate was chosen. The reason for this decision was based on the analysis of the graphs, which showed that even though 2.18 $mgCl_2$/L dosage with constant dosing rate recorded the highest free chlorine, the graph in Fig. 4-4 shows the varying 2.18 $mgCl_2$/L - 1.31 $mgCl_2$/L dosage at different dosing rate had a mean of free residual chlorine which were all within the guidelines of WHO and that of the Mozambican standards. Comparing it in terms of distance away from the WTP and also how the residual behaves when the supply resumes in the afternoon and lastly only 10% of the results of residual chlorine did not meet the guideline of 0.2 mg/L as compared to the percentage of results not meeting the required value of 0.2 mg/L of the other strategies which ranged between 14%, 15%, 26% and 33%, it was logical that the optimal strategy for chlorine dosage was a varying dosage of 2.18 $mgCl_2$/L - 1.31 $mgCl_2$/L. See Figure 4-7 and Figure 4-10.

In the validation experiment, 104 samples were collected from consumers taps, 65% was within the recommend value for free residual chlorine, 10% was above the recommended value suggested by the standards provided by the Mozambican authority and 25% was below 0.2 mg/L. A summary of the results of the validation experiment is shown in Table 4-7. The results after the validation however did not show an improvement in the chlorine levels as compared to the initial optimization experiment. The mean free residual chlorine was 0.52mg/L slightly below 0.6 mg/L which was the concentration of the free residual chlorine from the initial experiment.

The results showed that there were differences in the residual chlorine concentrations at the consumer taps during the chlorine optimization experiments. There was significant difference in the residual chlorine concentrations at the consumer taps when it was tested with the Kruskal Wallis test $H(5, N=170)= 15.9,\ p < 0.05$

Table 4-7 Free residual chlorine at the taps during the validation experiments

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	104	2.63	0.07	2.70	0.52	0.59	0.35
Total_Residual_Chlorine	104	2.59	0.16	2.75	0.62	0.59	0.35
Turbidity	104	21.24	3.96	25.20	9.15	3.29	10.80
Total_coliform	104	200.00	0.00	200.00	21.06	41.06	1685.69
E.coli	104	11.00	0.00	11.00	0.42	1.37	8

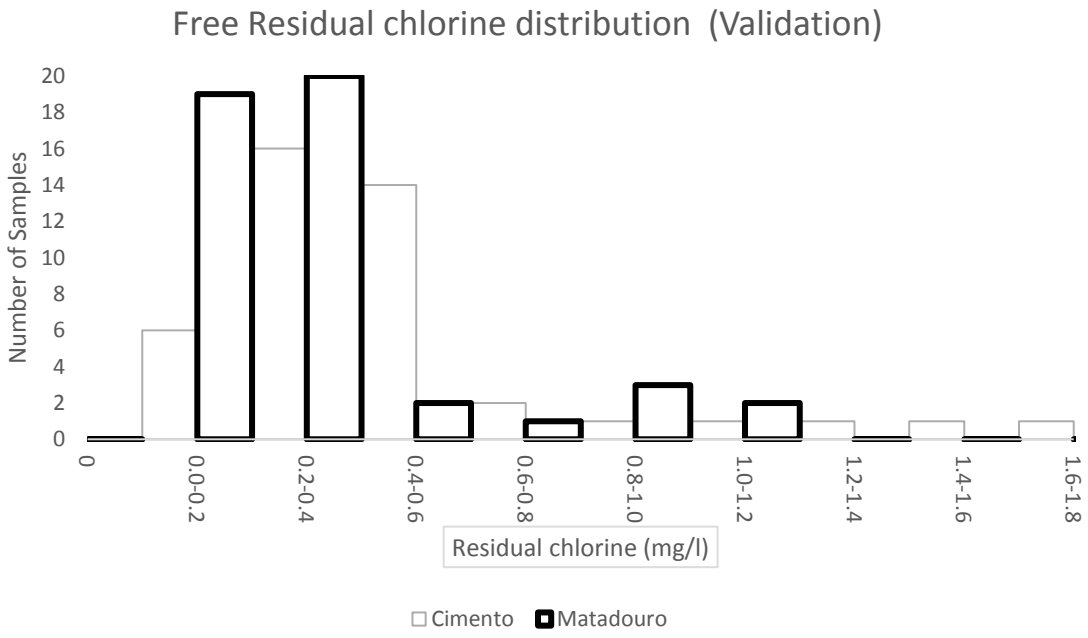


Figure 4-5 Free Residual chlorine distribution with sampling location

4.2.2 Turbidity

Turbidity monitoring was used to evaluate the degree of clarity/cloudiness in the sample of drinking water. The benchmark for turbidity used in this analysis was 5 NTU. High turbidity levels were observed generally as soon as the supply begun (first-flush). The mean value of turbidity level of the water from the outlet of water tower at the WTP was 9.8 NTU. Out of the 83 samples collected from the WTP 52 representing 63% was above this upper limit for turbidity (see Appendix B). It is worth noting that the turbidity levels varied widely with conditions on the day of sampling. The minimum turbidity recorded over the sampling period was 0.6 NTU with the maximum turbidity level recorded at all the sampling points was 37.7 NTU. In general, the turbidity of the water leaving the WTP was consistent even though majority of the samples had readings greater than 5 NTU. At the 4 sampling locations during the different dosing strategy experiment, the average turbidity reading was a high 7.5 NTU with the downstream of the distribution system being Matadouro contributing the highest number of grab sample with turbidity greater than 5 NTU. Out of the 475 grab samples, 219 was from Matadouro with 76% having turbidity level above 5 NTU. Cimento however had 256 samples out of which 68% was

above the 5 NTU. The high turbidity reading at the treatment plant can be attributed to particles that accumulate in the water tower having escaped the treatment process. Figure 4-6 shows the mean turbidity for all the samples under the different experimental phases. It is seen that turbidity increased with the different weather conditions and periods of the year.

Also in fig 4-7, it can be seen as indicated by the graph, that turbidity increased with distance. This is seen with the average of turbidity levels in each of the sampling points. The turbidity at Cimento 1 which is only 50 meters away from the WTP showed a mean turbidity reading of 5.4 NTU. The closest distance away from the WTP in Matadouro showed also a slightly lower turbidity reading of 5.8 NTU as compared to the farthest sampling point in Matadouro which had an average turbidity reading of 8.2 NTU. It is worth noting that the lowest turbidity reading was found at the closest sampling point which is 50 meters away from the WTP and the worst average turbidity reading was recorded at the farthest sampling point which is 2200 meters away from the WTP. The WTP turbidity show an average value of 5.2 NTU during the validation phase but increase to an average of 8.9 NTU at the consumer taps. However during the baseline and chlorine strategy phase the average WTP turbidity was high as compared to the turbidity at the consumer taps. Apart from the difference in the mean turbidity level during different phases of the experimentation, there was significant difference in the turbidity levels when it was tested with the Kruskal Wallis test $H(3, N= 130) = 37.7$, $p < 0.05$

The plot of the relationship between pressure and turbidity in Appendix does show some level of correlation indicating high turbidity levels being associated with the relatively high pressure readings.

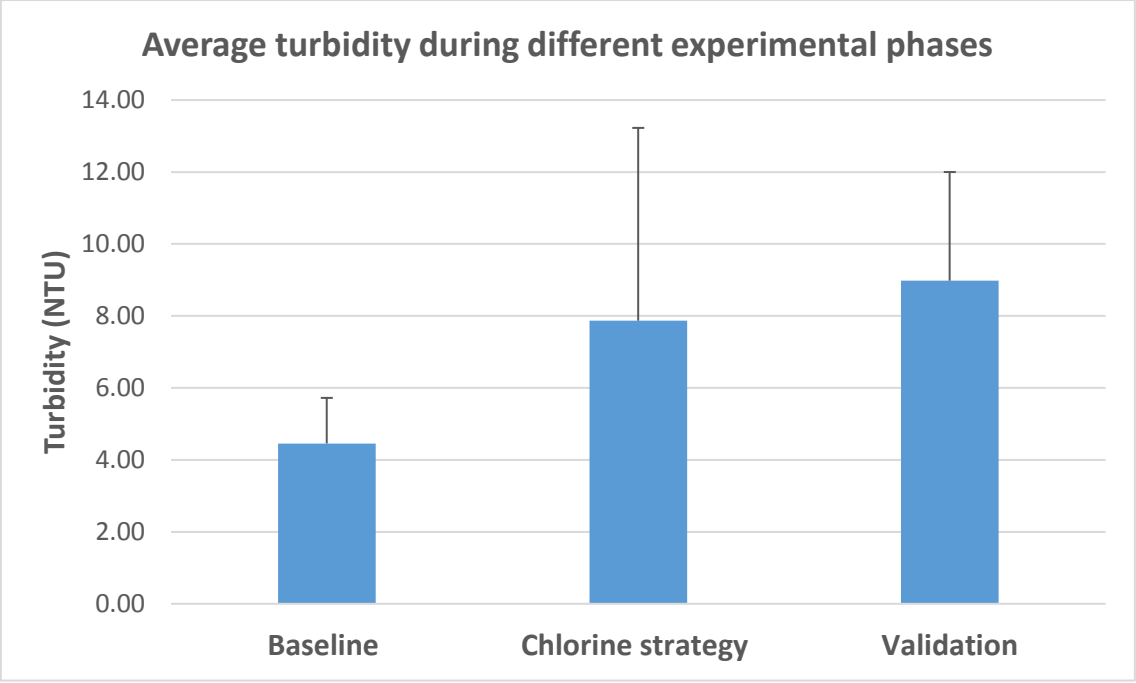


Figure 4-6 Average turbidity readings during different experimental phases at the taps

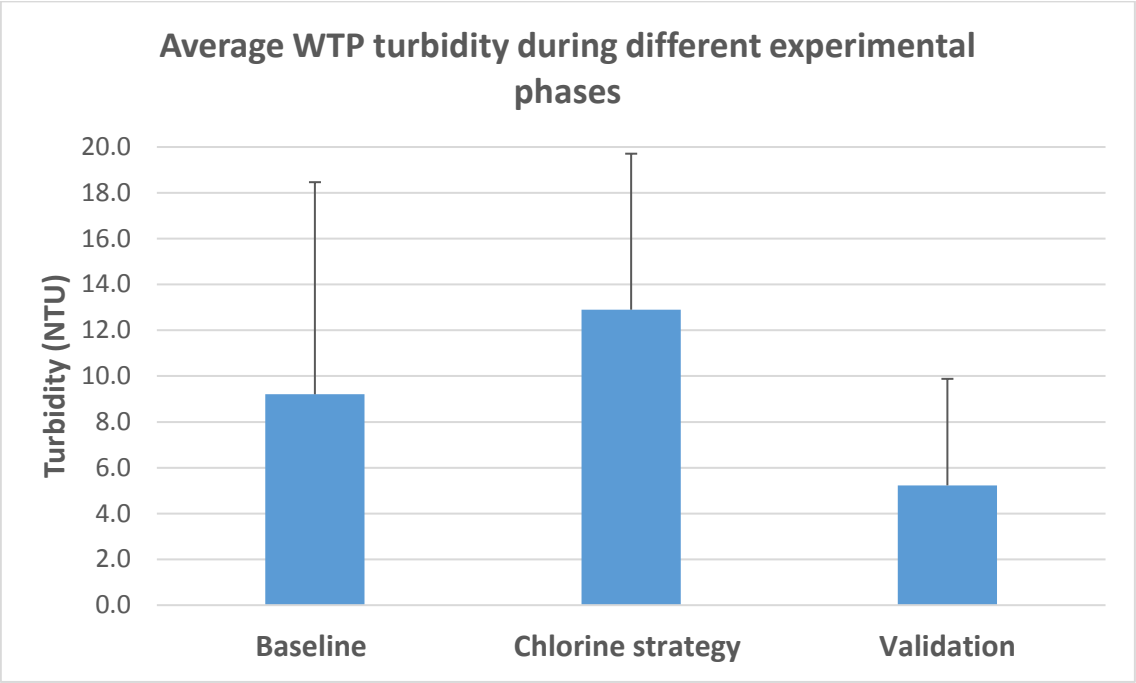


Fig. Showing Average WTP turbidity during different experimental phases

4.2.3 Microbiological water quality

The initial sampling undertaken during the baseline phase had 34 samples being analysed, with the range of *E.coli* being 0 CFU/100 ml to 16 CFU/100 ml. total coliform how ever had a wider range from 0 CFU/100ml to 200 CFU/100 ml. 23 out of the 34 samples plated had *E.coli*. 32% of the samples met the WHO guideline of 0 CFU/ 100ml. Table 4-8 and Table 4-9 indicates the number of samples that met the WHO guidelines in baseline and the average and range for both Total coliforms and *E.coli.*

Table 4-8 Baseline data on E.coli representation

		Frequency	Percent
Valid	Met WHO guideline	11	32.4
	Did not Meet WHO guideline	23	67.6
	Total	34	100.0

Table 4-9 E.coli and Total Coliform data

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Total coliform	34	200.00	.00	200.00	37.29	68.96	4755.85
E.coli	34	16.00	.00	16.00	2.26	3.38	11.41

Figure 4-8 shows a combination of total coliforms and *E.coli* levels within the distribution system at the different phases in. In Cimento, the neighbourhood closest to the water treatment plant during the validation phase, 84% of the samples collected had total coliform levels between 1 CFU/100 ml and 200 CFU/100ml. The downstream of the distribution system (M2) had 87

samples tested for total coliform and *E.coli*, 79 of the samples had total coliform present representing 91%. *E.coli* was found in 17% of the 104 samples collected. M2 samples being the farthest point in the distribution system had 69 samples analysed with 10 of the samples being positive for *E.coli* having a range from 0 CFU/100 ml to 4 CFU/100 ml. C2 the closest neighbourhood to the water treatment plant had 7% of the samples being positive for *E.coli*. The range was from 0 CFU/100 ml to 11 CFU/100ml.

In general, based on the fact that the values of *E.coli* concentration were very low, the data was analysed based on presence/absence. Thus most of the detection occurred during the baseline phase. The validation even though there was the presence of total coliform and *E.coli*, the results clearly showed an improvement with the water quality. With the baseline presence of *E.coli* being identified throughout most of the samples collected in the day, whereas the validation phase showed presence of *E.coli* during the start of the cycle only. The improvement was a seen when the comparison between the baseline results of *E.coli* which indicated only 32% of all the samples collected in both sampling points met the WHO guideline of 0 CFU/100mL as against the validation results of *E.coli* which indicates 83% of all the samples collected in similar sampling points as in the baseline meeting the WHO guideline of 0 CFU/100mL. In terms of total coliform, the mean in the baseline was 37 CFU/100mL as compared to the mean in the validation phase being 21 CFU/100mL. Table 4.6 shows the data statistics during the validation phase. Figure 4-8 and figure 4-9 shows *E.coli* representation in both the baseline and validation phase and total coliform in both baseline and validation phase respectively.

With the microbiological assessment, the Kruskal-Wallis test was performed with the null hypothesis that, "Baseline results for indicator bacteria and Validation results for indicator bacteria are the same." With the premise being the x^2 is greater than 5.99, reject the null hypothesis. H = 107.65, thus the null hypothesis is rejected. There is a significant difference between baseline *E.coli* and Validation *E.coli* with H (2, N= 138) = 347.73, $p < 0.05$.

However the total coliform results showed a reduction but with the Kruskal Wallis test, the change in total coliform concentration in the baseline and that of total coliform in the validation is not significant H(2, N= 139) = 0.18, $p < 0.05$

Table 4-10 Validation Microbiological data

WHO Guideline 0cfu/100 ml

		Frequency	Percent
Valid	Met WHO guideline (0cfu/100 ml)	86	83
	Did not Meet WHO guideline (> 0cfu/100 ml)	18	17
	Total	104	100.0

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Total_coliform	104	200.00	.00	200.00	21.06	41.06	1685.69
E.coli	104	11.00	.00	11.00	.42	1.37	1.88

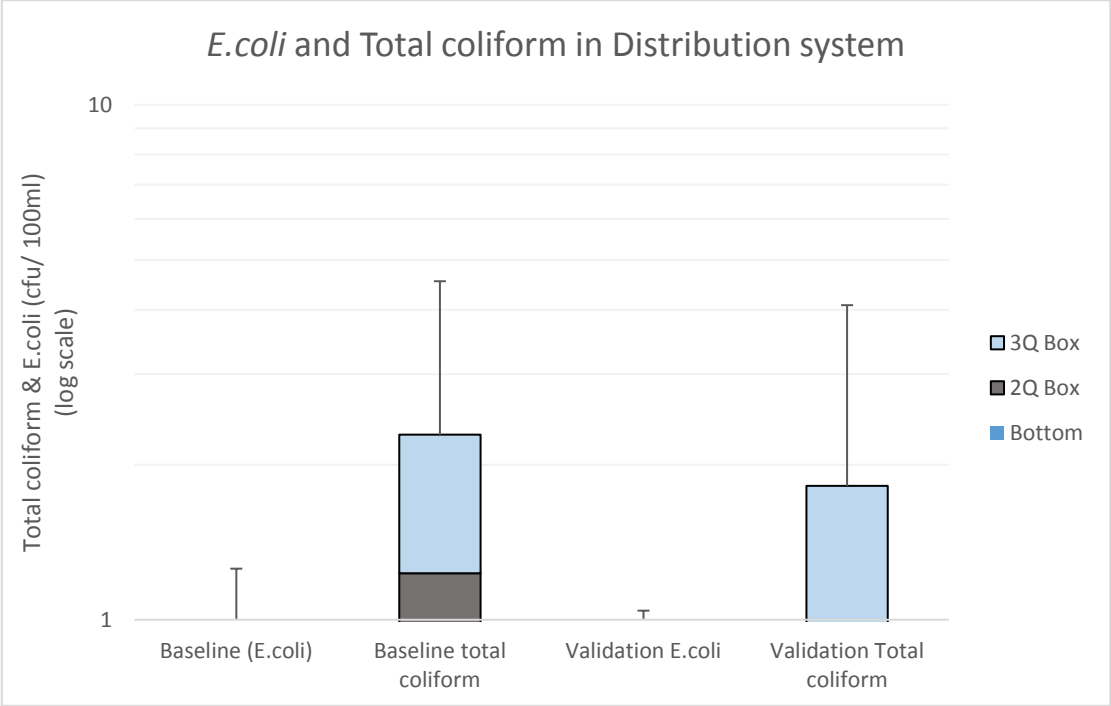


Figure 4-7 Box and Whisker plots indicating the median, lower and 3rd quartile of total coliform and E.coli during the baseline and validation phase

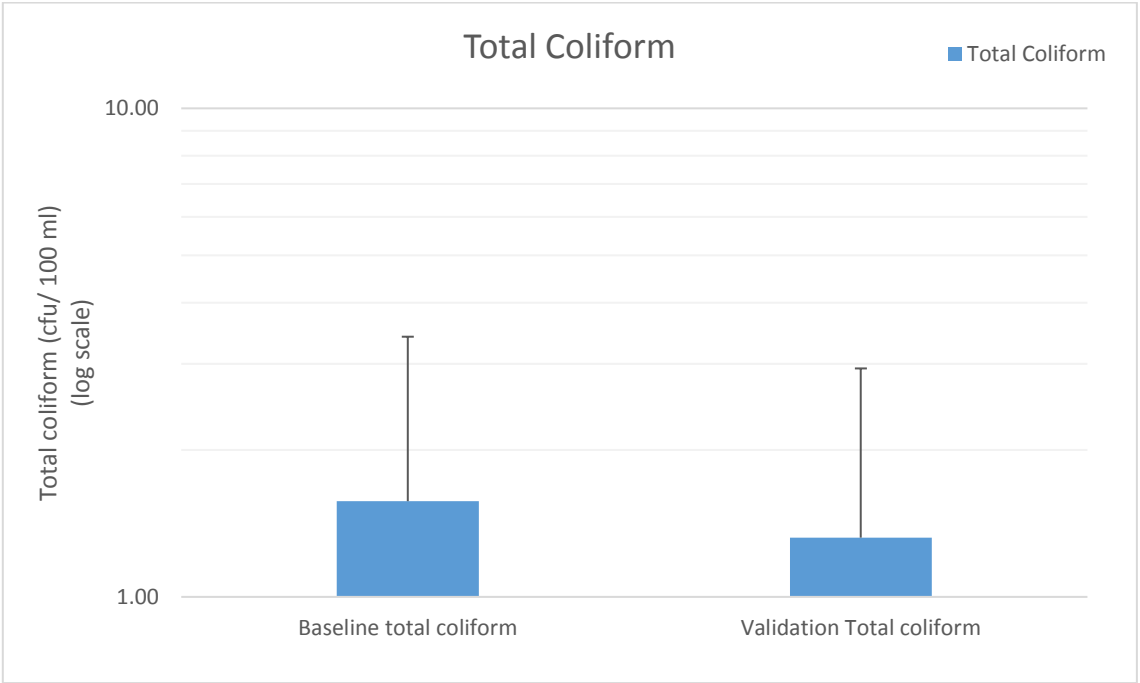
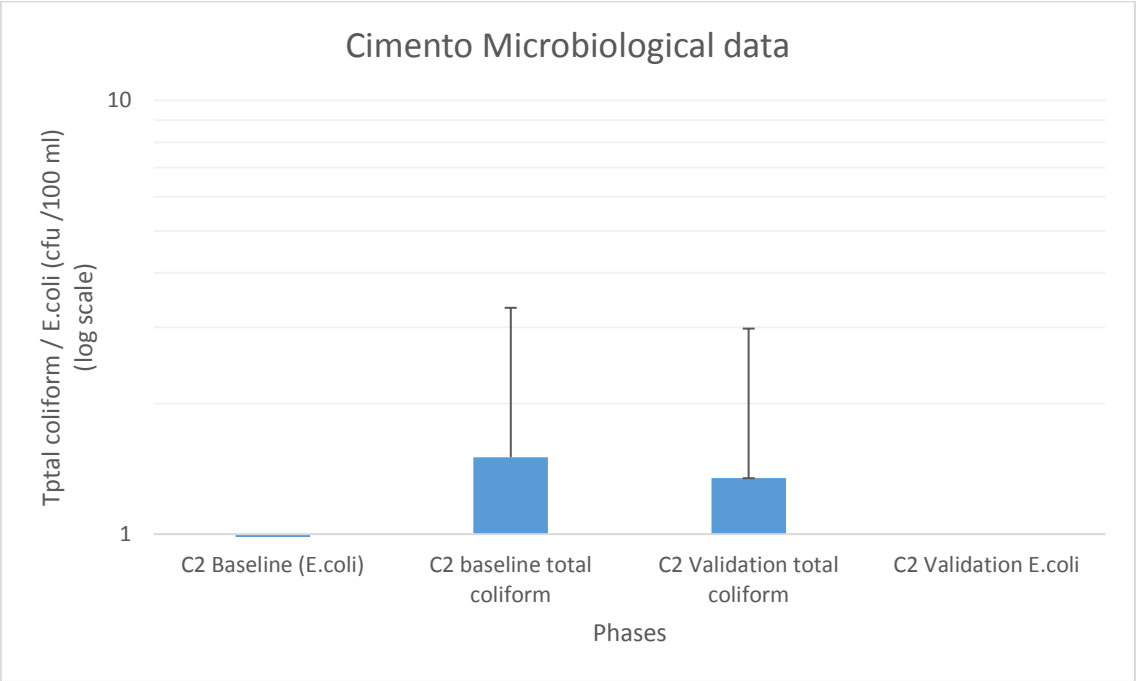


Figure 4-8 Average indicator bacteria at sampling points during baseline and validation phase showing standard deviations



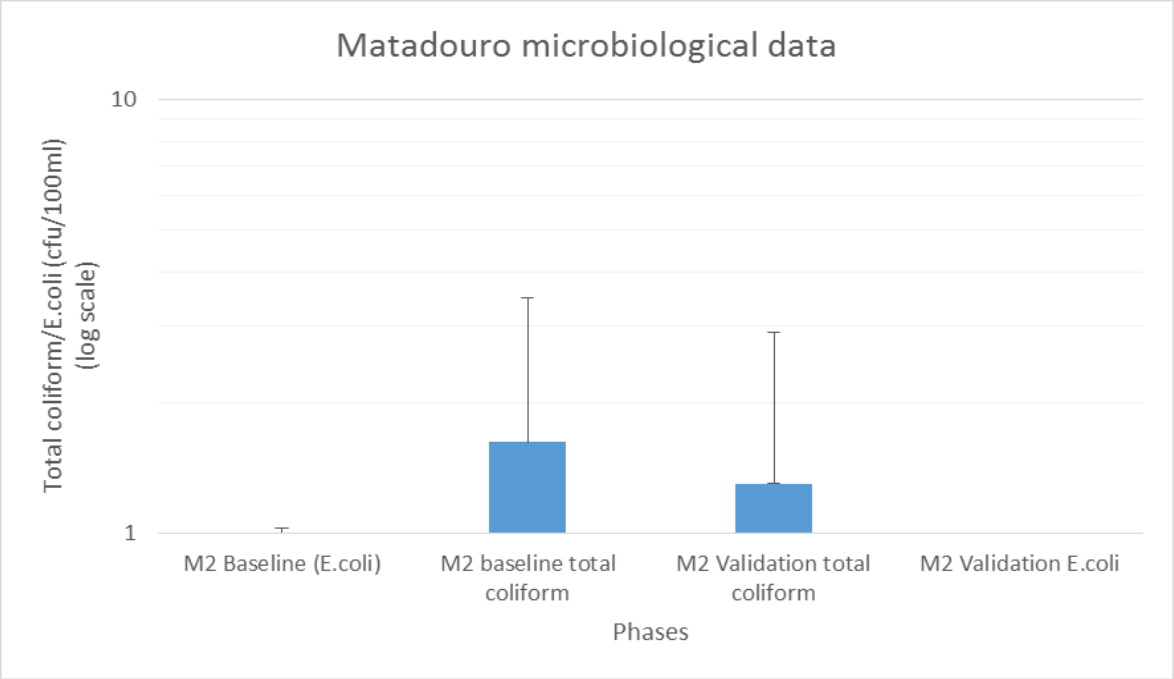


Figure 4-9 Indicator bacteria at different sampling points away from the WTP with standard error bars

4.2.4 Time Series Data

In analysing the data and considering the intermittent nature of the Moamba supply cycle, it is important in ascertaining its effect the different dosages and dosing strategies of $Ca(OCl)_2$. The data revealed a dynamic distribution system which exhibits different profiles at different sampling points. It also revealed that the physico-chemical parameters did not follow a strict trend with respect to the time within the supply cycle. The variation in chlorine profile when the same experiment was repeated for reproducibility, saw a difference in the chlorine profile and turbidity over the supply cycle, even-though the samples were taken at similar times of the supply cycle. It is also worth noting that, the only similarity that was observed considering the supply

cycle was the low level of residual chlorine after the supply starts again late in the afternoon. The difference in the residual chlorine can be attributed to be as a result of different demands on the distribution system. Using a time series data analysis, 8 hours of monitoring in an intermittent way of the distribution system showed events of chlorine drop with an average of 4 events of turbidity spikes within every sampling occasion. Pressure details of the period remained fairly constant.

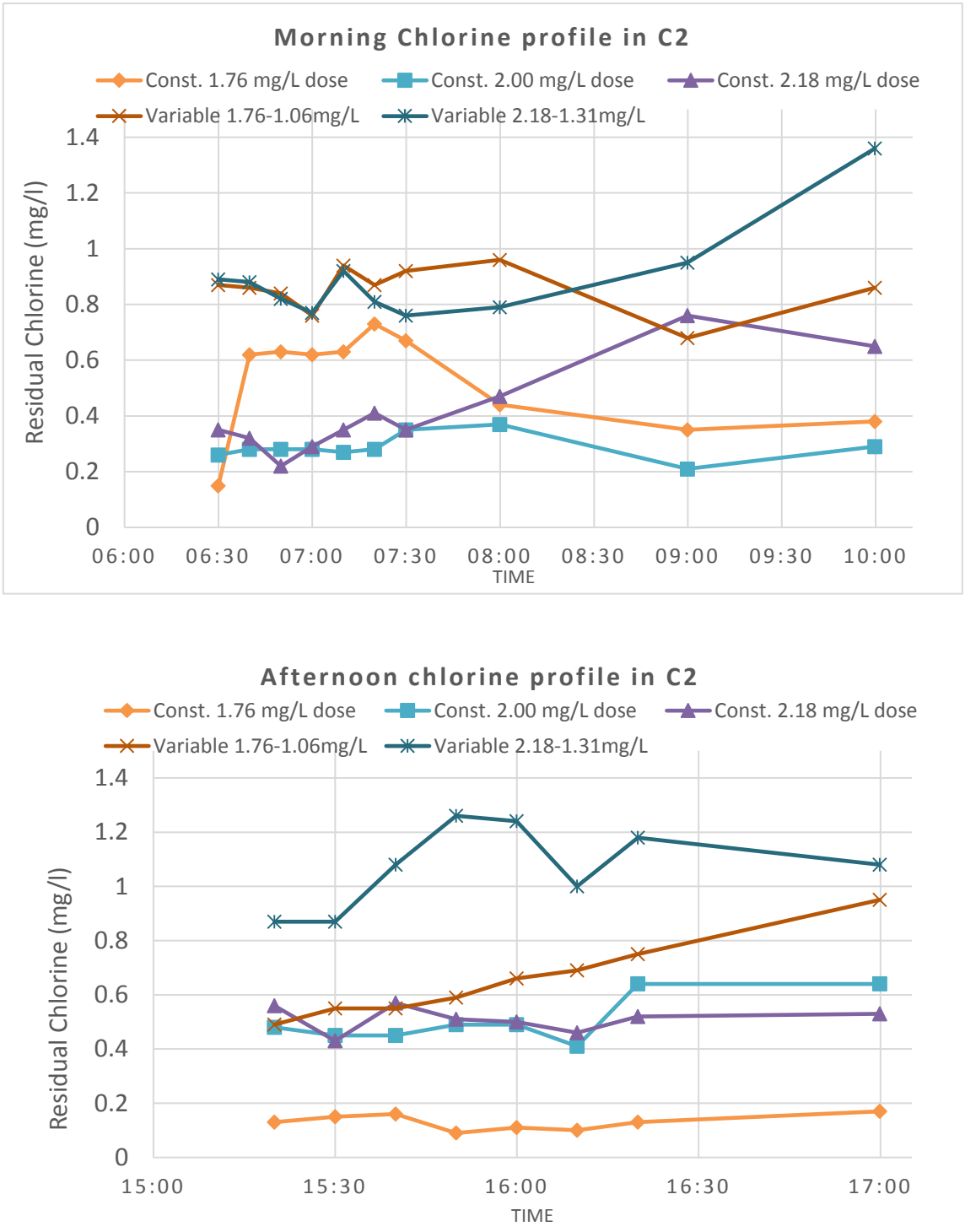


Figure 4-10 Residual chlorine at different dosages and dosing strategies within the time series

4.2.5 Distance from WTP

The addition of $Ca(OCl)_2$ which is done at the WTP and the treated water being transported over a long distance or otherwise to consumer taps, the decay of the chlorine in water will invariably bring different readings and varying water quality at different locations. The effect of distance and water quality and in this case intermittent supply is very important to analyse (Coelho, et al., 2003). The effect of distance with free residual chlorine, total residual chlorine, turbidity and the indicator bacteria was evident in the research. The distance apart as described in chapter 3, revealed that the water quality deteriorated at the farthest point in the distribution system within the neighbourhoods under consideration. The level of free residual chlorine reduction with respect to distance is seen in the mean levels of residual chlorine which is 0.55 mg/L in Cimento which is 800 meters away from water treatment plant and 0.36 mg/l in Matadouro which is 2200 meters away from the water treatment plant. The different dosages and different dosing strategies also showed that distance travelled by the treated water always affected the initial dose at the WTP. Comparing the daily readings of free residual chlorine at the water treatment plant and the corresponding readings at the consumer taps at the various sampling points at the different distances away, the average difference in the residual chlorine in samples from the WTP to Cimento was 0.47 mg/L and the average difference in samples at Matadouro with respect to the WTP was 0.62 mg/L. Turbidity levels within sampled also showed a relation between turbidity and distance. The turbidity increase with increasing distance away from the WTP. See fig 4.7.

With the indicator bacteria analysed (*E.coli* and total coliform), the results in section 4.2.3 indicates that samples taken from M2 during both the baseline and validation had high numbers for total coliform and E.coli.

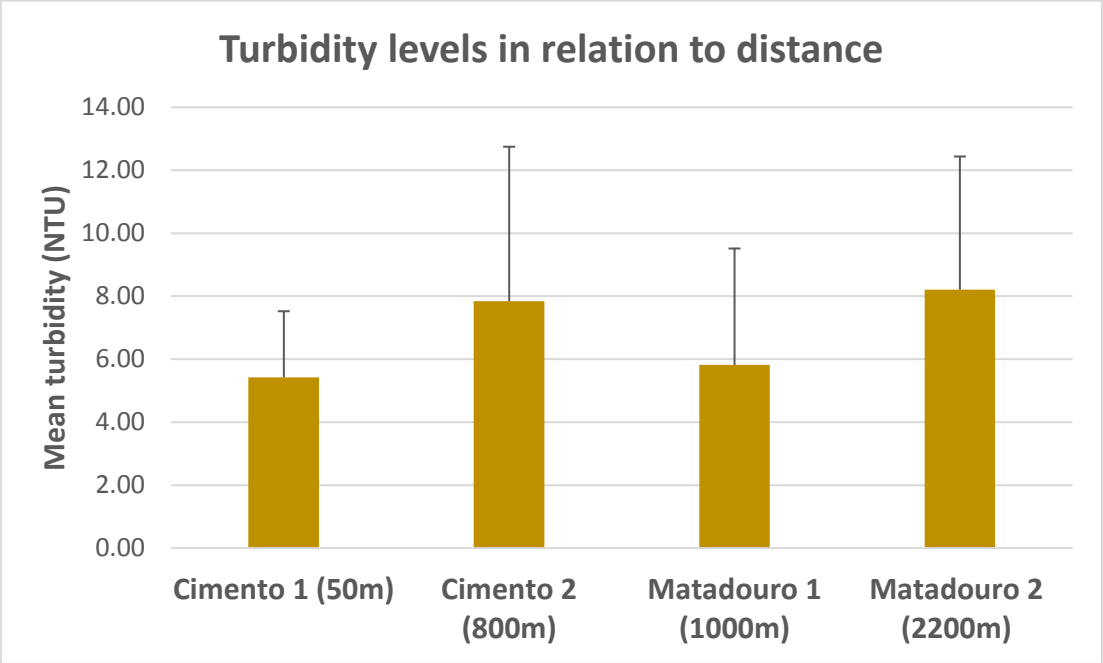


Figure 4-11 Turbidity readings with distance

4.2.6 Discussion

The results outlined show free residual chlorine, turbidity and indicator bacteria as the main parameters in assessing the water quality (Keegan, et al., 2012, LeChevallier, et al., 1981). The difference seen when comparing residual chlorine at consumer taps and the residual chlorine at the out of the WTP show that there is decay of chlorine during the transport of water.
The reduction in the residual chlorine at the consumer taps may be as a result of possible presence of sediments in the distribution system. The presence of the sediments can be verified by the turbidity levels which were recorded at the consumer taps. Reports from the WHO (2004) suggests that sediments in distribution networks have the tendency to increase chlorine decay rate. The plausible presence of sediments may also serve as a means for the attachment of nutrients for bacterial growth, thereby increasing the chlorine demand in the network. The studies conducted by (Kiéné and Lévi, 1996) showed that, after 2 hours of contact time, 55% of chlorine in the distribution network is consumed by sediments. This thus can be the reason for the chlorine decay. The mean residuals at the WTP and the sampling points was used to check the level of decay in the residual chlorine when it leaves the WTP. Another reason for the decrease in residual chlorine at the different sampling points at various distances apart as indicated in the results can be attributed to the level of stability of $Ca(OCl)_2$. The decomposition levels are very much dependent on time (Colborn, et al., 2011). Even though in the analysis of the data collected from the field did not show any correlation between temperature and residual chlorine, studies have suggested that decomposition of $Ca(OCl)_2$ doubled for every 5^0C increase (Colborn, et al., 2011). This means that at higher temperatures it is expected that active chlorine is lost. With $Ca(OCl)_2$ having a fast reaction with organic matter in water, the reduced levels of residual chlorine in comparison to the water at the WTP can be said to be caused by the active chlorine being used up by the present organic matter. The time series analysis in figure 4.8 showed a trend to buttress the point of the temperature being a factor in the reduced levels of residual free chlorine, with the results showing very much reduced level of free residual chlorine concentration at the start of sampling in the afternoon. The reduced level can also be attributed to the dosing strategy used as seen in the consumption profile in Fig 3-9, the peak consumption in Moamba is exactly at the start of the supply in the afternoon and gradually reduces in the day. The dosing strategy however used was opposite to the peak consumption. This is to say 60% rate of dosing can be an attributing factor for the low free residual chlorine at the start of the flow in the afternoon. Also in the constant dosing strategy, the period of no treatment and dosing prior to the start-up of the flow in the afternoon can also be said to contribute to the low residual chlorine in the afternoon.
It is worth noting that, though all the different dosages and dosing strategies followed similar trends, the optimal chlorine dosing strategy (varying 2.18 $mgCl_2/L$ – 1.31 $mgCl_2/L$ at different times) actually had better residual chlorine levels at the resumption of supply in the afternoon in C2 but in M2 the residual chlorine at the resumption of flow in the afternoon also showed reduced residual chlorine. Matadouro is thus a very critical point in the distribution system. With no official data available from the operators on the frequency of burst in both Cimento and Matadouro, but with experience gathered whilst in the field, the number of repairs undertaken on the distribution system in Matadouro is twice the frequency of bursts in Cimento. This could explain the very low free residual chlorine at the consumer taps in Matadouro. The results also outlines the effect the distance played in the decomposition of residual chlorine. This difference could be as a result of the difference in demand at the different neighbourhoods, thus influencing the travel time of the water and invariably the age of the water (Gibbs, et al., 2006). The number of customers in Matadouro is higher than that of the customers in Cimento, thus the demand in

Matadouro is higher, thereby reducing the pressure in the network in Matadouro. Ingress of contamination is more likely to occur with the low pressures. The optimal chlorine dosing strategy did not produce the highest free residual chlorine concentrations, however it was chosen due to the inability of the other dosing strategy to meet the minimum residual chlorine throughout the entire distribution system, the 2.18 $mgCl_2/L$ constant dosing rate resulted in very high residual chlorine concentration which were more than the upper limit for the standards for residual chlorine in Mozambique. The dosage and dosing strategy could lead to areas which are close to the WTP having problems with disinfectant by-products (DBP's) if the amount of organic matter in the water is revealed to be high, thus another reason not to choose it as the optimal dosing strategy. The presence or absence of indicator microorganism, a means to identify safe drinking water (G. Ferrero, 2017) and with the guidelines (WHO/UNICEF JMP, 2017) specifying the standards for drinking water to have 0 CFU/100 ml in terms of E.coli and Total coliforms. The optimal dosing strategy selected was also chosen due to the hypothesis expounded by (Camper and McFETERS, 1979), that fluctuating the chlorine dose in water increase the recovery time for "injured coliforms". The research suggests that the average recovery time from injuries caused to microorganism (*E.coli*) is averagely 2 hours, thus the hourly variation in the chlorine dose as expected resulted in the reduction of *E.coli* and total coliforms as can be seen in the validation phase of the experiment.

The results of the WTP turbidity level being high as compared to the turbidity level of the collected sample at the consumer taps during the baseline and chlorine strategy optimization phase, can be attributed to the ineffectiveness of treatment at the WTP or the filter inadequacy. Thus resultant high turbidity level of the water leaving the WTP. At the consumer taps, the reduction of this collected sample is likely be due to the low velocities within the distribution system thereby allowing settling to take place. The turbidity levels as indicated in the results showing low turbidity level at the WTP but increasing turbidity levels at the consumer during the validation phase can be alluded to be the reason for the persistent total coliform. This can be an indication of why the total coliform was still present in the validation phase using the optimal chlorine strategy. The shielding effect of turbidity for microorganism is thus verified, as even with the residual chlorine in the grab samples, total coliform is still present. The literature which also explains what constitutes total coliform also makes mention of the groups which make up the total coliform being the thermotolerant coliforms, faecal based bacteria and bacteria from environmental related conditions. Thus the persistent nature of the total coliform may or may not represent existing faecal contamination. The persistent nature of the total coliform in the validation phase can also be because of the development of resistant mechanism to withstand high levels of chlorine or different dosing strategy (Ridgway and Olson, 1982).

The findings with seasonal changes having an effect on turbidity (Kumpel and Nelson, 2013, Kumpel and Nelson, 2014) was corroborated in the results. The baseline phase was done in November, during which the dry season was just about ending. Between November and December when the summer season started in Mozambique with lots of rain, the chlorine strategy and validation phase of the experiment was undertaken. Although not the general case, the highest turbidity levels were recorded in the raining season in Mozambique, which started during the chlorine optimization phase (December).

The high levels of turbidity in the samples can also be a statement on the ineffectiveness of the treatment process. The need to improve the effectiveness is very essential. The increased turbidity levels begs the question if there is a need to have an improvement in the infrastructure available at the WTP to provide an additional barrier for turbidity removal. The operation/operators at the WTP may also need to be improved. Also the operational means of treatment should be varied with the changing turbidity levels especially as shown by the results

that seasonal changes has an effect on turbidity. The operational changes may range from increasing backwashing frequency, changing chlorine dosing strategy and monitoring of raw water quality to meet turbidity design capacity of the plant.
The intermittency nature of the system also led to different pressure readings within the distribution system at the different sampling points. The pressure monitored at the sampling points detected some low pressure reading but no negative pressure. Periods in-between "no supply" and just before the resumption of supply, expulsion of air from the consumer taps were observed. The presence of indicator bacteria in the grab sample can be attributed to the ingress of contaminants during the "no supply" period, in which there was no pressure within the distribution pipelines. Water stagnation, a main attribute of intermittent water supply and an avenue for the degradation of water quality can also be attributed to the persistent total coliform in the validation phase when the optimal chlorine strategy was used.

4.3 Assessing how the typology and duration of supply cycles affect water quality at the point of delivery.

4.3.1 Continuous water supply

In the 10 hours of continuous supply, the chlorine residual concentration at the consumer taps was averagely 0.62 mg/L as compared to 0.24 mg/L when the supply was continuous for 12 hours. See figure 4-12. The observation of the residual chlorine of the grab samples at the consumer taps during the 12 hours of supply revealed, 30% of the 25 samples collected did not meet the WHO standard of 0.2 mg/ L.

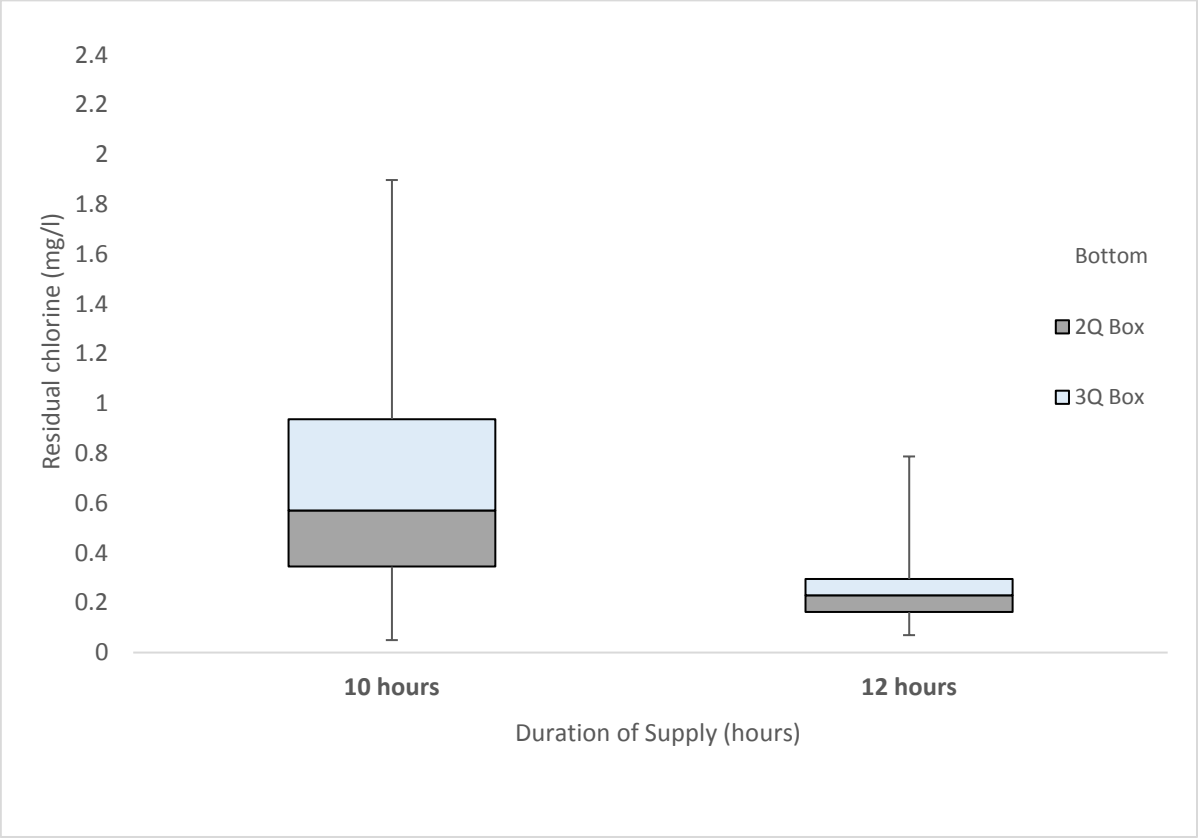


Figure 4-12 The residual chlorine at consumer taps showing the mean, second quartile, third quartile and outliers.

As earlier stated in 4.1.7, pressure within the distribution system can have an effect on both turbidity and contamination of the water at consumer taps. Figure 4-13 and figure 4-14 showed the results of turbidity and *E.coli* contamination.

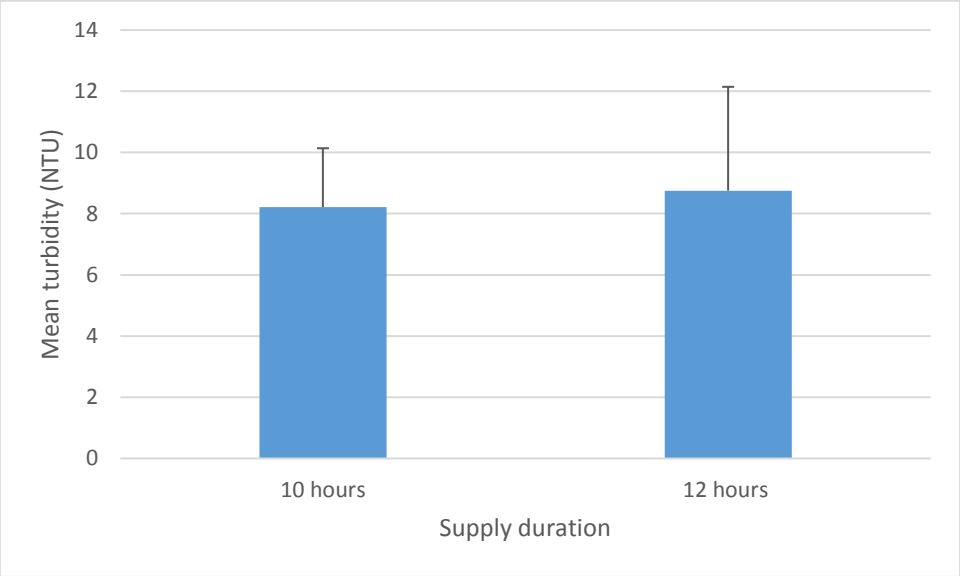


Figure 4-13 Error bar plot showing mean turbidity reading during different supply durations

The average pressure during the 10 hours of continuous supply recorded was 1.81 bar as compared to 1.27 bar when the supply duration was 12 hours. This results of the mean pressure during the different supply durations did not translate into confirming the studies that stated the relationship between pressure and turbidity. The turbidity level in 12 hours (8.8 NTU) was higher than that of 10 hours which has a higher average pressure.

The microbiological analysis of the grab samples was done to ascertain if there was any difference in the level of contamination with the different supply duration. *E. coli* was the parameter tested for. Results from the samples in figure 4-14 shows the presence of *E.coli* in the both supply duration.

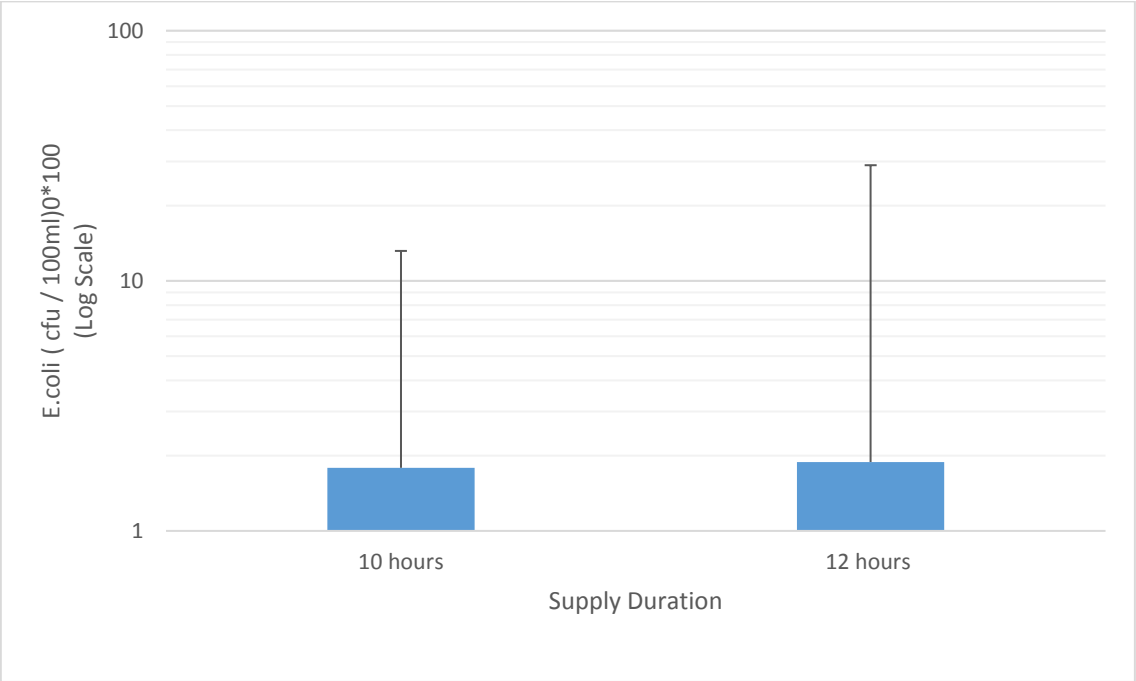


Figure 4-14 Error bars for E.coli contamination, showing the mean E.coli (CFU/100ml) with the standard deviation

The results show that, the mean value of *E.coli* during the 12 hours of supply was higher than that of the mean *E.coli* identified during the 10 hours of supply. The interpretation of the error bars however reveals that, there is a significant data from the 12 hours of supply duration which is lower or the same as that of the data on *E.coli* present in samples during the 10 hours of supply, thus the water quality based on *E.coli* results are inconclusive.

4.3.2 Discussion

The hypothesis which influenced the objective of assessing how the typology and duration of supply affect water quality was from the study conducted in Nepal. The study sought to seek the perception of consumers on intermittent supply. It was reported in the study that, majority of the respondent where of the opinion that, the quality of their water was dependent on the supply duration (Guragai, et al., 2017).

The parameters analysed except for residual chlorine did not show distinct difference between a supply duration of 10 hours and that of 12 hours. The difference in the residual chlorine concentration at the consumer taps showed a distinct difference in 10 hours of supply being 0.57 mg/L as compared to 0.23 mg/L. the difference can be attributed to the dynamics of chlorine in the distribution system daily. With the different demands happening possibly each day, the residual chlorine is likely to change. This is consistent with literature which ascribes that, during the day, variations of flow into the plant and the day-day variations in demand may have an effect on the rate of dosing chlorine and this would result in daily change in concentration of chlorine at sampling point (Gibbs, et al., 2006). The demands affect the velocity of flow within the distribution system which intend leaches some biofilms which can consume the chlorine within the system as was stated by the studies by (Lu, et al., 1999). The other factor for the reduced residual chlorine during the 12 hours of supply can possibly be the activity that took place before the experiment was undertaken. The no flow experience prior to the experiment could have contributed to this results due to the water age within the distribution system.

The other observation in verifying if the hypothesis alluded to was coherent or not, was to analyse the turbidity and microbiological contamination of the grab samples.

The turbidity levels shows no significant difference in their averages. With similar treatment processes used during both supply durations and the not so significant difference in pressure during these sampling periods, the turbidity levels are explained.

4.4 Evaluation of the first flush water quality at the beginning of each supply cycle.

4.4.1 First flush water quality

Samples of water were collected during the start-up of the supply. These samples were collected as soon as the supply began. There were 30 events when first flush was monitored with 15 first flush each in both neighbourhoods. In the analysis of the first flush events, the intermittent nature of the supply provided two different times the first flush was observed and sampled. The first sampling was done in the morning and the second done upon resumption of the flow again in the afternoon.

In the analysis, the first readings on each day of sampling for first flush events was grouped and the average used to plot the graph. Similar was done for all points for the first sixty minutes of first flush sampling in the morning and the first 60 minutes of first flush sampling in the afternoon. In the morning first flush, the variation of turbidity and free residual chlorine in both Matadouro and Cimento showed the residual concentration in the collected sample at Cimento starting at a high concentration relative to that of the concentration at Matadouro. This phenomenon saw the progression of free residual concentration at both sampling points. The mean free residual chlorine concentration during the first flush event was 0.6 mg/L at the start of flow and progressed to reduce to 0.58 mg/L with a standard deviation of 0.28 after 60 minutes of monitoring with mean turbidity remaining fairly constant after it reduced from 8.1 NTU at the start of flow and reduced to 6.7 NTU with a standard deviation of 2.7 after 30 minutes of flow. However in Matadouro, mean free residual chlorine concentration at the start of flow was 0.2 mg/L with a standard deviation of 0.15 after 60 minutes of monitoring but mean turbidity reading increased after 20 minutes of flow to 9.6 from 8.5 NTU with a standard deviation of 5.0. This high standard deviation for Matadouro shows the high degree of variability with the turbidity results. Figure 4-15 shows the average readings and the standard deviations of the variation between turbidity and residual chlorine at both Matadouro and Cimento.

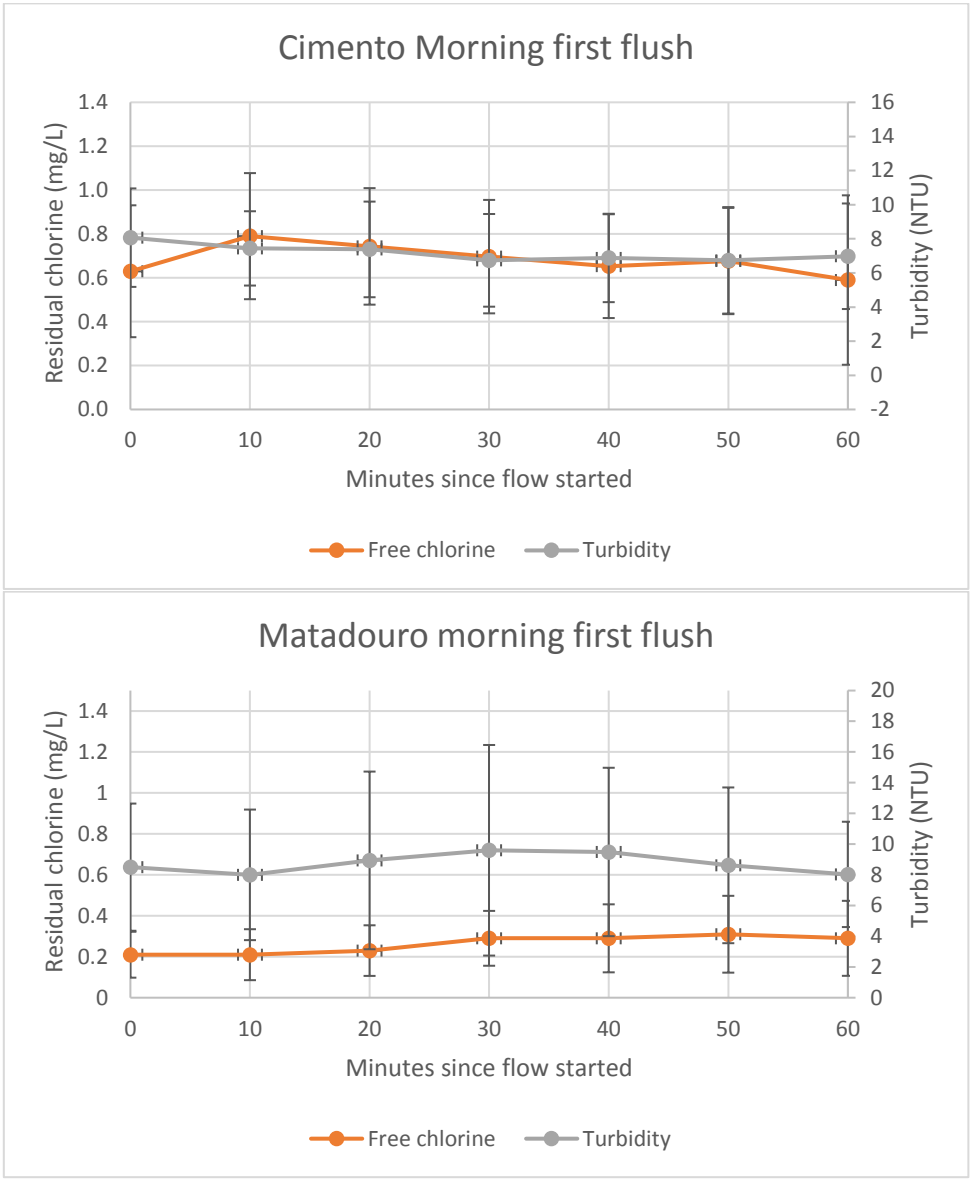
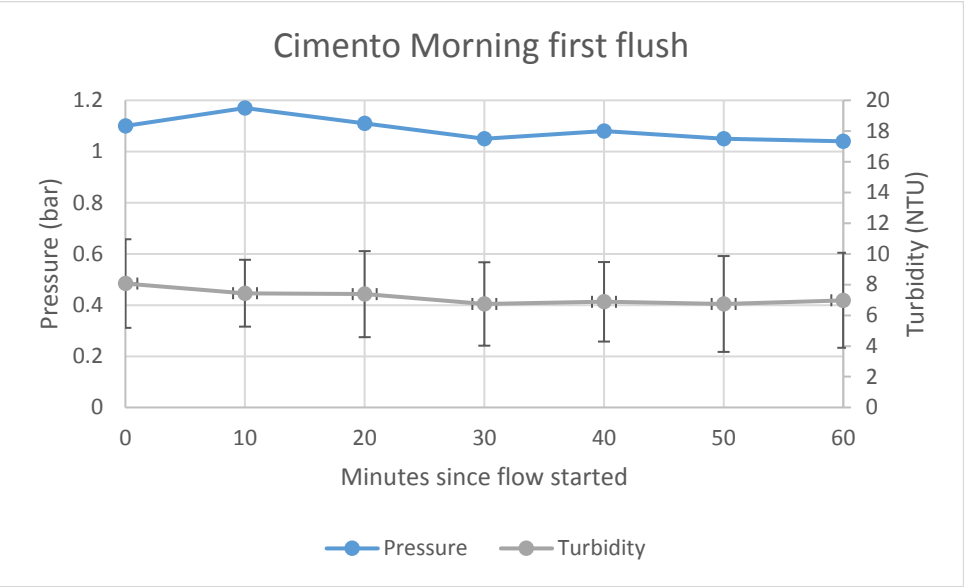


Figure 4-15 Cimento and Matadouro first flush showing a variation of turbidity and free residual chlorine

Monitoring the pressure variation with turbidity (Figure 4-16), the results showed that, at the highest pressure reading (1.5 bar) during the morning first flush event resulted in a corresponding hike in the turbidity reading (9.5 NTU) in Matadouro. The pressure readings in Cimento were fairly constant, with an average pressure of 1.1 bar which resulted in a turbidity reading of 6.7 NTU.



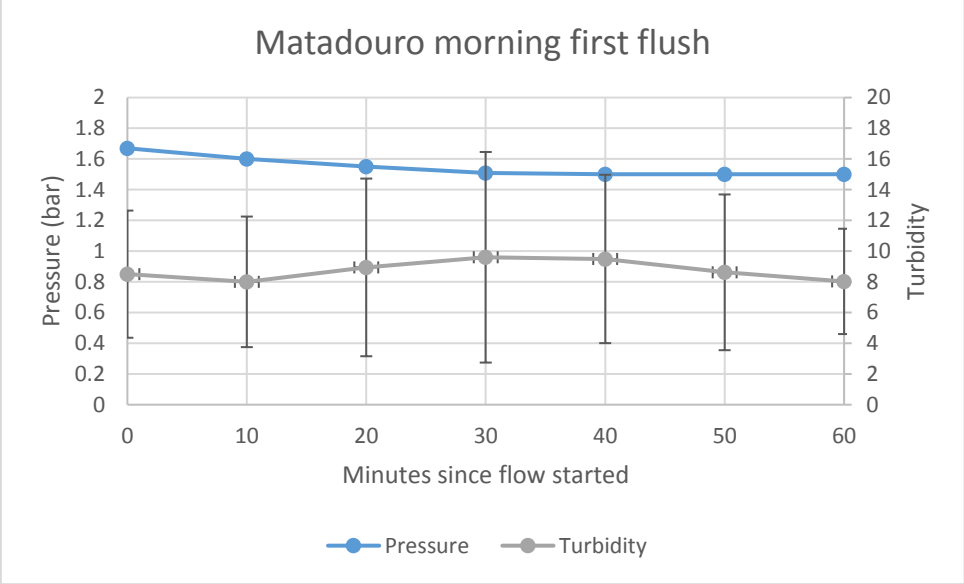


Figure 4-16 Morning first flush events showing pressure variation with turbidity with the standard deviations

The afternoon first flush event in Figure 4-17, showed a consistent behaviour of turbidity levels in both Cimento and Matadouro. Turbidity level at the start of flow was 9 bar and progressed to reduce after 20 minutes to 7 bar. Similar pattern for pressure and residual chlorine existed in the afternoon as it did in the morning first flush event. The results showed high pressures but low residual chlorine in Matadouro as compared to the pressure and residual chlorine in Cimento.

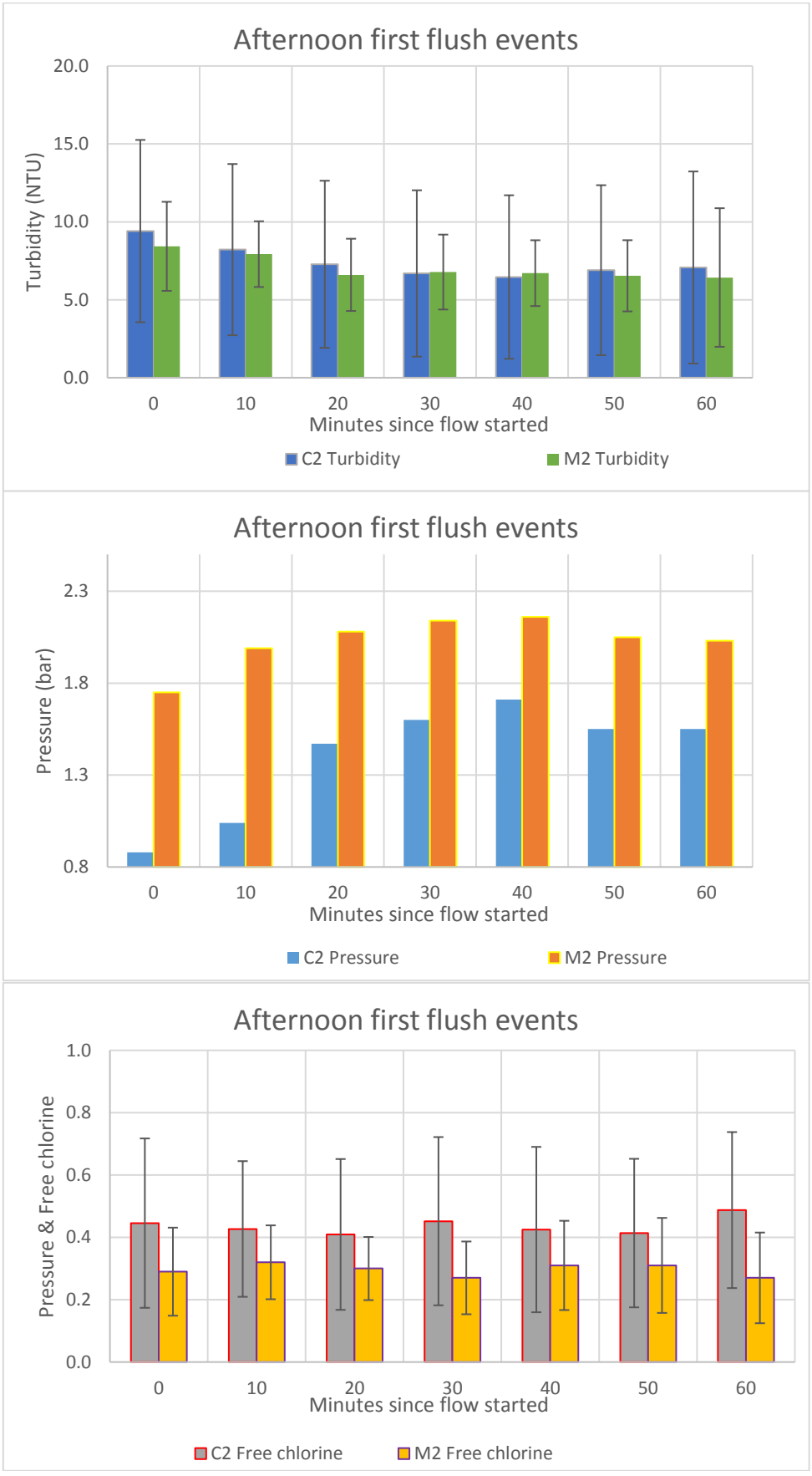


Figure 4-17 Afternoon first flush events showing a) Turbidity readings in C2 & M2.b) Showing afternoon results of pressure in both C2 & M2. c) Showing residual chlorine in the first flush event of the afternoon with standard deviations

In the 16 samples collected during the first flush analyses, 9 of these samples had the presence of *E.coli* identified. Total coliform was present in all the samples collected but two. Figure 4-18, shows total coliform was positive in the first sample collected when the supply started immediately. *E.coli* was however identified after 30 minutes of supply in the samples collected from Cimento. Samples from Matadouro showed the presence of *E.coli* after 10 minutes of supply start – up. Chlorine residuals had similar trends in both neighbourhoods, with a gradual increase in residual chlorine concentration throughout the first flush period. Similar first flush parameter were examined in the afternoon. With the first flush being monitored during the first 60 minutes of supply start-up

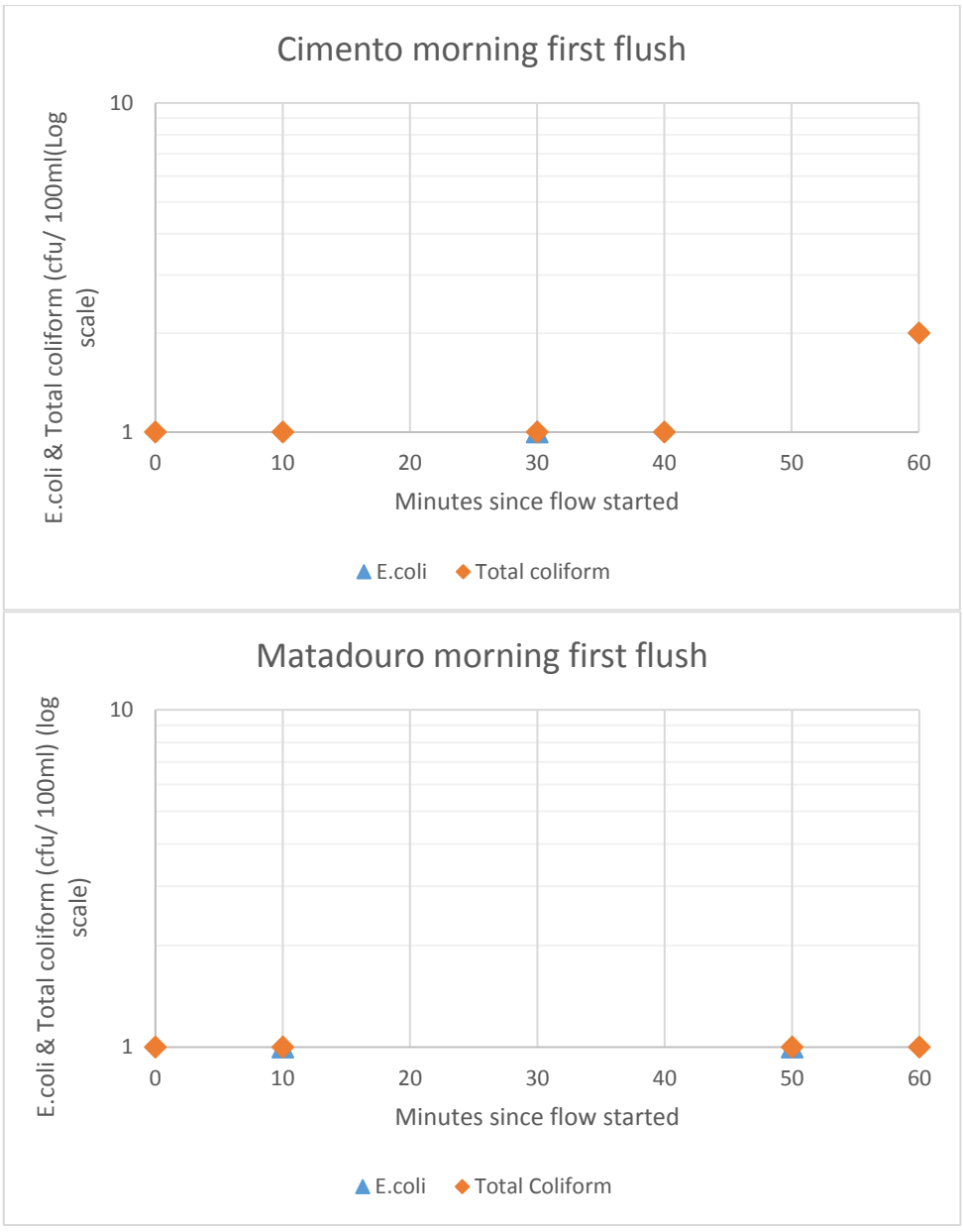


Figure 4-18 Morning first flush showing indicator bacteria in both Cimento and Matadouro respectively

A general comparison of the first flush events in both Cimento and Matadouro (Figure 4-19), reveals that, turbidity levels in Cimento at the start-up of flow is 8.1 NTU and reduces after 20 minutes to 6.5 NTU. Matadouro turbidity levels at the start of flow is 8.4 NTU and increase to 9.6 NTU for 30 minutes before reducing again in the mornings. Pressure is high in Matadouro both in the mornings and afternoon compared to Cimento.

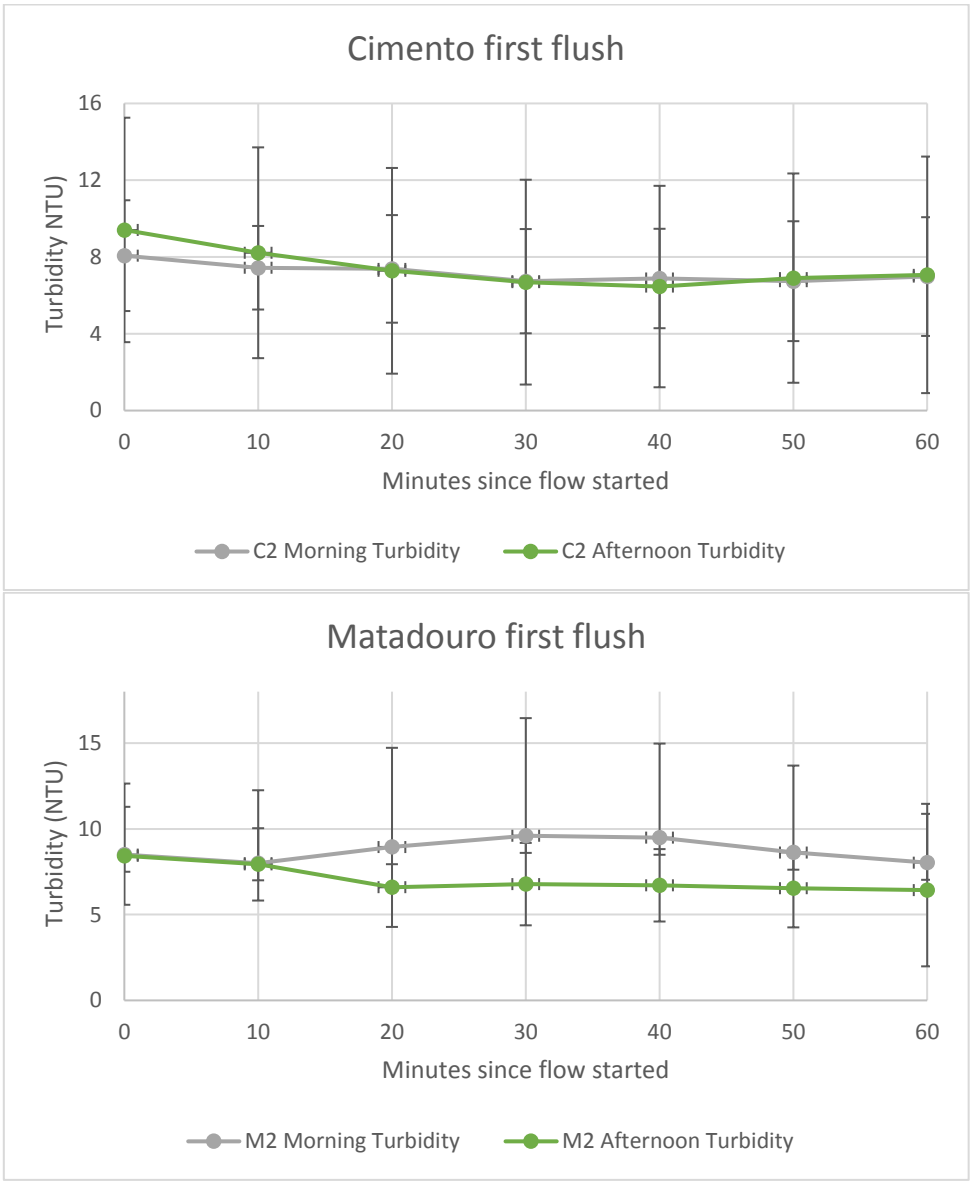


Figure 4-19 Turbidity Reading Cimento and Matadouro first flush events, both morning and afternoon

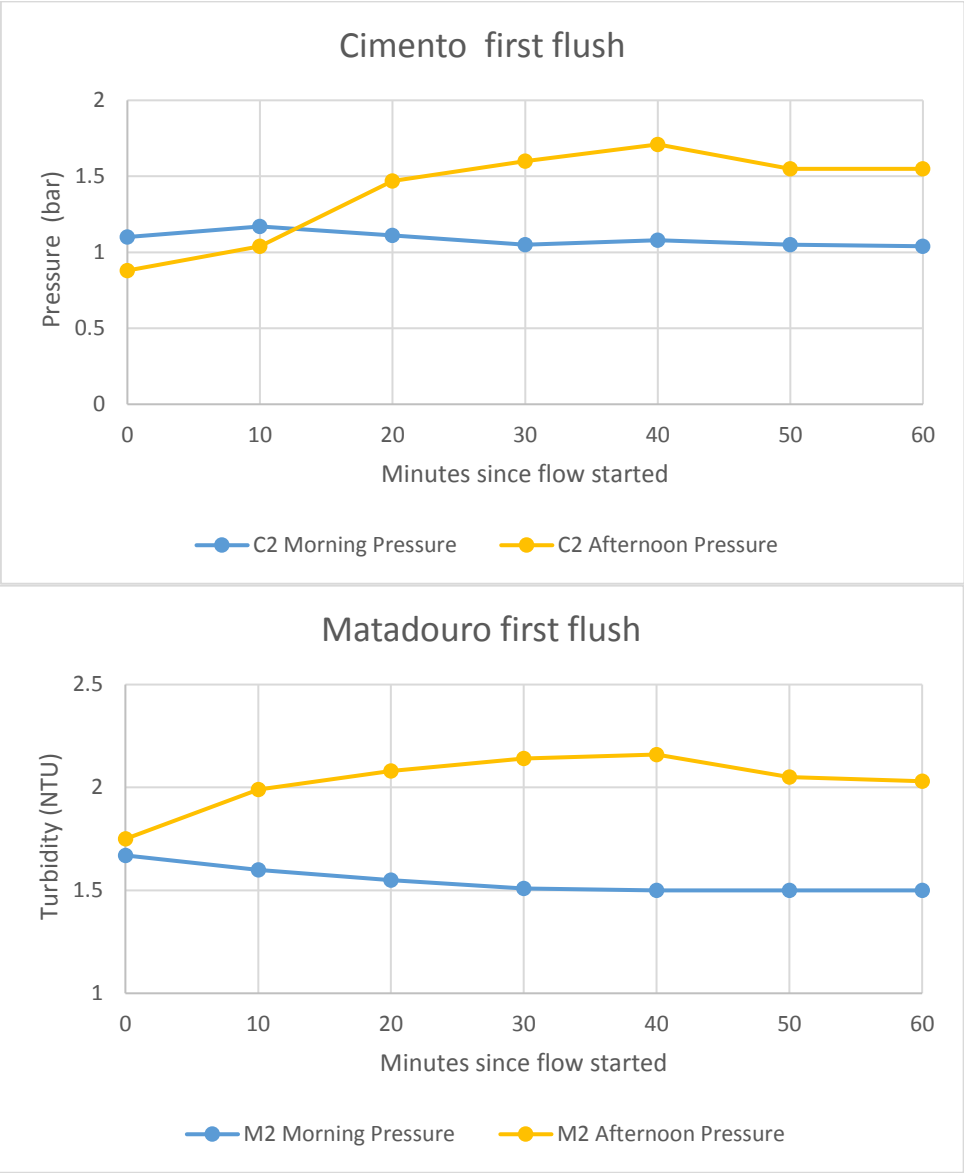


Figure 4-20 Pressures during first flush events in Cimento and Matadouro consumer taps

4.4.2 Discussion first flush water quality

Different factors can be the reasons for the quality of water in first flush. These factors range from the duration of "no supply" existing in the distribution system, the weather conditions of the area, and conditions within the pipelines. The pressure monitoring results indicating a charged up system at the start of supply can be the reason for the high turbidity reading and the presence of total coliform and *E.coli* 10 minutes into the start of supply. With the different studies done on leaching of biofilms from the internal pipe walls as a result of start-up pressure, the presence of indicator bacteria is thus consistent with the conclusion of these researches (Barbeau, et al., 2005, Lehtola, et al., 2004). From the data observed, the minimum time after which there is stability of the system with the physico-chemical parameters examined is 20 minutes after supply has started. For micro-biological indicator parameters, the quality of the water still had persistent total coliform throughout the first 60 minutes of supply. The number however are reduced after 40 minutes of supply. This phenomenon as observed with the indicator bacteria can be due to the conducive conditions created as a result of the hydraulic

nature of the distribution system. The initial start-up pressure will release the sediments into the distribution system from the internal walls of the pipe. This sediments thus will provide the needed area for attachment of organic matter and possibly a shielding effect for microorganism, thus preventing effective disinfection. The fairly constant pressure after the initial start-up pressure as the data shows, indicates a laminar flow, which is said to favour sediment accumulation in pipes (Barbeau, et al., 2005). This sediment accumulated will also consume the chlorine in the water and this explains the low residual chlorine in the first flush event.

The water quality observed during the first flush events in Matadouro can be possibly attributed to environmental conditions. The absence of sanitary inspection survey during this research limits the certainty to which local environmental conditions can be attributed to the first flush water quality in Matadouro. Literature by (Besner, et al., 2011, Kirmeyer and Martel, 2001, LeChevallier, et al., 2003), suggests the importance of identifying possible sources of contaminations such as backflow potentials. This backflow potentials can be identified by evaluating the presence of pathways, the approximated distances of sewer lines/ septic tanks from the pipeline and the possibility of cross contamination. The inability of this research to have this data thus the effect of local environmental conditions on the first flush water cannot be confirmed but only reported as a possibility.

With the data showing an increase in pressure in the afternoon and the corresponding concentration of *E.coli* reduced, the first flush events in the afternoon thus confirms existing literature that, at high pressure *E.coli* concentration is low (Erickson, et al., 2017, Kumpel and Nelson, 2014).

The high turbidity levels may be as a result of the treatment inefficiency as this is consistent with studies in CWS (Environmental Protection Agency 2010, Kumpel and Nelson, 2013). The persistent presence of indicator bacteria in the morning first flush requires that the first flush water in the first hour is treated as waste as suggested by Kumpel & Nelson (2014). In Moamba however this is not the case which is consistent with most cities having IWS system. Studies show that, one of the ways consumers cope with IWS is by the direct attachment of pumps to their pipeline to directly fill their storage tanks and this confirms the studies on the high level of contamination of water in storage tanks (Galaitsi, et al., 2016, Guragai, et al., 2017).

5

CONCLUSION

5.1 Objective 1: Determination of optimal strategy for chlorine dosage.

Different chlorine dosages and different dosing strategy were used to determine the "optimal" strategy for chlorine dosage. The validation of optimal strategy for chlorine dosage showed a reduction in the total coliform and *E.coli* presence in the distribution system. There was an improvement in the quality of water with the reduction of the number of positive samples as far as *E.coli* is concerned as a result of the optimal strategy for optimum chlorine dosage.

Variation in the turbidity levels were observed in the different neighbourhoods with respect to the distance. The observation showed turbidity levels at the farthest points within the two neighbourhoods had the worst turbidity level. Turbidity also showed to get worse during seasonal changes without recourse to the dosing strategy employed.

We found out that, comparing the free residual chlorine concentration at the consumer taps before the supply stops and when it resumes after a period of no supply, there is always a reduction in concentration. The conclusion is that the intermittent nature of the system results in reduction of chlorine residual at consumer taps.

5.2 Objective 2: Assess how the typology and duration of supply cycles affect water quality at the point of delivery.

The free residual chlorine at the consumer taps were generally within the guidelines of both the WHO and the Mozambican standards when the flow was continuous for 10 hours and 12 hours with a significant 74% of the samples collected > 0.2 mg/ L. This compared to the 4 hours supply cycle in the morning and 3 hours supply cycle in the afternoon using the optimal chlorine dosage and optimal dosing strategy which had 64% of the samples collected having met the guideline (>0.2 mg/L).

Turbidity levels with both typology were higher than the recommended value of 5 NTU. Thus there was no difference between the IWS system and the continuous supply for both 10 hours and 12 hours.

There was contamination observed with indicator bacteria *E.coli* being present in both IWS and the supply of water for 10 hours and 12 hours. The presence of *E.coli* in the continuous supply of water for 10 hours and 12 hours were sparingly during the supply. This was however not the case

during the intermittent supply, as there was a trend of *E.coli* being identified at the start of the supply after a period of no supply.

The duration of supply in the continuous water supply system did not show much difference between supply for 10 hours or 12 hours in terms of turbidity levels and *E.coli* presence.

The residual chlorine results showed that, the duration of supply of water does not influence the concentration of the free residual chlorine at the consumer taps, but conditions such as the internal pipe characteristics and operational conditions prior to the supply has an effect on residual chlorine.

5.3 Objective 3: Evaluation on the first flush water quality at the beginning of each supply cycle.

With regards to the first flush, the water quality in terms of turbidity is high and fluctuating during the first flush event and lasted for 20 minutes after which the turbidity level is fairly constant but still above 5 NTU.

Water quality with respect to microbiological parameters showed *E.coli* was normally absent in the first 30 minutes of supply during the first flush event, but total coliform was identified in the first flush events at the beginning of each cycle both morning first flush and afternoon first flush and persistent throughout the supply. This correlation between total coliform and turbidity is thus evident in the first flush events

First flush water quality at the beginning of each supply cycle sees free residual chlorine exhibiting a gradual increments at consumer taps within the first hour of supply start-up. From 0.2 mg/L to 0.3 mg/L at Matadouro and at Cimento 0.49 mg/L to 0.59 mg/L.

The duration of the first flush event at Cimento is 30 minutes. This is based on the parameters analysed during the first flush events in both cycles. The turbidity levels averaging 7.6 NTU with a standard deviation of 0.4 and fluctuating during the first 20 minutes before becoming stable afterwards, the presence of *E.coli* normally absent in the first 30 minutes of supply and residual chlorine of 0.5 mg/L throughout the first flush event. However the duration of the first flush event at Matadouro is 50 minutes based on the results of the absence/ reduced concentration of *E.coli* after 50 minutes of supply, the residual chlorine peaking to its maximum concentration of 0.29 mg/L after 40 minutes of supply. The turbidity levels in Matadouro varied showing reduction in turbidity (8.8 NTU – 8.0 NTU) after 50 minutes and (7.6 NTU – 6.4 NTU) after 20 minutes of supply in the morning and afternoon respectively

5.4 Recommendations

- With the “optimal” chlorine dosage and dosing strategy having achieved improvement in the water quality at consumer taps in the two neighbourhoods selected, the 5 other neighbourhoods supplied with water from the WTP should also be sampled to confirm

this optimal chlorine strategy. The variation in the chlorine dosage should be bigger than what was used in this research.

- The limitations of the dosing strategy was the non-correlation of the dosing rate in the afternoon with that of the peak consumption period in Moamba which occurs also in the afternoon after the resumption of the supply. The recommendation is to have the dosing rate correlate with the peak consumption period

- The treatment process at the WTP should be revised to help improve the turbidity levels at the consumer taps. With frequent sampling done in all the neighbourhoods that receives water from the WTP.

- Routine flushing should be undertaken when the water supply to the distribution system is resumed after a period a 24 hours of no supply. Spot flushing can also be introduced to help clean the distribution system.

- With the intermittency nature of the supply in Moamba being as a result of expansion of the village and the new developments of other towns, there is a need to consider expanding the infrastructure which can improve the supply duration and reduce the intermittency. This will reduce the low pressure periods and thus reduce contamination in the distribution system.

- The valves operation within the distribution system should be monitored and regularised to check the sudden changes in pressure during the “supply” and “no supply” operations to help reduce the turbidity levels.

Future Research

1. Points of contamination within the distribution system with respect to burst frequency and pressure variation.

2. What is the effect on water quality with an improvement in the distribution infrastructure or network configuration in the IWS system in Moamba?

6

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Volume 1
Recommendations
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7

APPENDICES

Appendix A: Statistical analysis in different locations and strategies

A1: Baseline Statistics

WHO Guideline 0cfu/100 ml

		Frequency	Percent
Valid	Met WHO guideline	11	32.4
	Did not Meet WHO guideline	23	67.6

Chlorine Residual Guidelines

		Frequency	Percent
Valid	Within guideline	17	50.0
	Below minimum guideline of 0.2 mg/l	17	50.0
	Total	34	100.0

WHO upper limit of 5 NTU

		Frequency	Percent
Valid	Below upper limit of 5 NTU	25	73.5
	Above upper limit of 5 NTU	9	26.5
	Total	34	100.0

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Total_coliform	34	200.00	.00	200.00	37.2941	68.96267	4755.850
E.coli	34	16.00	.00	16.00	2.2647	3.37826	11.413

A2: Cimento Statistics

Chlorine Residual Guidelines

		Frequency	Percent	Valid Percent	Cumulative Percent
	Within guideline	230	89.8	89.8	89.8
	Below minimum guideline of 0.2 mg/l	18	7.0	7.0	96.9
	Above Mozambique guideline 1.5 mg/l	8	3.1	3.1	100.0
	Total	256	100.0	100.0	

WHO upper limit of 5 NTU

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below upper limit of 5 NTU	81	31.6	31.6	31.6
	Above upper limit of 5 NTU	175	68.4	68.4	100.0
	Total	256	100.0	100.0	

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	256	2.28	.02	2.30	.5495	.37824	.143
Total_Residual_Chlorine	256	2.24	.14	2.38	.6476	.37892	.144
Turbidity	256	29.98	.72	30.70	7.3788	4.90130	24.023

Descriptives

Free_Residual chlorine

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
10kg (Varying) dose of Ca(OCl)2	35	.5614	.24401	.04125	.4776	.6452	.23	.96
12kg (Varying) dose of Ca(OCl)2	34	.7047	.34468	.05911	.5844	.8250	.26	1.36
10kg (Const) dose of Ca(OCl)2	51	.4245	.33520	.04694	.3302	.5188	.02	1.38
11kg (Const) dose of Ca(OCl)2	68	.4804	.21896	.02655	.4274	.5334	.15	1.16
12kg (Const) dose of Ca(OCl)2	68	.6284	.53725	.06515	.4983	.7584	.16	2.30
Total	256	.5495	.37824	.02364	.5029	.5960	.02	2.30

ANOVA

Free_Residual_Chlorine

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.368	4	.592	4.356	.002
Within Groups	34.114	251	.136		
Total	36.482	255			

A3: Matadouro Statistics

Chlorine Residual Guidelines

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Within guideline	139	63.5	63.5	63.5
	Below minimum guideline of 0.2 mg/l	73	33.3	33.3	96.8
	Above Mozambique guideline 1.5 mg/l	7	3.2	3.2	100.0
	Total	219	100.0	100.0	

WHO upper limit of 5 NTU

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below upper limit of 5 NTU	53	24.2	24.2	24.2
	Above upper limit of 5 NTU	166	75.8	75.8	100.0
	Total	219	100.0	100.0	

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Free_Residual_Chlorine	219	2.03	.06	2.09	.3635	.34979	.122
Total_Residual_Chlorine	219	2.14	.14	2.28	.4887	.36274	.132
Turbidity	219	26.37	1.74	28.11	7.6530	4.20235	17.660
Valid N (listwise)	219						

Descriptives

Free_Residual_Chlorine

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
10kg (Varying) dose of Ca(OCl)2	35	.21	.19	.03	.14	.28	.08	1.26
12kg (Varying) dose of Ca(OCl)2	17	.31	.13	.03	.24	.38	.12	.51
10kg (Const) dose of Ca(OCl)2	48	.27	.17	.02	.21	.32	.07	1.27
11kg (Const) dose of Ca(OCl)2	68	.32	.20	.02	.27	.37	.06	1.00
12kg (Const) dose of Ca(OCl)2	51	.62	.56	.07	.46	.78	.06	2.09
Total	219	.36	.34	.02	.31	.41	.06	2.09

A4: Validation Statistics

Chlorine Residual Guidelines

		Frequency	Percent
Valid	Within guideline	68	65.4
	Below minimum guideline of 0.2 mg/l	26	25.0
	Above Mozambique guideline 1.5 mg/l	10	9.6
	Total	104	100.0

WHO upper limit of 5 NTU

		Frequency	Percent	Valid Percent
Valid	Below upper limit of 5 NTU	5	4.8	4.8
	Above upper limit of 5 NTU	99	95.2	95.2
	Total	104	100.0	100.0

WHO Guideline 0cfu/100 ml

		Frequency	Percent	Valid Percent
Valid	Met WHO guideline (0cfu/100 ml)	86	82.7	82.7
	Did not Meet WHO guideline (> 0cfu/100 ml)	18	17.3	17.3
	Total	104	100.0	100.0

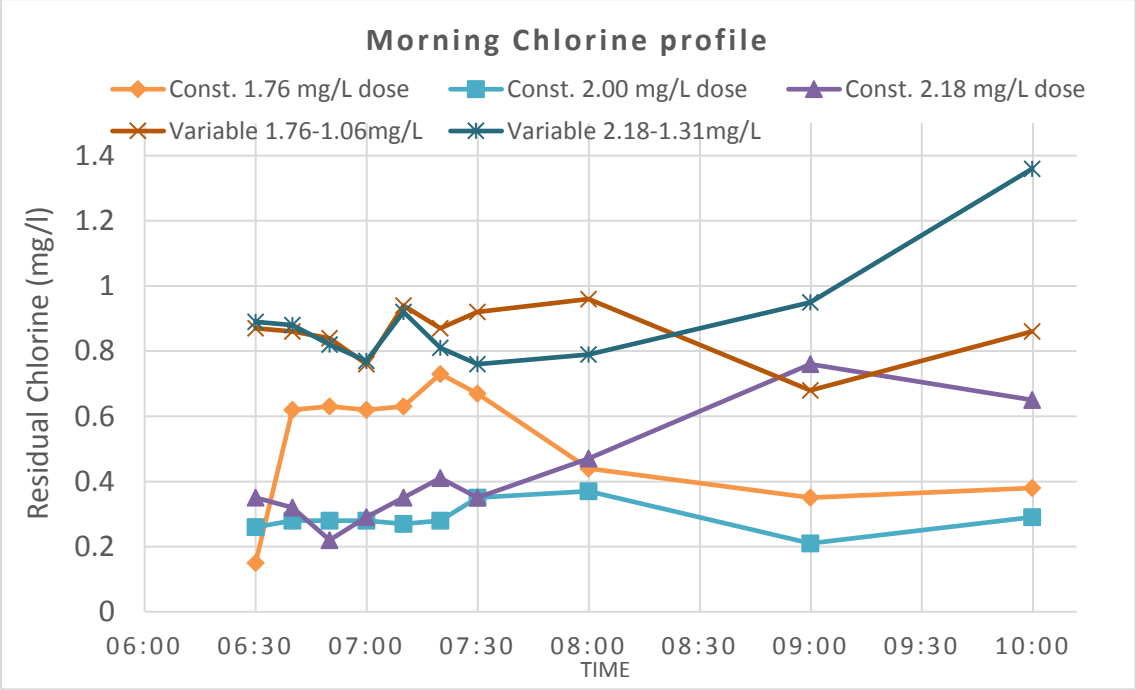
Descriptive Statistics

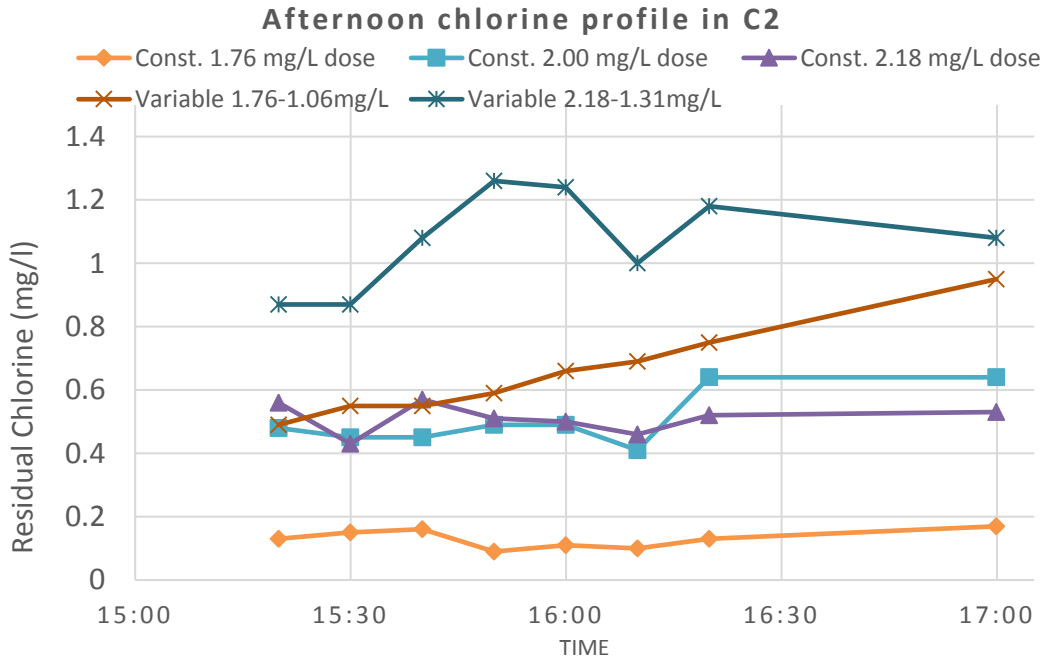
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Total_coliform	104	200.00	.00	200.00	21.05	41.05	1685.68
E.coli	104	11.00	.00	11.00	.42	1.37	1.87

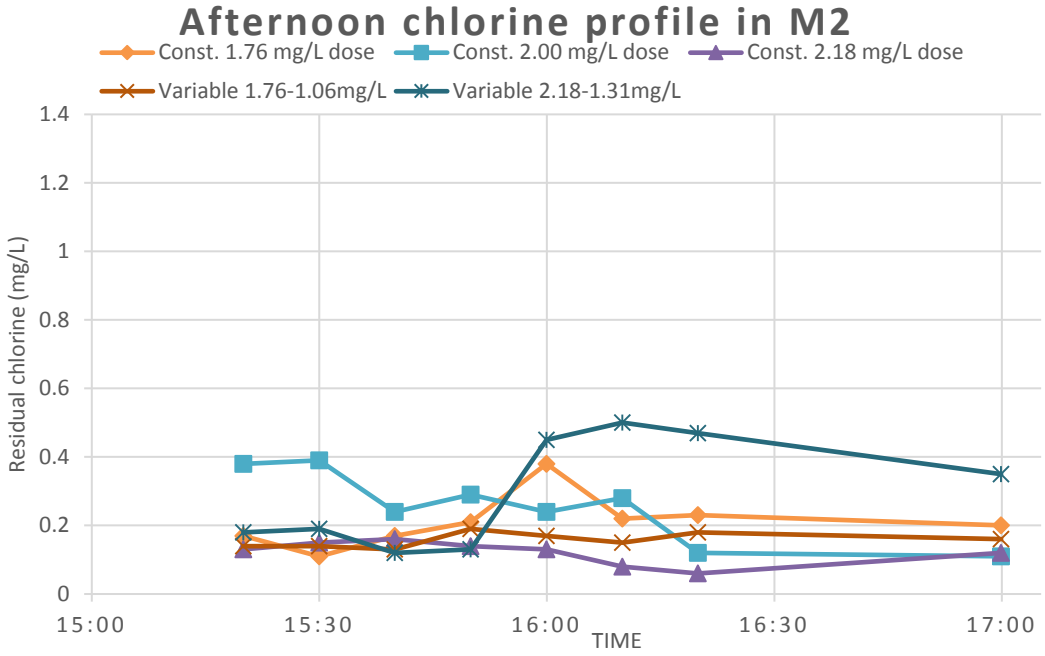
ANOVA

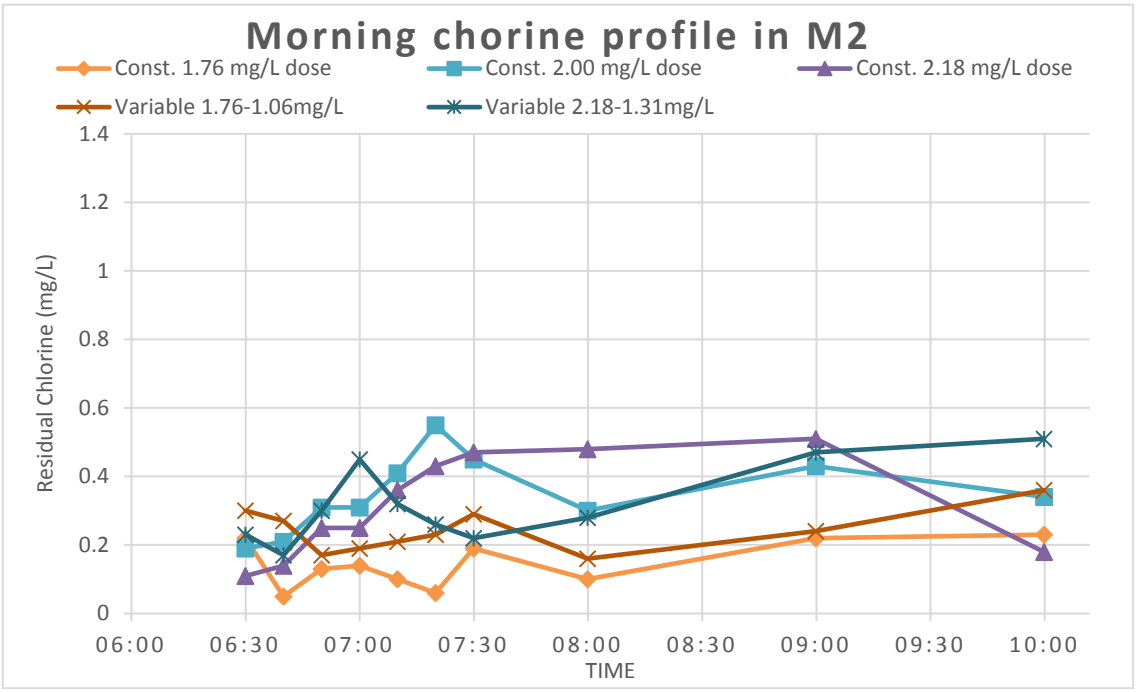
		Sum of Squares	df	Mean Square	F	Sig.
Free_Residual_Chlorine	Between Groups	.52	6	0.08	.24	.96
	Within Groups	34.98	97	0.36		
	Total	35.50	103			
Total_Residual_Chlorine	Between Groups	.48	6	0.08	.22	.96
	Within Groups	35.03	97	0.36		
	Total	35.52	103			
Turbidity	Between Groups	86.83	6	14.47	1.36	.23
	Within Groups	1025.26	97	10.57		
	Total	1112.09	103			

Appendix B: Graphs of Chlorine profile in Validation phase






Afternoon chlorine profile in M2
Const. 1.76 mg/L dose
Const. 2.00 mg/L dose
Const. 2.18 mg/L dose
Variable 1.76-1.06mg/L
Variable 2.18-1.31mg/L
Residual chlorine (mg/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
15:00
15:30
16:00
16:30
17:00
TIME


Morning chorine profile in M2
Const. 1.76 mg/L dose
Const. 2.00 mg/L dose
Const. 2.18 mg/L dose
Variable 1.76-1.06mg/L
Variable 2.18-1.31mg/L
Residual Chlorine (mg/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
TIME

Appendix B2: Graphs of other physico-chemical parameters

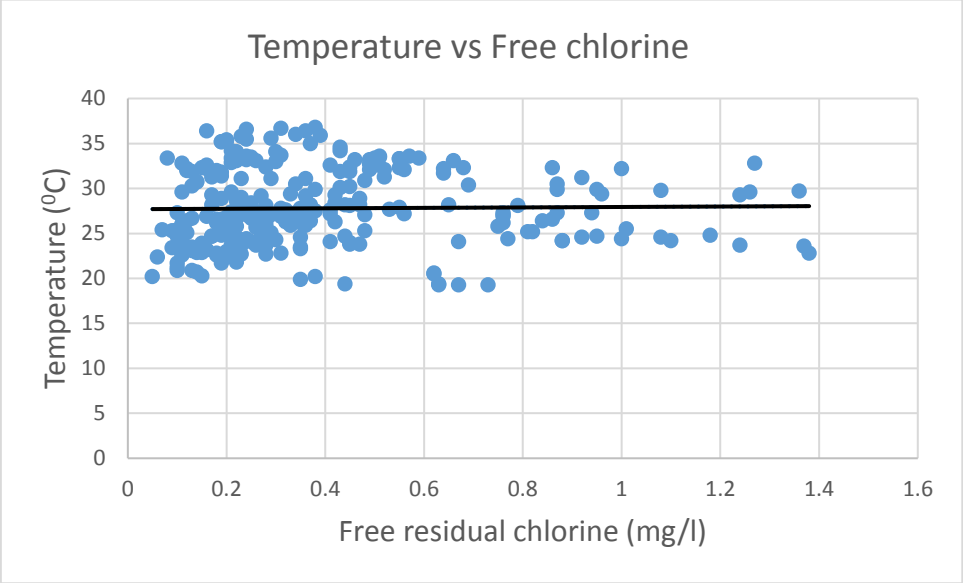


Figure: Variation of temperature with residual chlorine

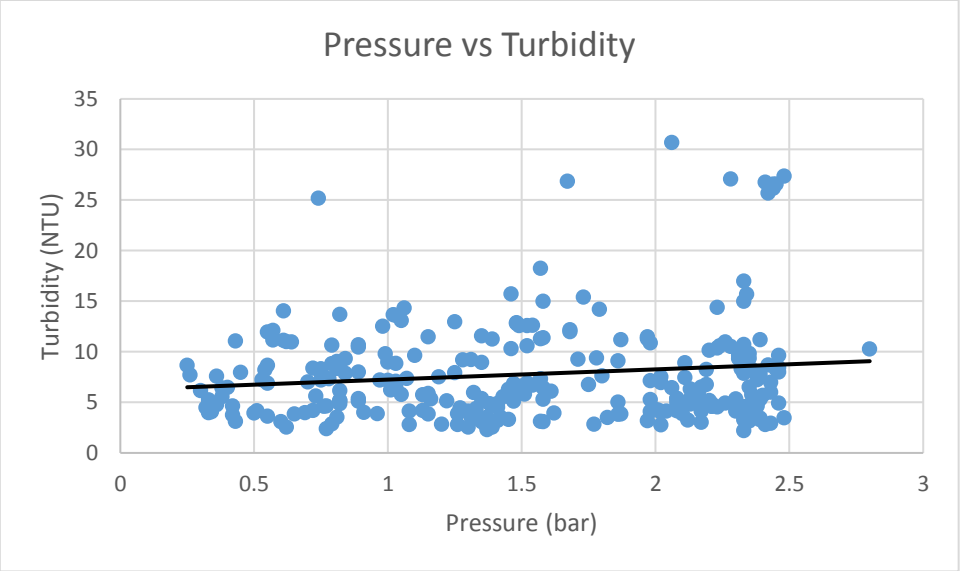
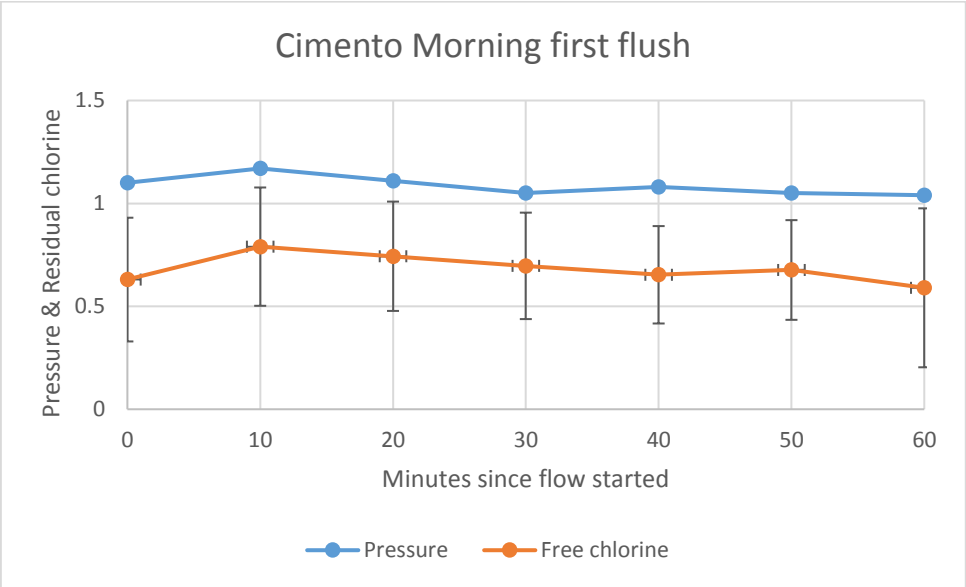
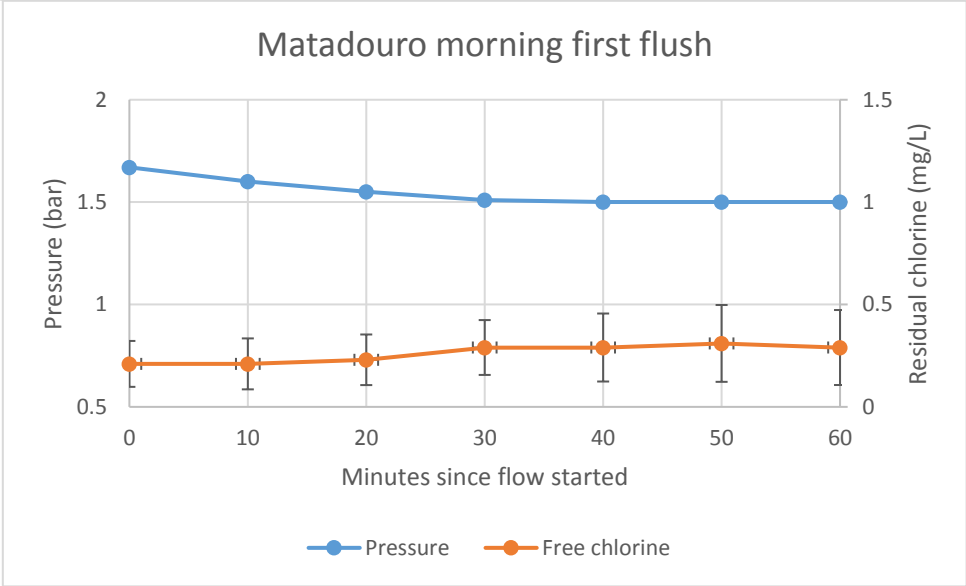
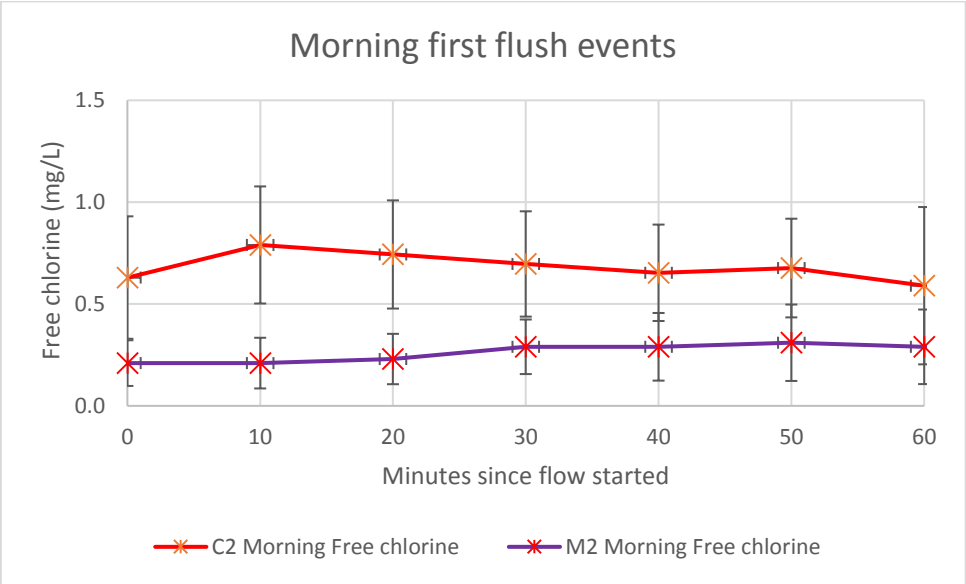


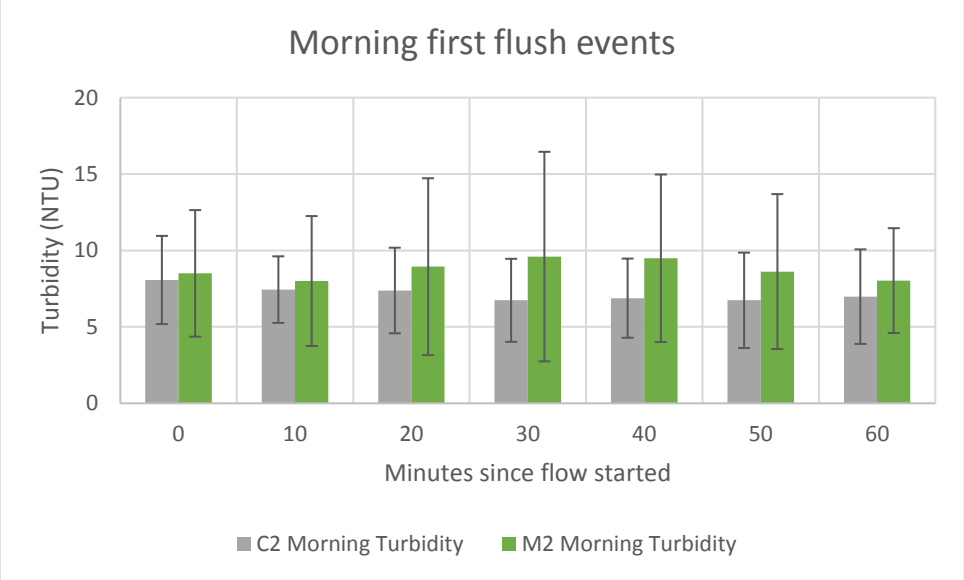
Figure: Variation of pressure and turbidity

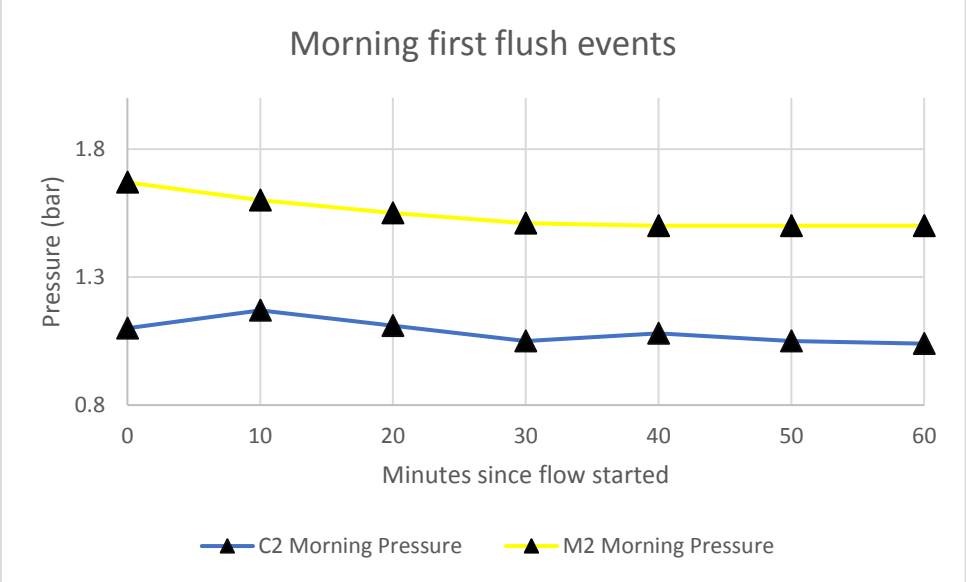
Appendix B3: Graphs of other first flush variations

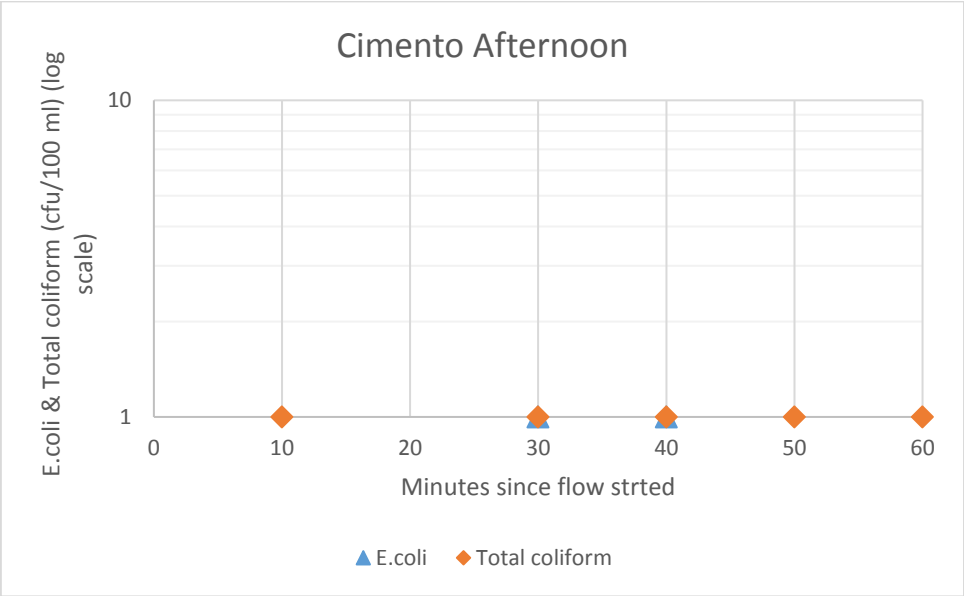


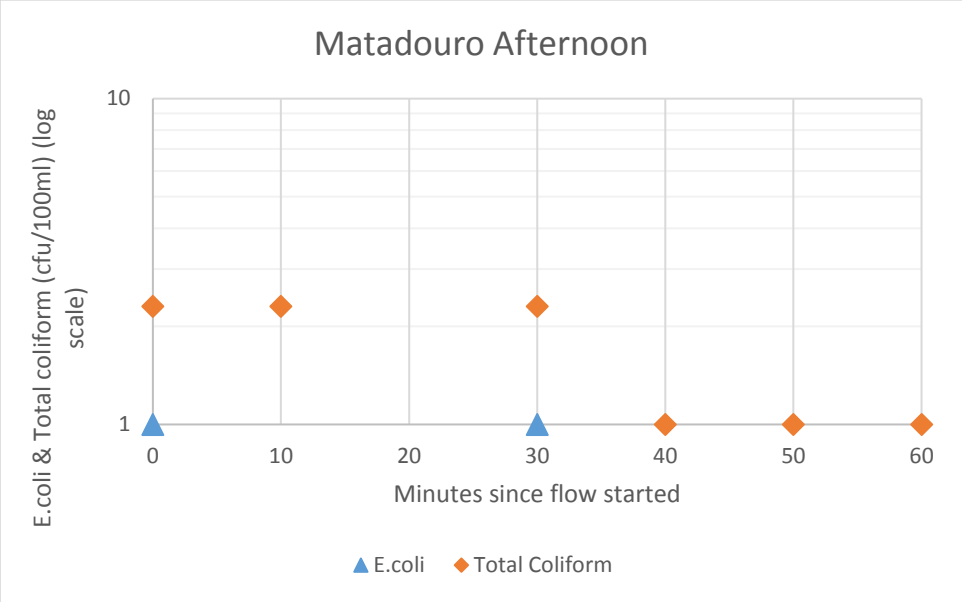


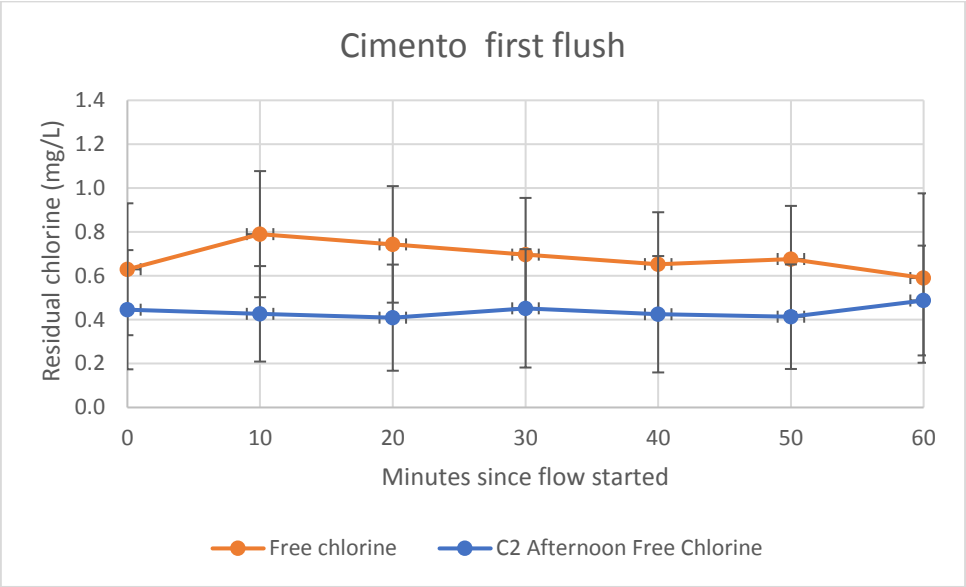

Morning first flush events
Free chlorine (mg/L)
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
Minutes since flow started
C2 Morning Free chlorine
M2 Morning Free chlorine

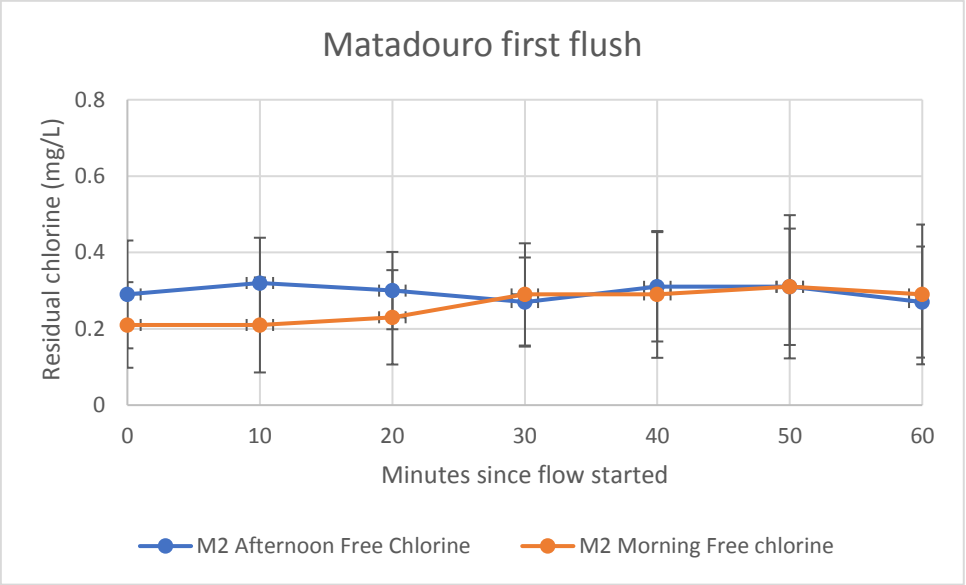

Morning first flush events
Turbidity (NTU)
20
15
10
5
0
0
10
20
30
40
50
60
Minutes since flow started
C2 Morning Turbidity
M2 Morning Turbidity


Morning first flush events
Pressure (bar)
1.8
1.3
0.8
0
10
20
30
40
50
60
Minutes since flow started
C2 Morning Pressure
M2 Morning Pressure


Cimento Afternoon
E.coli & Total coliform (cfu/100 ml) (log scale)
10
1
0
10
20
30
40
50
60
Minutes since flow strted
E.coli
Total coliform


Matadouro Afternoon
E.coli & Total coliform (cfu/100ml) (log scale)
10
1
0
10
20
30
40
50
60
Minutes since flow started
E.coli
Total Coliform


Cimento first flush
Residual chlorine (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
Minutes since flow started
Free chlorine
C2 Afternoon Free Chlorine


Matadouro first flush
Residual chlorine (mg/L)
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
Minutes since flow started
M2 Afternoon Free Chlorine
M2 Morning Free chlorine

Appendix C: Daily water consumption data

DATE	HOURS	PESSENE (m^3)	MOAMBA (m^3)
19.01.2018	06:00	15669	136882
	07:00	15670	136891
	08:00	15671	136900
	09:00	15672	136911
	10:00	15673	136920
	15:00	15674	136940
	16:00	15675	136949
	17:00	15676	136959
22.01.2018	06:00	15750	137271
	07:00	15751	137280
	08:00	15752	137289
	09:00	15753	137295
	10:00	15754	137300
	15:00	15755	137311
	16:00	15756	137316
	17:00	15757	137321
23.01.2018	06:00	15757	137321
NB: Power cut from 07:00 a.m. to 02:00 p.m.			
	07:00	15757	137321
	08:00	15757	137321
	09:00	15757	137321
	10:00	15757	137321
	15:00	15760	137320
	16:00	15761	137331
	17:00	15763	137336
24.01.2018	06:00	15763	137336
NB: no pumping due to lack of water in the capture			
	17:00	15763	137336
	06:00	15763	137336
	17:00	15763	137336
26.01.2018	06:00	15763	137336
	07:00	15766	137342
	08:00	15768	137343
	09:00	15770	137355
	10:00	15761	137363
	15:00	15792	137493

	16:00	15794	137501
	17:00	15796	137518
29.01.2018	06:00	15806	137687
	07:00	15810	137802
	08:00	15812	137819
	09:00	15814	137831
	10:00	15815	137843
	15:00	15836	137881
	16:00	15840	137890
30.01.2018	06:00	15875	137903
	07:00	15876	137914
	08:00	15877	137926
	09:00	15878	137948
	10:00	15879	137963
	15:00	15883	138007
	16:00	15884	138015
	17:00	15885	138023
31.01.2018	06:00	15901	138044
	07:00	15902	138059
	08:00	15902	138065
	09:00	15903	138074
	10:00	15905	138087
	15:00	15910	138090
	16:00	15913	138124
	17:00	15914	138138
01.02.2018	06:00	15922	138159
	07:00	15923	138167
	08:00	15923	138178
	09:00	15924	138195
	10:00	15926	138209
	15:00	15930	138220
	16:00	15932	138235
	17:00	15935	138256
02.02.2018	06:00	15949	138264
	07:00	15950	138271
	08:00	15951	138285
	09:00	15952	138299
	10:00	15953	138313
	15:00	15959	138341
	16:00	15961	138353

	17:00	15962	138378
12.02.2018	09:00	16229	139430
	10:00	16230	139439
	11:00	16231	139449
	12:00	16232	139456
	13:00	16234	139467
	14:00	16236	139473
	15:00	16236	139480
	16:00	16237	139491
13.02.2018	07:00	16254	139529
	08:00	16255	139541
	09:00	16256	139557
	10:00	16257	139560
	11:00	16257	139560
	12:00	16259	139573
	13:00	16260	139678
	14:00	16261	139684
	15:00	16262	139689
	16:00	16263	139694
	17:00	16264	139612
	18:00	16265	139619
14.02.2018	07:00	16280	139631
	08:00	16282	139646
	09:00	16283	139660
	10:00	16285	139673
	11:00	16286	139675
	12:00	16287	139677
	13:00	16288	139682
	14:00	16290	139689
	15:00	16291	139705
	16:00	16293	139716
	17:00	16295	139720
15.02.2018	07:00	16311	139748
	08:00	16312	139763
	09:00	16313	139776
	10:00	16314	139790
	11:00	16316	139800
	12:00	16317	139805
	13:00	16318	139811
	14:00	16319	139817

	15:00	16321	139821
	16:00	16322	139831
	17:00	16323	139844
	18:00	16324	139851
16.02.2018	07:00	16339	139869
	08:00	16340	139877
	09:00	16341	139889
	10:00	16342	139804
	11:00	16343	139811
	12:00	16345	139815
	13:00	16346	139920
	14:00	16347	139924
	15:00	16349	139929
	16:00	16350	139945
	17:00	16352	139959
	18:00	16353	139964

Volumes invoiced by neighbourhood Moamba 2017

#	Neighbourhood	August	September	October	Total	Average
1	Cimento	6,009.00	5,409.00	5,355.00	16,773.00	5,591.00
2	Matadouro	6,318.00	5,731.00	5,762.00	17,811.00	5,937.00
3	Madinguine	3,670.00	3,894.00	3,054.00	10,618.00	3,539.00
4	B. 25 de Junho	1,503.00	1,976.00	1,493.00	4,972.00	1,657.00
5	Central	3,210.00	2,276.00	2,122.00	7,608.00	2,536.00
6	Livivine	4,108.00	3,237.00	2,801.00	10,146.00	3,382.00
7	Sul	4,481.00	3,036.00	2,682.00	10,199.00	3,400.00
8	Maguaza	1,016.00	965.00	847.00	2,828.00	943.00
9	Pessene	2,236.00	1,928.00	1,369.00	5,533.00	1,844.00
10	Mahoche	472.00	502.00	292.00	1,266.00	422.00
11	Tenga	214.00	162.00	182.00	558.00	186.00
	Totais	**33,237.00**	**29,116.00**	**25,959.00**	**88,312.00**	**29,437.00**

Appendix D: Daily sampling weather conditions & circumstances

Experiment	Date	Inflow water	Outlet treatment	Preparation dosing chlorine	Chlorine dosing	Condition
					Started – stopped	
Baseline (Matadouro)	9/11/2017	1790	1640 m3	No new chlorine was added	Constant dosing 100% but the tube was smaller than what we used for the variation. That tube translate to 60% of the new tube we used for the variation. Dosing started at 5:50am stopped at 11:35am. Restarted at 3pm and stopped at 6:30pm	Clear weather
Baseline Cimento	10/11/2017	1860	1630 m3	New chlorine solution prepared	Constant dosing 100% but the tube was smaller than what we used for the variation. That tube translate to 60% of the new tube we used for the variation. Dosing started at 6:00am stopped at 12:00pm. Restarted at 3:10pm and stopped at 6:15pm	Clear weather
C2+ WTP (10kg)	14/11/2017	1960	1825m3	New chlorine solution was added	Constant dosing 100% but the tube was smaller than what we used for the variation. That tube translate to 60% of the new tube we used for the variation. Dosing started at 5:30 am stopped at 12:00pm. Restarted at 3:10pm and stopped at 6:15pm	Hot in the morning samples taken. After heavy rain samples for afternoon taken (Yes rain was around late morning 11:30 till 2:45pm) the same set-up was used)

C2 + WTP (10kg)	15/11/2017	1310	1222m3	No new chlorine solution was prepared	Old chlorine from previous day was used. Constant dosing 100% but the tube was smaller than what we used for the variation. That tube translate to 60% of the new tube we used for the variation. Dosing started at 6:15 am stopped at 12:05pm. Restarted at 3:20pm and stopped at 6:05pm	Clear weather
M2 +WTP (10kg)	16/11/2017	1480	1520 m3	New chlorine dose was prepared	60% since we used a smaller dosing tube compared to what we used for variation	Clear weather
M2 +WTP (10kg)	17/11/2017	1990	1870 m3	No new chlorine solution was prepared	Dosing started: 6:25am Stopped : 12:20am Started dosing again: 4:05pm Dosing stopped: 18:15	Clear weather
	18/11/2017	1650	1440 m3	New chlorine added	Dosing started: 6:00am Stopped : 11:40am Started dosing again: 3:05pm Dosing stopped: 18:05	Increased turbidity at WTP ➔ heavy rainfall in the night
Increase Cl_2 dosage (11kg)	20/11/2017	1760	1580 m3	New chlorine was prepared	Dosing started: 6:52am Stopped : 12:00pm Started dosing again: 3:15pm Dosing stopped: 19:05	Clear weather
Increase Cl_2 dosage (11kg)	21/11/2017	1670	1487m3	No new chlorine was prepared	Dosing started: 6:22am Stopped : 11:57am Started dosing again: 3:28pm Dosing stopped: 18:23	Backwash of filters done
Increase Cl_2 dosage (12kg)	22/11/2017	1690	1635 m3	New chlorine was prepared	Dosing started: 5:54am Stopped : 12:22pm Started dosing again: 3:02pm Dosing stopped: 18:54	Clear weather

Increase Cl_2 dosage (12kg)	23/11/2017	1790	1770 m3	No new chlorine was prepared	Dosing started: 6:24am Stopped : 11:35am Started dosing again: 3:08pm Dosing stopped: 17:55	Clear weather
Varying Cl_2 dosage according to water flow (10kg)	01/12/2017	1750	2330 m3	New chlorine was prepared	New chlorine injector tube was purchased and 100% was actually 14l/h Dosing started:6:00am Dosing ended:11.32 Dosing start again: 3:05pm Dosing Ended: 18:54	After 3 days of no water due to pipe break
Varying Cl_2 dosage according to water flow (10kg)	4/12/2017	1820	1710 m3	No new chlorine was prepared	Dosing started: 6:20am Stopped : 12:20pm Started dosing again: 3:05pm Dosing stopped: 18:45	Clear weather
Varying Cl_2 dosage according to water flow (12kg)	5/12/2017	1587	1560 m3	New chlorine was prepared	Dosing started: 5:58am Stopped : 11:50am Started dosing again: 3:00pm Dosing stopped: 18:35	Rain
Varying Cl_2 dosage according to water flow (12kg)	6 /12/2017	1569	1530 m3	No New chlorine was prepared	Dosing started: 6:25am Stopped : 12:18pm Started dosing again: 3:12pm Dosing stopped: 19:05	Clear weather
Validation of optimized Cl_2 dosage (12kg)	12/12/2017	1582	1590 m3	New chlorine was prepared and added at	Dosing started: 6:40am Stopped : 12:50pm Started dosing again: 3:12pm Dosing stopped: 18:24	After a pump problem at the intake, Backwash was also done
Validation of optimized Cl_2 dosage (12kg)	13/12/2017	1388	1370 m3	No new chlorine was added	Dosing started: 6:05am Stopped : 11:58am Started dosing again: 3:20pm Dosing stopped: 18:00	Rain
Continuous flow for 12 hours	19/12/2017	2030	2000	New chlorine was prepared	Dosing started: 5:45am	After 4 days of searching for

					Stopped : 18:00	new tube for injector and waiting for pumps
Continuous flow for 10 hours	20/12/2017	1750	1760	New chlorine was prepared	Dosing started: 6:50am Stopped : 16:00am	Clear weather
Continuous flow for 8 hours	21/12/2017	1810	1810	New chlorine was prepared	Dosing started: 6:50am Stopped : 14:00 pm Started dosing again: 17:05pm Dosing stopped: 19:15	Clear weather
Keeping Chlorine constant 10kg	9/01/2017	1370	1362	New chlorine was prepared and added at 10am	Dosing started: 6:05am Stopped : 12:34pm Started dosing again: 3:18pm Dosing stopped: 17:55	Rain in the afternoon
Increase Cl_2 dosage (11kg)	11/01/2018	1950	1940	New chlorine was prepared	Dosing started: 6:05am Stopped : 12:15am Started dosing again: 3:35pm Dosing stopped: 18:45	No light on the 10/01/2018
Increase Cl_2 dosage (11kg)	12/01/2018	1610	1560	No new chlorine was added	Dosing started: 6:20am Stopped : 12:00noon Started dosing again: 3:05pm Dosing stopped: 18:45	Clear weather
Increase Cl_2 dosage (12kg)	15/01/2018	1670	1480	New chlorine was prepared	Dosing started: 5:54am Stopped : 11:50am Started dosing again: 3:15pm Dosing stopped: 18:45	Clear weather
Increase Cl_2 dosage (12kg)	16/01/2018	1650	1570	No new chlorine was prepared	Dosing started: 6:12am Stopped : 12:10pm Started dosing again: 3:10pm Dosing stopped: 18:05	Clear weather
Validation of optimized Cl_2 dosage (12kg)	18/01/2018	1590	1490	New chlorine was prepared	Dosing started: 6:25am Stopped : 12:00pm Started dosing again: 3:25pm Dosing stopped: 18:30	Clear weather

Appendix E: Calculation of chlorine dosages

- **Calculate the concentration of the chlorine in dosing system**

Concentration of Solution

10kg of $Ca(ClO)_2$ = 10000g
200L of water
Active Chlorine is 65%

Amount of water in grams = $\frac{1000g\ x\ 200L}{1L} = \ 200000 grams\ of\ water$

Per cent composition = $\frac{65\%\ x\ 10000\ of\ Ca(ClO)2}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{6500g\ of\ Ca(ClO)2}{206500g\ of\ solution}\ x\ 100$ = 3.147%

Concentration of solution is 3.147%

- **100% = 14L per hour; how many water passed the dosing (inflow) and what is the calculated concentration of chlorine in the water (after dosing)**

Concentration of chlorine in water after dosing

31.5 g in 1L is the concentration of chlorine prepared for two days ∴ for 1 day 31.5 = 31.5g of available chlorine is dosed.
The injector doses 14L in 1 hour ; In 1 hour 31.5 * 14 = 441g of available chlorine is dosed.
Amount of average treated water is 250m^3/h = 250000 L/h
Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = \ 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{441g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{441g\ of\ available\ chlorine}{250000000g\ of\ solution}\ x\ 100$ = 0.0001764%

Concentration in ppm = 0.000001764 * 10^6
Concentration of solution is 1.76 mg Cl_2/L

- **What is the calculated concentration with 80% dosing.**

31.5 g in 1L is the concentration of chlorine prepared.
The injector doses 14L = 100% in 1 hour; dosing at 80% injector doses = 11.2L in 1 hour. ∴ 31.5 * 11.2 = 352.8g of available chlorine is dosed.
Amount of average treated water is 250m^3/h = 250000 L/h
Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = \ 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{352.8\ g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{352.8\ g\ of\ available\ chlorine}{250000000 g\ of\ solution}\ x\ 100$ = 0.0001411%

Concentration in ppm = $0.000001411 * 10^6$

Concentration of solution is 1.41 mg Cl_2/L

- **What is the calculated concentration with 60% dosing**

31.5 g in 1L is the concentration of chlorine prepared.
The injector doses 14L = 100% in 1 hour; dosing at 60% injector doses = 8.4L in 1 hour. ∴ 31.5 * 8.4 = 264.6g of available chlorine is dosed.

Amount of average treated water is 250m^3/h = 250000 L/h

Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{264.6g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{264.6g\ of\ available\ chlorine}{250000000 g\ of\ solution}\ x\ 100$ = 0.000106%

Concentration in ppm = $0.00000106 * 10^6$

Concentration of solution is 1.06 mg Cl_2/L

<u>Concentration of Solution</u>

11kg of $Ca(ClO)_2$ = 11000g
200L of water
Active Chlorine is 65%

Concentration of solution = $\frac{65\%\ x\ 11000\ of\ Ca(ClO)2}{volume\ of\ solvent}$

= $\frac{7150g\ of\ Ca(ClO)2}{200\ L\ of\ water}$ = 35.75 g/L

Concentration of solution is 35750 mg/L

- **100% = 14L per hour; how many water passed the dosing (inflow) and what is the calculated concentration of chlorine in the water (after dosing)**

<u>Concentration of chlorine in water after dosing</u>

35.75 g in 1L is the concentration of chlorine prepared for two days.
The injector doses 14L in 1 hour ; In 1 hour 35.75 * 14 = 500.5g of available chlorine is dosed.
Amount of average treated water is 250m^3/h = 250000 L/h
Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{500.5g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

$$= \frac{500.5g\ of\ available\ chlorine}{250000000g\ of\ solution}\ x\ 100 \quad = 0.0002002\%$$

Concentration in ppm = $0.000002002 * 10^6$

Concentration of solution is 2.00 mg Cl_2/L

Concentration of Solution

12kg of $Ca(ClO)_2$ = 12000g

200L of water

Active Chlorine is 65%

Concentration of solution = $\frac{65\%\ x\ 12000\ of\ Ca(ClO)2}{volume\ of\ \ solvent}$

$$= \frac{7800g\ of\ Ca(ClO)2}{200\ L}\ x\ 100 \quad = 39g/L$$

Concentration of solution is 39000ppm or 39000 mg/L

- **100% = 14L per hour; how many water passed the dosing (inflow) and what is the calculated concentration of chlorine in the water (after dosing)**

Concentration of chlorine in water after dosing

39 g in 1L is the concentration of chlorine prepared for two days

The injector doses 14L in 1 hour; in 1 hour 39 * 14 =546 g of available chlorine is dosed.0.

Amount of average treated water is 250m^3/h = 250000 L/h

Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = \ 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{546g\ of\ available\ chlorine}{gram\ of\ solute+gram\ of\ solvent}\ x\ 100$

$$= \frac{546\ g\ of\ available\ chlorine}{250000000g\ of\ solution}\ x\ 100 \quad = 0.0002184\%$$

Concentration in ppm = $0.000002184 * 10^6$

Concentration of solution is 2.18mg Cl_2/L

- **What is the calculated concentration with 80% dosing.**

39 g in 1L is the concentration of chlorine prepared.

The injector doses 14L = 100% in 1 hour; dosing at 80% injector doses = 11.2L in 1 hour. ∴ 39 * 11.2 = 436.8 g of available chlorine is dosed.

Amount of average treated water is 250m^3/h = 250000 L/h

Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = \ 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{436.8\ g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{436.8\ g\ of\ available\ chlorine}{250000000 g\ of\ solution}\ x\ 100$ = 0.000175%

Concentration in ppm = 0.00000175 * 10^6

Concentration of solution is 1.75 mg Cl_2/L

- **What is the calculated concentration with 60% dosing**

31.5 g in 1L is the concentration of chlorine prepared.
The injector doses 14L = 100% in 1 hour; dosing at 60% injector doses = 8.4L in 1 hour. ∴ 39 * 8.4 = 327.6g of available chlorine is dosed.

Amount of average treated water is 250m^3/h = 250000 L/h

Amount of water per hour dosed is 250000 L

Amount of water in grams = $\frac{1000g\ x\ 250000L}{1L} = 250{,}000{,}000\ grams\ of\ water$

Per cent composition = $\frac{327.6g\ of\ available\ chlorine}{gram\ of\ solute + gram\ of\ solvent}\ x\ 100$

= $\frac{327.6g\ of\ available\ chlorine}{250000000 g\ of\ solution}\ x\ 100$ = 0.000131%

Concentration in ppm = 0.000000131 * 10^6

Concentration of solution is 1.31 mg Cl_2/L

Appendix F: Drinking water guidelines and standards of Mozambique

5. Água para o consumo humano em situações de emergência

5.1. Frequência de amostragem

Fonte e modo de abastecimento	Amostras para análise
Camiões cisterna e equiparáveis	Sempre que chega um novo lote*

Nota: (*) – Para este efeito designa-se novo lote: novo camião, cisterna ou equiparável, nova fonte de água. A mudança de um deles corresponde a mudança de lote.

5.2. Parâmetros de qualidade

a) Parâmetros microbiológicos

Parâmetro	Limite máximo admissível	Unidades
Coliformes totais	Ausente	NMP* / 100 ml N.º de colónias / 100 ml
Coliformes fecais	Ausente	NMP* / 100 ml N.º de colónias / 100 ml
Vibrio cholerae	Ausente	1000 ml

* (NMP): Número Mais Provável

Nota – Estas determinações microbiológicas só poderão ser efectuadas se a fonte de água for consistentemente a mesma.

b) Parâmetros físicos e organolétpticos

Parâmetro	Limite máximo admissível	Unidades
Côr	15	TCU
Cheiro	Inodoro	
Condutividade	50-2000	µhmo/cm
PH	6,5-8,5	
Sabor	Insípido	
Sólidos totais	1000	mg/l
Turvação	5	NTU

c) Parâmetros químicos

Parâmetro	Limite máximo admissível	Unidades
Cloro residual total	0,25 - 1,0	mg/l
Outros (conforme a causa da emergência)	Variáveis em função dos parâmetros considerados	–

Anexo III

Métodos de referência para análise dos parâmetros

a) Parâmetros microbiológicos

Parâmetro	Modo de referência	Unidades
Coliformes totais	Tubos múltiplos Membrana filtrante	NMP* / 100 ml N.º de colónias / 100 ml
Coliformes fecais	Tubos múltiplos Membrana filtrante	NMP* / 100 ml N.º de colónias / 100 ml
Vibrio cholerae	Membrana filtrante	0/1000 ml

* (NMP): Número Mais Provável

b) Parâmetros físicos e organolépticos

* Parâmetro	Modo de referência	Unidades
Côr	Espectrofotómetro Diluição	TCU
Cheiro		
Condutividade	Electrometria	µhmo/cm
PH	Electrometria	
Sabor		
Sólidos totais dissolvidos	Gravimetria	mg/l
Turvação	Nefelométrico Espectrofotometria de absorção molecular	NTU

Appendix G: Raw data of water quality physico- chemical parameters at the different locations.

G1: Water tower outlet

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm
Outlet overhead tank	Distribution centre	0.46	0.53	25.6	4.21	8.65	726
Outlet overhead tank	Distribution centre	0.39	0.53	22.6	5.83	8.6	740
Outlet overhead tank	Distribution centre	1.4	1.48	21.9	6.85	9.2	883
Outlet overhead tank	Distribution centre	1.52	1.68	21.4	7.45	9.16	862
Outlet overhead tank	Distribution centre	1.62	1.84	21.4	6.54	9.15	858
Outlet overhead tank	Distribution centre	1.2	1.34	20.6	6.9	9.17	859
Outlet overhead tank	Distribution centre	1.18	1.3	21.6	7.88	9.15	853
Outlet overhead tank	Distribution centre	1.26	1.32	20.7	7.07	9.1	842
Outlet overhead tank	Distribution centre	1.42	1.44	21.7	5.39	9.09	868
Outlet overhead tank	Distribution centre	0.84	0.95	22.4	5.46	9.1	863
Outlet overhead tank	Distribution centre	0.69	0.77	24.3	4.73	9.05	863
Outlet overhead tank	Distribution centre	0.8	0.85	28.6	37.7	8.76	862
Outlet overhead tank	Distribution centre	0.44	0.62	29.1	29.9	8.76	855
Outlet overhead tank	Distribution centre	0.44	0.47	28.9	32.7	8.75	848
Outlet overhead tank	Distribution centre	0.34	0.37	28.4	23.1	8.77	846
Outlet overhead tank	Distribution centre	0.24	0.26	28.4	22.5	8.76	848
Outlet overhead tank	Distribution centre	0.18	0.26	27.9	20.2	8.75	851
Outlet overhead tank	Distribution centre	0.22	0.4	27.6	17.6	8.76	848
Outlet overhead tank	Distribution centre	0.31	0.55	25.4	19	8.8	845
Outlet overhead tank	Distribution centre	0.32	0.43	28.6	4.4	8.82	862
Outlet overhead tank	Distribution centre	0.46	0.52	28.9	3.57	8.88	858

Outlet overhead tank	Distribution centre	0.54	0.61	29.2	3.55	8.88	859
Outlet overhead tank	Distribution centre	0.52	0.62	29.1	4.45	8.87	853
Outlet overhead tank	Distribution centre	0.49	0.65	29.4	4.08	8.88	842
Outlet overhead tank	Distribution centre	0.51	0.53	29.5	4.32	8.85	868
Outlet overhead tank	Distribution centre	0.51	0.63	29.3	3.81	8.85	863
Outlet overhead tank	Distribution centre	0.49	0.59	30.7	4.74	8.8	863
Outlet overhead tank	Distribution centre	0.51	0.59	31.7	5.83	8.73	862
Outlet overhead tank	Distribution centre	0.15	0.15	27.9	3.72	8.76	855
Outlet overhead tank	Distribution centre	0.12	0.2	27.3	2.89	8.78	848
Outlet overhead tank	Distribution centre	0.12	0.18	27.7	2.94	8.75	846
Outlet overhead tank	Distribution centre	0.05	0.07	27.8	3.14	8.75	848
Outlet overhead tank	Distribution centre	0.13	0.16	27.6	3.73	8.75	851
Outlet overhead tank	Distribution centre	0.16	0.21	27.8	3.2	8.75	848
Outlet overhead tank	Distribution centre	0.07	0.12	27.6	2.97	8.73	845
Outlet overhead tank	Distribution centre	1.9	1.92	26.5	6.75	8.86	835
Outlet overhead tank	Distribution centre	1.66	1.88	26.7	3.55	8.74	855
Outlet overhead tank	Distribution centre	1.72	1.86	28.6	4.07	8.73	825
Outlet overhead tank	Distribution centre	1.82	1.84	28.2	6.45	8.7	840
Outlet overhead tank	Distribution centre	1.6	1.64	28.4	5.32	8.68	829
Outlet overhead tank	Distribution centre	1.7	1.92	28.1	5.84	8.7	762
Outlet overhead tank	Distribution centre	1.66	1.72	27.7	3.34	8.7	836
Outlet overhead tank	Distribution centre	1.64	1.76	27.7	3.52	8.67	843
Outlet overhead tank	Distribution centre	1.46	1.54	28.3	3.3	8.68	837
Outlet overhead tank	Distribution centre	0.65	0.78	36.7	3.54	8.45	858
Outlet overhead tank	Distribution centre	0.63	0.74	36.4	2.87	8.94	854
Outlet overhead tank	Distribution centre	0.63	0.74	35	4.5	8.6	849

Outlet overhead tank	Distribution centre	0.72	0.75	35.2	3.86	8.15	850
Outlet overhead tank	Distribution centre	0.75	0.82	35.8	3.47	7.8	852
Outlet overhead tank	Distribution centre	0.72	0.87	36.4	4.21	8.5	858
Outlet overhead tank	Distribution centre	0.3	0.35	23.6	20.6	8.31	625
Outlet overhead tank	Distribution centre	0.63	0.76	23.6	20	8.4	605
Outlet overhead tank	Distribution centre	0.72	0.9	24.3	20.1	8.32	614
Outlet overhead tank	Distribution centre	0.73	0.9	24.2	20.2	8.24	613
Outlet overhead tank	Distribution centre	0.88	0.94	24.3	20.4	8.26	611
Outlet overhead tank	Distribution centre	0.92	0.97	24.3	21	8.34	604
Outlet overhead tank	Distribution centre	0.88	1.08	24.3	20.9	8.27	600
Outlet overhead tank	Distribution centre	1.02	1.28	24.5	19.9	8.31	570
Outlet overhead tank	Distribution centre	1.22	1.36	25.5	20.7	8.36	675
Outlet overhead tank	Distribution centre	1.1	1.25	31.9	17.5	8.54	675
Outlet overhead tank	Distribution centre	0.74	0.92	32.2	17.85	8.49	678
Outlet overhead tank	Distribution centre	0.74	0.77	32	17.3	8.6	676
Outlet overhead tank	Distribution centre	0.64	0.72	31.7	16.87	8.51	675
Outlet overhead tank	Distribution centre	0.54	0.57	32.2	16.45	8.38	679
Outlet overhead tank	Distribution centre	0.48	0.56	30.7	15.35	8.5	676
Outlet overhead tank	Distribution centre	0.64	0.75	29.4	14.9	8.33	432
Outlet overhead tank	Distribution centre	0.72	0.81	22.3	6.12	8.35	502
Outlet overhead tank	Distribution centre	0.8	0.91	29.9	4.13	8.5	468
Outlet overhead tank	Distribution centre	0.72	0.91	35.4	6.39	8.35	439
Outlet overhead tank	Distribution centre	0.64	0.75	29.4	14.9	8.33	432
Outlet overhead tank	Distribution centre	1	1.11	28.7	5.57	8.37	488
Outlet overhead tank	Distribution centre	1	1.12	28.9	8.13	8.43	491
Outlet overhead tank	Distribution centre	0.72	0.82	34.2	0.63	8.27	445

Outlet overhead tank	Distribution centre	1.82	1.86	32	5.13	8.58	499
Outlet overhead tank	Distribution centre	1	1.11	28.7	5.57	8.37	488
Outlet overhead tank	Distribution centre	1	1.12	1	8.13	8.43	491
Outlet overhead tank	Distribution centre	1.82	1.86	28.1	5.13	8.58	495
Outlet overhead tank	Distribution centre	0.16	0.32	23.3	9.93	8.5	499

G2: Cimento Consumer taps (C1 & C2)

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Cimento 1	Cimento	0.3	0.51	24.4	9.1	8.39	458	-
Cimento 1	Cimento	0.31	0.44	23.7	7.18	8.51	432	-
Cimento 1	Cimento	0.27	0.43	23.2	7.44	8.37	431	-
Cimento 1	Cimento	0.3	0.44	23.3	6.44	8.38	430	-
Cimento 1	Cimento	0.33	0.41	23.6	5.65	8.37	433	-
Cimento 1	Cimento	0.37	0.49	23.4	6.35	8.36	434	-
Cimento 1	Cimento	1.16	1.34	24.8	5.92	8.28	439	-
Cimento 1	Cimento	0.73	0.83	27.8	4.57	8.27	450	-
Cimento 1	Cimento	0.32	0.5	34.2	6.24	8.27	445	-
Cimento 1	Cimento	0.38	0.47	35.8	5.61	8.26	454	-
Cimento 1	Cimento	0.58	0.65	35.2	5.63	8.23	454	-
Cimento 1	Cimento	0.44	0.75	35.2	5.99	8.19	461	-
Cimento 1	Cimento	0.48	0.56	35.4	6.29	8.19	448	-
Cimento 1	Cimento	0.34	0.47	33.8	6.12	8.24	443	-
Cimento 1	Cimento	0.37	0.49	32.2	5.93	8.35	438	-
Cimento 1	Cimento	0.23	0.31	25.0	5.86	8.39	482	-
Cimento 1	Cimento	0.17	0.25	24.6	5.97	8.51	483	-
Cimento 1	Cimento	0.16	0.31	23.4	5.94	8.37	475	-
Cimento 1	Cimento	0.27	0.31	23.6	5.92	8.38	476	-
Cimento 1	Cimento	0.17	0.27	23.6	6.13	8.37	485	-
Cimento 1	Cimento	0.23	0.4	23.3	5.56	8.38	477	-
Cimento 1	Cimento	0.17	0.25	23.1	6.13	8.36	485	-
Cimento 1	Cimento	0.2	0.26	22.6	6.25	8.28	489	-
Cimento 1	Cimento	0.63	0.72	21.7	6.24	8.27	499	-
Cimento 1	Cimento	0.24	0.36	23.5	5.16	8.27	504	-
Cimento 1	Cimento	0.21	0.35	25.1	5.93	8.26	504	-
Cimento 1	Cimento	0.19	0.3	25.0	4.62	8.26	504	-
Cimento 1	Cimento	0.24	0.38	24.3	4.82	8.19	498	-
Cimento 1	Cimento	0.22	0.38	24.2	4.66	8.19	500	-
Cimento 1	Cimento	0.21	0.29	24.2	4.28	8.24	501	-
Cimento 1	Cimento	0.7	0.78	24.1	5.96	8.35	526	-
Cimento 1	Cimento	0.48	0.56	27.4	6.85	8.32	542	-
Cimento 1	Cimento	0.33	0.43	26.9	7.15	8.49	497	-
Cimento 1	Cimento	0.41	0.5	26.5	12.1	8.52	492	-
Cimento 1	Cimento	0.37	0.43	26.1	9.19	8.52	488	-
Cimento 1	Cimento	0.34	0.4	26.3	7.17	8.48	488	-
Cimento 1	Cimento	0.31	0.39	26.6	5.22	8.44	486	-
Cimento 1	Cimento	0.29	0.36	26.4	3.78	8.45	485	-
Cimento 1	Cimento	0.25	0.33	25.9	4.02	8.45	486	-
Cimento 1	Cimento	0.39	0.47	27.2	3.92	8.41	484	-
Cimento 1	Cimento	0.71	0.79	25.1	7.32	8.43	487	-

Cimento 1	Cimento	0.23	0.29	33.6	2.73	8.34	492	-
Cimento 1	Cimento	0.24	0.3	33.5	5.07	8.33	488	-
Cimento 1	Cimento	0.27	0.37	34.1	3.96	8.34	494	-
Cimento 1	Cimento	0.24	0.36	33.1	4.35	8.34	491	-
Cimento 1	Cimento	0.23	0.26	32.8	4.12	8.35	490	-
Cimento 1	Cimento	0.59	0.67	32.1	6.93	8.45	485	-
Cimento 1	Cimento	0.55	0.73	30.8	7.33	8.46	481	-
Cimento 1	Cimento	0.5	0.6	28.7	4.3	8.47	483	-
Cimento 1	Cimento	0.3	0.51	24.4	9.1	8.39	458	-
Cimento 1	Cimento	0.31	0.44	23.7	7.18	8.51	423	-
Cimento 1	Cimento	0.27	0.43	23.2	7.44	8.37	431	-
Cimento 1	Cimento	0.3	0.44	23.3	6.44	8.38	430	-
Cimento 1	Cimento	0.33	0.41	23.6	5.65	8.37	433	-
Cimento 1	Cimento	0.37	0.49	23.4	6.35	8.36	434	-
Cimento 1	Cimento	1.16	1.34	24.8	5.92	8.28	439	-
Cimento 1	Cimento	0.73	0.83	27.8	4.57	8.27	450	-
Cimento 1	Cimento	0.32	0.5	35.4	0.99	8.26	454	-
Cimento 1	Cimento	0.26	0.35	35.8	1.29	8.26	454	-
Cimento 1	Cimento	0.38	0.47	35.2	1.12	8.23	454	-
Cimento 1	Cimento	0.58	0.65	35.2	0.93	8.19	461	-
Cimento 1	Cimento	0.44	0.58	35.4	0.72	8.19	448	-
Cimento 1	Cimento	0.48	0.56	33.8	1.39	8.24	443	-
Cimento 1	Cimento	0.34	0.47	32.2	1.45	8.35	438	-
Cimento 1	Cimento	0.37	0.49	31.8	1.47	8.33	4.38	-
Cimento 2	Cimento	0.15	0.18	20.3	4.07	8.85	730	-
Cimento 2	Cimento	0.62	0.7	20.6	5.9	8.64	726	-
Cimento 2	Cimento	0.63	0.72	19.4	4.99	8.63	723	-
Cimento 2	Cimento	0.62	0.66	20.5	4.19	8.59	718	-
Cimento 2	Cimento	0.63	0.67	19.3	4.97	8.58	717	-
Cimento 2	Cimento	0.73	0.8	19.3	4.63	8.55	725	-
Cimento 2	Cimento	0.67	0.74	19.3	5.36	8.53	726	-
Cimento 2	Cimento	0.44	0.54	19.4	5.31	8.58	717	-
Cimento 2	Cimento	0.35	0.45	19.9	5.05	8.58	716	-
Cimento 2	Cimento	0.38	0.54	20.2	4.41	8.62	719	-
Cimento 2	Cimento	0.13	0.20	23.5	7.63	8.68	742	-
Cimento 2	Cimento	0.15	0.16	22.9	5.41	8.68	733	-
Cimento 2	Cimento	0.16	0.17	23.2	4.25	8.66	730	-
Cimento 2	Cimento	0.09	0.13	23.4	4.17	8.66	738	-
Cimento 2	Cimento	0.11	0.15	22.7	2.8	8.66	730	-
Cimento 2	Cimento	0.10	0.15	20.9	3.2	8.68	730	-
Cimento 2	Cimento	1.38	1.39	22.8	9.13	8.92	852	-
Cimento 2	Cimento	1.37	1.44	23.6	10.34	8.84	854	-
Cimento 2	Cimento	1.24	1.33	23.7	12.83	8.8	847	-
Cimento 2	Cimento	1.10	1.21	24.2	12.64	8.82	836	-
Cimento 2	Cimento	1.00	1.08	24.4	14.22	8.76	832	-
Cimento 2	Cimento	0.88	0.96	24.2	15.73	8.74	834	-

Cimento 2	Cimento	0.67	0.79	24.1	15.44	8.73	835	-
Cimento 2	Cimento	0.48	0.51	25.3	18.27	8.71	842	-
Cimento 2	Cimento	0.36	0.44	25.9	26.87	8.64	848	-
Cimento 2	Cimento	0.48	0.58	27.1	30.7	8.67	664	-
Cimento 2	Cimento	0.32	0.35	27.4	27.4	8.6	645	-
Cimento 2	Cimento	0.28	0.36	26.8	26.8	8.49	644	-
Cimento 2	Cimento	0.24	0.26	27.1	27.1	8.52	641	-
Cimento 2	Cimento	0.26	0.29	26.6	26.6	8.52	631	-
Cimento 2	Cimento	0.18	0.23	26.2	26.2	8.53	637	-
Cimento 2	Cimento	0.18	0.24	26.6	26.6	8.56	627	-
Cimento 2	Cimento	0.36	0.46	27	9.66	8.7	883	-
Cimento 2	Cimento	0.38	0.44	27.5	6.33	9.11	862	-
Cimento 2	Cimento	0.36	0.51	27.7	4.95	9.12	858	-
Cimento 2	Cimento	0.37	0.45	27.9	3.29	9.12	859	-
Cimento 2	Cimento	0.33	0.45	29.4	3.3	9.07	853	-
Cimento 2	Cimento	0.42	0.52	29.3	2.83	9.09	842	-
Cimento 2	Cimento	0.43	0.54	30.1	3.47	9.08	868	-
Cimento 2	Cimento	0.34	0.47	30.5	3.26	9.06	863	-
Cimento 2	Cimento	0.20	0.37	35.4	4.63	8.95	863	-
Cimento 2	Cimento	0.20	0.35	35.3	5.14	8.92	862	-
Cimento 2	Cimento	0.22	0.36	25.8	7.16	8.76	855	-
Cimento 2	Cimento	0.28	0.29	25.8	8.29	8.96	848	-
Cimento 2	Cimento	0.1	0.27	25.4	6.52	8.98	846	-
Cimento 2	Cimento	0.12	0.25	25.1	4.66	9	848	-
Cimento 2	Cimento	0.11	0.21	24.8	3.19	9.02	851	-
Cimento 2	Cimento	0.11	0.18	24.2	2.96	9.02	848	-
Cimento 2	Cimento	0.10	0.18	24.7	3.48	9.01	845	-
Cimento 2	Cimento	0.28	0.38	26.5	15	8.25	467	-
Cimento 2	Cimento	0.28	0.39	26.6	12	8.15	462	-
Cimento 2	Cimento	0.28	0.36	26.2	12.2	8.13	459	-
Cimento 2	Cimento	0.27	0.33	27.1	11.2	8.12	460	-
Cimento 2	Cimento	0.28	0.4	26.9	10.9	8.1	448	-
Cimento 2	Cimento	0.35	0.43	26.2	11.6	8.12	446	-
Cimento 2	Cimento	0.37	0.45	26.4	11.5	8.14	450	-
Cimento 2	Cimento	0.21	0.34	26.6	8.69	8.24	435	-
Cimento 2	Cimento	0.29	0.32	31.1	10.7	8.27	444	-
Cimento 2	Cimento	0.48	0.59	30.9	13.7	8.39	436	-
Cimento 2	Cimento	0.45	0.55	30.2	9.36	8.36	427	-
Cimento 2	Cimento	0.45	0.55	31.9	9.05	8.32	432	-
Cimento 2	Cimento	0.49	0.60	32.1	8.86	8.35	432	-
Cimento 2	Cimento	0.49	0.54	32.7	8.97	8.35	431	-
Cimento 2	Cimento	0.41	0.51	32.6	9.01	8.4	431	-
Cimento 2	Cimento	0.64	0.72	31.7	9.22	8.38	427	-
Cimento 2	Cimento	0.64	0.69	32.2	9.41	8.43	421	-
Cimento 2	Cimento	0.32	0.40	27.6	3.86	8.48	481	-
Cimento 2	Cimento	0.22	0.35	26.9	3.84	8.47	457	-

Cimento 2	Cimento	0.29	0.34	27.1	2.85	8.46	457	-
Cimento 2	Cimento	0.35	0.41	27.4	3.51	8.47	456	-
Cimento 2	Cimento	0.41	0.46	27.6	3.96	8.48	458	-
Cimento 2	Cimento	0.35	0.52	27.8	3.25	8.48	453	-
Cimento 2	Cimento	0.47	0.58	28.9	3.35	8.48	458	-
Cimento 2	Cimento	0.65	0.82	28.2	4.53	8.49	467	-
Cimento 2	Cimento	0.56	0.64		2.59	8.4	458	-
Cimento 2	Cimento	0.43	0.54	32.1	2.53	8.38	472	-
Cimento 2	Cimento	0.57	0.66	31.9	2.96	8.4	469	-
Cimento 2	Cimento	0.51	0.61	33.6	2.89	8.39	481	-
Cimento 2	Cimento	0.5	0.56	33.5	3.56	8.39	486	-
Cimento 2	Cimento	0.46	0.63	33.4	4.2	8.43	483	-
Cimento 2	Cimento	0.52	0.65	33.2	7.21	8.38	480	-
Cimento 2	Cimento	0.53	0.7	31.3	2.86	8.45	473	-
Cimento 2	Cimento	0.86	0.93	26.4	7.02	8.51	528	-
Cimento 2	Cimento	0.84	0.93	26.1	5.34	8.48	496	-
Cimento 2	Cimento	0.76	0.89	26.6	5.77	8.49	501	-
Cimento 2	Cimento	0.94	1	26.4	5.7	8.5	492	-
Cimento 2	Cimento	0.87	0.95	26.9	6.02	8.51	495	-
Cimento 2	Cimento	0.92	1.01	27.3	4.89	8.53	500	-
Cimento 2	Cimento	0.96	1.06	27.3	5.21	8.52	495	-
Cimento 2	Cimento	0.68	0.73	31.2	5.07	8.43	509	-
Cimento 2	Cimento	0.86	0.95	29.4	6.79	8.39	505	-
Cimento 2	Cimento	0.49	0.59	32.3	14.4	8.21	500	-
Cimento 2	Cimento	0.55	0.68	32.3	8.28	8.38	480	-
Cimento 2	Cimento	0.55	0.68	33.2	6.52	8.43	491	-
Cimento 2	Cimento	0.59	0.65	33.3	4.96	8.44	470	-
Cimento 2	Cimento	0.66	0.72	33.3	4.61	8.43	492	-
Cimento 2	Cimento	0.69	0.79	33.4	4.51	8.45	492	-
Cimento 2	Cimento	0.75	0.82	33.1	4.59	8.44	492	-
Cimento 2	Cimento	0.95	1.04	30.4	4.17	8.49	484	-
Cimento 2	Cimento	0.88	0.98	25.8	5.35	8.48	525	-
Cimento 2	Cimento	0.82	0.93	24.7	4.57	8.48	495	-
Cimento 2	Cimento	0.77	0.87	24.2	4.09	8.47	494	-
Cimento 2	Cimento	0.92	1.01	25.2	3.79	8.46	490	-
Cimento 2	Cimento	0.81	0.98	24.4	4.09	8.47	494	-
Cimento 2	Cimento	0.76	0.91	24.6	4.28	8.47	495	-
Cimento 2	Cimento	0.79	0.91	25.2	3.99	8.47	493	-
Cimento 2	Cimento	0.95	1.12	26.2	4.67	8.5	498	-
Cimento 2	Cimento	1.36	1.44	28.1	6.51	8.54	504	-
Cimento 2	Cimento	0.87	0.97	29.9	5.57	8.26	499	-
Cimento 2	Cimento	0.87	0.98	29.7	11.1	8.28	507	-
Cimento 2	Cimento	1.08	1.16	30.5	7.35	8.47	506	-
Cimento 2	Cimento	1.26	1.42	29.9	3.96	8.57	493	-
Cimento 2	Cimento	1.24	1.34	29.8	4.02	8.58	493	-
Cimento 2	Cimento	1	1.18	29.6	4.16	8.58	494	-

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Cimento 2	Cimento	1.08	1.22	32.2	3.57	8.59	489	-
Cimento 2	Cimento	0.19	0.28	33.1	11.2	8.35	-	1.26
Cimento 2	Cimento	0.23	0.3	32.9	9.85	8.36	-	1.26
Cimento 2	Cimento	0.16	0.3	34.2	10.3	8.34	-	1.27
Cimento 2	Cimento	0.21	0.27	35.2	11.3	8.32	-	1.31
Cimento 2	Cimento	0.31	0.38	31.1	9.28	8.31	-	1.13
Cimento 2	Cimento	0.23	0.35	32.6	10.6	8.35	-	1.08
Cimento 2	Cimento	0.28	0.4	34.2	11.4	8.32	-	1.15
Cimento 2	Cimento	0.11	0.18	22.8	12.6	8.21	-	1.75
Cimento 2	Cimento	0.14	0.23	22.7	12.9	8.22	-	2.02
Cimento 2	Cimento	0.2	0.29	22.7	12.6	8.21	-	0.96
Cimento 2	Cimento	0.2	0.3	22.6	11.3	8.22	-	1.45
Cimento 2	Cimento	0.26	0.4	22.9	11.5	8.23	-	1.98
Cimento 2	Cimento	0.35	0.43	22.6	10.5	8.22	-	2
Cimento 2	Cimento	0.35	0.47	23	9.81	8.25	-	2.17
Cimento 2	Cimento	0.44	0.58	23.7	13.1	8.28	-	2.1
Cimento 2	Cimento	0.42	0.64	23.3	13	8.33	-	2.17
Cimento 2	Cimento	0.37	0.49	27.1	9.26	8.3	-	0.6
Cimento 2	Cimento	0.37	0.51	28.2	7.99	8.32	-	2.02
Cimento 2	Cimento	0.34	0.42	28.4	8.28	8.33	-	2.16
Cimento 2	Cimento	0.36	0.46	28.2	7.94	8.35	-	2.08
Cimento 2	Cimento	0.41	0.5	27.9	7.61	8.34	-	2.08
Cimento 2	Cimento	0.45	0.55	27.3	7.72	8.37	-	2.09
Cimento 2	Cimento	0.45	0.53	29.2	8.68	8.37	-	2.21
Cimento 2	Cimento	0.07	0.16	24.1	4.51	8.68	-	1.98
Cimento 2	Cimento	0.09	0.2	24	4.78	8.96	-	1.86
Cimento 2	Cimento	0.2	0.42	23.8	5.28	8.53	-	1.33
Cimento 2	Cimento	1.01	1.21	25.4	6.18	8.78	-	1.8
Cimento 2	Cimento	0.76	1.04	25.3	6.45	8.6	-	2.08
Cimento 2	Cimento	0.56	0.72	26.4	7.25	8.51	-	2.01
Cimento 2	Cimento	0.55	0.74	25.5	8.84	8.41	-	2.04
Cimento 2	Cimento	0.52	0.65	27.3	7.23	8.46	-	2.02
Cimento 2	Cimento	0.26	0.41	27.2	5.79	8.63	-	1.97
Cimento 2	Cimento	0.51	0.65	32.3	6.55	8.41	-	1.86
Cimento 2	Cimento	0.58	0.67	23.6	8.54	8.23	-	0.72
Cimento 2	Cimento	0.67	0.72	24.3	7.65	8.31	-	1.42
Cimento 2	Cimento	0.67	0.72	24.7	7.49	8.33	-	1.51
Cimento 2	Cimento	0.69	0.81	24.8	6.97	8.35	-	1.54
Cimento 2	Cimento	0.71	0.87	24.6	6.8	8.34	-	1.58
Cimento 2	Cimento	0.81	0.89	23.1	6.97	8.36	-	1.58
Cimento 2	Cimento	0.83	0.91	24.8	7.65	8.38	-	1.5

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Cimento 2	Cimento	0.64	0.76	25.7	7.05	8.62	-	2.13
Cimento 2	Cimento	0.62	0.71	26.4	6.9	8.54	-	1.35
Cimento 2	Cimento	0.65	0.77	26.1	5.58	8.61	-	1.15
Cimento 2	Cimento	0.67	0.75	26.8	4.69	8.54	-	0.55
Cimento 2	Cimento	0.78	0.88	27.1	7.96	8.52	-	0.89
Cimento 2	Cimento	0.95	1.03	26.3	5.63	8.52	-	0.82
Cimento 2	Cimento	1	1.1	26.2	6.01	8.52	-	0.84
Cimento 2	Cimento	0.93	1.03	27.6	5.85	8.52	-	0.81
Cimento 2	Cimento	1.08	1.15	28.4	6.21	8.47	-	1.03
Cimento 2	Cimento	0.22	0.29	31.4	7.52	8.44	-	1.35
Cimento 2	Cimento	0.27	0.36	33.4	4.03	8.42	-	1
Cimento 2	Cimento	0.23	0.35	34.2	4.5	8.45	-	1.28
Cimento 2	Cimento	0.24	0.4	35.3	4.17	8.45	-	1.78
Cimento 2	Cimento	0.25	0.32	35.2	3.86	8.46	-	1.87
Cimento 2	Cimento	0.29	0.3	30.9	4.38	8.48	-	1.86
Cimento 2	Cimento	0.35	0.42	34.2	4	8.47	-	1.77
Cimento 2	Cimento	0.37	0.47	34.3	4.45	8.46	-	1.82
Cimento 2	Cimento	0.37	0.57	24.8	7.82	8.34	-	1.62
Cimento 2	Cimento	0.49	0.53	24.9	8.6	8.3	-	1.41
Cimento 2	Cimento	0.45	0.52	25	7.69	8.25	-	1.45
Cimento 2	Cimento	0.51	0.58	25.1	6.68	8.28	-	1.41
Cimento 2	Cimento	0.55	0.62	25.3	7.12	8.27	-	1.41
Cimento 2	Cimento	0.5	0.57	26.3	6.74	8.26	-	1.3
Cimento 2	Cimento	0.45	0.55	27.4	7.04	8.28	-	1.37
Cimento 2	Cimento	0.59	0.71	31.3	6.71	8.41	-	1.36
Cimento 2	Cimento	0.63	0.7	30.3	7.08	8.43	-	0.79
Cimento 2	Cimento	0.15	0.23	29.9	10.6	7.96	-	0.81
Cimento 2	Cimento	0.56	0.63	29.4	7.54	8.29	-	0.51
Cimento 2	Cimento	0.63	0.68	29.6	6.13	8.38	-	1
Cimento 2	Cimento	0.66	0.74	29.5	6.05	8.4	-	1.2
Cimento 2	Cimento	0.76	0.88	29.7	5.79	8.44	-	1.47
Cimento 2	Cimento	0.67	0.74	30.4	6.24	8.4	-	1.52
Cimento 2	Cimento	0.66	0.72	29.4	5.16	8.46	-	1.45
Cimento 2	Cimento	0.52	0.6	29.8	6.17	8.44	-	1.43
Cimento 2	Cimento	1.98	2.02	26.8	12.8	8.61	-	0.42
Cimento 2	Cimento	2.3	2.38	27.1	11.2	8.59	-	0.34
Cimento 2	Cimento	2.2	2.3	27.1	9.01	8.59	-	0.34
Cimento 2	Cimento	1.9	1.98	27.3	8.9	8.57	-	0.33
Cimento 2	Cimento	2.1	2.2	25.9	8.73	8.53	-	0.42
Cimento 2	Cimento	1.8	1.88	25.3	8.63	8.55	-	0.4
Cimento 2	Cimento	1.78	1.82	24.7	8.63	8.56	-	0.38

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Cimento 2	Cimento	1.64	1.86	25.5	13.1	8.52	-	0.43
Cimento 2	Cimento	1.14	1.19	26.4	12.3	8.54	-	0.78
Cimento 2	Cimento	0.24	0.32	29	21.9	7.99	-	0.5
Cimento 2	Cimento	0.25	0.43	29.5	12.5	8.1	-	0.91
Cimento 2	Cimento	0.24	0.38	30.4	9.44	8.27	-	1.3
Cimento 2	Cimento	0.34	0.46	28.2	10.1	8.28	-	1.35
Cimento 2	Cimento	0.42	0.5	27.9	8.79	8.32	-	1.37
Cimento 2	Cimento	0.37	0.47	27.7	9.07	8.32	-	1.19
Cimento 2	Cimento	0.42	0.5	27.9	8.8	8.34	-	1.13
Cimento 2	Cimento	0.41	0.49	28.1	9.16	8.4	-	1.22
Cimento 2	Cimento	0.31	0.42	26.7	4.33	8.52	-	1.32
Cimento 2	Cimento	0.55	0.62	25.7	5.96	8.47	-	1.16
Cimento 2	Cimento	0.63	0.75	25.9	5.46	8.48	-	0.82
Cimento 2	Cimento	0.71	0.79	25.9	5.18	8.47	-	0.82
Cimento 2	Cimento	0.72	0.8	26	5.32	8.47	-	0.77
Cimento 2	Cimento	0.75	0.88	25.9	5.73	8.47	-	0.65
Cimento 2	Cimento	0.74	0.82	26.8	8.51	8.48	-	0.62
Cimento 2	Cimento	0.62	0.71	26.3	9.85	8.48	-	0.77
Cimento 2	Cimento	0.52	0.65	27.9	6.01	8.47	-	1.37
Cimento 2	Cimento	0.32	0.4	30.8	9.02	8.03	-	0.43
Cimento 2	Cimento	0.71	0.78	30.3	9.43	8.48	-	0.69
Cimento 2	Cimento	0.71	0.77	30.7	7.79	8.46	-	1.08
Cimento 2	Cimento	0.68	0.78	30.2	4.07	8.47	-	1.38
Cimento 2	Cimento	0.76	0.8	30.8	4.06	8.48	-	1.57
Cimento 2	Cimento	0.74	0.79	30.1	4.02	8.46	-	0.55
Cimento 2	Cimento	0.73	0.83	30.3	4.78	8.47	-	0.76
Cimento 2	Cimento	0.67	0.73	29.7	5.75	8.5	-	0.82
Cimento 2	Cimento	1.58	1.68	27.4	8.68	8.8	-	0.36
Cimento 2	Cimento	2.6	2.68	26.4	7.06	8.77	-	0.26
Cimento 2	Cimento	2.7	2.75	26.4	6.06	8.77	-	0.25
Cimento 2	Cimento	2.2	2.3	26.6	4.42	8.77	-	0.32
Cimento 2	Cimento	2.1	2.18	26.3	5.64	8.76	-	0.36
Cimento 2	Cimento	2.1	2.2	26.4	5.36	8.76	-	0.33
Cimento 2	Cimento	2	2.08	26.9	5.47	8.78	-	0.3
Cimento 2	Cimento	1.6	1.67	27.3	7.59	8.71	-	0.38
Cimento 2	Cimento	1.2	1.3	28.3	7.6	8.46	-	0.53
Cimento 2	Cimento	0.87	0.95	33.4	5.54	8.55	-	0.79
Cimento 2	Cimento	0.56	0.64	32.5	6.3	8.53	-	0.97
Cimento 2	Cimento	0.7	0.75	32.4	6.45	8.53	-	1.05
Cimento 2	Cimento	0.58	0.65	32.3	5.93	8.55	-	1.03
Cimento 2	Cimento	0.57	0.65	32.3	5.69	8.57	-	0.98

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature ºC	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Cimento 2	Cimento	0.51	0.6	31.9	6.61	8.58	-	1.03
Cimento 2	Cimento	0.53	0.62	31.1	6.18	8.6	-	1.02
Cimento 2	Cimento	0.55	0.65	31.2	6.82	8.61	-	1.06

G3: Matadouro Consumer taps (M1 & M2)

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 1	Matadouro	0.13	0.30	25.6	7.14	8.67	497	-
Matadouro 1	Matadouro	0.17	0.32	25.2	6.76	8.6	492	-
Matadouro 1	Matadouro	0.14	0.18	24.9	6.96	8.57	488	-
Matadouro 1	Matadouro	0.23	0.33	24.7	12.30	7.95	488	-
Matadouro 1	Matadouro	0.20	0.27	25.2	12.80	7.99	486	-
Matadouro 1	Matadouro	0.15	0.27	25.0	12.30	7.98	485	-
Matadouro 1	Matadouro	0.19	0.34	26.3	12.40	8.12	486	-
Matadouro 1	Matadouro	0.46	0.56	26.4	12.90	8.34	484	-
Matadouro 1	Matadouro	0.35	0.53	29.1	11.30	8.27	487	-
Matadouro 1	Matadouro	0.14	0.29	30.5	8.42	8.27	492	-
Matadouro 1	Matadouro	0.24	0.39	36.7	7.16	8.22	458	-
Matadouro 1	Matadouro	0.25	0.40	36.4	7.82	8.22	432	-
Matadouro 1	Matadouro	0.17	0.39	35.7	7.17	8.29	431	-
Matadouro 1	Matadouro	0.23	0.32	36.8	7.67	8.21	430	-
Matadouro 1	Matadouro	0.20	0.34	36.9	6.99	8.17	433	-
Matadouro 1	Matadouro	0.15	0.28	35.7	7.84	8.23	432	-
Matadouro 1	Matadouro	0.06	0.19	33.4	6.55	8.21	434	-
Matadouro 1	Matadouro	0.12	0.26	27.8	3.93	8.58	542	-
Matadouro 1	Matadouro	0.14	0.27	28.1	3.31	8.57	497	-
Matadouro 1	Matadouro	0.09	0.21	27.6	3.07	8.51	492	-
Matadouro 1	Matadouro	0.08	0.19	27.4	2.85	8.5	488	-
Matadouro 1	Matadouro	0.16	0.22	26.8	2.32	8.52	488	-
Matadouro 1	Matadouro	0.20	0.27	26.9	2.10	8.53	486	-
Matadouro 1	Matadouro	0.17	0.27	27.3	2.50	8.52	485	-
Matadouro 1	Matadouro	0.12	0.27	28.2	2.62	8.48	486	-
Matadouro 1	Matadouro	0.27	0.45	30.1	1.74	8.52	484	-
Matadouro 1	Matadouro	0.35	0.44	32.6	3.94	8.28	487	-

Matadouro 1	Matadouro	0.20	0.30	34.8	2.31	8.49	492	-
Matadouro 1	Matadouro	0.18	0.27	33.8	3.39	8.47	488	-
Matadouro 1	Matadouro	0.26	0.29	31.6	2.67	8.46	494	-
Matadouro 1	Matadouro	0.18	0.31	31.3	2.77	8.43	491	-
Matadouro 1	Matadouro	0.15	0.21	30.9	1.91	8.48	490	-
Matadouro 1	Matadouro	0.10	0.21	29.7	1.97	8.48	485	-
Matadouro 1	Matadouro	0.12	0.26	29.9	1.86	8.46	481	-
Matadouro 1	Matadouro	1.26	1.40	29.4	3.91	8.67	483	-
Matadouro 2	Matadouro	0.22	0.27	21.8	3.89	8.68	712	-
Matadouro 2	Matadouro	0.05	0.09	20.2	2.84	8.55	740	-
Matadouro 2	Matadouro	0.13	0.21	20.9	4.46	8.72	741	-
Matadouro 2	Matadouro	0.14	0.14	20.7	3.59	8.68	738	-
Matadouro 2	Matadouro	0.10	0.11	21.2	4.21	8.72	735	-
Matadouro 2	Matadouro	0.06	0.21	22.4	2.82	8.68	735	-
Matadouro 2	Matadouro	0.19	0.45	21.7	3.88	8.69	731	-
Matadouro 2	Matadouro	0.10	0.24	21.7	2.56	8.69	687	-
Matadouro 2	Matadouro	0.22	1.14	24.6	6.80	8.83	710	-
Matadouro 2	Matadouro	0.23	0.40	27.4	7.54	8.63	722	-
Matadouro 2	Matadouro	0.17	0.19	29.3	3.92	8.64	739	-
Matadouro 2	Matadouro	0.11	0.21	29.6	6.32	8.56	718	-
Matadouro 2	Matadouro	0.17	0.24	28.2	4.11	8.57	714	-
Matadouro 2	Matadouro	0.21	0.24	29.6	4.33	8.57	726	-
Matadouro 2	Matadouro	0.38	0.40	29.9	4.17	8.56	731	-
Matadouro 2	Matadouro	0.22	0.38	28.6	3.91	8.58	713	-
Matadouro 2	Matadouro	0.23	0.25	29.0	3.05	8.6	738	-
Matadouro 2	Matadouro	0.20	0.26	26.8	3.12	8.74	750	-
Matadouro 2	Matadouro	0.32	0.45	26.3	3.45	8.76	835	-
Matadouro 2	Matadouro	0.27	0.47	27.4	2.24	8.85	855	-
Matadouro 2	Matadouro	0.22	0.39	26.7	4.23	8.88	825	-
Matadouro 2	Matadouro	0.31	0.45	26.9	3.56	8.68	840	-

Matadouro 2	Matadouro	0.25	0.43	28.4	5.85	8.72	829	-
Matadouro 2	Matadouro	0.28	0.35	28.1	6.72	8.7	462	-
Matadouro 2	Matadouro	0.24	0.49	27.7	5.32	8.66	836	-
Matadouro 2	Matadouro	0.22	0.49	27.4	3.11	8.72	868	-
Matadouro 2	Matadouro	0.19	0.25	28.9	6.63	8.64	843	-
Matadouro 2	Matadouro	1.27	1.39	32.8	7.36	8.71	837	-
Matadouro 2	Matadouro	0.31	0.47	36.7	6.13	8.54	858	-
Matadouro 2	Matadouro	0.36	0.41	36.4	5.13	8.49	854	-
Matadouro 2	Matadouro	0.37	0.46	35.0	6.26	8.6	849	-
Matadouro 2	Matadouro	0.19	0.25	35.2	6.98	8.51	850	-
Matadouro 2	Matadouro	0.23	0.40	35.8	5.36	8.38	852	-
Matadouro 2	Matadouro	0.16	0.26	36.4	4.72	8.5	858	-
Matadouro 2	Matadouro	0.14	0.24	23.2	5.25	8.65	625	-
Matadouro 2	Matadouro	0.11	0.25	23.2	4.85	8.65	605	-
Matadouro 2	Matadouro	0.25	0.28	24.1	6.35	8.58	614	-
Matadouro 2	Matadouro	0.28	0.48	24.2	6.48	8.68	613	-
Matadouro 2	Matadouro	0.35	0.51	24.6	8.94	8.67	611	-
Matadouro 2	Matadouro	0.30	0.42	24.3	9.65	8.67	604	-
Matadouro 2	Matadouro	0.44	0.46	24.7	11.00	8.7	600	-
Matadouro 2	Matadouro	0.42	0.57	26.3	15.00	8.67	585	-
Matadouro 2	Matadouro	0.47	0.53	28.2	9.34	8.65	570	-
Matadouro 2	Matadouro	0.31	0.47	33.7	8.34	8.54	675	-
Matadouro 2	Matadouro	0.21	0.36	33.4	8.27	8.49	678	-
Matadouro 2	Matadouro	0.18	0.34	32.0	8.21	8.6	676	-
Matadouro 2	Matadouro	0.12	0.25	32.2	8.23	8.51	675	-
Matadouro 2	Matadouro	0.11	0.24	32.8	8.02	8.38	679	-
Matadouro 2	Matadouro	0.08	0.14	33.4	7.95	8.5	676	-
Matadouro 2	Matadouro	0.21	0.39	27.7	6.88	8.44	467	-
Matadouro 2	Matadouro	0.31	0.35	27.2	6.93	8.39	462	-
Matadouro 2	Matadouro	0.31	0.44	27.1	5.60	8.45	459	-

Matadouro 2	Matadouro	0.41	0.57	27.8	5.57	8.43	460	-
Matadouro 2	Matadouro	0.55	0.71	27.2	5.38	8.39	448	-
Matadouro 2	Matadouro	0.45	0.73	27.9	5.91	8.12	446	-
Matadouro 2	Matadouro	0.30	0.53	28.1	6.90	8.25	450	-
Matadouro 2	Matadouro	0.43	0.46	34.1	5.38	8.44	435	-
Matadouro 2	Matadouro	0.34	0.52	34.6	6.17	8.4	444	-
Matadouro 2	Matadouro	0.38	0.45	34.5	7.90	8.34	436	-
Matadouro 2	Matadouro	0.39	0.56	36.0	8.38	8.21	427	-
Matadouro 2	Matadouro	0.24	0.42	36.8	7.10	8.14	432	-
Matadouro 2	Matadouro	0.29	0.37	35.9	7.48	8.27	432	-
Matadouro 2	Matadouro	0.24	0.33	35.5	7.90	8.14	431	-
Matadouro 2	Matadouro	0.28	0.34	35.6	8.03	8.36	431	-
Matadouro 2	Matadouro	0.12	0.21	33.2	8.45	8.37	427	-
Matadouro 2	Matadouro	0.11	0.19	32.4	8.71	8.29	421	-
Matadouro 2	Matadouro	0.27	0.42	24.8	7.53	8.45	528	-
Matadouro 2	Matadouro	0.17	0.27	24.6	5.78	8.43	496	-
Matadouro 2	Matadouro	0.19	0.32	24.6	5.17	8.48	501	-
Matadouro 2	Matadouro	0.21	0.28	24.7	5.98	8.67	492	-
Matadouro 2	Matadouro	0.23	0.43	24.8	5.37	8.51	495	-
Matadouro 2	Matadouro	0.29	0.47	24.4	5.21	8.41	500	-
Matadouro 2	Matadouro	0.16	0.30	23.7	5.21	8.49	495	-
Matadouro 2	Matadouro	0.24	0.42	25.1	4.66	8.22	509	-
Matadouro 2	Matadouro	0.36	0.51	26.9	3.87	7.84	505	-
Matadouro 2	Matadouro	0.14	0.30	36.6	2.57	8.36	500	-
Matadouro 2	Matadouro	0.14	0.27	31.1	2.41	8.46	480	-
Matadouro 2	Matadouro	0.13	0.28	30.8	2.32	8.49	491	-
Matadouro 2	Matadouro	0.19	0.35	30.7	3.16	8.38	470	-
Matadouro 2	Matadouro	0.17	0.41	30.3	4.01	8.42	492	-
Matadouro 2	Matadouro	0.15	0.24	31.4	4.17	8.35	492	-
Matadouro 2	Matadouro	0.18	0.28	31.3	4.88	8.22	492	-

Matadouro 2	Matadouro	0.16	0.32	32.3	3.14	8.35	484	-
Matadouro 2	Matadouro	0.19	0.36	31.9	3.66	8.32	525	-
Matadouro 2	Matadouro	0.12	0.28	32.2	4.63	8.38	495	-
Matadouro 2	Matadouro	0.13	0.34	31.8	4.89	8.35	494	-
Matadouro 2	Matadouro	0.45	0.63	32.0	5.66	8.4	490	-
Matadouro 2	Matadouro	0.50	0.70	31.9	8.32	8.37	494	-
Matadouro 2	Matadouro	0.47	0.60	32.4	7.22	8.36	495	-
Matadouro 2	Matadouro	0.35	0.51	32.6	7.03	8.32	493	-
Matadouro 2	Matadouro	0.15	0.25	23.8	25.20	8.6	504	-
Matadouro 2	Matadouro	0.22	0.28	23.5	8.41	8.42	499	-
Matadouro 2	Matadouro	0.21	0.29	23.9	7.37	8.39	507	-
Matadouro 2	Matadouro	0.24	0.42	23.9	6.46	8.42	506	-
Matadouro 2	Matadouro	0.33	0.41	24.4	9.66	8.41	493	-
Matadouro 2	Matadouro	0.27	0.31	23.7	7.25	8.41	493	-
Matadouro 2	Matadouro	0.22	0.28	24.4	7.78	8.44	494	-
Matadouro 2	Matadouro	0.21	0.29	25.9	8.33	8.38	506	-
Matadouro 2	Matadouro	0.43	0.23	29.2	9.38	8.36	489	-
Matadouro 2	Matadouro	0.22	0.33	32.1	12.53	8.38	462	1.46
Matadouro 2	Matadouro	0.24	0.27	33.1	13.62	8.39	402	1.48
Matadouro 2	Matadouro	0.30	0.38	33.6	13.68	8.35	394	1.54
Matadouro 2	Matadouro	0.25	0.37	34.1	14.36	8.36	388	1.79
Matadouro 2	Matadouro	0.28	0.39	33.6	14.07	8.3	388	1.46
Matadouro 2	Matadouro	0.22	0.33	33.0	12.12	8.27	384	1.73
Matadouro 2	Matadouro	0.18	0.24	33.5	11.97	8.29	381	1.57
Matadouro 2	Matadouro	0.13	0.27	23.9	11.17	8.4	385	1.67
Matadouro 2	Matadouro	0.18	0.30	24.0	11.02	8.6	375	2.06
Matadouro 2	Matadouro	0.20	0.29	22.8	10.99	8.4	380	2.48
Matadouro 2	Matadouro	0.28	0.32	23.1	11.16	8.21	367	2.41
Matadouro 2	Matadouro	0.17	0.24	22.6	10.67	8.33	362	2.28
Matadouro 2	Matadouro	0.20	0.28	22.8	11.29	8.25	355	2.45

Matadouro 2	Matadouro	0.21	0.37	23.7	10.60	8.22	363	2.44
Matadouro 2	Matadouro	0.10	0.17	24.7	10.73	8.08	362	2.44
Matadouro 2	Matadouro	0.21	0.27	25.7	10.54	8.48	349	2.42
Matadouro 2	Matadouro	0.20	0.37	27.4	15.72	8..66	359	2.46
Matadouro 2	Matadouro	0.25	0.39	27.3	17.01	8.43	349	1.49
Matadouro 2	Matadouro	0.13	0.31	25.2	10.38	8.68	391	2.46
Matadouro 2	Matadouro	0.19	0.33	25.5	10.18	8.31	353	2.39
Matadouro 2	Matadouro	0.14	0.27	26.7	10.97	8.36	342	2.33
Matadouro 2	Matadouro	0.17	0.34	26.7	10.99	8.27	341	2.41
Matadouro 2	Matadouro	0.13	0.24	26.6	7.61	8.43	344	2.39
Matadouro 2	Matadouro	0.16	0.28	26.4	7.02	8.3	343	2.12
Matadouro 2	Matadouro	0.02	0.14	25.1	7.45	8.51	348	1.47
Matadouro 2	Matadouro	0.05	0.15	24.7	8.50	8.49	338	1.98
Matadouro 2	Matadouro	0.07	0.14	23.1	8.15	8.49	351	2.45
Matadouro 2	Matadouro	0.11	0.17	23.3	7.53	8.43	344	2.35
Matadouro 2	Matadouro	0.20	0.29	23.9	7.01	8.42	339	2.38
Matadouro 2	Matadouro	0.24	0.30	24.3	8.54	8.36	342	2.35
Matadouro 2	Matadouro	0.29	0.37	24.5	8.86	8.28	335	2.43
Matadouro 2	Matadouro	0.27	0.34	22.8	6.45	8.35	334	2.48
Matadouro 2	Matadouro	0.54	0.59	23.6	8.17	8.3	336	2.36
Matadouro 2	Matadouro	0.25	0.31	24.8	17.80	8.18	331	2.33
Matadouro 2	Matadouro	0.22	0.40	23.3	14.53	8.72	-	2.06
Matadouro 2	Matadouro	0.19	0.45	22.3	15.33	8.47	-	2.11
Matadouro 2	Matadouro	0.23	0.34	22.8	23.11	8.63	-	2.31
Matadouro 2	Matadouro	0.29	0.32	22.9	22.50	8.57	-	2.26
Matadouro 2	Matadouro	0.10	0.14	23.1	23.53	8.41	-	2.33
Matadouro 2	Matadouro	0.07	0.21	23.4	22.68	8.46	-	2.31
Matadouro 2	Matadouro	0.11	0.23	23.6	11.86	8.96	-	2.32
Matadouro 2	Matadouro	0.31	0.36	22.6	12.76	8.62	-	2.36

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 2	Matadouro	0.55	0.67	23.4	12.52	8.45	-	2.33
Matadouro 2	Matadouro	0.32	0.42	24.7	15.80	8.17	-	0.54
Matadouro 2	Matadouro	0.28	0.34	23.7	12.45	8.23	-	0.89
Matadouro 2	Matadouro	0.24	0.34	22.9	8.66	8.19	-	1.25
Matadouro 2	Matadouro	0.26	0.36	24.5	8.49	8.34	-	1.58
Matadouro 2	Matadouro	0.18	0.26	24.7	8.52	8.33	-	1.68
Matadouro 2	Matadouro	0.18	0.28	24.9	8.52	8.31	-	1.68
Matadouro 2	Matadouro	0.22	0.31	24.8	8.53	8.32	-	1.87
Matadouro 2	Matadouro	0.26	0.32	22.8	8.56	8.34	-	1.98
Matadouro 2	Matadouro	0.58	0.65	25.7	8.05	8.62	-	
Matadouro 2	Matadouro	0.60	0.71	26.4	7.77	8.54	-	1.35
Matadouro 2	Matadouro	0.62	0.69	26.1	6.58	8.61	-	1.15
Matadouro 2	Matadouro	0.64	0.75	26.8	5.68	8.54	-	0.55
Matadouro 2	Matadouro	0.67	0.74	27.1	5.97	8.52	-	0.89
Matadouro 2	Matadouro	0.84	0.92	26.3	4.98	8.52	-	0.82
Matadouro 2	Matadouro	0.87	0.97	26.2	4.78	8.52	-	0.84
Matadouro 2	Matadouro	0.89	1.00	27.6	5.58	8.52	-	0.81
Matadouro 2	Matadouro	1.00	1.10	28.4	5.85	8.47	-	1.03
Matadouro 2	Matadouro	0.40	0.58	31.4	12.60	8.75	-	2.11
Matadouro 2	Matadouro	0.52	0.66	33.4	9.05	8.61	-	2.33
Matadouro 2	Matadouro	0.34	0.45	34.2	6.27	8.58	-	2.46
Matadouro 2	Matadouro	0.31	0.39	35.3	5.28	8.53	-	2.46
Matadouro 2	Matadouro	0.32	0.44	35.2	5.39	8.56	-	2.42
Matadouro 2	Matadouro	0.20	0.40	30.9	4.81	8.57	-	2.43
Matadouro 2	Matadouro	0.23	0.33	34.2	4.36	8.42	-	2.39
Matadouro 2	Matadouro	0.17	0.31	34.3	3.15	8.63	-	2.36

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 2	Matadouro	0.11	0.24	25.0	15.67	8.35	-	2.4
Matadouro 2	Matadouro	0.16	0.26	24.7	17.15	7.35	-	2.43
Matadouro 2	Matadouro	0.32	0.45	25.4	19.19	7.75	-	2.21
Matadouro 2	Matadouro	0.40	0.43	25.7	28.11	7.46	-	2.2
Matadouro 2	Matadouro	0.17	0.66	26.0	17.08	7.75	-	2.17
Matadouro 2	Matadouro	0.41	0.28	26.2	9.20	7.46	-	2.19
Matadouro 2	Matadouro	0.23	0.20	26.7	8.30	7.67	-	2.23
Matadouro 2	Matadouro	0.07	0.15	27.4	8.16	8.46	-	2.19
Matadouro 2	Matadouro	0.21	0.31	27.8	8.08	8.44	-	2.17
Matadouro 2	Matadouro	0.28	0.47	32.2	10.32	8.46	-	2.26
Matadouro 2	Matadouro	0.35	0.56	30.2	10.98	7.21	-	2.33
Matadouro 2	Matadouro	0.28	0.32	29.4	3.43	8.50	-	2.35
Matadouro 2	Matadouro	0.15	0.26	29.8	3.51	8.41	-	2.34
Matadouro 2	Matadouro	0.26	0.36	29.4	3.48	8.52	-	2.3
Matadouro 2	Matadouro	0.20	0.28	29.3	3.67	8.41	-	2.3
Matadouro 2	Matadouro	0.07	0.14	28.9	3.96	8.74	-	2.23
Matadouro 2	Matadouro	0.10	0.21	28.7	4.05	8.41	-	2.37
Matadouro 2	Matadouro	1.90	2.08	26.8	7.17	8.83	-	0.73
Matadouro 2	Matadouro	2.09	2.20	27.1	7.30	8.65	-	0.75
Matadouro 2	Matadouro	2.08	2.28	27.1	7.14	8.43	-	0.75
Matadouro 2	Matadouro	1.81	1.98	27.3	8.17	8.70	-	0.7
Matadouro 2	Matadouro	1.78	1.92	25.9	8.27	8.63	-	0.68
Matadouro 2	Matadouro	1.61	1.80	25.3	8.37	8.75	-	0.74
Matadouro 2	Matadouro	1.68	1.99	24.7	8.32	8.65	-	0.72
Matadouro 2	Matadouro	1.21	1.33	25.5	7.30	8.61	-	1.07
Matadouro 2	Matadouro	0.30	0.41	26.4	8.06	8.55	-	1.58

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 2	Matadouro	1.15	1.24	29.0	9.84	8.64	-	1.1
Matadouro 2	Matadouro	1.10	1.27	29.5	12.43	8.56	-	2.38
Matadouro 2	Matadouro	0.83	0.99	30.4	10.36	8.73	-	2.39
Matadouro 2	Matadouro	0.73	0.91	28.2	10.69	8.61	-	2.35
Matadouro 2	Matadouro	0.66	0.85	27.9	9.90	8.60	-	2.35
Matadouro 2	Matadouro	0.70	1.01	27.7	14.31	8.51	-	2.39
Matadouro 2	Matadouro	0.59	0.68	27.9	5.30	8.61	-	2.35
Matadouro 2	Matadouro	0.57	0.69	28.1	5.23	8.52	-	2.8
Matadouro 2	Matadouro	0.14	0.21	26.9	10.31	8.56	-	1.97
Matadouro 2	Matadouro	0.28	0.38	26.6	9.82	8.37	-	1.71
Matadouro 2	Matadouro	0.24	0.34	25.1	16.62	8.32	-	1.52
Matadouro 2	Matadouro	0.29	0.38	25.4	13.02	8.41	-	1.58
Matadouro 2	Matadouro	0.30	0.36	25.8	15.54	8.65	-	1.49
Matadouro 2	Matadouro	0.35	0.41	26.0	15.11	8.33	-	1.48
Matadouro 2	Matadouro	0.36	0.46	26.8	12.50	8.43	-	1.52
Matadouro 2	Matadouro	0.39	0.49	27.6	10.10	8.41	-	1.57
Matadouro 2	Matadouro	0.29	0.39	29.0	6.47	8.25	-	1.97
Matadouro 2	Matadouro	0.21	0.28	30.8	8.50	8.03	-	0.89
Matadouro 2	Matadouro	0.64	0.71	30.3	9.10	8.48	-	0.99
Matadouro 2	Matadouro	0.61	0.69	30.7	7.87	8.46	-	1.05
Matadouro 2	Matadouro	0.51	0.61	30.2	5.03	8.47	-	1.25
Matadouro 2	Matadouro	0.62	0.70	30.8	5.21	8.48	-	1.31
Matadouro 2	Matadouro	0.68	0.77	30.1	5.25	8.46	-	0.45
Matadouro 2	Matadouro	0.69	0.78	30.3	5.36	8.47	-	0.75
Matadouro 2	Matadouro	0.51	0.61	29.7	6.75	8.50	-	0.75
Matadouro 2	Matadouro	0.14	0.30	28.9	8.17	8.40	-	0.61

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 2	Matadouro	0.25	0.48	28.3	9.01	8.29	-	0.57
Matadouro 2	Matadouro	0.25	0.40	28.3	6.53	8.31	-	0.55
Matadouro 2	Matadouro	0.36	0.59	28.7	6.91	8.31	-	0.57
Matadouro 2	Matadouro	0.43	0.58	29.4	10.20	8.30	-	0.62
Matadouro 2	Matadouro	0.47	0.64	29.0	11.10	8.33	-	0.64
Matadouro 2	Matadouro	0.48	0.68	28.2	11.70	8.31	-	0.61
Matadouro 2	Matadouro	0.51	0.72	29.1	12.30	8.34	-	0.79
Matadouro 2	Matadouro	0.18	0.28	28.9	10.50	8.22	-	1.39
Matadouro 2	Matadouro	0.13	0.37	29.4	5.91	8.41	-	2.24
Matadouro 2	Matadouro	0.15	0.21	30.4	5.20	8.4	-	2.33
Matadouro 2	Matadouro	0.16	0.29	31.3	4.92	8.43	-	2.28
Matadouro 2	Matadouro	0.14	0.24	31.6	6.03	8.44	-	2.34
Matadouro 2	Matadouro	0.13	0.23	31.6	6.13	8.41	-	2.33
Matadouro 2	Matadouro	0.08	0.16	31.5	6.35	8.39	-	2.23
Matadouro 2	Matadouro	0.06	0.16	29.5	5.35	8.44	-	2.2
Matadouro 2	Matadouro	0.12	0.26	31.2	5.02	8.43	-	2.13
Matadouro 2	Matadouro	0.16	0.21	27.5	16.01	8.75	-	2.08
Matadouro 2	Matadouro	0.07	0.19	26.5	8.53	8.67	-	1.84
Matadouro 2	Matadouro	0.19	0.28	26.5	7.02	8.69	-	1.23
Matadouro 2	Matadouro	0.17	0.25	26.7	7.52	8.61	-	1.31
Matadouro 2	Matadouro	0.15	0.22	27.2	5.85	8.52	-	1.15
Matadouro 2	Matadouro	0.21	0.31	27.7	3.96	8.54	-	1.05
Matadouro 2	Matadouro	0.28	0.36	27.9	5.06	8.39	-	1.36
Matadouro 2	Matadouro	2.20	2.30	28.4	8.08	8.54	-	1.05
Matadouro 2	Matadouro	2.20	2.30	29.8	4.84	8.42	-	1.09
Matadouro 2	Matadouro	1.06	1.20	31.9	12.96	8.64	-	1.44

Sampling collection Point	Area	Free Residual Chlorine mg/l	Total Residual Chlorine mg/l	Temperature °C	Turbidity NTU	pH -	Electric conductivity (EC) µS/cm	Pressure bar
Matadouro 2	Matadouro	1.12	1.28	29.6	8.96	8.68	-	1.25
Matadouro 2	Matadouro	0.94	1.10	29.4	7.44	8.56	-	0.52
Matadouro 2	Matadouro	0.80	0.98	30.1	7.29	8.42	-	0.48
Matadouro 2	Matadouro	0.86	1.05	30.7	9.54	8.33	-	1.04
Matadouro 2	Matadouro	0.68	0.76	30.9	5.84	8.65	-	1.21
Matadouro 2	Matadouro	0.50	0.58	31.3	5.22	8.63	-	0.58
Matadouro 2	Matadouro	0.38	0.54	28.3	5.08	8.76	-	0.79