University of Nairobi

Assessment of the hydrodynamics Process of Anaerobic ponds of Dandora Wastewater Treatment Plant: Radiotracer Application

by

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Declaration

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Omolo Wendy Mariam Adwet, S56/78904/2015

Signature .... Date 18/11/2019 ....

Supervisors' Approval

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Dedication

This study is dedicated to my family who have been my source of inspiration and continually supports me financially, emotionally, spiritually and morally.

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List of Abbreviations used

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DAS	Data Acquisition System
DO	Dissolved Oxygen
IAEA	International Atomic Energy Agency
I-131	Iodine-131 element
MBq	MegaBequerel
MRT	Mean Residence Time
RTD	Residence Time Distribution
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UV	Ultra Violet
WHO	World Health Organization
WSP	Wastewater Stabilization Pond
WWTP	Waste Water Treatment Plant

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Abstract

Wastewater is a serious environmental concern when released to the environment untreated. Dandora Waste Water Treatment Plant treats about 80,000 m^3(80%) of wastewater generated within Nairobi and its environs per day before disposal into Nairobi river. Therefore, this study has assessed the operations of Dandora Waste Water Treatment Pond for effectiveness, specifically, the anaerobic ponds by using radiotracer technology. Radiotracers are widely used in industries to optimize processes by investigating reactor mixing processes and troubleshooting. In waste water treatment plants processes, radiotracers are very sensitive and mostly applied in online diagnosis of various operations. Approximately 5000 MBq of Iodine-131 radiotracer was injected 40 m away from the inlet of anaerobic pond and its passage through the channel and the entire pond was monitored by seven (7) NaI detectors to determine the Residence Time Distribution (RTD). Volumetric flow rate of the inlet channel at the time of injection was estimated to be 0.059 m^3s^{-1} using radiotracer methods which provided the theoretical mean residence time (MRT) to be 3.5 days. The measured MRT was then compared with the theoretical MRT and dead volume was estimated, from which it was found that about 93% of the geometric volume within the pond was dead. The measured RTD was modeled using various RTD models and eventually a suitable model was identified to describe and visualize the flow pattern of wastewater within the pond. RTD obtained using the online detection system shows a typical bypass of 3.0 - 3.8% followed by mass flow homogenization of 96.2 - 97 %. It was evident that the retention time of anaerobic pond of interest was less than the theoretical retention time thus indicating a reduction in active volume of the pond due to sludge build-up and stagnant volumes. Based on the measured MRT, percentage of dead volume and identified flow patterns, it was concluded that the hydraulic performance of the pond was catastrophically poor and no longer suited for the purpose it was designed for. It is recommended that the pond be de-sludged and follow-up experiment conducted. The results of the wastewater effluents for weekly averages for COD, BOD, TSS and TDS exceed the design and Kenya standards limits.

Chapter 1: Introduction

1.1 Background

Wastewater is a mixture of various effluents generated from domestic, industrial, and commercial activities. It contains organic and inorganic matter which may be in suspended, dissolved or in colloidal state. Waste water also contains living organisms (Punmia *et al*., 1998). This is a serious environmental concern due to hazards, which when released to the environment untreated (UK Essays, 2013), pollutes the receiving water bodies, contaminates soils and causes ground water pollution and thereby results to loss of biodiversity. In general, waste waters can be characterized according to its physical, chemical and biological characteristics.

Wastewater treatment is the process of cleaning waste waters so that it can be returned safely to the environment (Budambula and Mwachiro, 2006).

The goal of wastewater treatment is to reduce pollutant load to minimize discharge to the environment through stabilization of the contaminant into the most appropriate steady thermodynamic form (IAEA, 2011), so that treated waste water can be used domestically; for both in agriculture and aquaculture.

Dandora wastewater treatment plant treats about 80,000m^3 daily, which is approximately 80% of wastewater generated within Nairobi and its environs (Environmental, 2016). In Dandora, treatment of wastewater is done through two processes; physical treatment (mechanical treatment facility) and biological treatment, which are waste stabilization ponds i.e., anaerobic, facultative and maturation ponds. There are four stages in which large organic solids are physically removed at the physical treatment facility both manually and mechanically namely; i) coarse bar screens, ii) cup screens, iii) grit traps and iv) classifiers. Wastewater then flows to biological ponds where it is retained as per their design, for approximate retention time of 60-90 days in each series (Environmental, 2016), before release for discharge to the Nairobi river. Figure 1.1. illustrates a schematic diagram of the waste water treatment process at the Dandora.

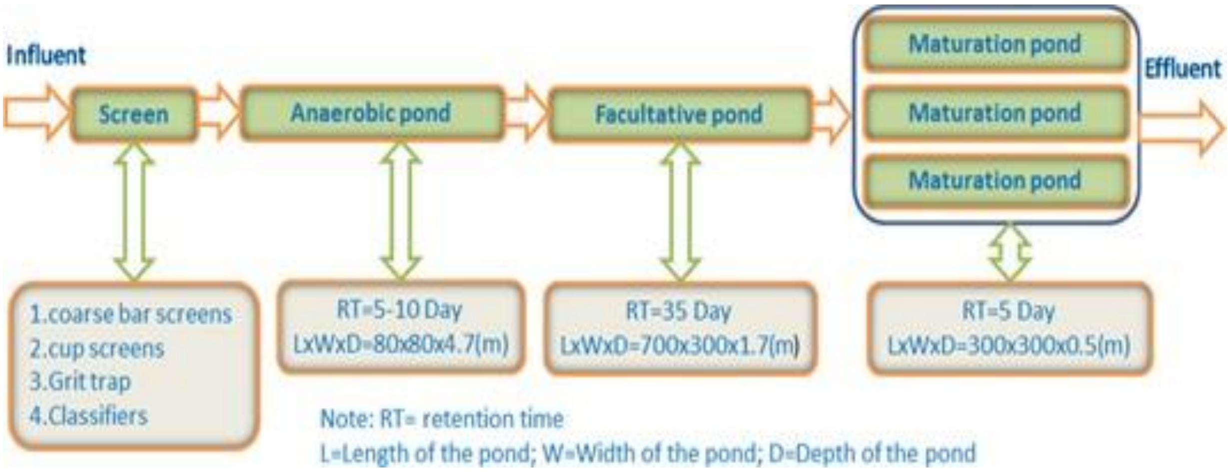


Figure 1.1: Schematic diagram of Dandora Wastewater Treatment plant (Wang et al., 2014)

In principle, Wastewater stabilization ponds at the treatment Plant consist of various natural occurring microorganisms which digest organic matter to produce water and carbon (IV) oxide. The non-biodegradable particles are known to occupy the bottom region of these ponds in the form of a sludge. In anaerobic pond, anaerobic condition is created by scum covering its surface. This condition activates anaerobic bacteria which act on organic load in the wastewater. It has a retention time of 5-10 days. Facultative pond also consists of facultative bacteria and both anaerobic and aerobic bacteria. The bottom of the pond has anaerobic bacteria, facultative bacteria in the middle of the pond, and aerobic bacteria at the top. The surface of this pond is covered with little scum as compared to anaerobic ponds. Typical retention time of facultative ponds is 35 days. At this stage, elimination of the organisms such as larvae and helminth eggs occurs. Finally, in maturation pond, sunlight penetrates to the bottom to kill pathogens following UV irradiation (Environmental, 2016).

Studies conducted on the effluents from Dandora wastewater treatment plant reveals some of the effluent challenges such as heavy metal contamination amongst others. Nairobi River has a significant amount of heavy metal accumulation, as found in fish species in the river (Budambula and Mwachiro, 2006). Study by Sewe (2010) concluded that the plant was not efficient in pollutant removal. This study was done so as to assess the effectiveness of the process and suggest remedial action.

Radioactive tracers were selected for this study to practically assess performance of wastewater treatment plant (IAEA, 2011). In general, the application of the radiotracers in industries is inclusive of optimization of the processes, saving the energy, solving the problems, reduction of the pollution and improvement of the product quality. Basically, the process is actualized by investigating mixing studies, flow rate measurement, residence time distribution, and troubleshooting of processes (Dawi, 2010; Farooq *et al.*, 2003).

Some of the industries that radiotracer technology has been successful applied include; petroleum and petrochemical industries, wastewater treatment sectors and mineral processing, where investigations are conducted by injecting radiotracer at the inlet of a system and monitoring using appropriate detectors at the outlet. These systems include fluidized beds, trickle bed reactors, sugar crystallizers, cement rotary kilns, inter-well communication and wastewater treatment units (IAEA, 2008).

1.2 Problem Statement

A study by Sewe (2010), revealed that the levels of most of the parameters analyzed for, in effluents discharged from Dandora wastewater treatment plant exceeded the Water Quality Regulations in Kenya. This led the author to conclude that the treatment plant is not efficient in pollutant removal.

Budambula and Mwachiro (2006) in their study found out that there was bioaccumulation of heavy metals in fish species in seven falls, downstream of Nairobi River, the final recipient of Dandora wastewater treatment plant effluent.

Kinyanjui (2011) in her study on the impact of water pollution on Nairobi River found that, the river is seriously polluted because of the intense release of the domestic, commercial, industrial effluents into the system of the river.

This study, therefore, has assessed the operations of Dandora WWTP for effectiveness specifically, the anaerobic ponds of Dandora wastewater treatment plant.

1.3 Objectives

1.3.1 Main Objective

The main aim was to assess the hydrodynamics processes of anaerobic units of Dandora wastewater treatment plant for effectiveness using radiotracer technology.

1.3.2 Specific Objectives

The specific objectives of the study were to:

1) Determine residence time distribution for anaerobic ponds from measurements of radioactivity following injection of ^{131}I radiotracer;

2) Analyze residence time distribution data obtained for dead volumes, channeling/bypassing, mean residence time, flow rate, for optimization of operation processes;

3) Assess the overall performance of the plant for the effectiveness of the treatment processes.

1.4 Justification, Scope and Significance

In practice, conventional tracers fail to be used in full-scale industrial systems owing to many constraints including possible interference with treatment processes among others. As such, radiotracers are widely used in industries to optimize industrial processes by investigating reactor mixing processes and their troubleshooting.

Radiotracers are known to be extremely sensitive and are majorly utilized for online diagnosis of the vast activities regarding the waste water treatment plants processes and therefore ideal for assessing anaerobic digesters operations in wastewater treatment plants (IAEA, 2011).

Radioactive tracers offer possibility of *in situ* and timely online measurement, also, gamma rays emitting radiotracers can be determined through radiation transmission. The presence of other materials in the system does not interfere with the emission of radiation. Consequently, on proper selection, the radiotracers are absolutely dormant to the microbes that are available in the digesters and has negligible influence on their biological activities.

Treatment of wastewater at Dandora Waste Water Treatment Plant (DWWTP) is done through two processes; physical treatment which is done at the mechanical treatment facility and biological treatment, through waste stabilization ponds which include, anaerobic, facultative and maturation ponds. The plant has a total of 23 anaerobic ponds, 10 facultative ponds and 22 maturation ponds. Principally, biological wastewater treatment takes approximately retention time of 60–90 days before discharging the effluents into the Nairobi river.

Specifically, the present study was carried out in an anaerobic pond (No. 18) of series 3. The aim was to assess the hydrodynamic performance of the ponds using radiotracer technology, for effectiveness of the biological processes. The pond was selected for the investigation as it was suspected to be having severe flow abnormalities; as one of its outlets was completely blocked. In addition, effluents were sampled for analyses of wastewater parameters for compliance to existing regulatory requirements.

Chapter 2: Literature Review

2.1 Principles of Industrial Radiotracer Technology and Measurements

The inherent properties of radiotracers make them excellent in studying the behavior of various processes following their injection into the system and recording its monitoring its concentration both at the inlet and also at the outlet of the system. It is often required to assess hydraulic parameters and evaluate hydrodynamic characteristics of either WSP system or individual pond of the system to validate the design parameters or to diagnose flow anomalies during the operation. Sometimes, the investigations are also carried out before revamping or modifying the design of the WSP systems. Tracer techniques are often used to measure retention time distribution (RTD), mean residence time (MRT), percentage of available dead volume and investigate hydraulic characteristics of industrial as well as wastewater systems (Robert and Kjellstrand, 2006; Jansons *et al.*, 2004; IAEA, 2001). The chemical, physical and biological properties of radiotracers enable for identification, to follow and observe fluid flow in real time as shown in Figure 2.1.

Radiotracers are the only alternative for measurement of flow parameters and investigation of flow characteristics of industrial process systems operating at harsh industrial conditions because of their many advantages such as online detection, high detection sensitivity, availability of wide range of compatible radiotracers and suitability for use in harsh industrial conditions (Charlton, 1986; IAEA, 1990; Chmielewski *et al.*, 1998; Potier et al., 1999; IAEA, 2001, 2008, 2011; Pant *et al.*, 2001; Gresch *et al.*, 2011; Sakar *et al.*, 2017).

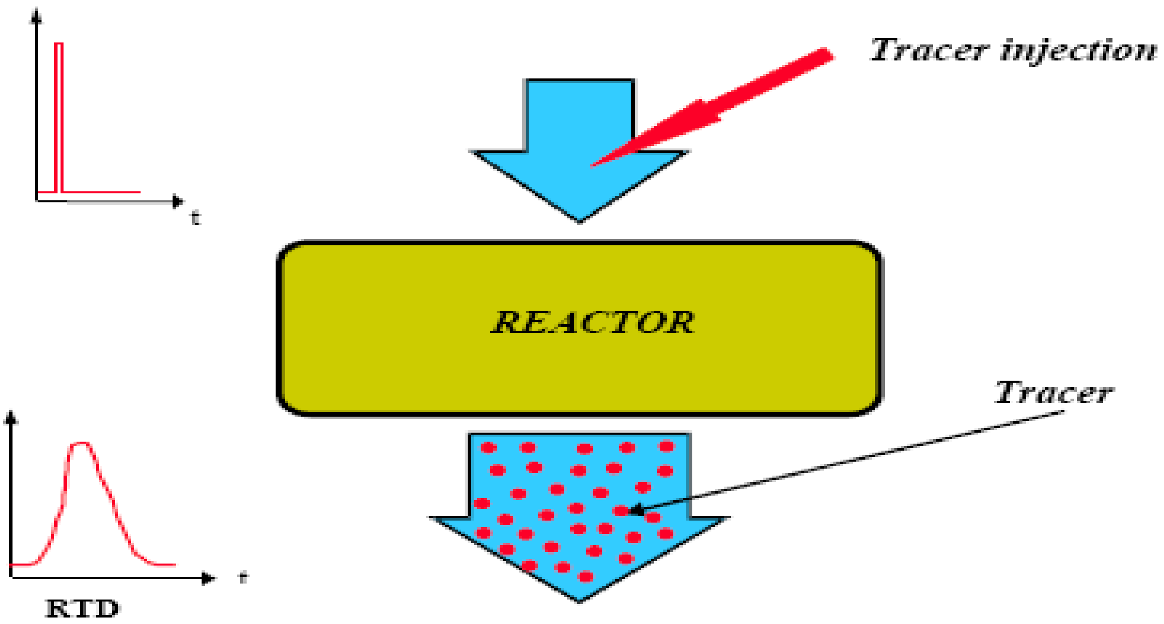


Figure 2.1: Principle of radiotracer applications (IAEA, 2008)

There are two types of radiotracers used in the study of industrial processes; intrinsic radiotracers and extrinsic radiotracers. Intrinsic radiotracers are molecules containing radioactive isotope of one of the natural element's molecules making the labeled particle to be detected in the system. The robust properties of the non-labeled particles have been traced for instance in the scenario involving the tritium and water ($^{1}H^{3}H^{16}O$). On the other hand, extrinsic radiotracers, also referred to as physical radiotracers, are made up of molecules or atoms that share the same mass flow behavior and the same dynamic characteristics as the investigated medium; in this case of water, ^{131}I.

2.1.1 Selection of radiotracers for use in Industrial Processes

The success of radiotracer experiment depends largely on the various important factors that have to be considered when selecting a radiotracer to be used. Most of these factors are drawn from the system to be investigated. Mean residence time of the system, detection geometry, form and properties of material to be traced and method of measurement helps in determining half-life of radiotracer to be used, type of radiation and the energy of radiation emitted, physical and chemical form as well as other properties of radiotracer. In addition, handling of radioactive material following radiological protection and regulations, specific activity of radiotracer, availability and cost of radiotracer have to be considered.

Radiotracer technology can be applied across a wide range of the industrial spectrum including, mineral processing industries, petroleum and petrochemical sectors, and wastewater treatment plants emerging to be the major beneficiaries. Examples of radiotracers and the industries where they are applied include; Gold-198 used for sand labelling to study coastal erosion and sand movements in river bed and ocean floor, Tritium, Iodine-131 and Technicium-99m used to study liquid wastes and sewage. The commonly used radiotracers are shown in table 2.1.

In practice, detection and measurement of radiotracer in a system is done with thallium activated sodium iodide(NaI) radiation detector, in which, there is conversion of incident radiation energy into an electrical signals, following injection of the media with radioactive material (Sood*et al.*, 2010). Radiation detection can be done, both online and offline depending on the nature of industrial process under consideration. (IAEA, 2008).

Table 2.1: Some of the commonly used radiotracers in industries (IAEA, 2008).

Isotope	Radiation emitted and energy(MeV)	Half-life	Tracing of phase	Chemical form
Argon-41	Gamma: 1.29(99%)	110min	Gases	Argon
Bromine-82	Gamma: 1.32(27%) 0.55(70%)	36h	Gases Organic Organic Aqueous	CH3Br,C2H5Br dibrobiphenyl , p-dibrom-benzane, Ammonium bromide
Chromium-51	Gamma: 0.320(9.8%)	28d	Aqueous	CrCl3, Cr-EDTA
Gold-198	Gamma: 0.41(99%)	2.7d	Aqueous/solids	Chloroauric acid
Iodine-131	Gamma: 0.64(9%) 0.36(80%)	8.04d	Organic Aqueous	Iodobenzane Potassium or Sodium iodide,
Krypton-79	Gamma: 0.51(15%)	35h	Gases	Krypton
Krypton-85	Gamma: 0.51(0.07%)	10.6y	Gases	Krypton
Lanthanum-140	Gamma: 0.82(27%) 0.92(10%) 2.54(4%) 1.16(95%)	40h	Solids Aqueous/solids	Lanthanum oxide Lanthanum chloride,
Mercury-197	Gamma: 0.077(19%)	2.7d	Mercury	Mercury metal
Scandium-46	Gamma: 1.84(100%) 0.89(100%)	84d	Aqueous/solids Solids	scandium chloride ScCl3(Sc3+) Scandium oxide,
Sodium-24	Gamma: 1.37 (100%) 2.75 (100%)	15h	Aqueous	Sodium carbonate
Technetium-99m	Gamma: 0.14(90%)	6h	Aqueous	Sodium pertechnetate(TcO4)
Tritium (3H)	Beta, 0.018(100%)	12.6 y	Aqueous	Tritiated water
Xenon-133	Gamma: 0.08(100%)	5.27d	Gases	Xenon

2.2 Principle of radiotracer technology for industrial and environmental application

2.2.1 Residence time distribution method: application of radiotracers

Residence Time Distribution, RTD, method requires accurate measurement of RTD experimental curve and its utilization on system analysis. This method is cost effective, safe and competitive with universal application, standard software and hardware (IAEA, 2011).

RTD principle consists of common impulse-response method where concentration-time curve, C(t), is recorded at the outlet of a system following injection of radiotracer at the inlet of the system under study. A detector is mounted at the inlet with time marked zero following the injection of the sharp pulse of radiotracer being conducted at the upstream of vessel. Ideally, the outlet of the vessel contains a second detector that records the transit of the tracer. The response of the second detector is the residence time distribution as shown in Figure. 2.2.

The RTD function E(t), is represented by (IAEA, 2011);

$$E(t) = \frac{C(t)}{\int_0^\infty C(t)dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; eqn\ 2.1$$

Where: C(t)- tracer concentration at the time, t, of the outlet of the system

E(t)- experimental RTD. It is evaluated from the count rate distribution at the outlet of the system, cpm or cps.

Theoretical Mean Residence Time (MRT) of the system t_{th}, for a given total volume of the system V, and a continuous constant flow rate Q, is given by:

$$t_{th} = \frac{V}{Q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; eqn\ 2.2$$

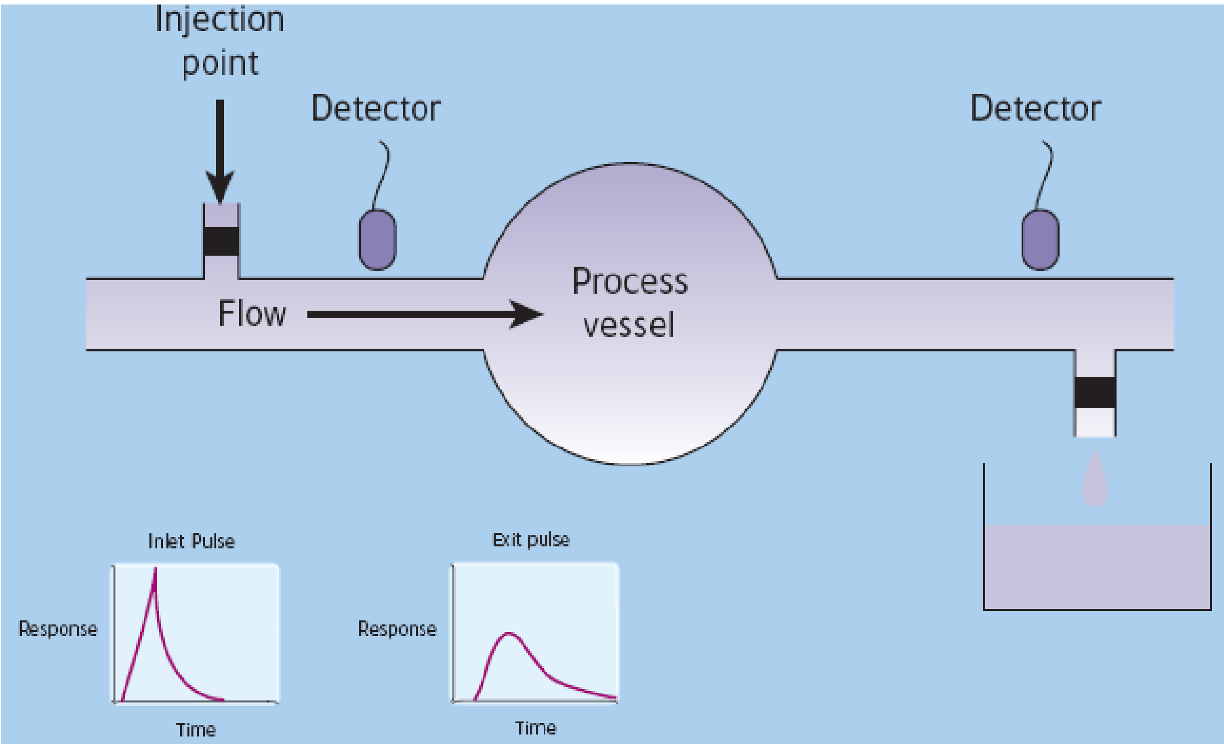


Figure 2.2: Principle of tracer residence time distribution (RTD) (IAEA, 2008).

In practice, effective Mean Residence Time (MRT) which provides for experimental RTD is lower than the theoretical or designed MRT. This is due to the availability of dead or semi-dead volumes, channeling, short-circuiting and/or by-passing, whereas ideal flow patterns are assumed in the design. Since malfunctions depend strongly on operating conditions, RTD is used to describe non-ideal flow behavior of industrial processes (IAEA, 2008).

Radiotracer applications for assessment of wastewater treatment processes have the following attributes; Firstly, majority of radiotracer application utilizes the radionuclides generated artificially which have very high detection sensitivity. Therefore, very small concentration can be used in large scale WWTP. These small quantities will not interfere with the dynamics of the processes under research and there will be no introduction of the extra pollution load. Secondly, radioactive tracers offer possibility of in situ and online measurement whereby in shortest time possible it provides the required information. Moreover, through radiation transmission, gamma emitting radiotracers can be estimated in the due process. Thirdly, the repetition of the experiment on the duplicate locality under the study is provided by the disappearance of radiotracer through radioactive decay. Spectrometry can be used to accurately determine characteristic emissions from several radiotracers used simultaneously. Finally, presence of other materials in the channel does not tamper with the emission of radiation. For that reason, when proper selection is done, the radiotracers are totally dormant to the microbes available in the digesters system and it negligible influence on the biological processes.

2.3 Review of studies on Evaluation Waste Water Treatment Plants

Wastewater treatment plant aims at removing the contaminants in waste waters before releasing effluents into the environment (IAEA, 2011). Removal of these contaminants comprises of multitude of elementary processes which involves complex multiphase fluid flow. For instance, sewage behavior can affect physical processes in settling tanks or biological processes in aeration tanks. For example, for proper analysis of mass transport in settling tanks, sedimentation curve of sludge and water flow structure are needed. Also, determination of flow structure is useful in improvement of performance of biological processes in aeration tank (Chmielewski *et al.*, 1999).

Therefore, the basic activities occurring in the system of the waste water treatment plant is greatly influenced by the flow behavior. Increase in flow rate in the settling tank results in bad decantation of sludge. Short circuits; reduced retention time in terms of design specifications of wastewaters are also observed and they increase solid rate in water output. In this case, the material transport as well as the hydrodynamic model of liquid and solid phases can be determined by the use of tracers. Stagnant volumes are also available in various parts of a wastewater installation. Tracer experiment can help in providing data for estimating stagnant volume and enable engineers to either maintain the design or change its design configuration to improve on efficacy.

In principle, radiotracers have been used to study liquid and solid phase in mix reactors by labelling and monitoring radioactivity changes. Examples of some of radiotracers used include; Pertechnetate Technetium (99m) from Mo/^{99m}Tc, Br-82 in the form of KBr aqueous solution, Lanthanum (La-140), Au-198 and Fe-59 (IAEA, 2001). Instantaneous radiotracer injection can be actualized in wastewater treatment processes since they have relatively long mean residence time which goes up to several days for digesters. This is done by simply introducing the radiotracer after breaking the ampoule container. Specific injection system may be used to introduce a liquid radiotracer directly to the stream, (IAEA, 2001).

A series of radiotracer experiment for measuring RTD have been carried out for assessing operations of different units of WWTP. In Islamabad, Pakistan, for example, a research was done on the municipal WWTP's operational units aiming at analyzing its flow structure by studying the dynamic behaviors of clarifiers, both primary and secondary, and aeration tank, with an aim of improving efficiency and economizes the performance of the process. In this case, the tracer used was ^{82}Br in form of water-soluble potassium bromide (KBr). About 2GBq of Br-82 was injected in these tanks and tracer detected at the inlet, outlet and two other internal points with submerged scintillation detectors. Experimental data was collected by on-line data acquisition system and RTD concept was used to investigate the efficiency of the tanks under study. Moreover, prior modeling and treatment of the tracer data was conducted. Short-circuiting (by-passing) with stagnant volume were found on primary and secondary clarifiers which significantly reduced their operating efficiencies. Comparison of mean residence time between theoretical value and experimental value revealed that there was dead volume in primary clarifier, 43%, and secondary clarifier, 57.4%, in aeration tank, the difference was negligible due to vigorous mixing process. The findings led into conclusion that analysis of the operations of WWTP can successfully be done by utilizing radiotracer method which will in turn lead to improvement of its performance.(Farooq *et al.,* 2003).

The other case studies were done in Poland and France where research was one on petrochemical wastewater treatment plants. This involved biological aeration chamber with settler, final sedimentation basin and equalizer-clarifier. Radiotracer used in these studies for liquid phase was Br-82 in KBr solution and for sediments was labeled with Lanthanum-140 in form $La(NO_3)_3$ which has a good absorption on sediment surface. RTD for both sediment and water phases was determined simultaneously. Results obtained from the experiments provided a potential model of sediment and liquid flow patterns and estimated the efficiency of purification. These results led to design improvement and increase in purification efficiency (IAEA, 2001).

In another related study done in South Korea, an experiment performed in submerged bioreactor of wastewater treatment facility using a radiotracer to investigate the feasibility of bypassing flow and existence of stagnant regions. About 20 mCi of I-131 was injected instantaneously at the inlet of the bioreactor. Thallium activated sodium iodide scintillation detectors were used at outlet of each compartment to measure radioactivity concentrations emitted. Lavenberg-Marquardt Algorithm approach was used to find optimal parameters of the RTD model which showed that the simulated RTD response and the experimental RTD response agreed. Parameters obtained from RTD model were used to diagnose stagnant region within the submerged bioreactor (Shin *et al.,* 2003).

Another radiotracer study was done to investigate low efficiency suspected in wastewater chlorination process. The purpose of this study was to diagnose water phase hydrodynamic by performing two radiotracer (^{99m}Tc) tests which were done on the reservoir before and after changes on the design characteristics. Dead volume found was 2-3% which was so minimal to affect the overall efficiency. However, the reservoir experienced poor and non-uniform micro mixing of chlorine with water which majorly affected the efficiency due to very large range of water residence time. After installation of baffles, the RTD curve was symmetrical which showed that the micro mixing was improved, resulting in improved efficiency of chlorination processes. (IAEA, 2011).

In Cuba, radiotracer study was done in sugar WWTP's anaerobic digester with the aim of showing the prospect of utilizing pertechnetate ion ($^{99m}TcO_4^-$) radiotracer in the determination of the RTD of liquid part of the non-transparent anaerobic digesters. From the study, it was noted that, the computed redox potential of the channel was not sufficient to chemically reduce the TcO_4^- to $TcO(OH)_2$. Nonetheless, the rate of sorption between 0.083% h^{-1} and 0.045% h^{-1} was noticed which was related to the radiotracer's retention by the biomass. This was due to metabolization as well as the catalytic reduction as a result of the microbiological activity. The estimation of the RTD was not affected by this phenomenon. The same radiotracer has been applied in modelling the flow behavior in the digester of a sugar WWTP following determination of RTD, (Borroto *et al.*, 2003).

Other conventional methods have been used in the past to evaluate performance of WWTP. Kavitha *et al.*(2013), did a study in dairy WWTP in India with an objective of evaluating the removal of pollutants; BOD, COD, TDS, TSS, oil and grease, total hardness, alkalinity, chlorides and dissolved oxygen removal and to assess the performance of effluent treatment plant using Upflow Anaerobic Sludge Blanket tank & extended aerobic tank. The plant was monitored for 6 months by collecting samples from the effluent treatment plant for characteristic analysis. This study showed that the average of BOD, COD, TDS, TSS, oil and grease, chlorides and alkalinity removal was 85 mg/l,155 mg/l,661 mg/l, 34.5 mg/l, 6.3 mg/l, 81 mg/l and 7.05 respectively, which all met the effluent standard for disposal. The efficiency of the plant performance was also assessed and the reactor pollutant removal achieved efficiency of 77.0 %, 87.0 %, 47.1%, 57.0 %, 92.0 % and 49.8 % corresponding to COD, BOD, TSS, TDS, oil and grease and chlorides respectively. They concluded that the overall treatment method and technology use of Upflow Anaerobic Sludge Blanket tank & extended aerobic tank was satisfactory.

A performance study was done by Hegazy and Gawad (2016) in Egypt to evaluate the efficiency of Shoubra Al Khaima (Balqus) wastewater treatment plant in decreasing pollutant level. Their analysis defined the performance measuring plan based on important parameters that can be reliable and applicable for any WWTP. These parameters included, BOD, TSS, COD and Oil and Grease removal efficiency. Sampling was done for a period of 6 months at different sampling point which were WWTP influent, outlet of primary sedimentation tanks, outlet of secondary treatment process and outlet of disinfection stage. Laboratory analyses were then done in accordance to the Standard Methods for investigating wastewater and water. From the research, Balqus WWTP had efficiencies higher than 90% on BOD, TSS, COD and Grease and Oil removal.

Miruka(2016) evaluated efficiency of Kariobangi Sewerage Treatment Plant in Nairobi by analysing chemical parameters, physico-chemical parameters, heavy metals, bacteriological presence and oil & grease. The physico-chemical parameters analyzed were COD, settleable solids (SS) and BOD after five days (BOD_5). The chemical parameters analyzed included phosphates and nitrates. The heavy metals analyzed included chromium (Cr), lead (Pb), and cadmium (Cd). Oil & grease was also analyzed while Total coliforms were analyzed as the bacteriological parameter. Imhoff cone was used to determine the level of settleable solids. Potassium dichromate titration method was used to determine the COD. Sample incubation process which gave daily readings of BOD for five days was used to determine the concentrations of BOD_5. Ascorbic acid method was used for phosphate determination. Flame Atomic Absorption Spectrometry was used to analyze the samples for cadmium, chromium and lead presence. Solvent extraction was used to find the concentration of oil & grease. The nutrient-culture method was used to establish the concentrations of total coliforms. The results for various parameters, i.e; Percentage reduction efficiency for settleable solids was between 74.7 - 96.7 % while COD (88.3 - 98 %), BOD_5 (43.6 - 84.5 %), Nitrates (-17 to 36.5 %) and phosphates (-13.2 to 36.5 %). The % reduction efficiency for oil and grease was between 14.4 - 92.6 % and total coliforms was -32.7 to 66.9 %. With the average outflow volume of 109.3 litres/second the pollution loadings were of 139,357 mg/s, 35,303.9 mg/s, 20,493.76 mg/s, 22.36 mg/s, 111.78 mg/s, 82.78 mg/s, 375,718,750 counts/s for settleable solids, COD, BOD5, Cd, Cr, Oil & grease and total coliform respectively. It was concluded that the plant’s effluent quality did not conform to standards hence there was huge pollution load discharged into the Nairobi River.

In the year 2009, research was conducted on Dandora WWTP to find if its end effluent attained the standards required by Kenya together with assessment of its efficiency. Grab samples in the treatment plant were collected at the outlet and inlet for the analysis. In the dry season, the content of the Dissolved Oxygen (DO) was found to be below the 5.0 mgO_2/L acting as the threshold necessity for the effluents released into surface water. During the wet season, the DO ranged from 2.76 to 19.77 mgO_2/L. The TSS, COD, and (BOD_5) in the endmost effluents did not achieve expectation design of 30 mg/L, 280 mgO_2/L and 20 mgO_2/L respectively. The treated effluent did not attain the essential standards for discharging it into surface water bodies. To improve the quality of the final product measures should be enacted in place as per the recommendation. Basically, the regular maintenance and dissociation of the domestic waste from industrial waste are required (Sewe, 2010).

In general, a wide range of industrial scale application of radiotracers have been done in wastewater treatment plants under different technological conditions. In summary, some of the major conclusions drawn from these experiments include the following:

1) Similar results for aeration tanks were obtained for different configuration. Perfect mixing cells in series can be used to model aeration channel. The number of mixing cells should be adjusted according to geometrical configuration and flow rates. Using perfect mixing cell in series with back mixing is another equivalent possibility (IAEA, 2011).
2) Residence Time Distribution (RTD) of separate phases in clarifiers, digesters, aeration tanks and equalizers give good results on working conditions of the system. For settling tanks, it is difficult to determine reliable model due to decantation effect.
3) Utilizing computer data acquisition system performing *in situ* multipoint measurements is recommended to obtain larger information on flow pattern map inside water installation system. Experimental data obtained from measuring points located in the installation can be used to verify the proposed model.
4) Continuous measurement of flow rate is strongly recommended during industrial scale tracer experiments. This is because, the validity of proposed models and process parameter evaluation are greatly affected by the uncertainties and fluctuations of flow rate during the whole experiment time. Also, it is recommended to perform conventional measurements of COD, pH, oxygen concentration and total sediment content to ease interpretation.

2.4 Summary of literature review

Radiotracers are excellent in studying the behavior of various processes following their injection into the system and recording its concentration both at the inlet and outlet of the system. The success of radiotracer experiments depends largely on the various important factors that have to be considered when selecting the type of a radiotracer to be used and the accurate measurement of RTD experimental curve and its use on system analysis.

In practice, radiotracer applications for assessment of wastewater treatment processes has the following attributes; very high detection sensitivity, possibility of in situ and online measurement, the repetition of the experiment on the duplicate locality, amongst others. The industrial applications of radiotracer technology have been demonstrated in various studies on Evaluation Waste Water Treatment Plants processes.

Chapter 3: Methodology

3.1 Description of the Study Area

Dandora wastewater treatment plant is located 26 km to the East of Nairobi, Kenya. It treats about 80,000 m^3 (80%) of wastewater generated within Nairobi and its nearby towns per day (Environmental, 2016). The schematic layout of the Dandora plant is shown in Figure. 3.1 and 3.2.

The plant consists of eight (8) series with a total of twenty-three (23) anaerobic ponds, ten (10) facultative ponds and twenty-two (22) maturation ponds as shown in Figure. 3.1 and 3.2. The treatment plant uses two treatment processes; physical treatment in a mechanical facility followed by biological treatment in WSPs. The large organic solids are manually and mechanically following four stages, namely; coarse bar screens, cup screens, grit traps and classifiers. The wastewater is subsequently distributed to different chains of the pond systems where it is retained according to their design, for approximate retention time of 60–90 days in each series (Environmental, 2016), before discharging the treated effluent into the Nairobi river.

The wastewater entering into each anaerobic pond is distributed through two inlets (inlet-1 and inlet-2) and flows out through two outlets (outlet-1 and outlet-2) connected to a common outlet channel.

The present study was carried out in an anaerobic pond (No. 18) of series 3 having length and width of 63 m and depth of 4.5 m as shown in Figure. 3.2. Out of the 23 anaerobic ponds, the pond number 18 was selected for the investigation as it was suspected to be having severe flow abnormalities and also because of the logistics reasons. The outlet-2 of the pond number 18 was completely blocked due to deposition of the sediments at its mouth and hence only outlet-1 was used for monitoring the radiotracer at the outlet of the pond during the experiment.

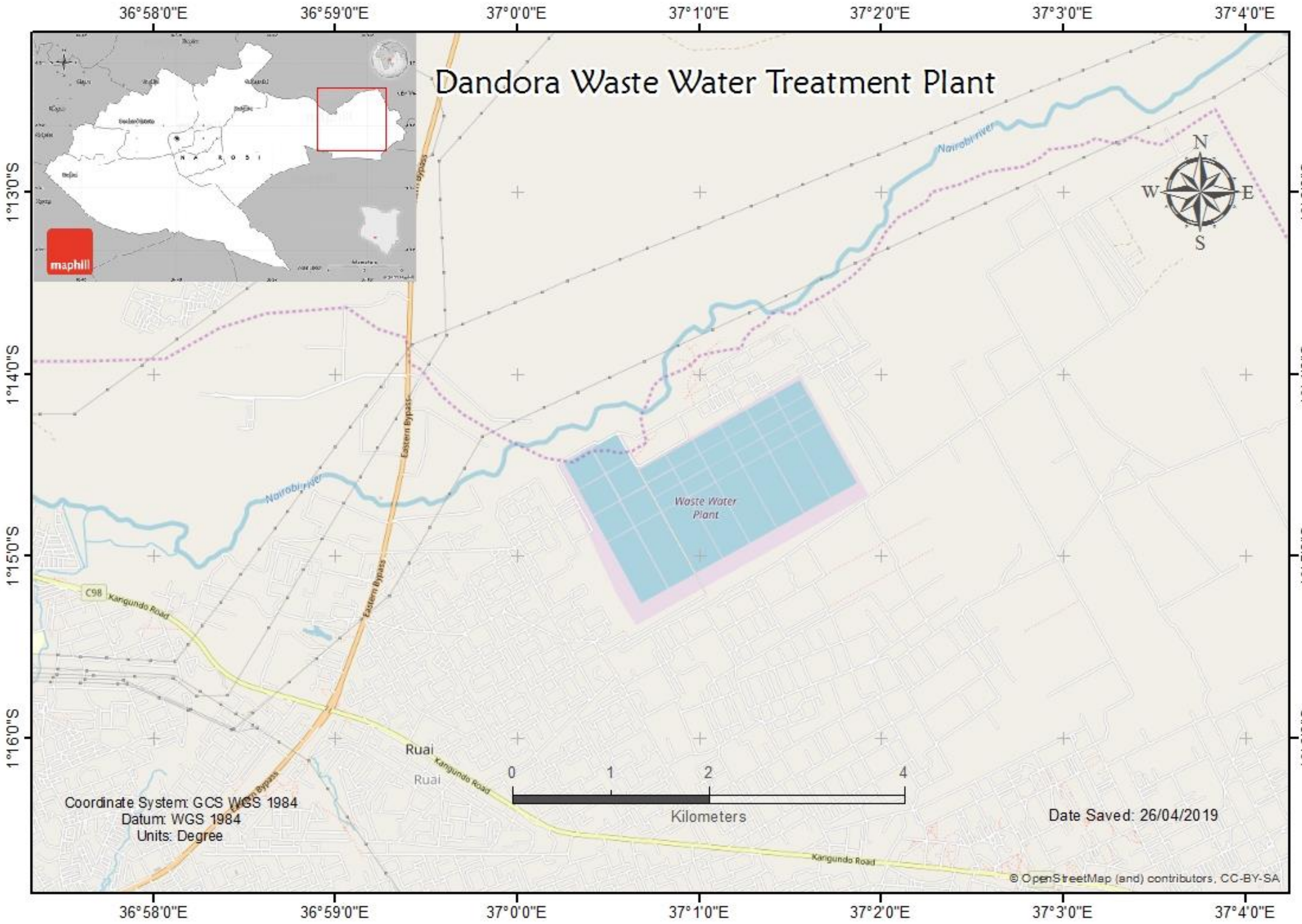


Figure3.1: Dandora Waste Water Treatment Plant.

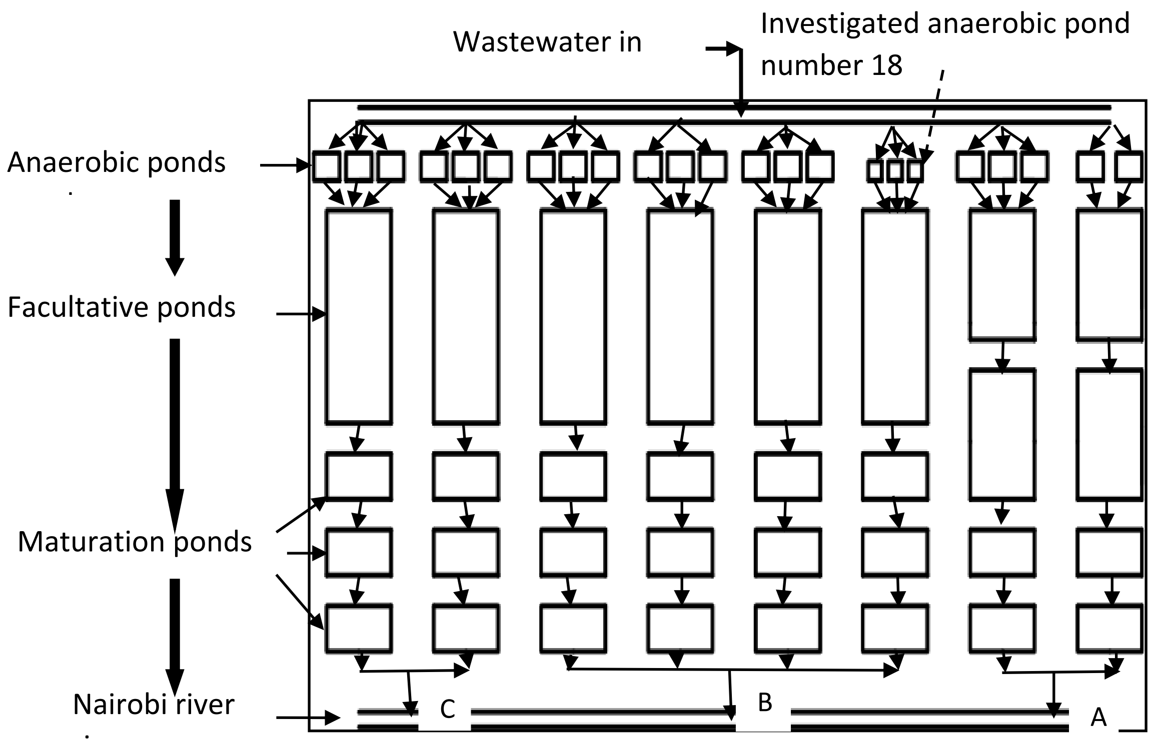


Figure 3.2: Schematic layout of Dandora waste water treatment plant

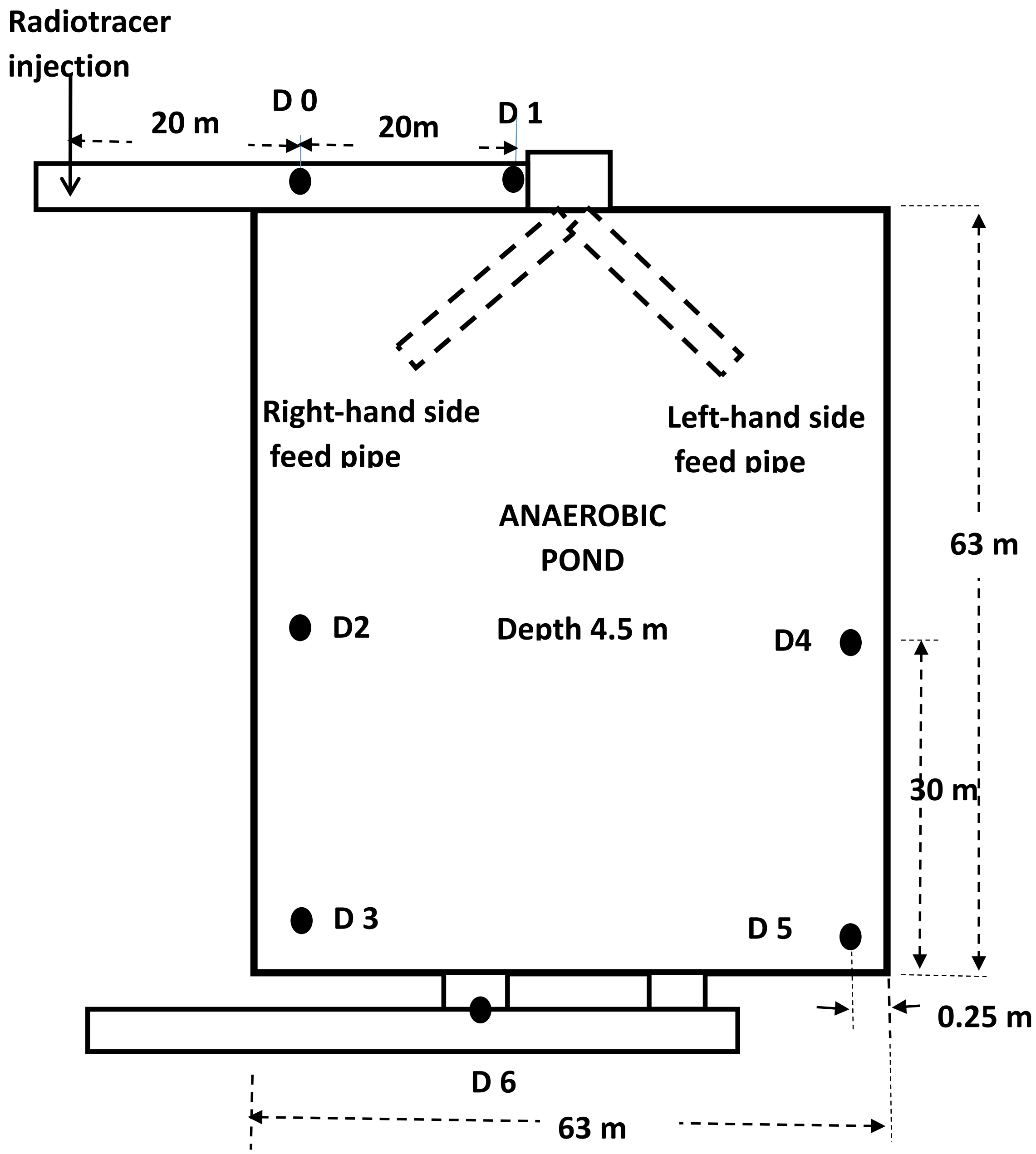


Figure 3.3: Schematic diagram of experimental setup for flow rate and RTD measurements in anaerobic pond

3.2 Radiotracer measurements: Materials & Instrumentation

3.2.1 Instrumentation

The gamma ray detection was obtained through thallium activated sodium iodide crystal associated RTC (RF1 XP2072B) photomultiplier. The detector specification provided are as follows (Figure: 3.5 a & b):

a) Scintillation Crystal: NaI(Tl) (1.5’’ x 2’’)
b) PMT.......................: 10 stage

c) Connector..............: BR2
d) Resolution at 662 keV: 7.3%
e) Temperature range: $-5^{0}C$ - $85^{0}C$
f) Gamma Energy Range: 25 to 2500 KeV
g) Cables BR2-BR2 50m on roll

CAESAR 12- multichannel (12channel) data acquisition module that incorporates software for radioactive tracers and nucleonic control systems applications was used- Figure: 3.6 (Altaix Systems, 2012).

In principle, the typical data acquisition sequence was as follows:

a) Choice of parameters: sampling time, calculation or not on each channel, duration of experiment (the acquisition can be stopped at any moment)
b) Acquisition
c) Choice of the display when acquisition is running, and of the channel to be displayed.

(a) (b)

Figure 3.4 Thallium activated sodium iodide detectors (a) and Connecting cable 50m long (b)

Figure 3.5 Altaix Data Acquisition System

3.2.2 Radiotracer Measurements

A radiotracer investigation was performed for flow rate measurement in an inlet channel and RTD measurement in an anaerobic pond of a WSP system. The schematic diagram of the anaerobic pond and the experimental setup for flow rate and RTD measurements is shown in Figure. 3.3.

Since the design residence time of the wastewater within the pond was of the order of 5–10 days, iodine-131 (half-life: 8 days, gamma energy: 365 keV (82%)) as sodium iodide(NaI) was selected for use as a radiotracer. Based on the detection sensitivity, dilution of radiotracer between injection point and detection point and also background radiation levels, about 5.0 GBq (135 mCi) of Iodine-131 (^{131}I) was used in this investigation. The radiotracer used was procured from NTP Radioisotopes, South Africa through M/s AEC-Amersham SOC Limited, South Africa. The procured radiotracer weighing approximately 500 mg was diluted in 1.5 l aqueous solution of inactive sodium iodide and inactive sodium thiosulphate (0.1 N) in ratio of 1:2 to avoid oxidation of iodide to iodine gas (I_2) (Dawi, 2010). The radiotracer solution was instantaneously injected into the inlet channel to generate a Dirac delta function at a location

40 m upstream as shown in Figure. 3.3. The radiotracer was monitored at two locations in the inlet channel and at other five different locations in the pond using a12-channel ALTAIX data acquisition system. The detector D0 and D1 mounted were mounted 20 m apart so as to be used to determine the flow rate. The response of the detector D1 also provided the time entry time of the radiotracer into the pond.

The radiotracer was injected 20 m upstream so that it is fully mixed within the whole cross section of the channel before it reaches the first measurement point at D0. The detectors D2, D3, D4 and D5 mounted at different locations within the pond were used to investigate distribution of the radiotracer into different sections of the pond, whereas the detector D6 was used to monitor RTD of the wastewater within the pond (Figure. 3.3). All the seven detectors, encased in 1cm thick lead collimator, were linked to a common data acquisition platform set in order to record the radiotracer concentration at an interval of 1 s. All the seven detectors were checked and set to provide uniform radiation responses prior to the experiment. Before actual injection of the radiotracer was done, the levels of background radiation were determined at all the seven different locations.

3.3 Data Analyzes for Flow rate, RTD, Dead Volume, Channeling and Short Circuiting

3.3.1 Flow Rate Measurements

Pulse velocity method was used in determining the flow rate. The radiotracer concentration data measured at two locations in the channel, D0 and D1 as shown in Figure.3.3, was analyzed for measurement of mean residence time. The data analysis was done after correcting for background only.

The radiotracer concentration curves corresponding to inlet measurements at D0 and D1 were used to determine the First moment (centroids) i.e. mean residence time of each curve. Evaluated according to the given equation in 3.1.

$$\bar{t} = \frac{\int_0^\infty tC(t)dt}{\int_0^\infty C(t)dt} \dots\dots\dots\dots\dots\dots\dots eqn\ 3.1$$

The difference of the first moment of the two curves provided mean residence time of radiotracer between the two monitoring locations within the channel (Levenspiel, 1972; IAEA, 1990):

$$\bar{\mathbf{t}} = \bar{\mathbf{t}}_2 - \bar{\mathbf{t}}_1 \dots\dots\dots\dots\dots\dots\dots eqn\ \ 3.2$$

where, $\bar{\mathbf{t}}_1$ and $\bar{\mathbf{t}}_2$ are first moment (centroid) of the concentration curves measured in the two locations within the channel.

The flow rate was determined using the following relation;

$$Q(m^3|d) = V(m^3)/t((d)) \dots \dots \dots \dots \dots .. eqn\ .3.3$$

3.3.2 The RTD and Dead Volume measurements

RTD obtained was used to identify malfunctions within the anaerobic ponds. For instance, a short residence time of radiotracer in the pond compared to design residence time characterizes short circuiting. The RTD was measured for a total duration of about 6 days with a sampling time of 1 s.

The radiotracer concentration data measured at the outlet of the pond was treated for background correction, zero-shift, dwell time and tail correction before estimating the MRT, dead volume and modelling the data. Exponential regression method was used to extrapolate and complete the tail. In order to accommodate the RTD data for modelling, the numbers of data point were reduced by changing the sampling time interval to 14 s. THYNRTD software was used for data reduction (IAEA, 1996).

After the correction for background, the data was normalized as given in this equation:

$$\mathbf{E_i(t_i)} = \frac{\mathbf{C_i(t_i)}}{\int_0^t \mathbf{C_i(t_i)dt}} \dots \dots \dots \dots \dots \dots \dots eqn\ 3.4$$

where, $C_i(t_i)$: concentration at time t_i, $E_i(t_i)$: normalized RTD curve. From the treated curve, the MRT $(\mathbf{t})$ of the wastewater was determined using:.

$$\bar{\mathbf{t}} = \int_0^\infty \mathbf{t\, E(t) dt} \dots \dots \dots \dots \dots \dots \dots eqn\ 3.5$$

If V is the volume of the system and Q is the flow rate through the system, the theoretical MRT of the system is given as: $\boldsymbol{\tau} = \frac{\mathbf{V}}{\mathbf{Q}} \dots \dots \dots \dots \dots \dots \dots eqn\ 3.6$

The comparison of the measured and theoretically calculated MRTs provides estimates of dead (V_d) and active (V_a) volumes within the reactor. Thus:

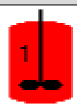
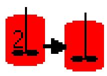
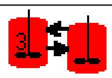
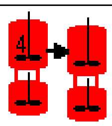
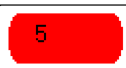
$$\text{Dead volume } (\mathbf{V_d}, \%) = \left(\mathbf{1} - \frac{\bar{\mathbf{t}}}{\boldsymbol{\tau}}\right). \mathbf{100} \dots \dots \dots \dots \dots \dots \dots \text{eqn } 3.7$$

3.3.3 DTSPRO software: Flow model Simulation

DTSPRO is software a tool used to simulate flow compartment models following injection of radiotracer. This is achieved by developing characteristic relationship between corresponding material concentrations balances at the inlet and at the outlet of a system. The inlet molecules in a system are radiotracer labelled during a given time interval and then counted as a function of time at the outlet (DTSPRO Software V4.2, 2000).

DTSPRO software consists of 8 basic fundamental modules for simulations models; Perfect mixing cell, Perfect mixing cells in series, Perfect mixing cells in series with back mixing, Perfect mixing cells in series exchanging with dead volume, Plug flow reactor, plug flow reactor with axial dispersion closed to the diffusion, plug flow reactor with axial dispersion open to the diffusion and plug flow reactor with axial dispersion half open to the diffusion for modelling flow compartments. Each of these modules consist of a combination of either in series or parallel of the following simple elementary reactors like plug flow, perfect mixing cells in series or perfect mixing cell. A complex network can also be created by interconnecting elementary reactors to form a model. In principle, a model consists of interconnected modules forming a network having one inlet and one outlet. The interconnection is done by nodes and branches. Nodes are components in the network having algebraic sum of flow rates equal to zero except at the outlet and inlet. Branches are defined by a node at the arrival and a node at the departure and is oriented in the flow direction

Elementary modules available in this software which are sufficient in most industrial cases include:

Modules	Symbol
1. Perfect mixing cell	
2. Perfect mixing cells in series	
3. Perfect mixing cells in series with back mixing	
4. Perfect mixing cells in series exchanging with dead volume	
5. Plug flow reactor	

Impulse response in most cases is intermediary between two boundaries; in plug flow reactor, the flow consists of parallel sections without any exchange of fluid from one section to another and in perfect mixing cells, concentration is identical everywhere. Association of one or more ideal reactors allows the modelling of flows, however some of these associations have become classic.

The following are the input Parameters for elementary reactors modules in DTSPRO software:

Elementary reactor	**Parameters**
Perfect mixing cell	Mean residence time: τ Or Volume: V
Plug flow reactor	Mean residence time: τ Or Volume: V
Perfect mixing cells in series	Mean residence time: τ Or Volume: V Number of mixing-cell: J
Perfect mixing cells in series exchanging with a dead zone	Mean residence time : $\tau = V/Q$ Or Volume: V V1 volume of one of the mixing cells in series and V2 the volume of the associated dead zone. V=J*V1 is the volume which should be indicate when using the software Number of mixing-cell: J Exchange time constant:$t_{m} = V_2/\beta Q$ Volume ratio: K=V2/V1 β is the proportion of flow rate exchanging with the dead volume
Perfect mixing cells in series with back-mixing	Mean residence time: τ Number of mixing-cell: J Back flow-rate ratio (can be higher than 1) : α
Plug flow reactor with axial dispersion Closed to the diffusion	Mean residence time: τ Peclet number: Pe
Plug flow reactor with axial dispersion Half closed to the diffusion	Mean residence time: τ Peclet number: Pe
Plug flow reactor with axial dispersion Open to the diffusion	Mean residence time : τ Peclet number: Pe

In this study, DTSPRO software was used to simulate input of any complex network of elementary reactors interconnected properly. Mathematical models were used to fit the outlet response curves with the help of DTS pro and “RTD Software”.

Simulation of the model was done by specifying the inlet signal, measured outlet signal and the models and their parameter values. Measured outlet data signal was treated for radioactive decay, background correction before simulation. Some factors to consider during treatment include having complete data at uniform time interval. An appropriate module was then selected, based on the specifications of the reactor system being investigated, for input of the in initial values for model parameters. During model simulation, calculations are made in Laplace domain in which numerical inversion is achieved using Fast Fourier Transform for fit of experimental RTD data. Upon successful calculation during simulation, visualization of the plot is realized for a closer model that describes best the fluid dynamics of the material in the reactor. Otherwise a repeat of simulations done with different set of initial set of initial parameters or change of the model is recommended.

3.4 Laboratory measurements for pollutants: TDS, TSS, COD, BOD

Laboratory studies were done at Dandora WWTP laboratory for the measurements of TDS, TSS, COD and BOD to assess the overall performance of the plant for the period between September 2017 to April 2018.

3.4.1 Determination of Total Dissolved Solids (TDS)

Total Dissolved Solids, TDS, which is like conductivity, provides details on the levels of the dissolved compounds present in the water. TDS contains the inorganic salts; principally, bicarbonates, sodium, sulphates calcium, magnesium, chlorides and potassium. Furthermore, it incorporates minute levels of the dissolved organic matter in water. The concentration of the TDS is the sum of the positively charged ion (cations) and negatively charged ions (anions)in the water. TDS act as measure utilized in the determination of the water quality in general. High TDS concentration can give an indication that some metal levels, such as lead, or aluminium are very high.

The following apparatus were used for determination of Total Suspended and Dissolved Solids in samples: Evaporating dish; Oven ; Water bath; Desiccators; Analytical balance; Graduated cylinders; Vacuum pump ; Dish tongs; Gooch crucible; Crucible tongs; Forceps, smooth-tipped.

A standard glass fibre filter was used in filtering the sample aliquots of approximately half a liter from inlet and outlet of ponds system which was followed by the evaporation of the filtrate to complete dryness inside a previously weighed evaporating dish to a constant weight at the temperatures of 179^0C to 181^0C. The TDS was represented by the increase in weight. The formula below was used to calculate TDS (APHA, 2005).

$$TDS\left(\frac{mg}{l}\right) = \frac{difference\ in\ weight \times 1000}{mL\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ 3.8$$

3.4.2 Determination of Total Suspended Solids (TSS)

TSS is inclusive of all the particles in volume of liquid that is known to be impossible for them to pass via a filter with a pore size of 1.2 µm. The measurements for TSS is mg/l. The filter solid fraction is composed of the dissolved and colloidal solids of fragment of organic, inorganic molecules and ions. The size of the particles is known to be 10^{-3}-10^{-6} m (Tchobanoglous, 1991). The levels of the molecules removed during the process of treatment is usually measured by the TSS.

Sample aliquots of approximately half a liter from inlet and outlet of waste water treatment ponds system was filtered via a weighed and dried filter paper. The filtered paper was then dried at 103-105^0C to constant weight and weighed to determine the TSS using the equation below (APHA, 2005).

$$TSS\left(\frac{mg}{l}\right) = \frac{difference\ in\ weight \times 1000}{mL\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ 3.9$$

3.4.3 Determination of Chemical Oxygen Demand (COD)

COD is the level of the oxygen required to conduct a chemical oxidation of the organics present in water. The oxidation of the organic matter is achieved by use of Potassium dichromate is a very strong oxidizing agent instead of the microorganism utilized in BOD. Generally, the COD is higher than the BOD since most of the compounds can be oxidized chemically than the biologically. BOD and COD have different translations depending on the types of water. (Kiely, 1997 and Tchobanoglous, 1991).

COD is the measure of pollutants in wastewater and natural waters by quantifying the levels of designated oxidant (dichromate) that react with the sample under conditions that are controlled. The oxygen equivalence is the parameter that is in representing the quantity of oxidant consumed.

The table 3.1 summaries the apparatus used in this study to determine the COD. All chemicals used in this study were of annular grade (>99% purity).

Table 3.1: Apparatus and chemicals used for COD measurement

Apparatus required	Chemicals needed
1) COD digester	1) Annular grade Potassium dichromate, $K_2Cr_2O_7$(digestion solution), Mol Wt: 294.182 g/mol
2) Burette and its stand	2) Organic free distilled water
3) COD vial with stand	3) Ferrous ammonium sulphate
4) 250ml conical flask	4) Mercury sulphate
5) Pipette	5) Ferrous indicator
6) Pipette bulb	6) Silver sulphate (catalyst)
7) Wash bottles	7) Sulphuric acid

Sample aliquots of approximately 2.5 ml from inlet and outlet of waste water treatment ponds system was refluxed with 1.5 ml sulphuric acid and potassium dichromate in presence of 3.5 ml silver sulphate, which neutralized the effects of chloride and also acted as a catalyst. The quantity of potassium dichromate that was used was directly proportional to the oxidisable organic matter in wastewater sample. COD was obtained with equation below; (APHA, 2005)

$$M\ of\ FAS = \frac{volume\ of\ 0.01667K_2CrO_7\ solution\ titrated\ mL\ \times 0.1000}{volume\ of\ FAS\ used\ in\ titration} \ldots\ldots eqn\ 3.10$$

$$COD\left(\frac{mgO_2}{l}\right) = \frac{A - B \times M \times 8000}{mL\ Sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ 3.11$$

Where: FAS- Ferrous Ammonium Sulphate

A- mL FAS used for blank
B- mL FAS used for sample
M- molarity of FAS
8000- milliequivalent weight of oxygen x 1000mL/L

3.4.4 Determination of Biochemical Oxygen Demand (BOD)

BOD gives the measurements for the readily biodegradable organic carbon. Moreover, it quantifies the dissolved oxygen utilized by the micro-organisms in their process of carrying out the oxidation of the organic matter.

BOD determines the relative oxygen requirement of waste water and polluted waters. This test determines the removal efficiency of the BOD and the water loading to treatment in the same plants. This is conducted through the measurement of the molecular oxygen used in defined incubation period (5 days) for biochemical breakdown of organic material and oxygen utilized in the oxidation of the inorganic materials such as sulphides and ferroin iron. The BOD value for the clean is less than 1 mg/l while a value of 150-1000 mg/l is the range value for the waste waters (Kiely, 1997).

Respirometric method by OxiTop®measuring system was applied which is based on pressure measurement achieved by piezo-resistive electronic pressure sensors.

The table 3.2 summaries the apparatus used in this study to determine the BOD.

Table 3.2 Apparatus and chemicals used for BOD measurement

Apparatus required	Chemicals required
1) OxiTop measuring system	1) Sodium hydroxide pellets 2) Nitrification inhibitor
2) Brown sample bottles	
3) Magnetic Stirring bar	
4) Rubber sleeve	
5) Incubator thermostat box	

Sample aliquots of approximately half a liter from inlet and outlet of waste water treatment ponds system was placed in brown sample bottles then nitrification inhibitor was added. Magnetic stirrer bar and two sodium hydroxide pellets in rubber sleeve were inserted in the bottle. OxiTop®measuring head was tightly screwed. Finally, set and measure button was pressed simultaneously so as to start measurement. BOD bottles were then placed in an incubator set at 20^{0}C for 5 days. BOD_5 value was read after 5days by pressing on the measuring button on theOxiTop®measuring head(envcoglobal.com, 2008).

Chapter 4: Results and Discussions

4.1 Radiotracer Parameters Measurements

Figure 4.1 shows the radiotracer concentration variations corresponding to inlet measurements at D0 and D1, while Figure4.2 shows the radiotracer concentrations at the outlet detector D6.

In this study, the mean residence time (t) between the two detectors was determined to be 21 seconds. The volume V, between the two locations was determined to be 1.24 m3. The flow rate in the inlet channel to the pond was determined to be 5101 m3/d.

Since the geometrical volume of the pond was 17860.5 m^3 and the flow rate determined at the inlet of the system during the experiment was 5101 m3/d, the theoretical MRT was estimated to be 3.5 days. The comparison of the measured and theoretically calculated MRTs gives estimates of dead volumes and active volumes within the reactor.

Thus the dead volume within the wastewater stabilization pond was estimated to be 93%. This implies that only 7% volume was available for flow of the wastewater through the anaerobic pond.

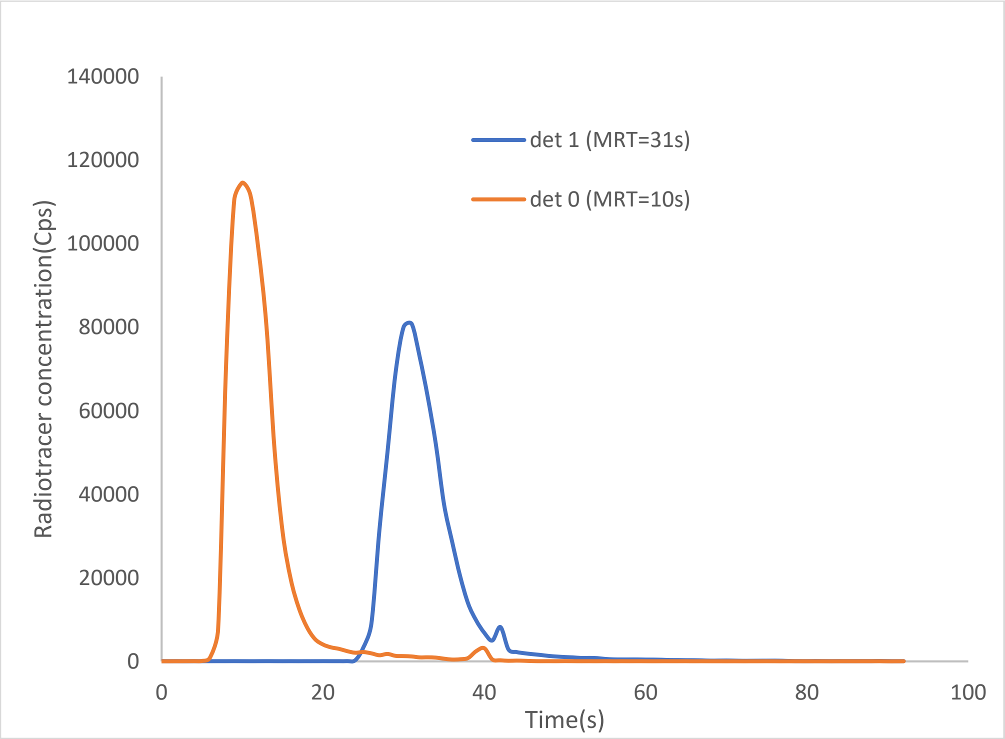


Figure 4.1: Flow rate measurement using pulse velocity method

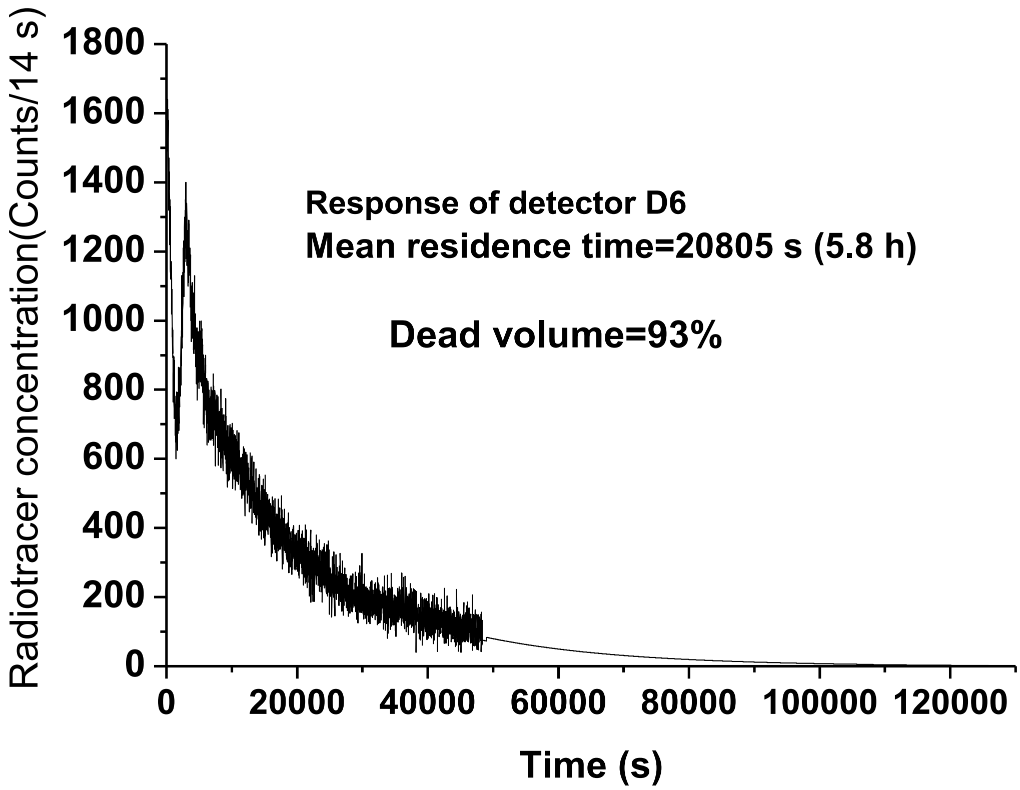


Figure 4.2: Treated radiotracer concentration curve measured at the outlet of the pond

4.2 Data treatment and analysis for the flow in the Anaerobic pond

Figure. 4.3 shows the uncorrected radiotracer concentration monitored at four (4) locations (D2, D3, D4, D5) within the anaerobic pond over the six-day period of sampling.

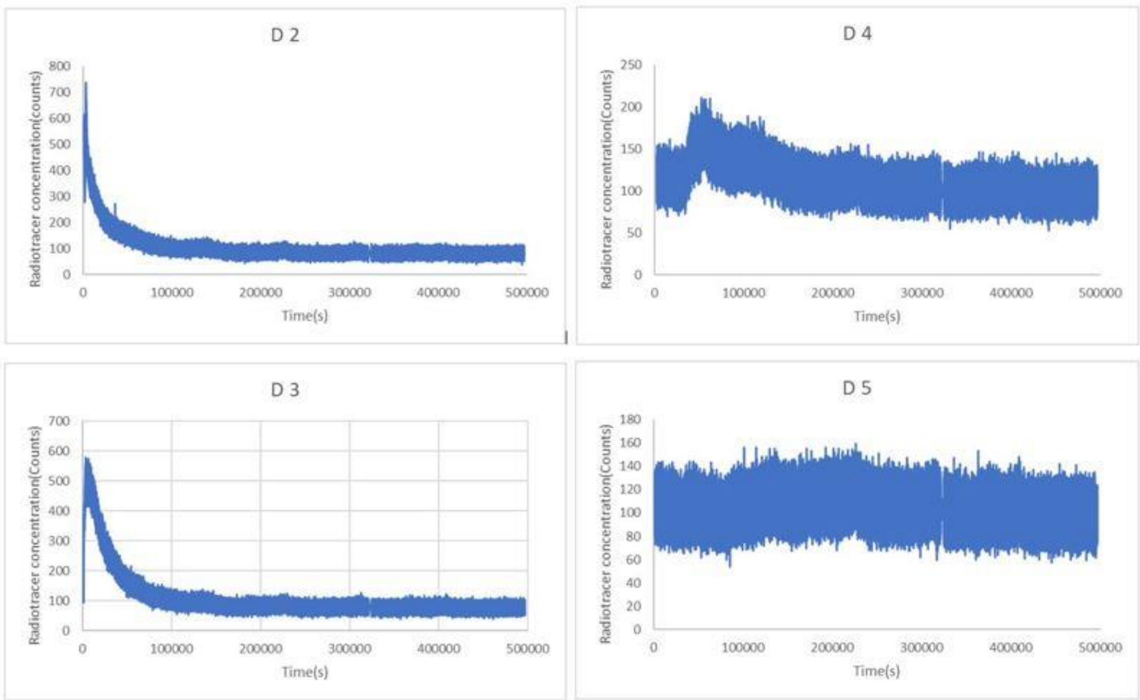


Figure 4.3: Radiotracer concentration within the ponds over the 6-day measurement period.

In order to visualize and identify the wastewater flow within the pond, appropriate mathematical models are utilized to model the measured RTD curve. Several mathematical models were tested. Eventually three models were found to be appropriate to fit the measured RTD well. These are illustrated in Figures.4.4, 4.5, and 4.6. The comparison of the model simulated and experimental (D6) RTD curves, for the three models, are shown in Figures4.7, 4.8 and 4.9. The model parameters values for the best fit curves are given in Tables 4.1, 4.2 and 4.3.

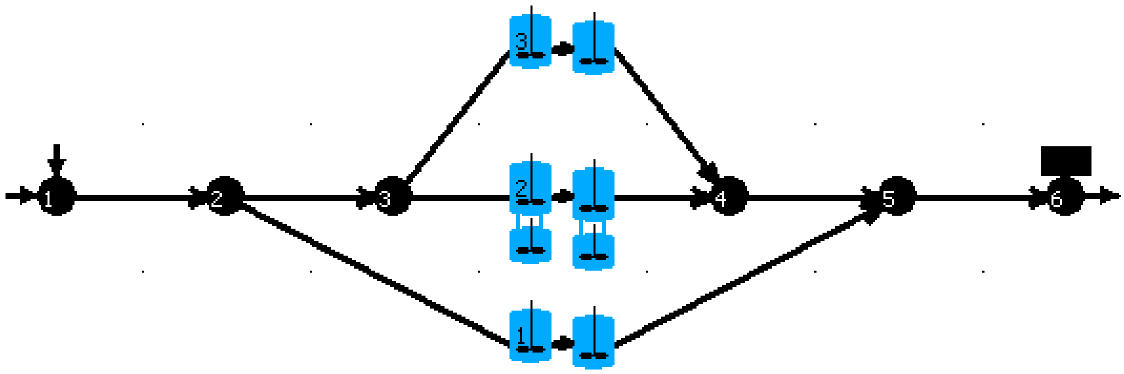


Figure 4.4: Block diagram of Model-A

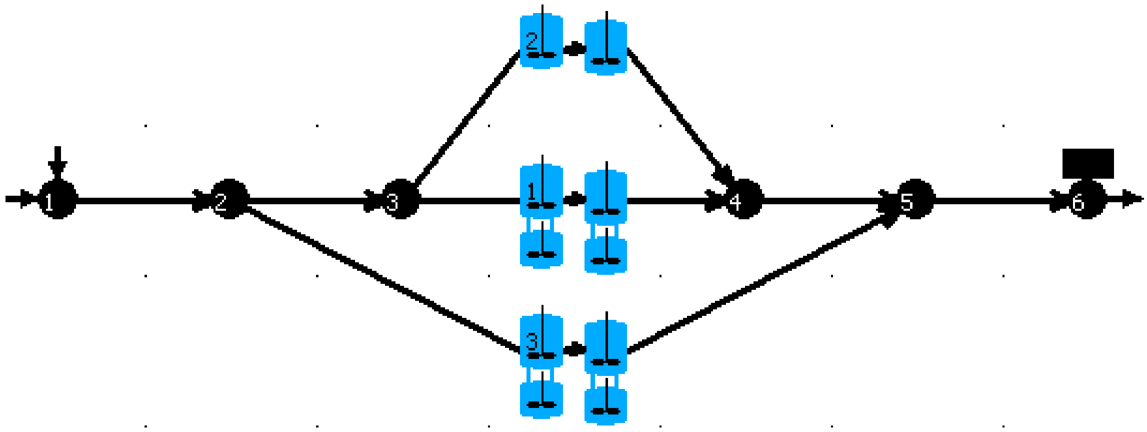


Figure 4.5: Block diagram of Model-B

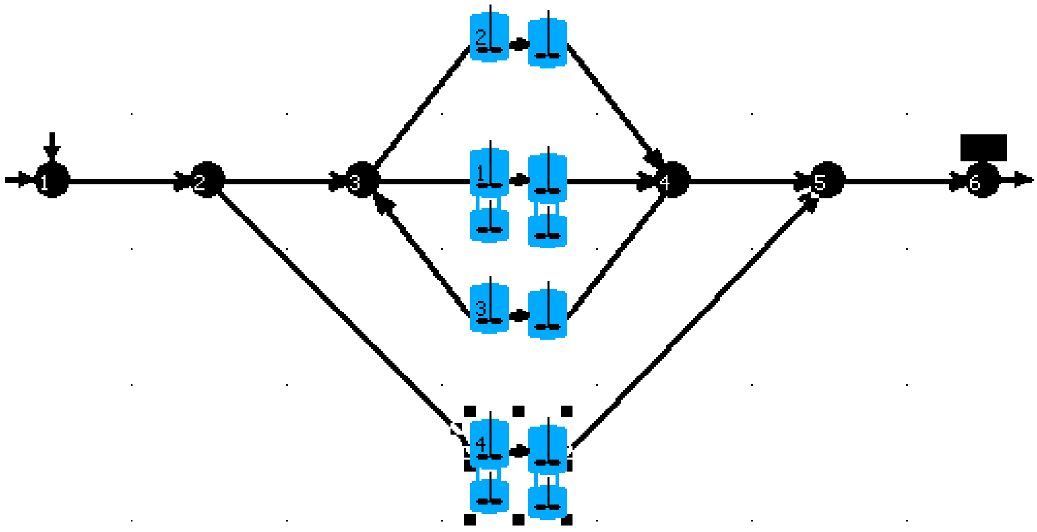


Figure 4.6: Block diagram of Model-C

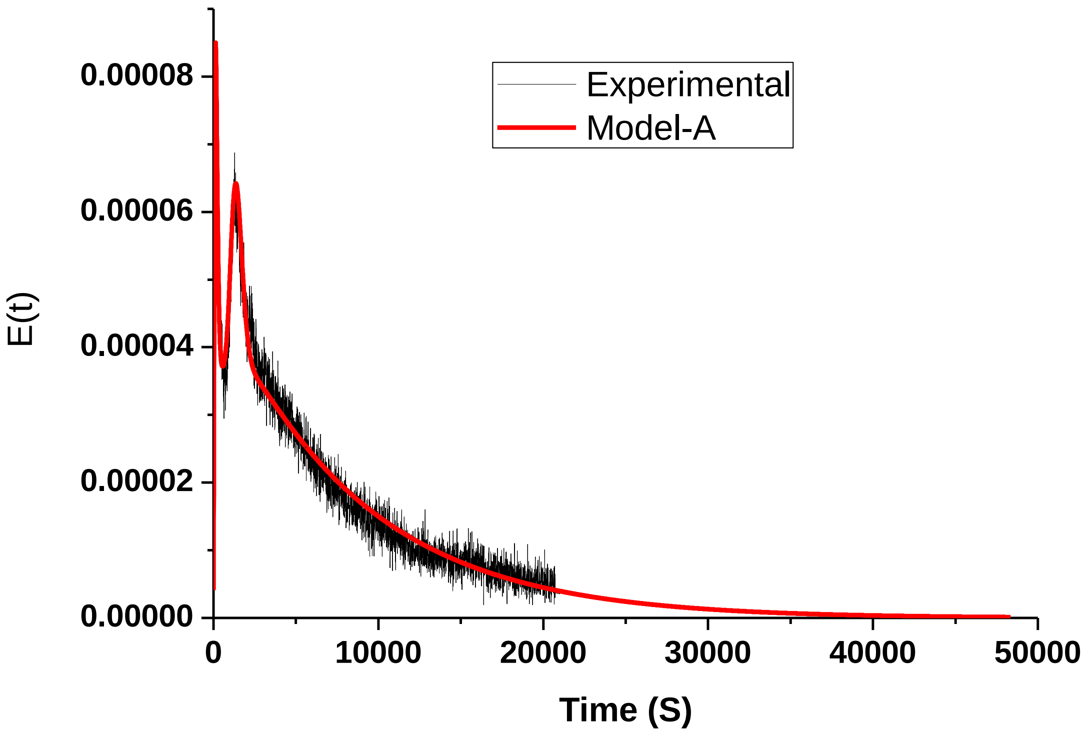


Figure 4.7: Experimental and Model-A simulated RTD curves

Table 4.1: Parameters of Model-A

Flow Streams	Main Flow stream		Bypass flow stream
Flow Fraction	0.97 (97%)		0.03 (3%)
Sub Streams	Parallel flow stream-1	Parallel flow stream-2	--
Flow Fraction	0.05 (5%)	0.92 (92%)	--
τ_m(s)	3350	17000	420
N	18	1	3
τ_{ex}(s)	--	7000	--
K	--	0.18	--
τ_m: Model predicted MRT, τ_{ex}: Time of exchange between active and dead volume, N: Tank number, K: Exchange ratio			

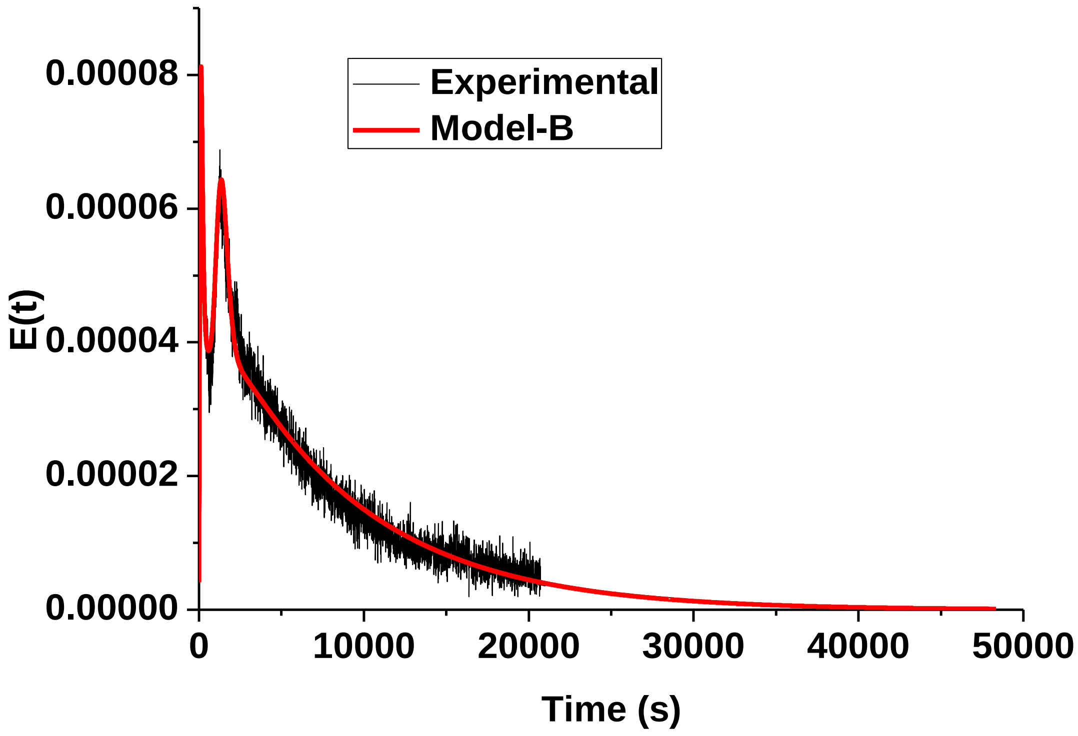


Figure 4.8: Experimental and Model-B simulated RTD curves

Table 4.2: Parameters of Model-B

Flow Streams	Main Flow stream		Bypass flow stream
Flow Fraction	0.97 (97%)		0.03 (3%)
Sub Streams	Parallel flow stream-1	Parallel flow stream-2	--
Flow Fraction	0.05 (5%)	0.92 (92%)	--
τ_m(s)	3350	17000	410
N	18	1	3
τ_{ex}(s)	--	7000	500
K	--	0.17	0.19
τ_m: Model predicted MRT, τ_{ex}: Time of exchange between active and dead volume, N: Tank number, K: Exchange ratio			

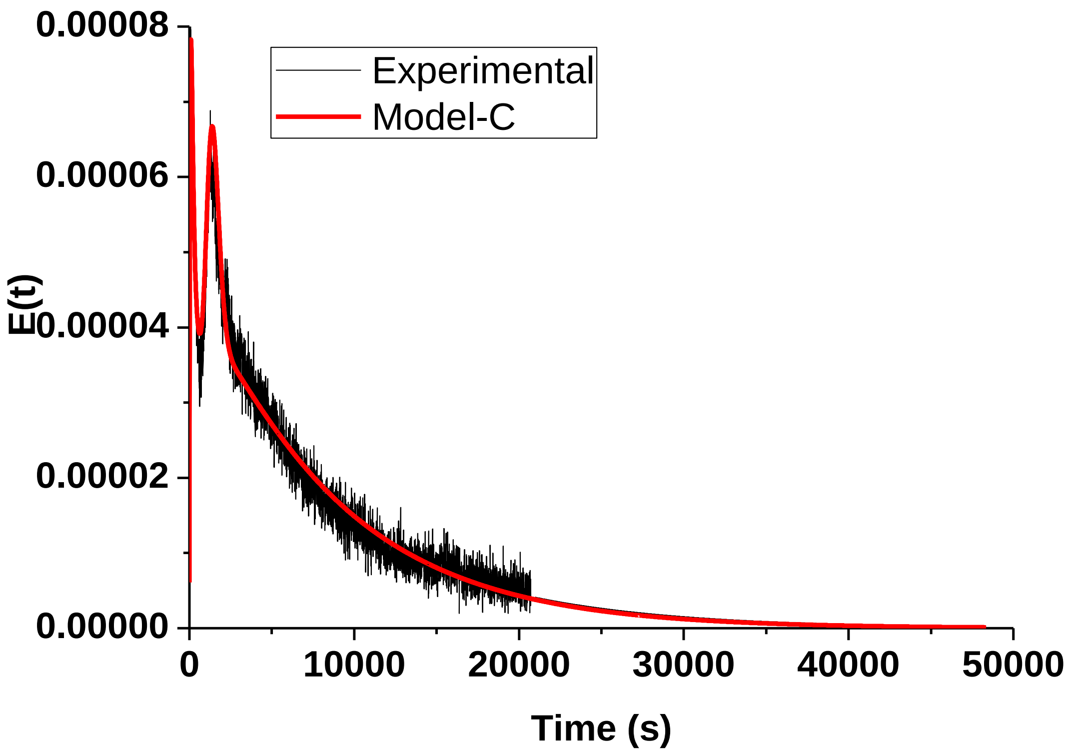


Figure 4.9: Experimental and Model-C simulated RTD curves

Table 4.3: Parameters of Model-C

Flow Streams	Main Flow stream			Bypass Flow stream
Flow Fraction	0.962 (96.2%)			0.038 (3.8%)
Sub Streams	Parallel flow Stream-1	Parallel flow Stream-2	Recirculation Stream	--
Flow Fraction	0.08 (8%)	1.002 (100.2%)	0.12 (12%)	--
τm(S)	3450	16000	300	470
N	18	1	3	2
τex(S)	--	7000	--	500
K	--	0.11	--	0.2
τ_m: Model predicted MRT, τex: Time of exchange between active and dead volume, N: Tank number, K: exchange ratio				

4.3. Results and Discussion

The Dirac Delta function curve was indicated at the inlet of the pond (D1) was used to record the radiotracer entry time into the pond. The uncorrected radiotracer concentration curves at other four locations within the pond are shown in Figure. 4.3. It is observed that the intensity of radiotracer recorded by detector D4 and D5 was low as compared to the intensity of the radiotracer recorded by D2 and D3. This indicated that a high proportion of the wastewater flowed into the pond through Inlet-1 as compared to flow in the inlet-2, which could be due to partial blockage of the inlet pipe from deposition of sediments.

The corrected response curve recorded by the detector D6 at the outlet of the pond is shown in Figure. 3.3. The first moment (equation 1) of the curve provided the MRT of the wastewater within the pond and was determined to be 5.8 h (0.24 d). Comparison of the theoretical and experimental MRTs reveals that the dead volume with the pond is approximately 93 %. This implied that only 7 % of the geometrical volume of the pond was presently available for flow of anaerobic process. This implied about 93% geometric volume of the pond was occupied by the sludge deposited on the bottom of the pond and stagnant water within the pond.

The RTD curve recorded at the outlet of the pond (Figure. 4.2), has two distinct peaks (bimodal distribution) indicating two parallel flow streams. First peak indicates bypass flow of the wastewater, whereas the second exponentially reducing peak in the later part of the distribution represents the bulk flow of wastewater.

In order to quantify the fraction of flow and to identify the detailed flow pattern within the pond, several models were conceptualized and used to simulate the flow structure within the pond. Eventually, three models appropriately named Model-A, Model-B and Model-C were found to fit the measured RTD curve. These were shown in Figures. 4.7, 4.8 and 4.9 as a result of bypass and main flow stream with the main flow stream. The model parameters obtained after simulations using the three models are given in Table 4.1, Table 4.2 and Table 4.3.

However, based on the profile of the measured RTD curve, visual observations about the pond, the model C shown in Figure. 4.6 was conceptualized and used to describe flow behaviour in the pond. The model assumes that the wastewater entering into the pond splits into two parallel streams (bypass and main flow stream). The main flow stream further splits into two other parallel flow streams i.e. stream-2a and stream-2b.

According to the model A, for example, the flow in bypass stream is represented by tanks-in-series model, whereas the same is represented by tanks-in-series with dead volume and exchange model in Model-B and Model-C. The two parallel flow streams of the main flow stream are represented by tanks-in-series and tanks-in-series with dead volume and exchange. In Model-C, a fraction of the outlet of the main flow stream recirculates back to the inlet and gets added to the main flow.

The model simulation results show that the fraction of the flow in the bypass stream and main flow stream ranged from 3.0 - 3.8% and 96.2 - 97 %, respectively and flow fractions in the parallel flow streams 1 and 2 range between 5-8% and 92-100.2%. The Model-C indicates that about 12% of the flow of the main stream recirculates back to the inlet stream. It has been observed that the degree of dispersion (N) in bypass, parallel flow paths of the main stream, to be identical for the three models. The degree of mixing (N) in bypass stream was moderate (N=3) whereas degree of mixing in parallel flow stream 1 and 2 was minimum (N=18, plug flow) and maximum possible (N=1, perfect mixing). The exchange rate between active and stagnant volume in bypass and main flow stream in all the three models ranged 0.1-0.2, which is quite low. This indicates that most of the volume within the pond is dead because of the deposition of the solid sludge and sedimentation.

However, Model-C best describes the flow pattern within the anaerobic pond.

4.4. Wastewater Parameters measurements: TDS, TSS, COD and BOD

The overall performance of the plant was assessed from measurements of TDS, TSS, COD, and BOD for the period, September 2017 to April 2018 on daily basis - Appendix 1. Appendix 2 shows the monthly averages of waste water parameters during the sampling period.

Figure 4.10 and Figure 4.11 shows the flowrate for the main inlet and the pump station inlet during the study period. Figure 4.12 shows the flowrate variations at the outlets.

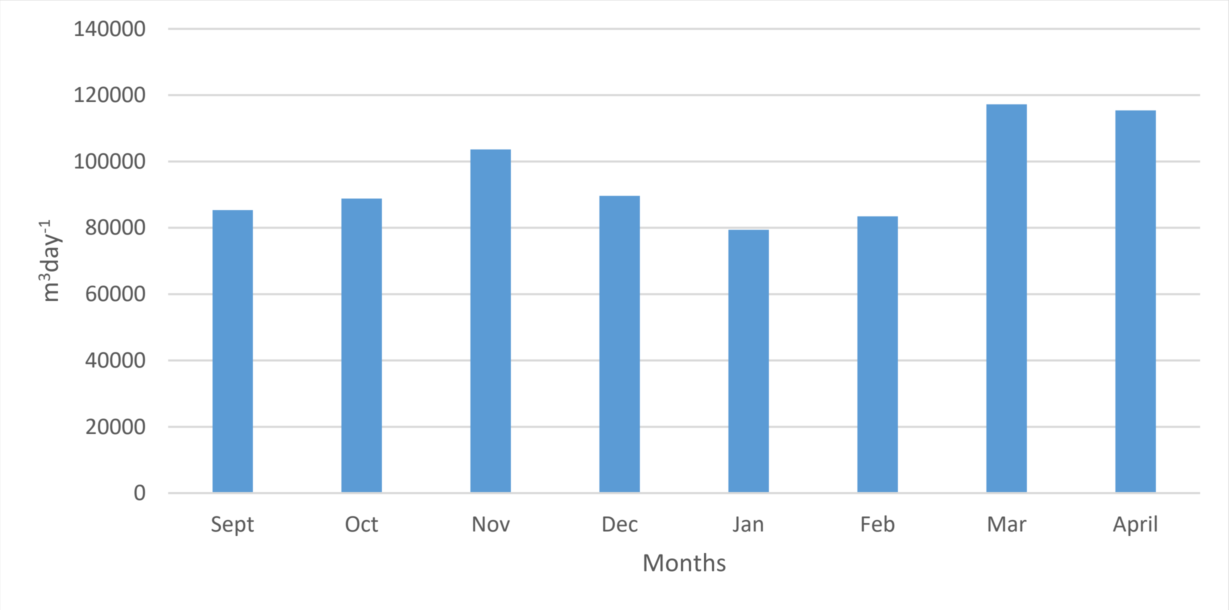


Figure 4.10: Variation of flowrate at the main inlet

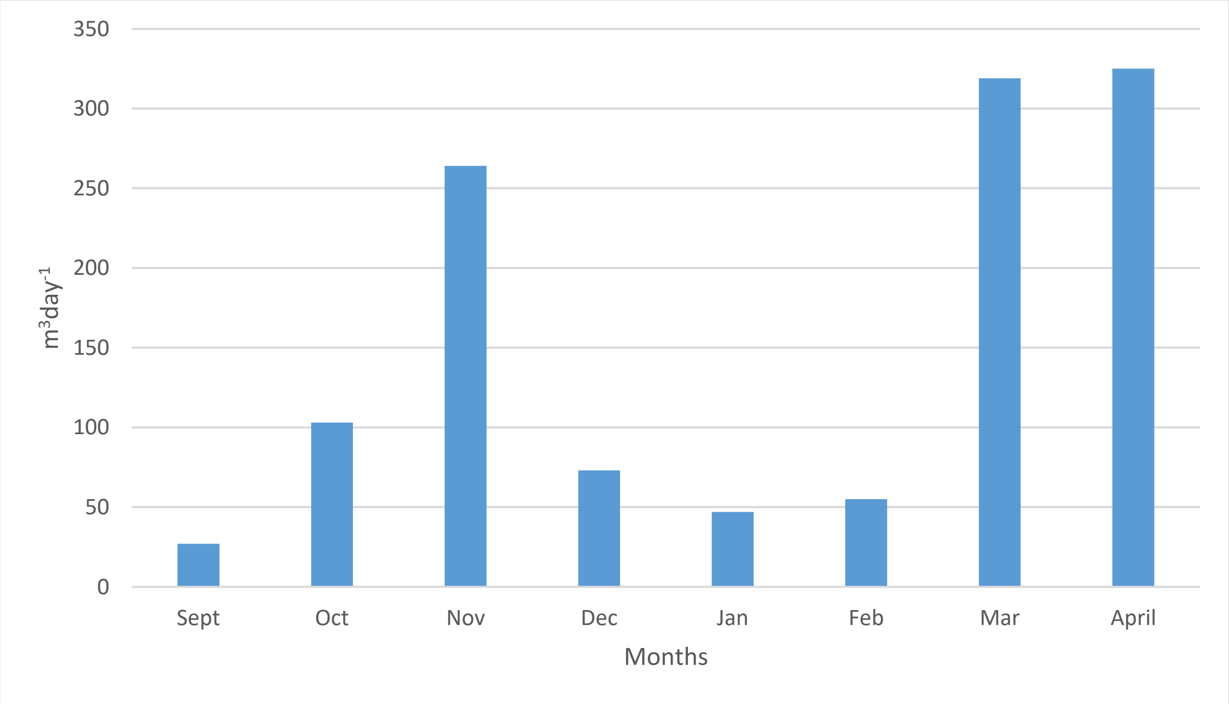


Figure 4.11: Variation of flowrate at the pump station inlet

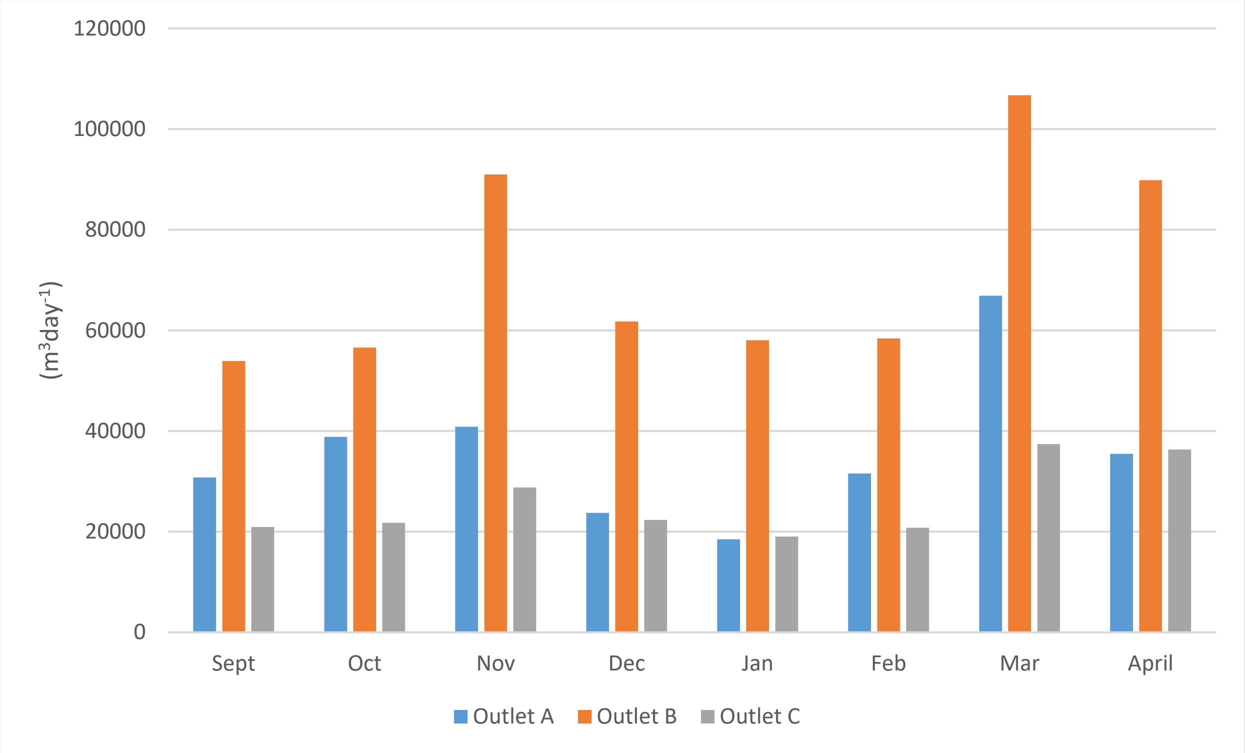


Figure 4.12: Variation of flowrate at the outlets

In general, the flowrate at the main inlet was significantly higher than at the pump station inlet, with monthly mean of 95,353 m^3/day with the highest (117,229 m^3/day) recorded in March and the lowest average level (79,415 m^3/day) recorded in January. Pump Station inlet had monthly average of 151 m^3/day, with highest average of 325 m^3/day in March and the lowest average of 27 m^3/day in February. The plant capacity is 120,000 m^3/day.

Estimated effluent discharge average was 133,740 m^3/day with outlet A, B and C having averages of 35,815 m^3/day, 72,018 m^3/day and 25,906 m^3/day respectively during the sampling period.

Fig.4.13 and Figure 4.14 shows the Monthly variations for BODs at the inlet and outlet respectively.

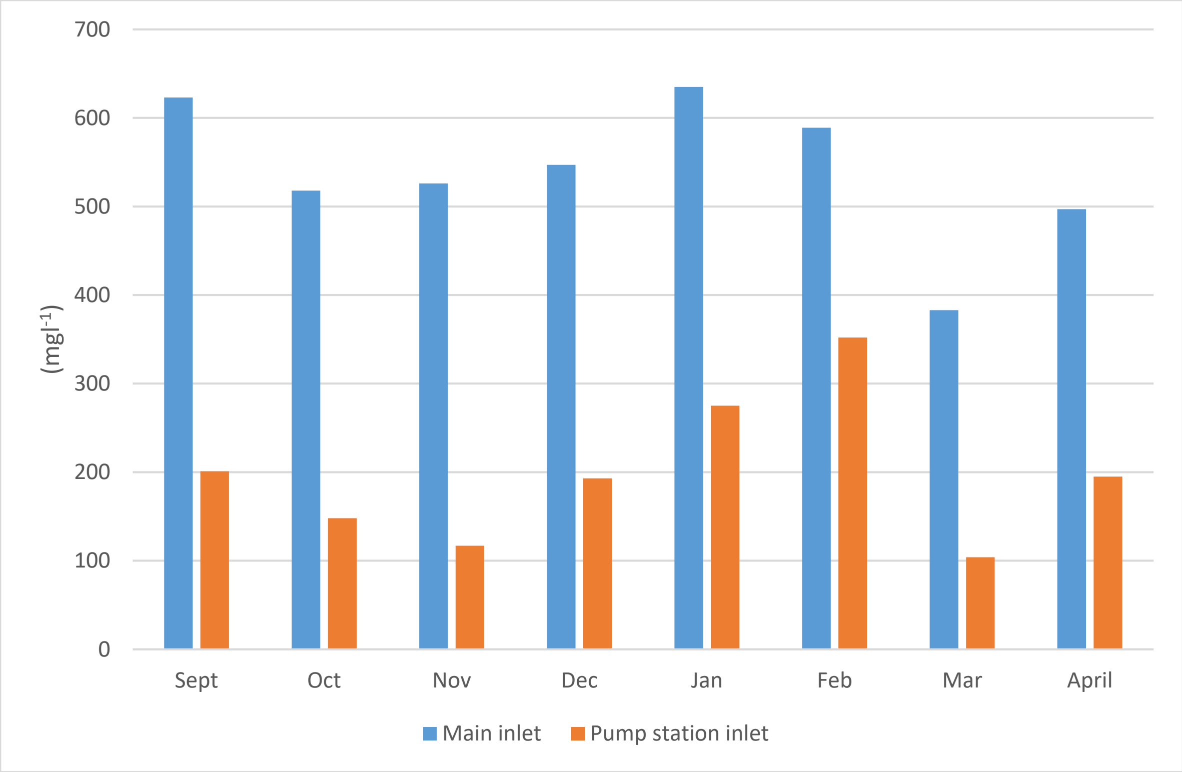


Figure 4.13 Variation of BOD level in Influent

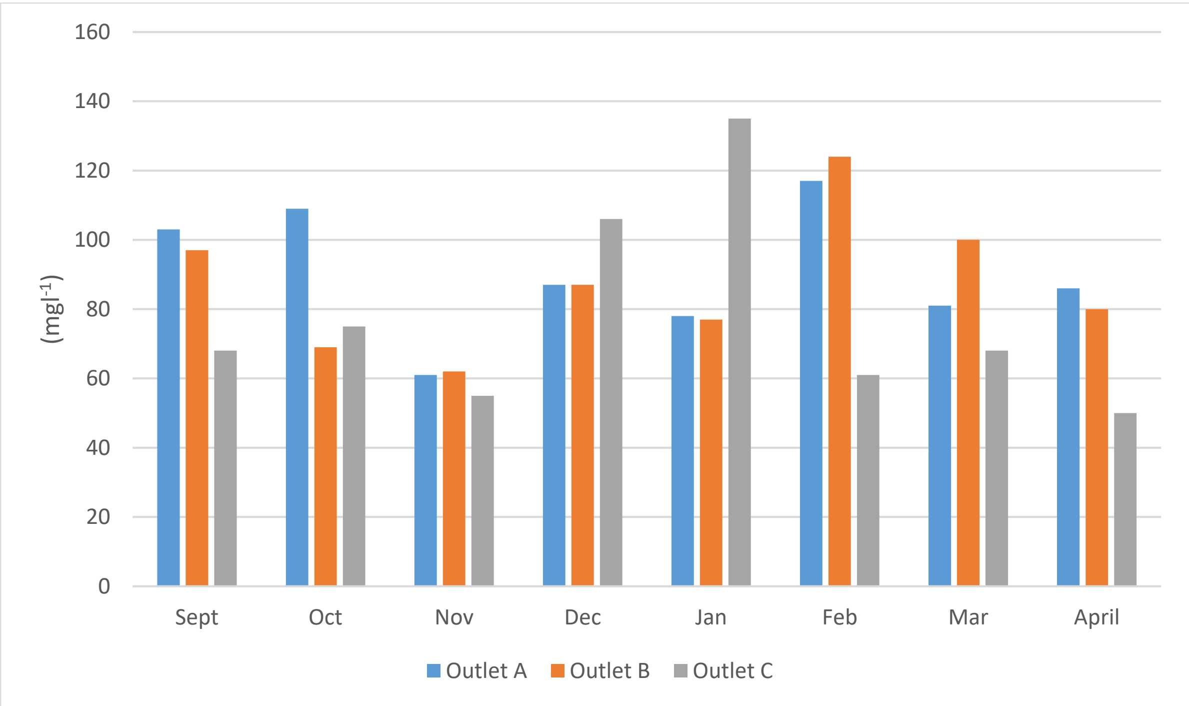


Figure 4.14: Variation of BOD level in Effluent

BOD levels in the influent was significantly higher at the main inlet compared with levels at pump station inlet, having monthly mean of 539 mg/l with the highest average level of BOD (635 mg/l) recorded in January and the lowest average level (383 mg/l) documented in March, 2018. Pump station inlet had monthly average of 198 mg/l with the month of February recording highest average of 352 mg/l and March having the lowest average of 104 mg/l. The BOD levels at the influent is within the design specifications of 512 mg/l.

Effluent had a BOD average of 84 mg/l with outlet A, B and C having averages of 90 mg/l, 87 mg/l and 77 mg/l, respectively. This levels exceed the design specification limit of 20 mg/l and the Kenya Standards limit of 30 mg/l (Alexander & Partners., 1988; Water Quality Regulations, 2006).

Fig.4.15 and Figure 4.16 shows the Monthly variations for CODs at the inlet and outlet respectively.

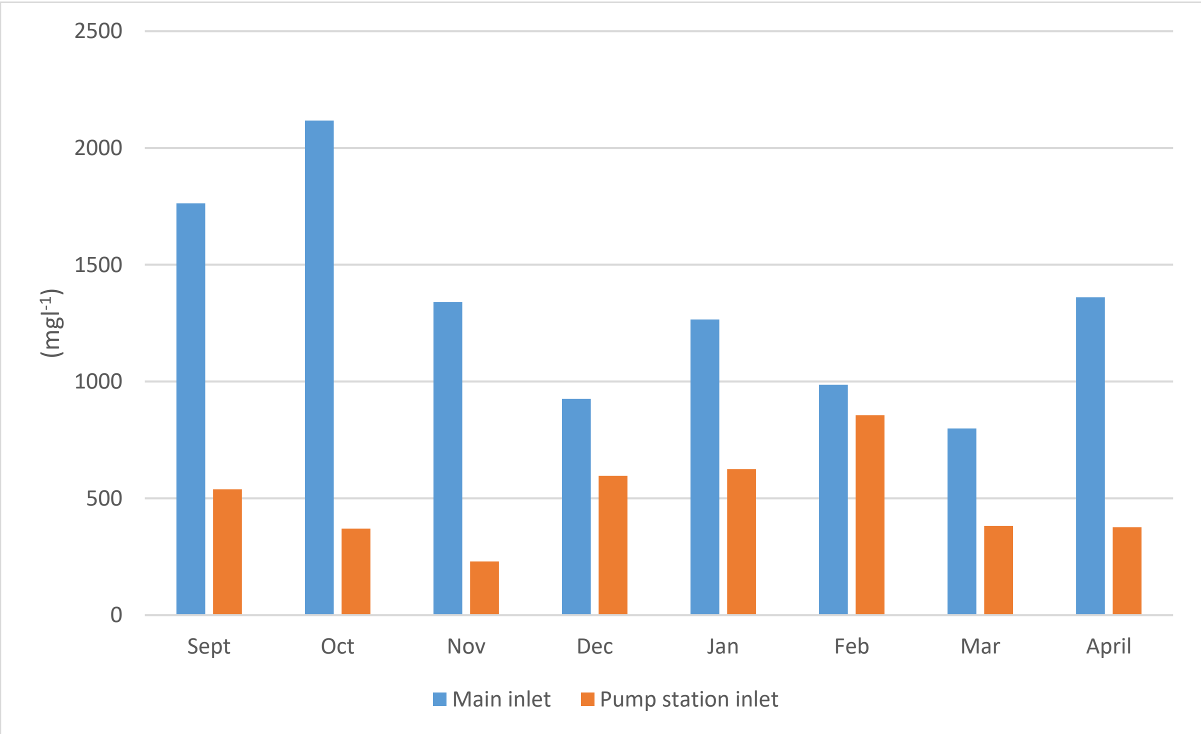


Figure 4.15: Variation of COD level in Influent

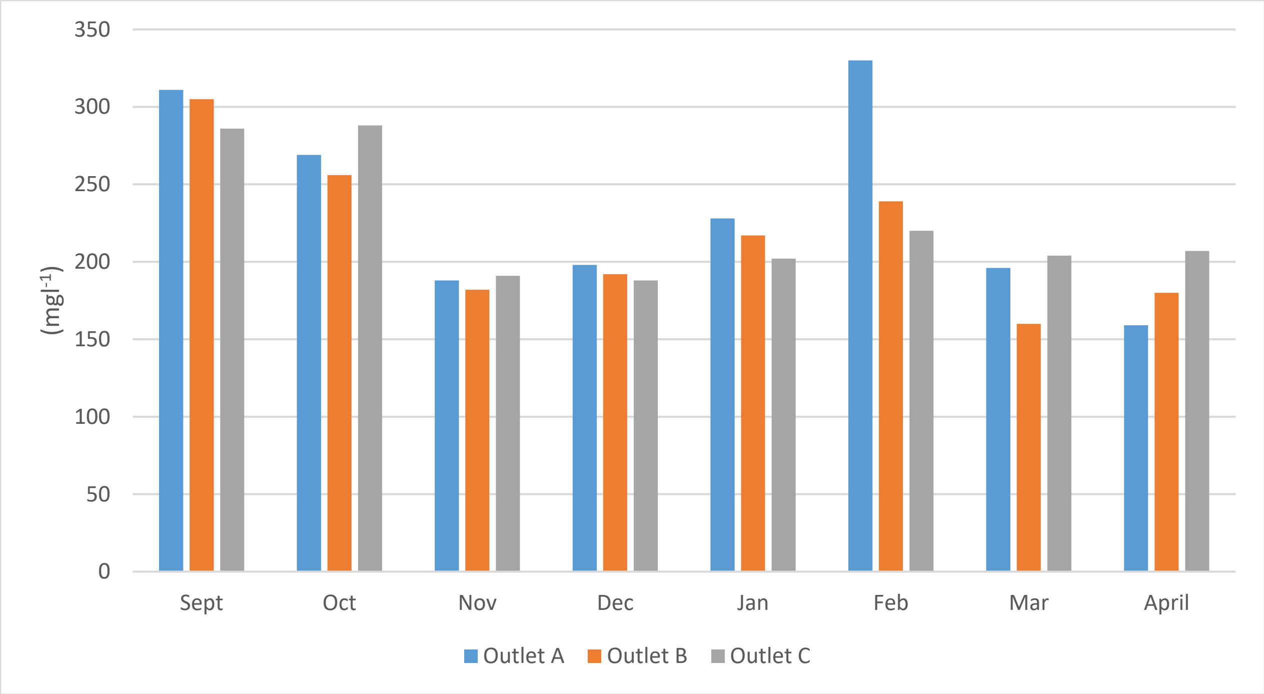


Figure 4.16: Variation of COD level in Effluent

COD level in the influent was significantly higher at the main inlet compared with levels at pump station inlet, having monthly mean of 1319 mg/l with the highest average level of COD (2117 mg/l) recorded in October and the lowest average level (799 mg/l) documented in March. Pump station inlet had monthly average of 496 mg/l with the month of February recording highest average of 856 mg/l and November having the lowest average of 230 mg/l.

Effluent had a COD average of 224 mg/l with outlet A, B and C having averages of 234 mg/l, 216 mg/l and 223 mg/l respectively. These levels exceeds Kenyan Standards limit of 50 mg/l.

Figure.4.17 and Figure 4.18 shows the Monthly variations for TSS at the inlet and outlet respectively.

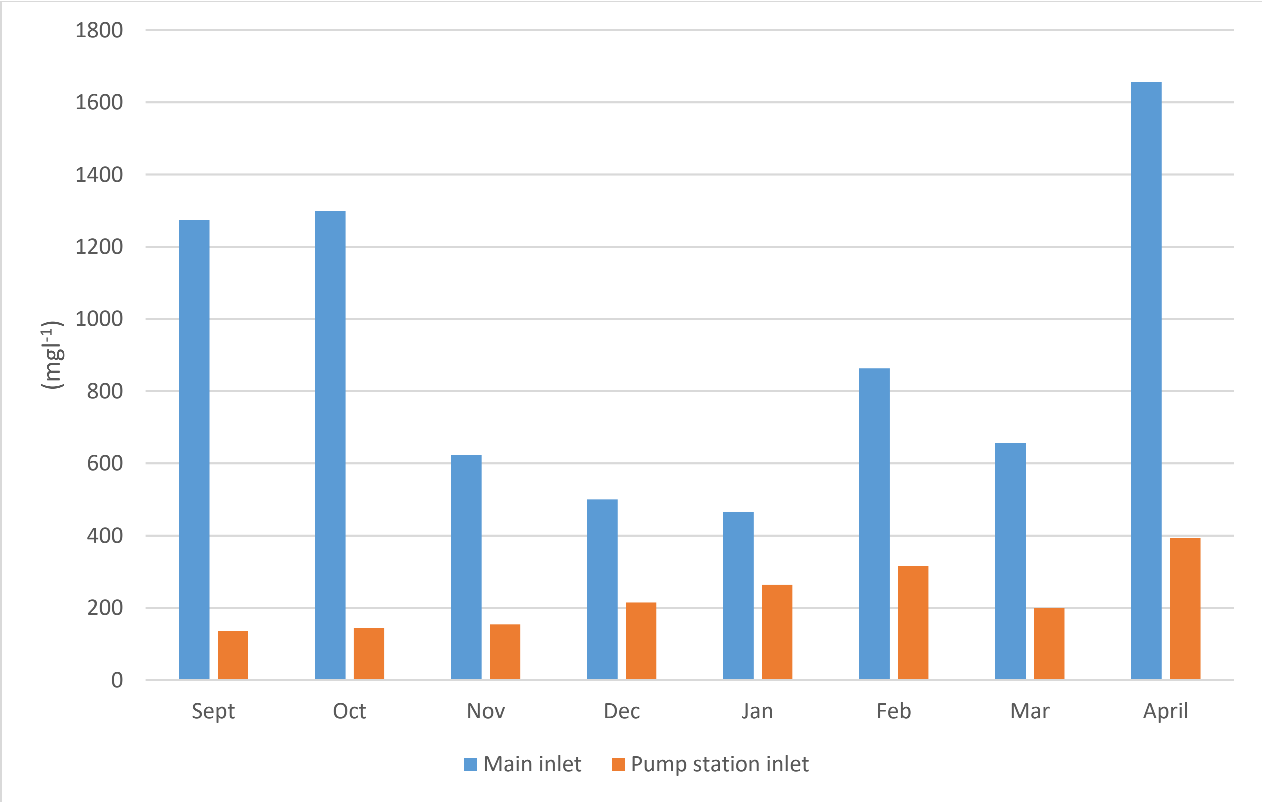


Figure 4.17: Variation of TSS level in Influent

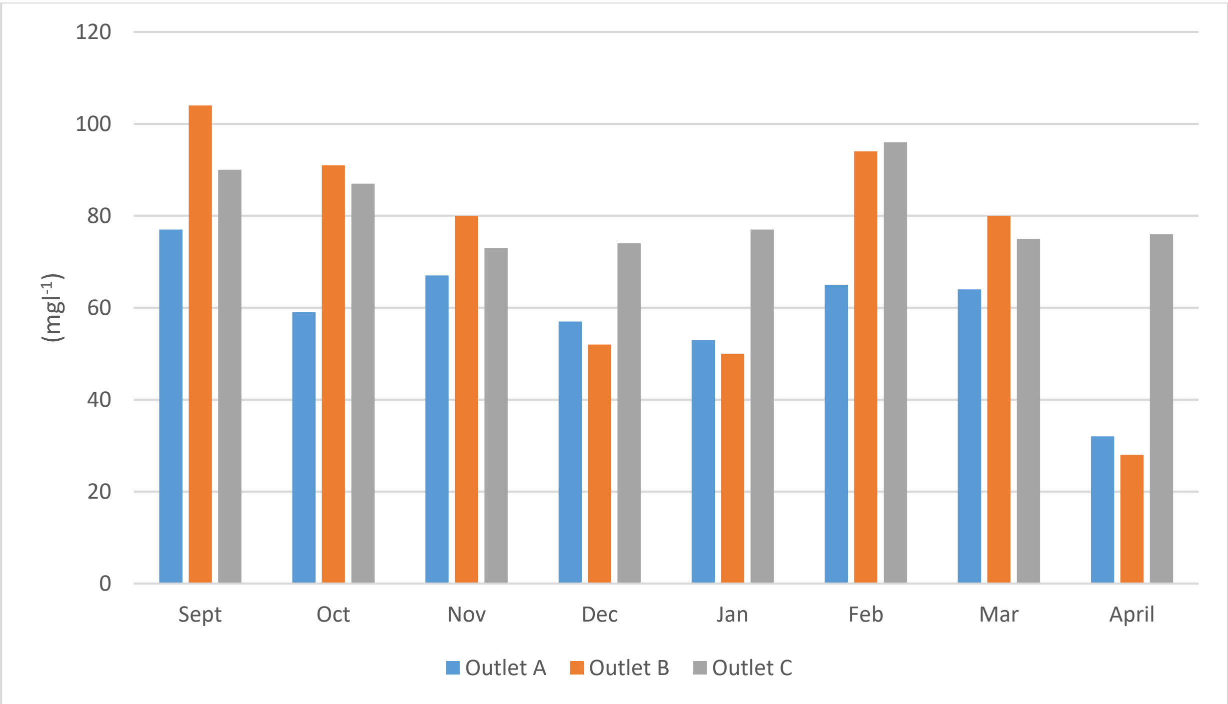


Figure 4.18: Variation of TSS level in Effluent

TSS level in the influent was significantly higher at the main inlet compared with levels at pump station inlet, having monthly mean of 917 mg/l with the highest average level of TSS (1656 mg/l) recorded in April and the lowest average level (466 mg/l) documented in January. Pump station inlet had monthly average of 227 mg/l with the month of April recording highest average of 394 mg/l and September having the lowest average of 136 mg/l. These levels exceeds design specifications limit of 655 mg/l.

Effluent had a TSS average of 70 mg/l with outlet A, B and C having averages of 59 mg/l, 72 mg/l and 81 mg/l respectively. These levels exceeds design specification and Kenya Standards limit of 30mg/l.

Figure 4.19 and Figure 4.20 shows the Monthly variations for TDS at the inlet and outlet respectively

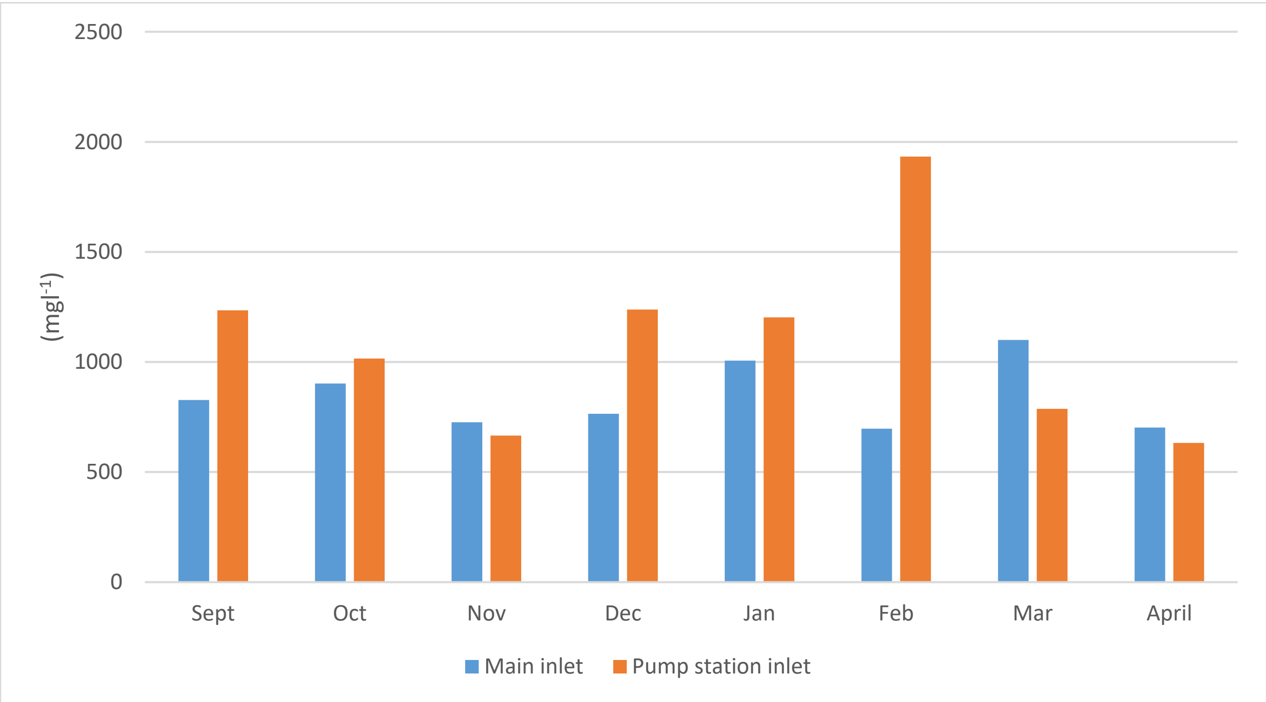


Figure 4.19: Variation of TDS level in Influent

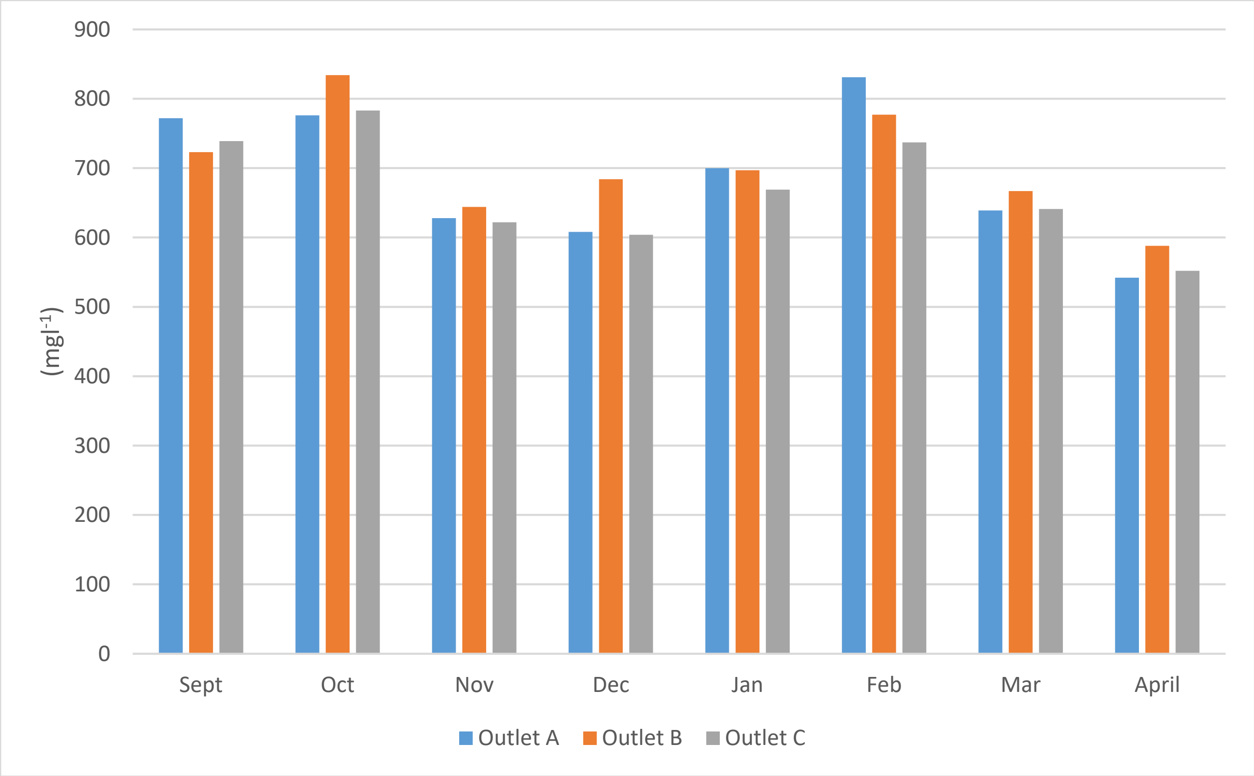


Figure 4.20: Variation of TDS level in Influent

TDS level in the influent was higher at the pump station inlet compared with levels at the main inlet, having monthly mean of 1088 mg/l with the highest average level of TDS (1833 mg/l) recorded in February and the lowest average level (632 mg/l) documented in April. Main inlet had monthly average of 840 mg/l with the month of March recording highest average of 1100 mg/l and February having the lowest average of 697 mg/l.

Effluent had a TDS average of 685 mg/l with outlet A, B and C having averages of 687 mg/l, 701 mg/l and 668 mg/l respectively. These values are below Kenya Standards limit of 1200 mg/l.

In general, high values of BOD, COD, and TSS recorded for the effluents could be due; to higher influent inputs levels greater than the plant design specifications requirements, which invariably affects plant treatment processes. The other reason could be attributed to the fact that the ponds have not been desludged for a considerable period, resulting to reduction of active pond volume hence less retention period within the ponds.

Chapter 5: Conclusions and Recommendations

5.1 Conclusions

A radiotracer research was successfully carried out to measure RTD of wastewater stabilization pond in Kenya. The MRT and dead volume were estimated and found to be 5.8 h and 93%, respectively. This implied that only 7 % of the volume (geometric) of the pond was available for flow of the wastewater. The majority of the volume of the pond was dead because of deposition of the sludge on the bottom of the pond and stagnant wastewater.

The radiotracer intensity measured within the pond indicated that flow of wastewater was predominantly towards detector D2 and D3 through the Inlet-1 of the pond. This could be due to partial chocking of the Inlet-2 of the pond. A model consisting of three parallel flow streams was proposed and found suitable to be suitable in describing the flow behaviour of wastewater inside the pond. The model simulation results revealed that a small fraction (3 %) of the flow bypassed the pond and major fraction of the wastewater (97 %) flowed with two parallel flow streams.

The results of the wastewater effluents for weekly averages COD, BOD and TSS exceed the design and Kenya standards limits.

The results of this investigation confirmed that there existed several flow abnormalities and the flow behaviour of the pond was not suitable for anaerobic treatment of the wastewater. The investigation was first of its kind conducted in Kenya and will go a long way to promote the use of radiotracer technology in Kenya.

5.2 Recommendations

On the basis of the results of this investigation, it was recommended that:

1) The plant authorities should take necessary measures for desilting of the sludge and modifications in the design of the pond to improve its flow behaviour.
2) Computational Fluid Dynamics to be conducted so as to localize and visualize flow pattern in the ponds.

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APPENDIX 1

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 8th SEPTEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		02-Sep	03-Sep	04-Sep	05-Sep	06-Sep	07-Sep	08-Sep
Inflow	m3/d	83949	70796	92156	110475	79057	84191	85618
BOD	mg/l					340	860	700
COD Total	mg/l			512	1633	689	2300	1826
TSS	mg/l			268		308		950
TDS	mg/l			806		814		
PUMP STATION								
Inflow	m3/d	24	24	17	21	25	24	20
BOD	mg/l					160	160	310
COD Total	mg/l			309	742	347	384	573
TSS	mg/l			78		72		148
TDS	mg/l			898		698		2990
Outflow A	m3/d			29764	32576	32576	31159	29764
BOD	mg/l					115	115	60
COD Total	mg/l			351	395	299	328	478
COD Filtered	mg/l			253		244		313
TSS	mg/l			38		144		60
TDS	mg/l			872		722		754
Outflow B								
Outflow	m3/d			45343	42715	59242	65139	65139
BOD	mg/l					50	60	180
COD Total	mg/l			307	282	221	328	261
COD Filtered	mg/l			138		118		165
TSS	mg/l			86		86		68
TDS	mg/l			766		754		700
Outflow C Character								
Outflow	m3/d			29978	33460	25730	22833	21428
BOD	mg/l					60	30	60
COD Total	mg/l			314	323	244	296	243
COD Filtered	mg/l			146		95		171
TSS	mg/l			148		14		88
TDS	mg/l			768		830		706

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 15th SEPTEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		09-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep
Inflow	m3/d	84432	75801	77800	75294	80419	80531	70667
Inflow character								
BOD	mg/l					360		500
COD Total	mg/l			1962	3078	654	757	1210
TSS	mg/l			864		310		744
TDS	mg/l			902		800		820
PUMP STATION								
Inflow	m3/d			23	16	23	22	31
Inflow character								
BOD	mg/l					200		210
COD Total	mg/l			454	692	724	496	508
TSS	mg/l			222		160		158
TDS	mg/l			906		1134		1220
Outflow A Character								
Outflow A	m3/d			35470	28391	31159	32576	32576
BOD	mg/l					105		135
COD Total	mg/l			277	315	291	358	339
COD Filtered	mg/l			208		244		97
TSS	mg/l			30		74		158
TDS	mg/l			840		818		750
Outflow B Character								
Outflow	m3/d			53535	66642	50754	56364	60699
BOD	mg/l					80		80
COD Total	mg/l			215	200	268	244	298
COD Filtered	mg/l			112		142		169
TSS	mg/l			94		38		116
TDS	mg/l			766		784		744
Outflow C Character								
Outflow	m3/d			16752	18049	13655	18048	20738
BOD	mg/l					50		80
COD Total	mg/l			131	300	228	423	315
COD Filtered	mg/l			123		150		137
TSS	mg/l			54		110		160
TDS	mg/l			782		730		740

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 22nd SEPTEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep
Inflow	m3/d	108133	90259	83210	81968	91772	87844	86009
Inflow character								
BOD	mg/l					600	460	800
COD Total	mg/l			4804	2113	1797	659	1211
TSS	mg/l			4912		678		1178
TDS	mg/l			708		898		684
PUMP STATION								
Inflow	m3/d	47	53	49	47	33	23	22
Inflow character								
BOD	mg/l					60	230	300
COD Total	mg/l			402	465	547	457	611
TSS	mg/l			146		98		38
TDS	mg/l			840		1864		1188
Outflow A Character								
Outflow	m3/d			41500	41500	34013	32576	27039
BOD	mg/l					115	105	110
COD Total	mg/l			323	240	298	279	254
COD Filtered	mg/l			236		203		190
TSS	mg/l			86		42		44
TDS	mg/l			732		796		692
Outflow B Character								
Outflow	m3/d			69683	59242	54943	63647	66642
BOD	mg/l					90	90	90
COD Total	mg/l			425	279	328	302	468
COD Filtered	mg/l			197		188		190
TSS	mg/l			130		80		170
TDS	mg/l			694		724		510
Outflow C Character								
Outflow	m3/d			24995	20737	20737	22833	16116
BOD	mg/l					80	80	40
COD Total	mg/l			315	264	172	240	349
COD Filtered	mg/l			205		102		286
TSS	mg/l			122		64		38
TDS	mg/l			658		728		672

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 29th SEPTEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep
Inflow	m3/d	94654	79585	89245	84708			
Inflow character								
BOD	mg/l					680	720	840
COD Total	mg/l			3190	1895	2044	1485	1443
TSS	mg/l			3514		636		928
TDS	mg/l			896		856		812
PUMP STATION								
Inflow	m3/d	28	29	28	33	35	26	23
Inflow character								
BOD	mg/l					60	260	270
COD Total	mg/l			662	883	548		447
TSS	mg/l			250		176		92
TDS	mg/l			2064		900		828
Outflow A Character								
Outflow	m3/d			27038	23118	21857	23118	27039
BOD	mg/l					95	75	110
COD Total	mg/l			234	289	317	289	268
COD Filtered	mg/l			223		246		130
TSS	mg/l			102		72		82
TDS	mg/l			760		766		762
Outflow B Character								
Outflow	m3/d			60626	63647	32742	22634	18557
BOD	mg/l					150	80	120
COD Total	mg/l			246	289	349	500	301
COD Filtered	mg/l			239		143		179
TSS	mg/l			112		170		102
TDS	mg/l			750		738		746
Outflow C Character								
Outflow	m3/d			19377	19377	20053	14258	19377
BOD	mg/l					40	90	140
COD Total	mg/l			380	297	286	258	350
COD Filtered	mg/l			143		230		187
TSS	mg/l			150		28		104
TDS	mg/l			730		758		776

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 6th October 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		30-Sep	01-Oct	02-Oct	03-Oct	04-Oct	05-Oct	06-Oct
Inflow	m3/d				73783	78264	81372	79193
Inflow character								
BOD	mg/l			140		920		880
COD Total	mg/l			1551	1400	3104	1533	2500
TSS	mg/l			808		1178		1544
TDS	mg/l			918		916		1070
PUMP STATION								
Inflow	m3/d	24	26	22	30	34	30	
Inflow character								
BOD	mg/l			152		320		150
COD Total	mg/l			438	400	292	815	500
TSS	mg/l			128		170		40
TDS	mg/l			898		2328		1744
Outflow A Character								
Outflow	m3/d			29764	23118	23118	21857	23118
BOD	mg/l			126		95		90
COD Total	mg/l			221	480	258	306	365
COD Filtered	mg/l			198		217		222
TSS	mg/l			40		62		60
TDS	mg/l			844		828		856
Outflow B Character								
Outflow	m3/d			16621	17580	14758	15681	16621
BOD	mg/l			139		40		30
COD Total	mg/l			275	336	258	282	349
COD Filtered	mg/l			81		117		151
TSS	mg/l			80		78		226
TDS	mg/l			808		806		792
Outflow C Character								
Outflow	m3/d			18709	19377	18050	20737	18709
BOD	mg/l			125		70		60
COD Total	mg/l			283	440	433	347	381
COD Filtered	mg/l			151		233		183
TSS	mg/l			50		194		116
TDS	mg/l			816		774		826

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 13th October 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		07-Oct	08-Oct	09-Oct	10-Oct	11-Oct	12-Oct	13-Oct
Inflow	m3/d	67213	76945	61991	76242	83598	113091	119538
Inflow character								
BOD	mg/l					200	860	300
COD Total	mg/l			3906	1335	885	11875	582
TSS	mg/l			3058		458		992
TDS	mg/l			1200		926		1042
PUMP STATION								
Inflow	m3/d	27	26	24	23	241	246	241
Inflow character								
BOD	mg/l					230	190	60
COD Total	mg/l			613	654	331	1058	194
TSS	mg/l			186		156		238
TDS	mg/l			1142		704		984
Outflow A Character								
Outflow	m3/d			25709	21857	24403	27039	49469
BOD	mg/l					90	75	130
COD Total	mg/l			195	301	241	292	357
COD Filtered	mg/l			164		150		225
TSS	mg/l			70		32		128
TDS	mg/l			790		782		702
Outflow B Character								
Outflow	m3/d			26973	36378	35152	40139	52138
BOD	mg/l					50	40	110
COD Total	mg/l			218	308	226	117	256
COD Filtered	mg/l			125		38		31
TSS	mg/l			128		122		41
TDS	mg/l			742		752		830
Outflow C Character								
Outflow	m3/d			13062	15488	18049	20053	27221
BOD	mg/l					80	80	120
COD Total	mg/l			226	346	286	292	310
COD Filtered	mg/l			141		68		271
TSS	mg/l			80		112		55
TDS	mg/l			750		752		846

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 20th OCTOBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
Inflow	m3/d	94734	102315	83900	97074	97129	96132	113873
Inflow character								
BOD	mg/l					540		
COD Total	mg/l			3024	547	1145	179	
TSS	mg/l			2462		678		
TDS	mg/l			1200		810		
PUMP STATION								
Inflow	m3/d	73	53	43	58	65	38	53
Inflow character								
BOD	mg/l					70		
COD Total	mg/l			210	249	149	258	
TSS	mg/l			72		322		
TDS	mg/l			1374		488		
Outflow A Character								
Outflow	m3/d			57890	43056	46226	34013	
BOD	mg/l					110		
COD Total	mg/l			295	320	290	206	
COD Filtered	mg/l			225		130		
TSS	mg/l			68		36		
TDS	mg/l			1136		778		
Outflow B Character								
Outflow	m3/d			80674	27978	105960	80674	
BOD	mg/l					80		
COD Total	mg/l			318	234	351	175	
COD Filtered	mg/l			186		313		
TSS	mg/l			88		72		
TDS	mg/l			1334		914		
Outflow C Character								
Outflow	m3/d			22127	27978	27978	28168	
BOD	mg/l					60		
COD Total	mg/l			248	234	282	167	
COD Filtered	mg/l			217		145		
TSS	mg/l			76		60		
TDS	mg/l			1100		740		

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 27TH OCTOBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct
Inflow	m3/d	105033	78871	95806	106379			99302
Inflow character								
BOD	mg/l				470			360
COD Total	mg/l			2205	2038			821
TSS	mg/l			2380				432
TDS	mg/l			856				432
PUMP STATION								
Inflow	m3/d	607	156	86	142			115
Inflow character								
BOD	mg/l				140			20
COD Total	mg/l			102	177			92
TSS	mg/l			112				32
TDS	mg/l			544				324
Outflow A Character								
Outflow	m3/d			59627	59627			52784
BOD	mg/l				160			105
COD Total	mg/l			187	134			292
COD Filtered	mg/l			126				183
TSS	mg/l			94				30
TDS	mg/l			696				528
Outflow B Character								
Outflow	m3/d			60698	72768			93874
BOD	mg/l				45			90
COD Total	mg/l			268	142			208
COD Filtered	mg/l			181				92
TSS	mg/l			108				32
TDS	mg/l			866				628
Outflow C Character								
Outflow	m3/d			20737	21428			26472
BOD	mg/l				25			60
COD Total	mg/l			307	185			308
COD Filtered	mg/l			205				258
TSS	mg/l			100				52
TDS	mg/l			770				580

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 3RD NOVEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		28-Oct	29-Oct	30-Oct	31-Oct	01-Nov	02-Nov	03-Nov
Inflow	m3/d	93730	65966	90641	90929	87441	84409	103707
Inflow character								
BOD	mg/l					720	820	780
COD Total	mg/l			645	962	1846	1260	1846
TSS	mg/l			302		736		894
TDS	mg/l			554		682		276
PUMP STATION								
Inflow	m3/d	202	65	61	57	55	61	102
Inflow character								
BOD	mg/l					160	180	120
COD Total	mg/l			281	223	335	349	236
TSS	mg/l			134		88		82
TDS	mg/l			646		1064		622
Outflow A Character								
Outflow	m3/d			38446	36948	35470	32576	39963
BOD	mg/l					80	55	75
COD Total	mg/l			172	200	223	202	177
COD Filtered	mg/l			156		85		146
TSS	mg/l			34		94		12
TDS	mg/l			600		576		572
Outflow B Character								
Outflow	m3/d			63647	65139	74327	77479	74327
BOD	mg/l					70	80	80
COD Total	mg/l			258	200	254	240	246
COD Filtered	mg/l			117		131		123
TSS	mg/l			28		88		66
TDS	mg/l			712		726		650
Outflow C Character								
Outflow	m3/d			22833	20053	24267	27222	25730
BOD	mg/l					50	60	60
COD Total	mg/l			203	208	231	240	177
COD Filtered	mg/l			156		115		108
TSS	mg/l			62		54		94
TDS	mg/l			620		666		536

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 10TH NOVEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		04-Nov	05-Nov	06-Nov	07-Nov	08-Nov	09-Nov	10-Nov
Inflow	m3/d	100153	103622	109833	115393	112013	103177	98835
Inflow character								
BOD	mg/l					460	130	260
COD Total	mg/l			2635	1066	930	446	1976
TSS	mg/l			1150		422		325
TDS	mg/l			876		826		695
PUMP STATION								
Inflow	m3/d	74	81	82	123	143	409	345
Inflow character								
BOD	mg/l					60		20
COD Total	mg/l			100	155	194	326	333
TSS	mg/l			190		312		90
TDS	mg/l			506		568		570
Outflow A Character								
Outflow	m3/d			39963	39963	41500	43056	44632
BOD	mg/l					65	65	85
COD Total	mg/l			239	202	163	209	224
COD Filtered	mg/l			138				163
TSS	mg/l			54		42		185
TDS	mg/l			648		664		585
Outflow B Character								
Outflow	m3/d			97278	98993	118524	109502	102457
BOD	mg/l					60	70	50
COD Total	mg/l			215	171	186	240	194
COD Filtered	mg/l			131				155
TSS	mg/l			74		72		205
TDS	mg/l			674		758		555
Outflow C Character								
Outflow	m3/d			32657	34270	40973	35908	35085
BOD	mg/l					50	60	60
COD Total	mg/l			246	209	209	186	202
COD Filtered	mg/l			138				93
TSS	mg/l			50		38		165
TDS	mg/l			666		718		610

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 17TH NOVEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov
Inflow	m3/d	95097	118904	135809	127721	127646	102702	114207
Inflow character								
BOD	mg/l					240	500	
COD Total	mg/l			421	524	648	1856	806
TSS	mg/l			344		518		624
TDS	mg/l			540		672		836
PUMP STATION								
Inflow	m3/d	1118	1113	646	616	270	140	85
Inflow character								
BOD	mg/l					40	20	
COD Total	mg/l			95	56	72	47	50
TSS	mg/l			120		108		144
TDS	mg/l			390		674		584
Outflow A Character								
Outflow	m3/d			74120	68562	63151	54469	54469
BOD	mg/l					80	90	
COD Total	mg/l			206	230	224	172	193
COD Filtered	mg/l			71		120		161
TSS	mg/l			60		44		172
TDS	mg/l			666		758		660
Outflow B Character								
Outflow	m3/d			122199	122199	114886	105960	92188
BOD	mg/l					50	100	
COD Total	mg/l			222	79	200	219	153
COD Filtered	mg/l			159		48		121
TSS	mg/l			124		56		144
TDS	mg/l			660		696		596
Outflow C Character								
Outflow	m3/d			40973	39260	35908	34269	31070
BOD	mg/l					80	100	
COD Total	mg/l			254	127	224	156	209
COD Filtered	mg/l			103		144		154
TSS	mg/l			112		54		200
TDS	mg/l			684		680		576

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 24TH NOVEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov
Inflow	m3/d	117544	97033	114204	105201	101662	96756	104215
Inflow character								
BOD	mg/l					620	360	700
COD Total	mg/l			3485	840	1426	523	1866
TSS	mg/l			422		1264		608
TDS	mg/l			694		830		984
PUMP STATION								
Inflow	m3/d	577	608	55	65	68	64	74
Inflow character								
BOD	mg/l					140	160	250
COD Total	mg/l			232	317	293	291	470
TSS	mg/l			102		116		348
TDS	mg/l			868		596		992
Outflow A Character								
Outflow	m3/d			51118	47838	43056	24402	24402
BOD	mg/l					50	35	90
COD Total	mg/l			189	141	164	171	177
COD Filtered	mg/l			94		70		108
TSS	mg/l			78		68		8
TDS	mg/l			580		596		732
Outflow B Character								
Outflow	m3/d			97278	97278	90512	75898	59242
BOD	mg/l					50	60	60
COD Total	mg/l			157	156	133	163	115
COD Filtered	mg/l			102		94		100
TSS	mg/l			88		10		8
TDS	mg/l			548		646		716
Outflow C Character								
Outflow	m3/d			30287	31860	28741	28741	31070
BOD	mg/l					30	60	60
COD Total	mg/l			189	141	180	147	192
COD Filtered	mg/l			126		109		46
TSS	mg/l			10		32		20
TDS	mg/l			572		596		680

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 1ST DECEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov	01-Dec
Inflow	m3/d	121635	112401	90108	80055	84740	95218	97930
Inflow character								
BOD	mg/l			360		880	540	400
COD Total	mg/l			1240		1725	794	388
TSS	mg/l			44		760		178
TDS	mg/l			588		942		872
PUMP STATION								
Inflow	m3/d	80	150	670	593	136	67	67
Inflow character								
BOD	mg/l			160		120	100	150
COD Total	mg/l			396		291	206	301
TSS	mg/l			164		142		150
TDS	mg/l			524		702		576
Outflow A Character								
Outflow	m3/d			25709		25709	24402	20620
BOD	mg/l			35		25	35	25
COD Total	mg/l			132		178	140	155
COD Filtered	mg/l			124		78		62
TSS	mg/l			32		34		20
TDS	mg/l			536		598		636
Outflow B Character								
Outflow	m3/d			97278		68157	60699	65139
BOD	mg/l			60		30	60	30
COD Total	mg/l			140		202	155	147
COD Filtered	mg/l			109		124		100
TSS	mg/l			20		88		30
TDS	mg/l			520		636		672
Outflow C Character								
Outflow	m3/d			33459		22127	22127	24995
BOD	mg/l			60		10	30	10
COD Total	mg/l			202		155	155	163
COD Filtered	mg/l			109		93		100
TSS	mg/l			56		66		56
TDS	mg/l			488		614		620

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 8TH DECEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		02-Dec	03-Dec	04-Dec	05-Dec	06-Dec	07-Dec	08-Dec
Inflow	m3/d	96102	97843	80360	89302	84296	85037	97121
Inflow character								
BOD	mg/l	280				440	560	460
COD Total	mg/l	603		992	629	699	882	794
TSS	mg/l			484		266		264
TDS	mg/l			740		756		744
PUMP STATION								
Inflow	m3/d	57	56	54	61	60	455	408
Inflow character								
BOD	mg/l	300				190	230	45
COD Total	mg/l	460		738	2419	314	420	1111
TSS	mg/l			224		136		460
TDS	mg/l			1348		1110		396
Outflow A Character								
Outflow	m3/d	20620		39963	31159	29764	27039	29764
BOD	mg/l	95				75	70	80
COD Total	mg/l	185		150	266	167	193	175
COD Filtered	mg/l			87		97		127
TSS	mg/l			38		26		36
TDS	mg/l			568		606		576
Outflow B Character								
Outflow	m3/d	68157		114886	53535	52138	56364	60699
BOD	mg/l	80				100	80	120
COD Total	mg/l	121		198	242	221	202	294
COD Filtered	mg/l			95		128		186
TSS	mg/l			62		38		40
TDS	mg/l			630		694		672
Outflow C Character								
Outflow	m3/d	22126		22833	19377	18709	20053	23546
BOD	mg/l	130				90	110	120
COD Total	mg/l	202		174	347	143	185	198
COD Filtered	mg/l			71		97		151
TSS	mg/l			82		80		44
TDS	mg/l			578		602		560

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 15TH DECEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		09-Dec	10-Dec	11-Dec	12-Dec	13-Dec	14-Dec	15-Dec
Inflow	m3/d	110394	104579	105722	92677	98928	95486	90716
Inflow character								
BOD	mg/l					260	640	726
COD Total	mg/l			626		592	860	1851
TSS	mg/l			288		220		1008
TDS	mg/l			524		744		724
PUMP STATION								
Inflow	m3/d	84	66	67	57	59	62	58
Inflow character								
BOD	mg/l					190	120	166
COD Total	mg/l			417		357	236	402
TSS	mg/l			260		120		36
TDS	mg/l			1888		1012		916
Outflow A Character								
Outflow	m3/d			32576		32576	28391	23118
BOD	mg/l					60	95	104
COD Total	mg/l			236		310	172	205
COD Filtered	mg/l			213		63		126
TSS	mg/l			72		74		96
TDS	mg/l			504		602		544
Outflow B Character								
Outflow	m3/d			68157		59242	65139	63647
BOD	mg/l					80	100	110
COD Total	mg/l			181		238	164	197
COD Filtered	mg/l			102		127		165
TSS	mg/l			68		56		36
TDS	mg/l			616		716		640
Outflow C Character								
Outflow	m3/d			25730		25730	22832	24995
BOD	mg/l					90	120	147
COD Total	mg/l			197		230	124	173
COD Filtered	mg/l			31		151		94
TSS	mg/l			100		112		104
TDS	mg/l			556		606		540

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 22nd DECEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		16-Dec	17-Dec	18-Dec	19-Dec	20-Dec	21-Dec	22-Dec
Inflow	m3/d	89373	83883	92553	97054	88864	79812	80358
Inflow character								
BOD	mg/l			520				900
COD Total	mg/l			833	839	827	890	2441
TSS	mg/l			198		712		1184
TDS	mg/l			1002		768		840
PUMP STATION								
Inflow	m3/d	55	51	53	65	50	47	
Inflow character								
BOD	mg/l			440				160
COD Total	mg/l			1105	685	496	419	346
TSS	mg/l			522		148		152
TDS	mg/l			2246		2926		728
Outflow A Character								
Outflow	m3/d			21857	20620	17057	23118	21857
BOD	mg/l			120				110
COD Total	mg/l			209	228	213	209	181
COD Filtered	mg/l			132		134		110
TSS	mg/l			96		36		48
TDS	mg/l			704		698		616
Outflow B Character								
Outflow	m3/d			53535	53534	62167	62167	53534
BOD	mg/l			90				120
COD Total	mg/l			171	181	165	194	157
COD Filtered	mg/l			147		134		94
TSS	mg/l			48		56		112
TDS	mg/l			784		748		636
Outflow C Character								
Outflow	m3/d			20737	20737	21428	21428	17397
BOD	mg/l			110				120
COD Total	mg/l			194	181	173	163	189
COD Filtered	mg/l			109		39		110
TSS	mg/l			132		54		24
TDS	mg/l			624		684		608

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 29TH DECEMBER 2017 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		23-Dec	24-Dec	25-Dec	26-Dec	27-Dec	28-Dec	29-Dec
Inflow	m3/d	87789	78222	84709	76334	78822	75530	77925
Inflow character								
BOD	mg/l					940	440	
COD Total	mg/l					1318	621	
TSS	mg/l					702		
TDS	mg/l					702		
PUMP STATION								
Inflow	m3/d	39	45	37	41	46	53	39
Inflow character								
BOD	mg/l					200	130	
COD Total	mg/l					295	213	
TSS	mg/l					160		
TDS	mg/l					476		
Outflow A Character								
Outflow	m3/d					19407	17057	
BOD	mg/l					125	85	
COD Total	mg/l					147	167	
COD Filtered	mg/l					116		
TSS	mg/l					94		
TDS	mg/l					636		
Outflow B Character								
Outflow	m3/d					56364	53534	
BOD	mg/l					70	70	
COD Total	mg/l					209	190	
COD Filtered	mg/l					93		
TSS	mg/l					34		
TDS	mg/l					718		
Outflow C Character								
Outflow	m3/d					20737	20053	
BOD	mg/l					85	140	
COD Total	mg/l					194	167	
COD Filtered	mg/l					109		
TSS	mg/l					26		
TDS	mg/l					676		

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 5TH JANUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		30-Dec	31-Dec	01-Jan	02-Jan	03-Jan	04-Jan	05-Jan
Inflow	m3/d	77041	88211	78285	83426	81121	77088	72502
Inflow character								
BOD	mg/l						620	320
COD Total	mg/l				531	1551	1106	686
TSS	mg/l					240		300
TDS	mg/l					1618		712
PUMP STATION								
Inflow	m3/d	42	52	46	53	63	48	49
Inflow character								
BOD	mg/l						220	190
COD Total	mg/l				461	411	504	452
TSS	mg/l					174		124
TDS	mg/l					868		848
Outflow A Character								
Outflow	m3/d				15920	14809	18220	21857
BOD	mg/l						115	90
COD Total	mg/l				178	178	186	218
COD Filtered	mg/l					101		129
TSS	mg/l					104		28
TDS	mg/l					680		676
Outflow B Character								
Outflow	m3/d				53534	60699	82287	65139
BOD	mg/l						70	60
COD Total	mg/l				186	171	295	298
COD Filtered	mg/l					124		129
TSS	mg/l					48		52
TDS	mg/l					766		688
Outflow C Character								
Outflow	m3/d				20053	21423	27977	20737
BOD	mg/l						160	140
COD Total	mg/l				217	202	194	258
COD Filtered	mg/l					116		121
TSS	mg/l					74		104
TDS	mg/l					712		668

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 12TH JANUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		06-Jan	07-Jan	08-Jan	09-Jan	10-Jan	11-Jan	12-Jan
Inflow	m3/d	81495	77996	55264	96350	84679	83602	81265
Inflow character								
BOD	mg/l					640	600	580
COD Total	mg/l			729	539	1404	1317	788
TSS	mg/l			200		620		164
TDS	mg/l			924		800		828
PUMP STATION								
Inflow	m3/d	50	38	34	37	34	48	47
Inflow character								
BOD	mg/l					380	280	360
COD Total	mg/l			591	369	1076	420	748
TSS	mg/l			254		712		416
TDS	mg/l			1710		1190		992
Outflow A Character								
Outflow	m3/d			20620	19408	20620	19408	20620
BOD	mg/l					90	90	70
COD Total	mg/l			150	200	231	168	181
COD Filtered	mg/l			134		146		173
TSS	mg/l			32		58		20
TDS	mg/l			700		716		752
Outflow B Character								
Outflow	m3/d			79071	57797	52138	57797	57797
BOD	mg/l					60	110	50
COD Total	mg/l			158	177	200	199	181
COD Filtered	mg/l			71		131		87
TSS	mg/l			36		50		32
TDS	mg/l			716		736		720
Outflow C Character								
Outflow	m3/d			18049	17397	18709	19377	19377
BOD	mg/l					160	160	70
COD Total	mg/l			189	200	208	130	244
COD Filtered	mg/l			134		154		126
TSS	mg/l			70		90		108
TDS	mg/l			692		704		712

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 19TH JANUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		13-Jan	14-Jan	15-Jan	16-Jan	17-Jan	18-Jan	19-Jan
Inflow	m3/d	78623	69299	85723	88477	91461	86718	84642
Inflow character								
BOD	mg/l					420	540	740
COD Total	mg/l			774	769	513	698	1890
TSS	mg/l			166				
TDS	mg/l			866				
PUMP STATION								
Inflow	m3/d	29	35	35	47	65	50	45
Inflow character								
BOD	mg/l					260	250	280
COD Total	mg/l			536	698	514	620	706
TSS	mg/l			348				
TDS	mg/l			1862				
Outflow A Character								
Outflow	m3/d			19408	19408	19408	17057	19408
BOD	mg/l					110	65	75
COD Total	mg/l			183	163	287	287	282
COD Filtered	mg/l			111				
TSS	mg/l			40				
TDS	mg/l			738				
Outflow B Character								
Outflow	m3/d			56364	50754	57797	62167	57797
BOD	mg/l					100	90	70
COD Total	mg/l			357	209	230	194	221
COD Filtered	mg/l			206				
TSS	mg/l			54				
TDS	mg/l			712				
Outflow C Character								
Outflow	m3/d			18049	17397	20737	20053	17397
BOD	mg/l					160	60	180
COD Total	mg/l			167	240	205	201	229
COD Filtered	mg/l			127				
TSS	mg/l			88				
TDS	mg/l			680				

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 26TH JANUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		20-Jan	21-Jan	22-Jan	23-Jan	24-Jan	25-Jan	26-Jan
Inflow	m3/d	72582	79436	84253	79221	81511	79409	78378
Inflow character								
BOD	mg/l					760	800	840
COD Total	mg/l			3307	1686	1322	590	1987
TSS	mg/l			932		842		444
TDS	mg/l			2262		924		398
PUMP STATION								
Inflow	m3/d	41	36	31	41	54	53	37
Inflow character								
BOD	mg/l					300	260	280
COD Total	mg/l			613	674	653	699	376
TSS	mg/l			180		246		66
TDS	mg/l			1062		988		508
Outflow A Character								
Outflow	m3/d			29075	25053	20620	20620	18219
BOD	mg/l					80	85	5
COD Total	mg/l			274	333	264	301	231
COD Filtered	mg/l			210		223		137
TSS	mg/l			92		74		46
TDS	mg/l			772		758		342
Outflow B Character								
Outflow	m3/d			47348	51444	54237	53535	56364
BOD	mg/l					70	100	70
COD Total	mg/l			153	225	223	211	291
COD Filtered	mg/l			81		99		179
TSS	mg/l			32		90		4
TDS	mg/l			744		736		352
Outflow C Character								
Outflow	m3/d			14562	15178	18378	17396	18709
BOD	mg/l					150	180	160
COD Total	mg/l			226	279	215	276	103
COD Filtered	mg/l			161		116		60
TSS	mg/l			92		100		2
TDS	mg/l			714		712		320

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 2ND FEBRUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		27-Jan	28-Jan	29-Jan	30-Jan	31-Jan	01-Feb	02-Feb
Inflow	m3/d			76085	78126	81833	71724	80645
Inflow character								
BOD	mg/l					760	540	740
COD Total	mg/l			2658	1550	1473	1477	1673
TSS	mg/l			346		874		1376
TDS	mg/l			758		980		616
PUMP STATION								
Inflow	m3/d			54	61	61	36	46
Inflow character								
BOD	mg/l					240	520	540
COD Total	mg/l			748	1550	349	1591	827
TSS	mg/l			222		168		204
TDS	mg/l			2410		820		2616
Outflow A Character								
Outflow	m3/d			17635	11141	10646	18220	18220
BOD	mg/l					70	60	60
COD Total	mg/l			252	194	295		284
COD Filtered	mg/l			181		209		244
TSS	mg/l			34		60		56
TDS	mg/l			782		786		712
Outflow B Character								
Outflow	m3/d			57797	59969	57797	54943	79071
BOD	mg/l					80	100	90
COD Total	mg/l			205	225	186	227	213
COD Filtered	mg/l			110		101		126
TSS	mg/l			64		90		144
TDS	mg/l			730		770		564
Outflow C Character								
Outflow	m3/d			17397	18378	19714	20054	19377
BOD	mg/l					40	40	40
COD Total	mg/l			181	140	155	174	165
COD Filtered	mg/l			118		85		102
TSS	mg/l			58		70		120
TDS	mg/l			712		740		600

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 9TH FEBRUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		03-Feb	04-Feb	05-Feb	06-Feb	07-Feb	08-Feb	09-Feb
Inflow	m3/d	79571	76014	69546	108177	92366	92625	84038
Inflow character								
BOD	mg/l					500	400	480
COD Total	mg/l			935	1076	598	551	734
TSS	mg/l			420		554		224
TDS	mg/l			940		694		768
PUMP STATION								
Inflow	m3/d	48	55	57	59	70	53	57
Inflow character								
BOD	mg/l					280	220	240
COD Total	mg/l			1642	1136	536	394	556
TSS	mg/l			542		178		96
TDS	mg/l			5478		860		800
Outflow A Character								
Outflow	m3/d			17057	14809	19407	25053	29.75
BOD	mg/l					75	55	75
COD Total	mg/l			275	267	289	307	310
COD Filtered	mg/l			183		259		198
TSS	mg/l			120		172		48
TDS	mg/l			782		704		780
Outflow B Character								
Outflow	m3/d			48023	52138	56364	49382	57797
BOD	mg/l					90	140	70
COD Total	mg/l			214	410	223	142	206
COD Filtered	mg/l			168		140		151
TSS	mg/l			92		120		88
TDS	mg/l			784		680		756
Outflow C Character								
Outflow	m3/d			19377	21428	24269	19714	23546
BOD	mg/l					50	40	60
COD Total	mg/l			191	323	181	165	254
COD Filtered	mg/l			107		91		151
TSS	mg/l			72		38		64
TDS	mg/l			746		754		712

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 16TH FEBRUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		10-Feb	11-Feb	12-Feb	13-Feb	14-Feb	15-Feb	16-Feb
Inflow	m3/d	88853	81949	86550	83166	72674	75152	84958
Inflow character								
BOD	mg/l					580	440	720
COD Total	mg/l			553	1480	909	653	1196
TSS	mg/l			98		488		440
TDS	mg/l			868		878		1164
PUMP STATION								
Inflow	m3/d	61	51	55	49	70	54	50
Inflow character								
BOD	mg/l					340	230	260
COD Total	mg/l			420	820	603	1308	447
TSS	mg/l			182		184		392
TDS	mg/l			770		1074		884
Outflow A Character								
Outflow	m3/d			39963	25709	41500	34013	35470
BOD	mg/l					290	115	65
COD Total	mg/l			359	332	493	318	408
COD Filtered	mg/l			298		281		
TSS	mg/l			68		66		0
TDS	mg/l			842		900		872
Outflow B Character								
Outflow	m3/d			64392	62127	41421	50754	45343
BOD	mg/l					170	150	110
COD Total	mg/l			282	236	264	302	149
COD Filtered	mg/l			107		107		
TSS	mg/l			94		88		44
TDS	mg/l			796		834		820
Outflow C Character								
Outflow	m3/d			19714	20737	24995	24995	15488
BOD	mg/l					40	40	40
COD Total	mg/l			221	236	223	261	251
COD Filtered	mg/l			137		58		
TSS	mg/l			58		98		72
TDS	mg/l			762		796		760

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 23RD FEBRUARY 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		17-Feb	18-Feb	19-Feb	20-Feb	21-Feb	22-Feb	23-Feb
Inflow	m3/d	90129	82829	82944	97672	82820	84573	93624
Inflow character								
BOD	mg/l					390	940	660
COD Total	mg/l							
TSS	mg/l			3200		938		636
TDS	mg/l			1010		870		768
PUMP STATION								
Inflow	m3/d	54	58	58	56	67	53	53
Inflow character								
BOD	mg/l					419	300	400
COD Total	mg/l							
TSS	mg/l			336		164		704
TDS	mg/l			1872		956		2132
Outflow A Character								
Outflow	m3/d			46226	46226	46226	44631	39963
BOD	mg/l					98	175	180
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			44		96		28
TDS	mg/l			900		874		904
Outflow B Character								
Outflow	m3/d			73546	73546	62167	53535	57797
BOD	mg/l					158	120	110
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			70		94		136
TDS	mg/l			832		788		820
Outflow C Character								
Outflow	m3/d			18049	20737	23546	21428	17397
BOD	mg/l					13	130	120
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			70		194		184
TDS	mg/l			760		700		752

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 2ND MARCH 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		24-Feb	25-Feb	26-Feb	27-Feb	28-Feb	01-Mar	02-Mar
Inflow	m3/d	87354	90068	86348	87133	75766	90800	103173
Inflow character								
BOD	mg/l					680	660	780
COD Total	mg/l							
TSS	mg/l			1226		756		1464
TDS	mg/l			2204		828		792
PUMP STATION								
Inflow	m3/d	56	66	65	68	68	75	63
Inflow character								
BOD	mg/l					480	300	360
COD Total	mg/l							
TSS	mg/l			516		296		320
TDS	mg/l			2674		1882		1412
Outflow A Character								
Outflow	m3/d			38446	38447	38446	41500	41500
BOD	mg/l					165	165	130
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			54		28		100
TDS	mg/l			854		848		836
Outflow B Character								
Outflow	m3/d			61431	63647	62167	82827	93030
BOD	mg/l					190	110	150
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			48		110		152
TDS	mg/l			840		812		792
Outflow C Character								
Outflow	m3/d			20737	21428	20737	22833	29125
BOD	mg/l					130	80	100
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			112		70		56
TDS	mg/l			766		746		840

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 9TH MARCH 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		03-Mar	04-Mar	05-Mar	06-Mar	07-Mar	08-Mar	09-Mar
Inflow	m3/d	118144	125110	133825	121372	140621	137203	133155
Inflow character								
BOD	mg/l					80	300	80
COD Total	mg/l							
TSS	mg/l			802		234		668
TDS	mg/l			3494		500		652
PUMP STATION								
Inflow	m3/d	14	136	1054	1847	1444	313	167
Inflow character								
BOD	mg/l					20	40	50
COD Total	mg/l							
TSS	mg/l			394		268		60
TDS	mg/l			682		534		792
Outflow A Character								
Outflow	m3/d			66742	85659	97742	108209	91634
BOD	mg/l					125	95	105
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			166		54		72
TDS	mg/l			834		680		628
Outflow B Character								
Outflow	m3/d			107726	124050	124050	124050	105960
BOD	mg/l					140	130	150
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			64		90		92
TDS	mg/l			858		706		672
Outflow C Character								
Outflow	m3/d			28741	53624	46225	46255	37571
BOD	mg/l					80	90	90
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			74		110		20
TDS	mg/l			792		654		672

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 16TH MARCH 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar
Inflow	m3/d	122322	114681	132775	142787	142322	133945	151
Inflow character								
BOD	mg/l					320	440	180
COD Total	mg/l							
TSS	mg/l			36		1078		1144
TDS	mg/l			832		620		812
PUMP STATION								
Inflow	m3/d	108	142	202	532	313	924	950
Inflow character								
BOD	mg/l					30	70	30
COD Total	mg/l							
TSS	mg/l			192		240		148
TDS	mg/l			434		812		456
Outflow A Character								
Outflow	m3/d			63151	57890	54469	54469	54469
BOD	mg/l					55	50	55
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			12		22		68
TDS	mg/l			662		594		632
Outflow B Character								
Outflow	m3/d			90512	102457	116700	116700	116700
BOD	mg/l					120	100	90
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			96		36		112
TDS	mg/l			704		718		612
Outflow C Character								
Outflow	m3/d			33460	40113	38412	39263	38837
BOD	mg/l					50	70	80
COD Total	mg/l							
COD Filtered	mg/l							
TSS	mg/l			84		76		32
TDS	mg/l			686		646		612

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 23RD MARCH 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar
Inflow	m3/d	117787	128680	151435	142130	130832	126049	126179
Inflow character								
BOD	mg/l					80	240	600
COD Total	mg/l					261	520	1180
TSS	mg/l			728		88		1220
TDS	mg/l			2614		542		748
PUMP STATION								
Inflow	m3/d	646	1289	876	391	205	95	92
Inflow character								
BOD	mg/l					10	20	210
COD Total	mg/l					38	331	356
TSS	mg/l			238		40		204
TDS	mg/l			730		462		1692
Outflow A Character								
Outflow	m3/d			83697	160694	99807	77904	70399
BOD	mg/l					60	120	40
COD Total	mg/l					176	142	112
COD Filtered	mg/l					92		40
TSS	mg/l			26		92		92
TDS	mg/l			688		572		472
Outflow B Character								
Outflow	m3/d			124050	124050	113082	120357	112281
BOD	mg/l					60	80	60
COD Total	mg/l					84	157	192
COD Filtered	mg/l					168		80
TSS	mg/l			74		30		140
TDS	mg/l			612		660		512
Outflow C Character								
Outflow	m3/d			42710	124050	35085	39259	31070
BOD	mg/l					50	60	60
COD Total	mg/l					176	252	120
COD Filtered	mg/l					168		80
TSS	mg/l			144		80		116
TDS	mg/l			648		664		492

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 30TH MARCH 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar
Inflow	m3/d	122421	114117	133967	119877	116569	125551	115366
Inflow character								
BOD	mg/l					340	880	
COD Total	mg/l			793	833	608	1398	
TSS	mg/l			217		214		
TDS	mg/l			854		742		
PUMP STATION								
Inflow	m3/d	89	137	212	88	84	73	70
Inflow character								
BOD	mg/l					100	120	
COD Total	mg/l			179	516	315	944	
TSS	mg/l			184		116		
TDS	mg/l			600		840		
Outflow A Character								
Outflow	m3/d			52784	47838	46226	43056	
BOD	mg/l					35	30	
COD Total	mg/l			98	302	296	110	
COD Filtered	mg/l							
TSS	mg/l			20		50		
TDS	mg/l			584		494		
Outflow B Character								
Outflow	m3/d			112281	104204	100721	87191	
BOD	mg/l					70	50	
COD Total	mg/l			106	159	277	150	
COD Filtered	mg/l							
TSS	mg/l			20		60		
TDS	mg/l			600		566		
Outflow C Character								
Outflow	m3/d			52683	38412	36736	32657	
BOD	mg/l					40	40	
COD Total	mg/l			170	214	388	110	
COD Filtered	mg/l							
TSS	mg/l			82		36		
TDS	mg/l			562		430		

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 6TH APRIL 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		31-Mar	01-Apr	02-Apr	03-Apr	04-Apr	05-Apr	06-Apr
Inflow	m3/d	110763	103237	117345	115085	113672	102634	111616
Inflow character								
BOD	mg/l					720	740	320
COD Total	mg/l				2204	1071	1417	1218
TSS	mg/l					1656		
TDS	mg/l					702		
PUMP STATION								
Inflow	m3/d	65	93	80	31	82	76	30
Inflow character								
BOD	mg/l					460	180	280
COD Total	mg/l				856	555	236	580
TSS	mg/l					394		
TDS	mg/l					632		
Outflow A Character								
Outflow	m3/d				36948	23118	27039	31160
BOD	mg/l					20	110	115
COD Total	mg/l				144	50	229	202
COD Filtered	mg/l					25		
TSS	mg/l					32		
TDS	mg/l					542		
Outflow B Character								
Outflow	m3/d				80673	92188	85546	72768
BOD	mg/l					60	50	70
COD Total	mg/l				186	143	268	244
COD Filtered	mg/l					84		
TSS	mg/l					28		
TDS	mg/l					588		
Outflow C Character								
Outflow	m3/d				33460	38412	33460	30287
BOD	mg/l					40	30	30
COD Total	mg/l				314	328	189	244
COD Filtered	mg/l					76		
TSS	mg/l					76		
TDS	mg/l					552		

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 13TH APRIL 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		07-Apr	08-Apr	09-Apr	10-Apr	11-Apr	12-Apr	13-Apr
Inflow	m3/d	112223	94442	100841	98937	129322	105542	120679
Inflow character								
BOD	mg/l					460	380	440
COD Total	mg/l			4350	177	1680	696	903
TSS	mg/l							
TDS	mg/l							
PUMP STATION								
Inflow	m3/d	72	73	114	126	330	106	557
Inflow character								
BOD	mg/l					320	40	90
COD Total	mg/l			398	213	1289	48	213
TSS	mg/l							
TDS	mg/l							
Outflow A Character								
Outflow	m3/d			28391	31159	28391	32576	36948
BOD	mg/l					100	105	90
COD Total	mg/l			163	165	133	192	172
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							
Outflow B Character								
Outflow	m3/d			82287	95571	72768	74327	74327
BOD	mg/l					90	120	60
COD Total	mg/l			154	126	148	160	230
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							
Outflow C Character								
Outflow	m3/d			31070	33460	27222	35085	27978
BOD	mg/l					50	50	50
COD Total	mg/l			114	141	188	120	180
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							

WEEKLY REPORT FOR DANDORA WWT PLANT WEEK END 20TH APRIL 2018 (LABORATORY)								
Measurement	Unit	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Day		14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr
Inflow	m3/d	120088	129559	131480	147925	138633	91982	127186
Inflow character								
BOD	mg/l						340	580
COD Total	mg/l			2358	404	346	882	1360
TSS	mg/l							
TDS	mg/l							
PUMP STATION								
Inflow	m3/d	1017	285	779	298	1725	175	
Inflow character								
BOD	mg/l						20	170
COD Total	mg/l			96	97	114	66	504
TSS	mg/l							
TDS	mg/l							
Outflow A Character								
Outflow	m3/d			39963	43056	44632	44632	54469
BOD	mg/l						80	70
COD Total	mg/l			96	170	171	148	192
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							
Outflow B Character								
Outflow	m3/d			113082	115792	118523	107726	79071
BOD	mg/l						90	100
COD Total	mg/l			73	170	187	189	248
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							
Outflow C Character								
Outflow	m3/d			43587	63331	44471	40113	28741
BOD	mg/l						60	20
COD Total	mg/l			130	235	187	238	296
COD Filtered	mg/l							
TSS	mg/l							
TDS	mg/l							

APPENDIX 2

MONTHS	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	**Mean**
Flowrate (m^3day^{-1})									
Main inlet	85347	88788	103606	89611	79415	83452	117229	115382	95353.75
Pump station inlet	27	103	264	73	47	55	319	325	151.625
Outlet A	30740	38845	40843	23727	18478	31546	66872	35469	35815
Outlet B	53896	56559	90992	61750	58032	58377	106714	89829	72018.63
Outlet C	20926	21755	28771	22338	19013	20753	37390	36305	25906.38
BOD(mgl^{-1})									
Main inlet	623	518	526	547	635	589	383	497	539.75
Pump Station inlet	201	148	117	193	275	352	104	195	198.125
Outlet A	103	109	61	87	78	117	81	86	90.25
Outlet B	97	69	62	87	77	124	100	80	87
Outlet C	68	75	55	106	135	61	68	50	77.25
COD(mgl^{-1})									
Main inlet	1763	2117	1340	926	1266	986	799	1361	1319.75
Pump Station inlet	539	370	230	596	625	856	382	376	496.75
Outlet A	311	269	188	198	228	330	196	159	234.875
Outlet B	305	256	182	192	217	239	160	180	216.375
Outlet C	286	288	191	188	202	220	204	207	223.25
TSS(mgl^{-1})									
Main inlet	1274	1299	623	500	466	863	657	1656	917.25
Pump Station inlet	136	144	154	215	264	316	200	394	227.875
Outlet A	77	59	67	57	53	65	64	32	59.25
Outlet B	104	91	80	52	50	94	80	28	72.375
Outlet C	90	87	73	74	77	96	75	76	81
TDS(mgl^{-1})									
Main inlet	827	902	726	765	1006	697	1100	702	840.625
Pump Station inlet	1235	1016	666	1238	1203	1933	787	632	1088.75
Outlet A	772	776	628	608	700	831	639	542	687
Outlet B	723	834	644	684	697	777	667	588	701.75
Outlet C	739	783	622	604	669	737	641	552	668.375