GEORGE MUNICIPALITY

GWAING WASTEWATER TREATMENT WORKS

OPERATIONS & MAINTENANCE MANUAL

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CONTENTS

1 INTRODUCTION

1.1 IMPORTANCE OF EFFLUENT QUALITY

Increased consumption of water resources due to population increase and industrial factors has driven the implementation of stringent measures by regulatory agencies for treatment of wastewater to remove organic matter and other toxic material such as heavy metals and nutrients. The increase in fresh water contaminants originating from agricultural runoff of fertilizers, industrial effluents and poor treatment of domestic wastewater has exacerbated the continuing depletion of fresh water resources, thus putting a strain in natural means for the environment to deplete the pollutants.

In order to remove the burden from the natural environment, wastewater treatment works can be used to mimic natural conditions to remove pollutants, pathogens and the high energy contained in the wastewater. A growing concern for the concentration of nitrogen as nitrate or ammonium and phosphorus has seen more wastewater treatment works have to include nutrient removal as part of the treatment process.

As such the purpose of wastewater treatment is to:

(i) Satisfy the oxygen demand of the sewage. This can be split into two different categories – that of the organic compounds (DOD) and that of the ammonia. This requires the supply of oxygen to the sewage. In the activated sludge plant this is supplied by mechanical aerators, and in the biofilter works the oxygen is absorbed as the water trickles over the stones exposed to the atmosphere.

(ii) Nutrient Removal - Nitrogen and Phosphorus (N as NH_4^+ / NO_3^- and P as PO_4^{2-}) – this reduces the chance of eutrophication (nutrient enrichment of water) of the receiving waters. Eutrophication in warm climates generally results in algal blooms which pollute the water and can be toxic.

(iii) Removal of solids – solids in the final effluent will tend to settle in the receiving river or dam and affect the normal biological processes by covering the bottom of the water body. In addition to this the solids absorb oxygen which lowers the dissolved oxygen in the river and kills the natural biota and causes fish kills.

(iv) Removal of Pathogens - Pathogens infect human beings and animals upon ingestion, and can result in disease which can at times be fatal. This is particularly serious where HIV positive individuals with reduced immunity are involved. The cost of disinfection is generally far lower than treating the diseases which would arise in the absence of disinfection.

In summary, wastewater is treated in order to render it safe to return to the river for further use. As such it should have a low oxygen demand, low nutrients and solids, and the pathogens should be disinfected.

1.2 LEGAL REQUIREMENTS FOR EFFLUENT COMPLIANCE

Table XXX: Final Effluent Quality required

Parameter	Original Standard	After 2006
COD mg/l	<75	<65
Ammonia mgN/l	<10	<3
Nitrate + nitrite mgN/l	Not specified	<15
Orthophosphate mgP/l	Not Specified	<1
Total SS mg/l	<25	<18

The “2006” standards were provided by DWAF with the proviso that should the standards not be achievable an application could be made for them to be relaxed. The chief standard of concern is that for ammonia which appears to stem from the General Authorisation for works <2Ml/d and has subsequently been increased to 6mg/l as it is too stringent.

1.3 ENERGY CONSIDERATIONS

Electricity is becoming expensive in South Africa and has an associated carbon footprint which results in global warming. As such the energy used should be kept to a minimum and thus wherever possible the most energy efficient route should be taken. In the case of the Gwaing WWTW this means:

- The biofilter works should be run whenever possible as the first choice of treatment. This may however be a problem in that the phosphate standard would be difficult to achieve.

- The aeration and pumping rates on the activated sludge plant should be kept to a minimum. As such the aeration setpoint for DO should be set as low as possible and the pumping rates should be reduced whenever possible, particularly at night and over weekends when flows are decreased.

1.4 PROCESS SELECTION

The Gwaing Wastewater Treatment Works was developed in 3 phases:

(i) Phase I (Mid 1970's) – A 6Ml/d conventional biological filter works was constructed including primary settling tanks and anaerobic digesters.

(ii) Phase 2 (1998) - the plant was extended to treat 11Ml/d. The use of primary sedimentation tanks and the anaerobic digesters was discontinued, being substituted with a set of two anaerobic and two facultative ponds. After passing through the ponds the effluent was passed over the biological filters (Petro process).

(iii) Phase 3 (2008) - the existing mothballed primary sedimentation tanks and digesters for the biofilter plant were re-commissioned to restore this process back to its original form but with a decreased capacity (3.6Ml/d instead of 6Ml/d) to increase nitrification and hence the quality of the effluent. In addition to this the Petro process ponds were replaced with a Biological Nutrient Removal (BNR) plant (UCT process) which is the state of the art technology for nutrient removal. The capacity of the BNR plant is 7.3Ml/d, which together with the biofilter plant gives a total treatment capacity of 11Ml/d (ADWF). The waste activated sludge generated by the UCT process is mechanically thickened and dewatered.

2 ABBREVIATIONS

The following abbreviations are used in this manual

ADWF – Average Dry Weather Flow
BNR – Biological Nutrient Removal
COD – Chemical Oxygen Demand
DO – Dissolved Oxygen
HMI – Human Machine Interface
MLSS – Mixed Liquor Suspended Solids
PST – Primary Settling Tanks
PWWF - Peak Wet Weather Flow
RAS – Return Activated Sludge
SST – Secondary Settling Tanks

UCT – University of Cape Town
VFA's – Volatile Fatty Acids
WAS – Waste Activated Sludge
WWTW – Wastewater Treatment Works

3 PROCESS FLOW DIAGRAM

Please see Appendix A

4 PROCESS MONITORING

4.1 STATUTORY MONITORING

Weekly samples of the raw sewage and final effluent are taken and analysed at the George Municipal Laboratory.

4.2 PROCESS MONITORING

The activated sludge plant operation is monitored as follows:

Sample	Analysis	Frequency
Mixed liquor	MLSS	2 x weekly
Final effluent	SRP Nitrate Ammonia	Daily
Final effluent	pH Alkalinity Temperature	4 hourly

5 PROCESS TROUBLESHOOTING

A Process Troubleshooting matrix is given in Appendix C.

6 PROCESS DESCRIPTION

The plant consists of the following:

6.1 PRE-TREATMENT

Description	Function	Capacity
Head of Works 1. Vacuum tanker offload bay 2. Nightsoil offload bay 3. Coarse screen (100mm) 4. Mechanical drum screens (2N^{o}) 5. Vortex degritter 6. Grit channels	1. Vacuum tanker emptying 2. Nightsoil offloading – includes dilution sumps 3. To remove large foreign objects such as branches or sacks 4. To remove foreign objects such as plastic bags and rags 5. To remove inorganic substances such as small stones and sand 6. To remove inorganic substances such as stones and sand	11Ml/d (ADWF)
Splitter or division box	To divide the flow between the biofilter plant (3.7Ml/d) and the activated sludge process (7.3Ml/d)	11Ml/d (ADWF)

6.2 BIOFILTER PLANT (3.7ML/D)

Description	Function
Primary sedimentation tanks (2N$^{o.}$)	To remove settleable COD for treatment in digester
Biofilters (2N$^{o.}$)	To remove COD, nitrify and denitrify
Humus tanks (2N$^{o.}$)	To remove the settleable material (humus) from the biofilter effluent
Biofilter recycle pumps (2N$^{o.}$)	To recycle the biofilter effluent back to the biofilter to improve nitrification
Humus recycling pumps (2N$^{o.}$)	To recycle the humus tank underflow to the primary settling tanks
Primary sludge pumps (2N$^{o.}$)	To transfer the raw sludge from the primary settling tanks to the anaerobic equipment
Anaerobic digester for primary sludge	To process the raw sludge by a process of lysis, acidogenesis and methanogenisis to reduce the COD and solids in the sludge and render it stable for disposal.
Drying beds	For drying the anaerobically digested sludge

6.3 BNR ACTIVATED SLUDGE PLANT (7.3ML/D)

Description	Function
Anaerobic basin receiving recycle from the anoxic basin (R-recycle) and equipped with two vertical shaft mixers to suspend biomass	Phosphate release from the activated sludge floc takes place under anaerobic conditions
Anoxic basin equipped with four vertical shaft mixers to suspend biomass	Denitrifies nitrates to nitrogen gas under anoxic conditions
Aeration basin with six surface mounted aerators	To oxidise organics and nitrify ammonia – the first two aerators run permanently, the next four aerators run in cycle depending on the DO level at the end of the aeration basin
Secondary settling tanks (SSTs) – flat bottom, sludge suction design	Separates the activated sludge biomass from the final effluent. The underflow is pumped back to the anoxic tank
A – Recycle pumps (3N^{o}) – axial flow	Recycle of nitrified activated sludge from aeration basin to anoxic basin
R – recycle (3N^{o}) – axial flow	Recycle of denitrified activated sludge from anoxic basin to anaerobic basin
S - Recycle pumpstation (2N^{o}) in RAS/WAS pumpstation	Transfers Return Activated Sludge (RAS) from SST's to anoxic basin
WAS pumps (2No) in RAS/WAS pumpstation	Transfers RAS to WAS sump at dewatering plant

6.4 TERTIARY TREATMENT

Description	Function
Chlorination	To dose chlorine to the final effluent
Maturation ponds (4N^{o})	To allow aeration and dissipate chlorine

6.5 SLUDGE HANDLING

Description	Function
Sludge storage sump (Outeniqua)	To hold DAF thickened sludge pumped from Outeniqua WWTW
Sludge storage sump (Gwaing)	To hold XXX sludge from Gwaing WWTW
Beltpress for Outeniqua DAF thickened WAS	No linear screen upfront due to DAF thickening
Beltpress for Gwaing WAS	Linear screen upstream due to no DAF thickening of WAS

7 PROCESS THEORY

7.1 BIOFILTER THEORY

7.1.1 INTRODUCTION

One of the earlier methods of treating sewage was to run it into a tank filled with loose stone. After some 12 hours contact, the sewage was drained away and the stone left in contact with air. After a period of time a biological slime grew on the stone, which affected the oxidation of the sewage. These units were known as contact filters.

A modification to convert them to continuous operation, rather than batch, was made in 1893. The sewage was distributed across the surface of the contact bed by means of a moving mechanism. This was to prevent all the sewage falling on one spot and short-circuiting the greater mass of stone. The modern biological filter also known as tricking or percolating filter, was developed from this concept.

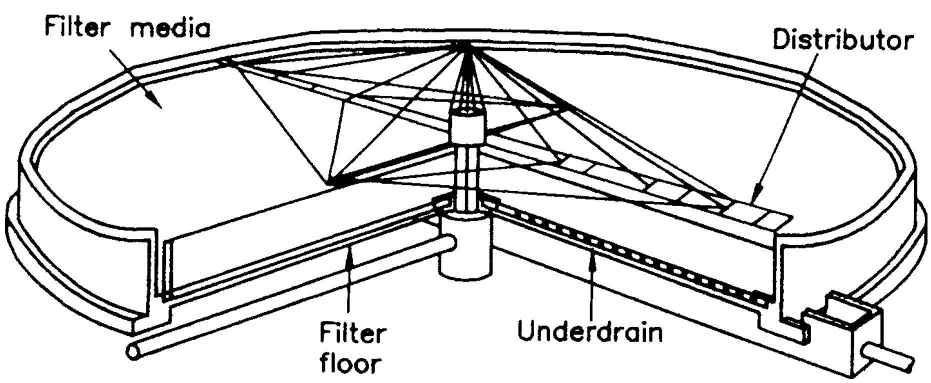


Figure :7.1 Cutaway view of a trickling filter

7.1.2 DESCRIPTION OF A BIOLOGICAL FILTER

A cutaway view of such a filter is given above. Not all biological filters are circular; the older designs were often rectangular in shape to save space. The principle of the operation remains the same irrespective of the shape.

The filter consists of an outer shell often made of concrete or interlocking cement retaining blocks. There are under-drains on the floor of the filter, which fulfil two requirements:

- To collect the effluent from the bottom of the filter and discharge it into a main drain.
- To allow the free passage of air through the filter.

This is important, as the micro-organisms, which grow in a filter, require oxygen from the air to live.

The shell is filled with filter media, the most common being crushed stone which has been carefully graded to ensure that flat pieces are eliminated. The size of stone commonly varies from 25 - 100 mm in diameter. The depth of the media also varies from 900 - 4 000 mm, the average being approximately 1 800 mm.

The filter media can also consist of coke, gravel, blast furnace slag, broken bricks, etc, but if used these commodities must be strong enough to support their own mass without failure. The media should also be weather resistant and not dissolve in the sewage. In the last 20 years, specifically designed plastic media has been available which has a much higher specific surface area and provides a support on which the bacteria can grow and its surface should, therefore be reasonably rough. All media should provide adequate air spaces between the individual pieces of media for ventilation. This is particularly important at higher loadings such as apply to plastic media.

Effluent from the primary clarifiers should desirably be applied to the biological filters in such a way that the distribution mechanism does not stick in one place thus continuously overloading that portion of the media. Placing a small balancing or dosing siphon between the primary clarifiers and the filter often overcomes this difficulty.

It is important in any distribution system that every portion of the media receives the same quantity of flow. In the case of circular filters, this means that distributor arms must be constructed to permit proportionately increasing amounts of effluent to be discharged from the inner pivot point to the outer circumference of the filter. This is done by spacing the holes closer together towards the ends.

Rotation is achieved by forcing water through the distribution holes and pushing the freely moving pipe away from the falling water. The available head of water and the size of the holes in the distribution pipe control the speed of rotation

7.1.3 PRINCIPLES OF BIOLOGICAL FILTRATION

Sewage is a suitable source of food for the micro-organisms in a biological filter as it contains nitrogen, organic carbon compounds, phosphorus and trace elements. Air circulates in the voids between the media, taking oxygen to the slime layer on the surface of the media. As sewage trickles over the media, the various organic substances are absorbed onto the biological film thus supplying the organisms with food.

Oxygen, which is present in the voids of the filter, dissolves in the water and is then transported to the slime layer. Metabolism of the substrate then takes place. If either food or oxygen is absent, this metabolism will stop. End products, which result from metabolism, are mainly water and carbon dioxide, which are liberated from the slime layer back into the main water flow. This process is most efficient when the slime layer is thin and totally aerobic.

The settled sewage sludge takes less than half an hour to trickle down over the media of a 3 600 mm high filter. This does not mean that all the settled sludge has been purified in such a short time. Dissolved impurities and the fine suspended matter, which is taken up into the biological film, take several hours or even days before they are broken down and leave the filter as end products.

The micro-organisms in the biological film multiply and grow as they utilise the available food and air. Thus the film becomes thicker. The organisms closest to the media will obtain food and oxygen last. These organisms then go into the endogenous phase of growth, i.e. they consume themselves because no other food is available. These organisms then lose their ability to cling to the surface of the media with the result that the biological film is washed off the media. Almost immediately a new biological film is formed, which again grows and then falls off so the process is repeated. The phenomenon of the biological film coming off the media is sometimes called sloughing. It is fortunate that sloughing occurs otherwise the film would grow to such an extent that all the voids between the media would close and then the aerobic organisms would be deprived of air and die. The biological film, which comes off the media, is allowed to pass out of the filter with the effluent. It is collected in a humus tank and then digested together with the primary sludge in a digester.

The biological life in the film consists of a host of aerobic and facultative bacteria fungi and protozoa. Higher forms of animals such as worms, insects, larvae, snails, etc., are present, usually on the surface of the biological film. It is interesting to note that all the organisms in a biological filter are in an ecological balance, i.e. no single organism is allowed to proliferate.

7.1.4 LOADING OF A BIOLOGICAL FILTER - HYDRAULIC LOADING

This refers to the daily flow, which is applied to the surface of the filter. It is important because, if the hydraulic load is too high, the biofilm can be washed off the media by the sheer force of the water. On the other hand, if the loading is too low, insufficient food and air will be carried to the organism and septic conditions will develop, resulting in unnecessary death of the micro-organisms

For a normal biological filter the hydraulic load would be in the range 1.2 to 5.0 $m^3/m^2.d$.

The calculation of the hydraulic load is obtained by dividing the flow to the filter in m^3/d by the surface area of the filter in m^2.

The above figures refer to the average daily flow. The actual flow rate of course varies throughout the day. During the day the flow is generally greater than the average but at night this becomes much less. In order to provide sufficient flow to turn the sprinkler mechanism, a device known as a dosing siphon is used. This stores the settled sewage in a small tank into which a siphon is installed As soon as the depth in the tank reaches a certain mark, the siphon primes and discharges at a fixed rate that will be sufficient to turn the mechanism

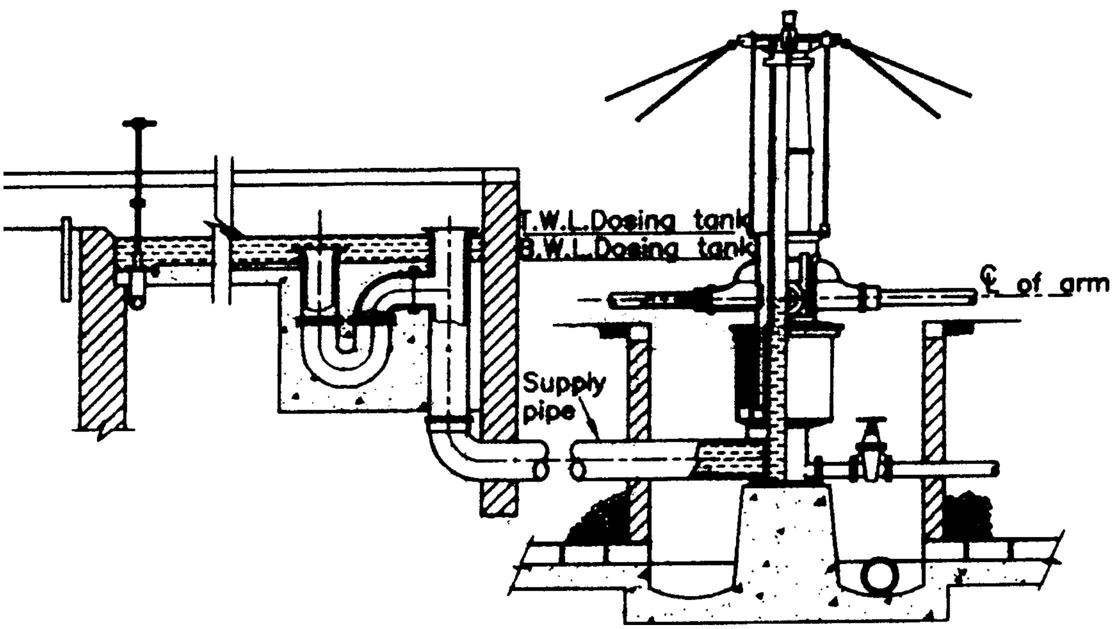


Figure :7.2 Dosing siphon

An alternative to a dosing siphon is to recirculate effluent continuously so that the filter arms keep turning at night

7.1.5 LOADING OF A BIOLOGICAL FILTER - ORGANIC LOADING

This is sometimes referred to as the BOD or COD loading. As the name implies it is related to the mass of COD or BOD applied per day per unit volume of filter. The normal organic loading rate is 80 - 400 g BOD/m^3.d.

In the high rate filter this is increased to 400 - 800 g BOD/m^3.d. The organic loadings on a filter will dictate the effluent quality. Generally, biological filters can remove 70% of applied BOD. If only carbon oxidation is required, a high organic load is generally used. If nitrification is required, i.e. where ammonia is oxidised to nitrates, a low organic load is applied.

7.1.6 RECIRCULATION

In certain cases it is advantageous to recirculate portion of the treated filter effluent through the filter. In cases where the incoming sewage is very strong, this will result in excessive growth of the biofilm, which could lead to the closing of the void volumes and failure of the filter. This phenomenon is sometimes referred to as ponding and should be avoided at all times. To overcome the problem of a strong waste, recirculation is introduced which results in the dilution of the wastewater. Recirculation is also serves to reduce odour and fly nuisance problems and keeps the distributor arms turning at low flow. The recirculation ratio is defined as the volume recycled divided by the feed volume and is often set at about 1:1.

7.1.7 PROBLEMS

Most problems in biological filtration are overcome by keeping the sewage as fresh as possible, and by not overloading the filters above their design capacity. Where this is not possible, the difficulties that can develop are ponding due to clogging of the surface layers of the filter media, the development of bad odours and excessive breeding of the psychoda filter fly. Chlorination of the settled sewage applied to the beds can relieve these troubles.

Chlorination can be carried out with chlorine gas from cylinders, or by adding bleaching powder. Another temporary remedy for ponding is to fork over the top layers of the bed concerned, or to apply powerful jets of water from a 75 mm fire hose. Excessive psychoda fly breeding can also be relieved by the cautious application of certain insecticides but these can damage the whole biological life of the bed. If certain limits are exceeded (e.g. excessive discharge of industrial wastes containing poisonous metallic salts, strong acids or alkalis into the sewers) or if overloading of the wastewater works is too great, then the above problems will occur as the result of the decreased efficiency of the filters Complete breakdown of the normal biological purification processes in the filters may also occur.

7.1.8 MAINTENANCE

Although simple to operate, biofilters still need maintenance. One of the most common causes of poor filter performance results from the unequal distribution of the settled sewage over the surface of the filter. The design of the arms allows for this in the spacing of the nozzles; the spacing being greater nearer the centre where the distance travelled each revolution is least. The nozzles, however, are liable to block as a result of the carryover of plastic materials, frogs, and small animals falling into the settled sewage or the growth of slime. These can generally be flushed out by opening the valves at the outer end of the arms and by brushing within the nozzles. The distribution from the nozzles should be checked at least daily and preferably at each shift change so that appropriate action may be taken at the time.

The seals should be checked periodically to ensure that the settled sewage is not bypassing the filters at the central column. For good reasons, the mercury type seal is less frequently encountered and the tendency has been to use water seals and air seals. Maintenance and repair should be in accordance with the manufacturer's instructions.

Bearings should be lubricated in accordance with the manufacturer's instructions and checked to ensure that the mechanism rotates freely. Tension in the stay-wires should be periodically checked to ensure that the arms are straight and level and that they do not foul any obstruction.

7.2 ACTIVATED SLUDGE THEORY

Domestic sewage needs to be treated before release to the environment in order to remove organic pollutants, suspended solids, nutrients and pathogens. There are many means of domestic sewage including anaerobic digestion, trickling biofilters, rotating bio-contactors and activated sludge. This paper focuses on the latter technique.

Activated sludge is an extremely effective and efficient tool in treating a wide variety of domestic sewages and industrial effluents. Originally discovered at the turn of the last century the process has undergone a great deal of development in the last few decades, enabling not only the reduction of organic pollutants, but that of the nutrients nitrogen and phosphorous which lead to algal growth once released to surface waters.

It is a proud fact that much of this development has been conducted in South Africa by James Barnard, founder of the Bardenpho process, and the University of Cape Town. One of the main reasons for the interest in this field in South Africa is the scarcity of water which often requires the released effluent to be processed again downstream for further use. Unlike some countries the dilution factors in South Africa are small; eliminating the maxim “The solution to pollution is dilution!”

7.2.1 THE NEED FOR EFFLUENT TREATMENT

Why should a municipality treat sewage? There are both soft and hard issues which necessitate effluent treatment. These can be summarised as follows:

- Simple social responsibility
- Retain water quality and safety for downstream users
- Maintain a healthy environment
- Legal requirements for release into surface waters
- Reduction in WDCS charges
- Water reuse

7.2.2 WHAT IS ACTIVATED SLUDGE TREATMENT?

Activated sludge treatment was first observed in the UK where sewage was stored in pits before being irrigated onto land on so-called sewage farms. In order to reduce odours the engineers aerated these pits and soon observed that upon switching of the aeration the quality of the stored sewage was markedly better. This was due to the action of bacteria naturally occurring within the sewage which "fed" upon the constituents of the sewage using the oxygen for aeration. This batch system was then modified to produce a continuous process which consisted of an aerated tank followed by a settling tank with a recycle back to the head of the aerated tank as shown in Figure 1.

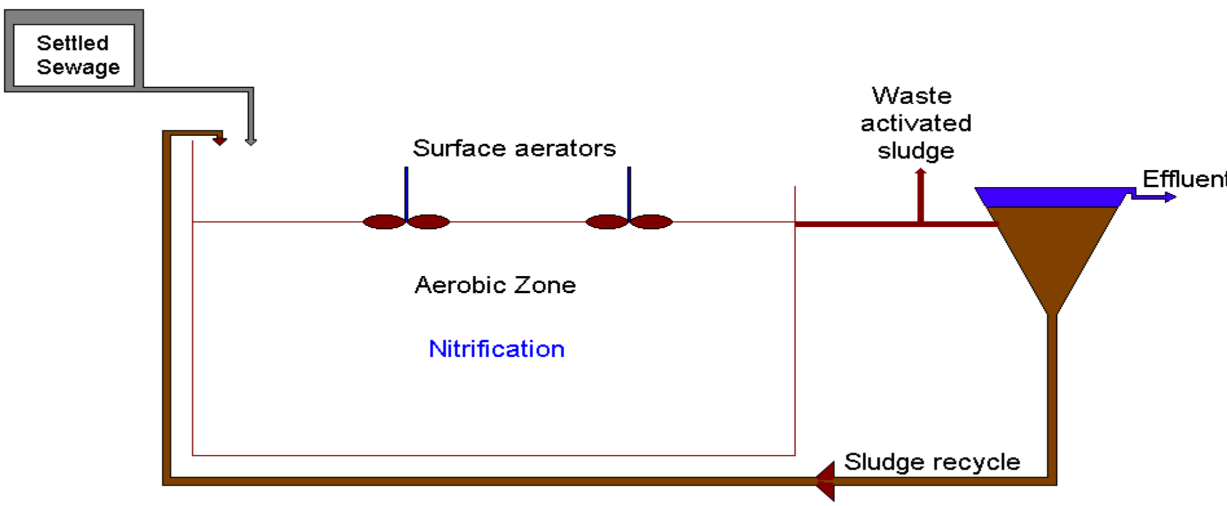


Figure :7.3 Simple activated sludge flow diagram

The bacteria in the sewage forms flocs as it grows and these then settle in the settling tank and are re-introduced into the aeration basin to continue the process. The greater the bacterial population the more the capacity to treat sewage within the limits of the reactor tank. If the floc concentration becomes too high then the settling tank becomes overloaded and the floc is discharged with the final effluent. Thus a certain fraction of the floc mass must be discarded or wasted daily. If a tenth of the floc or sludge mass is discarded daily then the mean cell residence time or sludge age is ten days, if one twentieth is discarded the sludge age is said to be twenty days. This is expressed mathematically as:

$$\text{Sludge age} = \frac{\text{Total mass of sludge in system}}{\text{Daily mass of sludge wasted}}$$

The sludge age is a very important parameter and will be further discussed later.

7.2.2.1 Nitrification

It was later discovered that not only were the organic pollutants in the sewage removed by the activated sludge process, but that ammonia could also be removed according to the equations:

$$NH_4^+ + 3/2\ O_2 \text{ (Nitrosomonas)} \rightarrow NO_2^- + H_2O + 2H^+$$

$$NO_2^- + ½O_2 \text{ (Nitrobacter)} \rightarrow NO_3^-$$

This was highly desirable as it reduced the ammonia odour, oxygen demand, and toxicity.

7.2.2.2 Denitrification

Further investigations showed that when the aeration was switched off for a period, the nitrates produced above were removed by bacteria which used the oxygen in the nitrate as an oxygen source for respiration. The equation for this reaction is:

$$NO_3^- + COD \rightarrow N_2 + CO_2 + H_2O + OH^- + \text{biomass}$$

This of course is highly desirable as it almost totally removes the nitrogen from the sewage thereby eliminating it as a nutrient. This could be included in a continuous process by introducing an unaerated anoxic zone in which the oxygen in the nitrate was the only oxygen source. This zone is usually placed in front of the aerobic zone to ensure sufficient food for the bacteria to denitrify. This arrangement is shown in Figure 7.4.

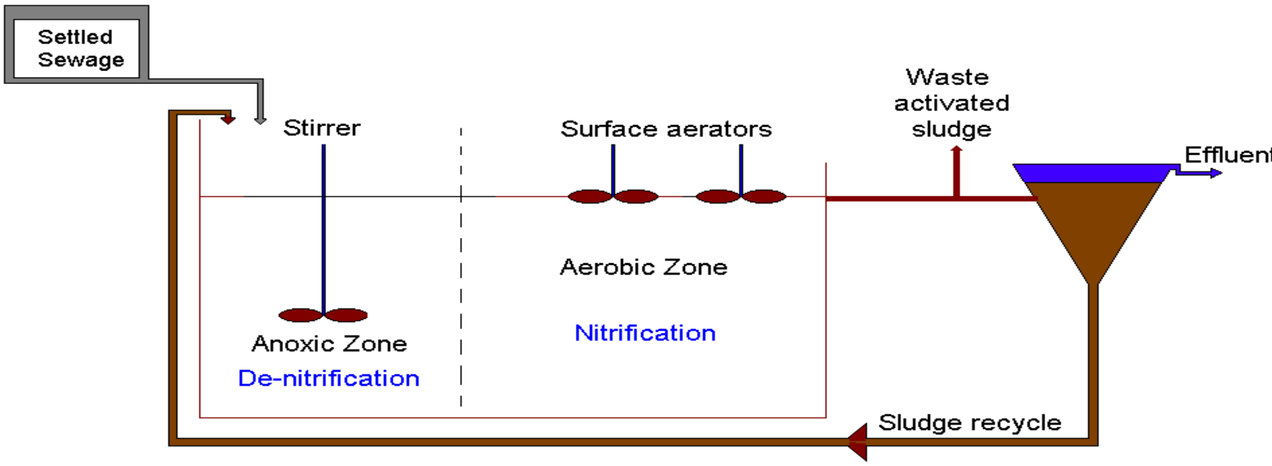


Figure :7.4 : Activated sludge with denitrification

7.2.2.3 Phosphate Removal

During the optimisation of denitrification it was further discovered that the insertion of an anaerobic zone ahead of the anoxic could produce phosphate removal. This is a result of the recycled bacteria desperately wanting to eat the sewage, but not having any oxygen to use for respiration. As an alternative to oxygen the bacteria actually release phosphate to gain energy by converting adenosine triphosphate (ATP) to adenosine diphosphate (ADP) which can be summarised by the equation:

$$\text{ATP} \longrightarrow \text{ADP} + \text{P} + \text{energy}$$

Once these bacteria reach the aerobic zone they take up phosphate once again, but do so in excess resulting in a net removal of phosphate. The process flow diagram is shown in Figure 7.5

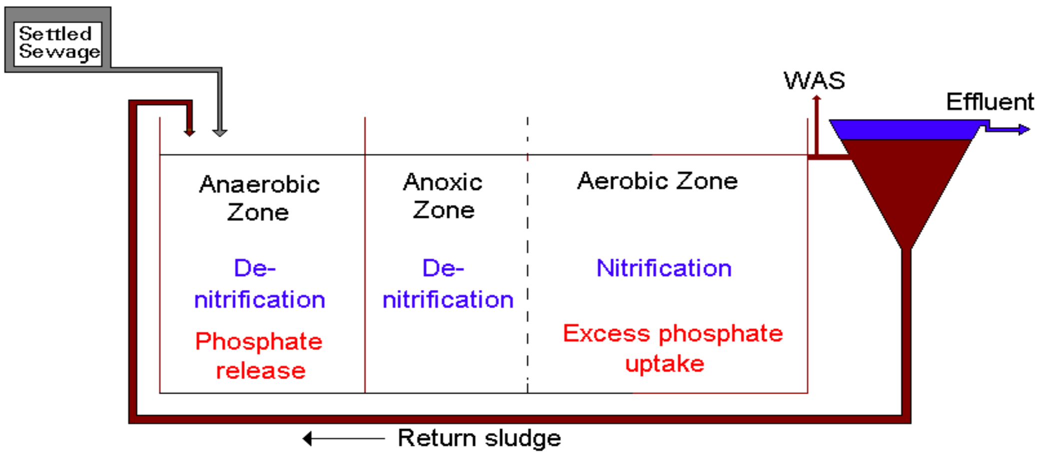


Figure :7.5 Phosphorous removal activated sludge

The Gwaing WWTW uses the UCT BNR Process which is best represented as follows:

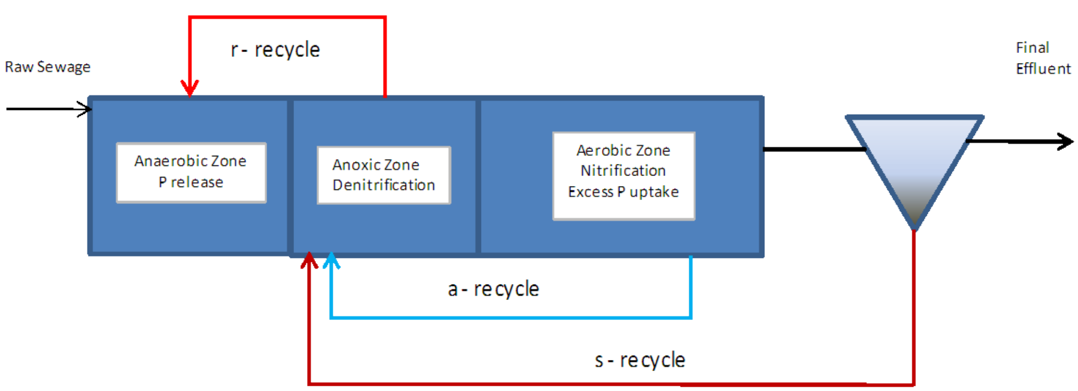


Figure :7.6 : Activated sludge with denitrification

7.3 DISINFECTION THEORY

7.3.1 INTRODUCTION

Raw sewage is considered a hazardous waste because it contains human waste, and human wastes contain, to a greater or lesser extent all known human pathogens. Typically, raw sewage contains high numbers of micro-organisms and each unit process used in treating wastewater reduces the number of micro-organisms as shown in the table below.

Table :7.1 - Removal of bacteria by different processes

Process	Percentage Removal
Coarse screens	0-5
Fine screens	10-20
Grit chambers	10-25
Primary sedimentation	25-75
Trickling filters	90-95
Activated sludge	98-99

There still remain high numbers of pathogenic micro-organisms in the treated wastewater even after the best possible biological treatment. To ensure that the effluent is safe for discharge to a public stream, some additional treatment is required. The most common additional process is disinfection.

The goal of water disinfection is to remove or inactivate pathogenic micro-organisms. Disinfection is not synonymous with the sterilization of water, in which all organisms are killed. In disinfection the primary pathogenic micro-organisms targeted for inactivation include bacteria, viruses and protozoan cysts.

The disinfection of water has been practiced for several hundred years, even though initially there was no understanding of the principals involved. Historical records show that the boiling of water had been recommended at least as early as 500 B.C.

Chlorine was identified as a chemical element in the early 1800s. Because of its characteristic colour, the name chlorine was derived from the Greek word chlorous, meaning pale green. It was not until sometime later, however, that its value as a disinfectant was recognised.

7.3.2 DISINFECTION WITH CHLORINE

Chlorine has been the dominant disinfectant of wastewater. It is available in different forms.

7.3.2.1 Liquid/gas chlorine

This is the basic chlorine compound and is used in large quantities for sanitary purposes; household bleaches, restaurant sanitizers, potable water treatment, wastewater treatment, swimming pools, cooling waters and other industrial process water treatment. Liquid-gas chlorine is the principal form of chlorine used m wastewater disinfection. It is also used for odour control, destruction of hydrogen sulphide, prevention and control of septicity and for elimination of activated sludge bulking.

7.3.2.2 Hypochlorite

Can be provided either in the form of sodium or calcium hypochlorite. Sodium hypochlorite is a clear liquid available in concentrations of up to 15% available chlorine by weight. Calcium hypochlorite is available either as a dry granular white powder or in tablet form in strengths of 70% available chlorine by weight.

7.3.2.3 On-site hypochlorite generation

Complete systems are available in South Africa for the on-site manufacturing of chlorine and hypochlorite solutions by electrolysis from salt (sodium chloride) which also avoids the potential hazard of handling the liquid-gas chlorine in pressurised containers. The solution strength of this hypochlorite solution is normally about 0.7%

7.3.2.4 Chloramines

A combination of chlorine and ammonia, chloramines are less efficient as a biocide as compared with free chlorine, but react to form fewer organic by-products.

7.3.3 CHLORINATION PRACTICE

Chlorination may be carried out by direct use of gaseous chlorine obtained from cylinders via purpose-designed chlorinators, or by dosage of hypochlorite solution which contains chlorine. Only the former will be discussed here.

7.3.3.1 Gas Chlorinators

Chlorine is obtained in 68 kg or 900 kg cylinders. The chlorine is compressed to a high pressure in the cylinders so that it is stored in liquid form. Chlorine is normally drawn off as a vapour or gas from the cylinders. When the gas is drawn off some of the liquid chlorine evaporates to replace it. The evaporation process requires heat and cools the surroundings. There is, therefore, a limit on the rate of draw-off of chlorine from a cylinder if freezing is to be avoided. The maximum draw-off is approximately 2 kg/h for a small cylinder and 10 kg/h for a large cylinder. This depends on the area, however, and should be checked with the suppliers.

A chlorinator basically consists of a vacuum regulator with adjustable gas flow measurement by needle valve via a float tube and an ejector on a pressure water line. The water passing through the ejector creates a vacuum, which sucks the chlorine gas into the water at the ejector and into solution. The solution of chlorine in water is then added to the effluent at a suitable point. The amount of gas drawn into the water at the ejector is regulated by a valve and measured on the float tube. Safety devices are normally built into the chlorinator to close off the gas in the event of water supply failure and to prevent water entering the gas lines.

Wet chlorine gas or chlorine solution is extremely corrosive and normal materials cannot be used. Most metals, lubricants and packing compounds are attacked. Special plastics and synthetic compounds are therefore used.

7.3.4 CHLORINE SAFETY PRECAUTIONS

Apart from being corrosive, chlorine is also very poisonous and can be explosive under certain conditions. The storage and use of chlorine therefore requires rigid adherence to safe practice procedures. Full details regarding these can be obtained from the suppliers who, from time to time, also conduct courses in the use and handling of chlorine.

In general, one must ensure that no chlorine leaks occur. These are readily detected by means of a cloth or cottonwool dampened with ammonia solution, which will produce white fumes when chlorine gas is encountered.

Where a leakage is possible or has been detected, suitable gas masks or respirators should be worn when entering the affected area. Cartridge type masks should only be used for limited periods and respirators with their own air supply should be used when entering a chlorine house whenever there is a leak requiring corrective procedures. Never enter an area if you are alone and the local emergency services should always be notified.

Ventilation of the storage and dosage area must be designed to prevent accumulation of chlorine gas, which is heavier than air. Floor level discharge ducts and fresh air fans entering near the ceiling as is a semi-open type of structure are common practice.

7.4 ANAEROBIC DIGESTION THEORY

When raw sludge enters the anaerobic digesters the COD rich solids are mixed with the digesting sludge already in the digester and three processes take place simultaneously:

- The settled particles are broken down into much smaller particles by enzymes in a process called hydrolysis.
- These microscopic particles are than converted to volatile fatty acids (VFA's) through a process of acetogenesis or acidogenesis.
- The volatile fatty acids are turn converted to carbon dioxide and methane by means of methanogenesis. Carbon dioxide and methane are both gases and are generally released to the atmosphere. If the gas is captured it can be converted to electricity by means of a generator.

The processes are shown in the flowing diagram:

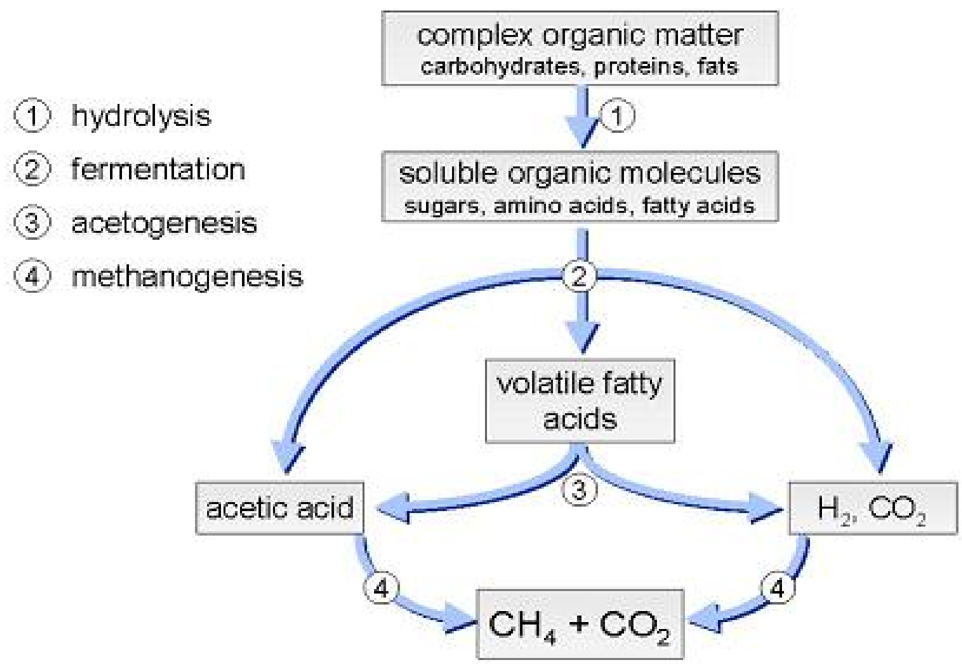


Figure :7.7 Anaerobic digestion processes

In summary, the COD in the particles is converted into gas which is released. This process consumes volatile solids, and results in their reduction. VSS removal by anaerobic processes in digesters is generally about 45%.

Digester can be mixed or unmixed, heated or unheated. Mixed digesters have required lower residence times than unmixed digesters, while heating digesters to 34-37C van halve their retention times.

7.5 DRYING BED THEORY

Drying beds are used both for dewatering digested sludge and for dewatering and drying waste activated sludge. The application rates are different for the two processes but the basic principles are similar.

7.6 PRINCIPLES OF DRYING BED OPERATION

Sludge on sand beds is mainly dewatered by a three-step process, namely drainage, decantation and evaporation:

1. **Drainage:** The sludge solids settle onto the surface of the sand forming a layer through which much of the water drains. Drainage occurs from the time the sludge is applied to the bed, with the water moving downwards under the influence of gravity into the sand layer, where underdrains remove it. It is the sludge characteristics that determine the drainage rate, as the water has to flow through the consolidating layer of sludge. This step, normally requiring a few days, lasts until the sand clogs with fine particles or until all the free water drains.

2. **Decantation:** A layer of supernatant water forms on the surface, which is drawn off (decanted) in certain bed designs thus reducing the volume of water that must be drained or evaporated from the sludge. This step also removes rainwater that, if allowed to accumulate on the surface, would slow down the drying process. Decanting may also be necessary to remove free water released by chemical conditioning of the sludge.

3. **Evaporation:** Finally, drying of the sludge occurs through the loss of moisture to the atmosphere by evaporation until the desired solids concentration is reached (about 30 to 40% total solids for digested sludge or even somewhat higher for activated sludge).

7.7 VARIABLES WHICH AFFECT THE DRYING PROCESS

The performance of sand drying beds is affected by the following factors:

7.7.1 WEATHER CONDITIONS

Open air-drying is especially suited to warm and dry weather areas. High wind velocities improve drying while high relative humidity and rainfall retard drying. In cold or wet climates, air-drying systems should be covered.

7.7.2 SLUDGE CHARACTERISTICS

Anaerobically digested primary sludge will dewater more easily and to a higher solids concentration than either a mixture of anaerobically digested primary and waste activated sludge, waste activated sludge alone, or aerobically digested sludge. Furthermore, sludge that is only partially digested will not drain as rapidly and dries more slowly than a well-digested sludge. The stabilised concentration of solids in the feed sludge also affects the drying time; the higher the solids concentration, the shorter the drainage and evaporation time. Some sludges, particularly aerobically digested sludges are not amenable to mechanical dewatering. These sludges can generally be dewatered on sand drying beds with good results.

7.7.3 SYSTEM DESIGN

The type of sand media, distribution of piping and drains, sludge distribution system and pumping equipment can all affect the operation and maintenance of an air drying system.

7.8 DESCRIPTION OF A TYPICAL SLUDGE DRYING BED

Sludge dewaters by drainage through the sludge mass and supporting sand and gravel, by decantation of the supernatant liquor and by evaporation from the surface exposed to the air. The main features of a sand drying bed are discussed below:

7.8.1 PIPING TO THE BEDS

Piping to the sludge beds should drain to the beds and should be designed for a velocity of at least 0.75 m/s. Cast-iron or plastic pipes are frequently used. In cold climates arrangements should be made to flush the lines if blockages occur and to prevent their freezing in cold climates.

7.8.2 SLUDGE INLET ARRANGEMENT

Distribution boxes are required to divert the sludge flow into the selected bed. One or two inlet points per bed are generally adequate and provision for preventing erosion of the sand base must be made using splash plates. The inlet flow should be controlled with a valve so as to apply an even layer of sludge over the bed.

7.8.3 SUPERNATANT OUTLET ARRANGEMENT

A supernatant withdrawal arrangement should be provided which should be positioned at the end opposite the inlet. Typical adjustable overflow weirs enable the clarified liquor to be decanted from the surface as this greatly increases the rate of drying.

7.8.4 SAND SELECTION

The sand layer should be from 230 - 300 mm deep Deeper sand layers generally retard the draining process. The sand should have a uniformity coefficient of not more than 4.0 and an effective size of 0.3 to 0.75 mm.

7.8.5 UNDERDRAINAGE

Most of the water leaves the sludge by drainage to a central sump. Drying beds are equipped with lateral drainage lines (vitrified clay pipes laid with open joints or perforated plastic pipe lines, with a diameter of at least 110 mm), sloped at a minimum of 1 % and spaced 2 5 - 6 m apart. The drainage lines should be adequately supported and covered with coarse gravel or crushed stone. The drying beds generally have a concrete floor slab laid at a slope of 1:12.

7.8.6 SIZE OF INDIVIDUAL BEDS

The drying area should be partitioned into rectangular, individual beds, maximum approximately 6 m wide by 20 - 30 m long. For smaller works a convenient size should be chosen so that one or two beds will be filled by a normal loading cycle, such as withdrawal of sludge from the digesters or wasting activated sludge at the desired sludge age.

7.8.7 SLUDGE DEPTH APPLIED

Most of the resistance to drainage comes from the sludge layer itself. The thickness of the sludge layer is all-important to the economics of the process. A thin layer of 100 mm will drain, cake and crack within a few days. For digested sludge a layer of some 200 - 300 is considered suitable. For waste activated sludge the amount wasted should give a dry cake about 15 mm thick. In comparison, thicker layers will take so much longer to dry that the overall drying rate is significantly reduced.

8 OPERATIONAL PROCEDURES – HEAD OF WORKS

8.1 VACUUM TANKER OFFLOAD BAY

The vacuum tankers must ensure that they offload their contents as hygienically as possible and their staff must rinse the area until it is properly clean to ensure that it is odour free and hygienic for the next customer.

8.2 NIGHTSOIL OFFLOAD BAY

Proper protective equipment should be used while offloading nightsoil, and the area should be rinsed once the operation has been completed. The contents of the sumps should be replenished as necessary.

8.3 COARSE SCREEN

The coarse screen should be cleaned as required with the custom made rake. Every attempt should be made to remove as much of the screenings as possible and to prevent screenings breaking loose and passing through.

8.4 MECHANICAL SCREENING

There are two mechanical drum screens. The units are fully automated in terms of their cycles, being triggered by headloss. The screenings are automatically rinsed into a centreless screw and transported to a conveyor belt for removal and compaction. The screenings should be disposed of in a manner acceptable to the Department of Water Affairs.

The screens should be inspected at least twice a day for any foreign objects such as branches or planks which may have passed through the coarse screen into the fine screen and have potential to cause damage.

The screens can be started on the SCADA or locally.

8.5 VORTEX DEGRITTER

The vortex degritter is designed to remove organic solids by means of centrifugal forces with the solids hitting the side wall and settling to the sump at the base of the unit. From there the grit is pumped by an airlift pump to a selector to allow the excess water to be removed and to return any organic solids back to the mainstream.
The pumping cycle of the degritter is automated and can be optimised by changing the interval between the pump operating and the pump operating duration itself.

If the grit removal from the sump experiences problems it is highly likely that the airlift pump has become blocked with debris and needs to be cleaned.

The quantity of the grit removed should be recorded on a regular basis. A sudden increase in grit coming into the works can mean a structural problem in the outfall sewer, allowing sand into the system.
The degritter can be started using the SCADA or locally.

8.6 GRIT CHANNELS

The grit channels remove the remaining grit after the vortex degritter. They must be isolated and cleaned out on a regular basis as determined by the plant superintendent to prevent grit entering the rest of the works as this will cause deposits in the basins, damage to the pumps and accumulation in the digesters. The channels may need to be cleaned more often during the wet season due to higher flows carrying more grit.

8.7 PARSHALL FLUME

A Parshall flume is a venturi like structure through which the sewage passes. The upstream level of the sewage flow can be converted to a flow by means of an equation. The design of the flume is such that little rubbish adheres to it. The level is generally read using an ultrasonic probe. Should the probe ever fail the depth can be read using a measuring stick and then converted to a flow.

8.8 DIVISION STRUCTURE 1

The influent from the inlet works flows to division box no.1 where the flow is split to 7.3Ml/d for the BNR system and 3.7Ml/d for the Biofilter Plant.

9 OPERATIONAL PROCEDURES – BIOFILTER PLANT

The theory, operation and maintenance of biofilters have been dealt with in detail above.

9.1 OPERATING THE BIOFILTER PLANT

In order to operate the biofilter plant the following steps should be taken:

- Ensure that the PST drives are functional
- Ensure that the primary sludge pumps are operational
- Ensure that the biofilter arms are free to move
- Ensure that the humus tank outlets are not blocked
- Ensure that the recycle pumps are operational
- Ensure that the humus pumps are operational
- Ensure that the anaerobic digester is functional

Once all these checks have been done flow can be introduced to the PST's and hence the biofilters.

The recycle pump will recycle the outflow from the biofilter back to the upstream side of the biofilter. The object of this exercise is twofold:

- To ensure that the biofilter keeps operating regularly even when flows are low to prevent it drying out and the biomass dying.
- To enhance nitrification – without the recycle nitrification will be poor.

Never operate the biofilter without the recycle operating – the effluent quality will deteriorate

The following maintenance is extremely important:

- The openings in the rotating arms must be cleaned out on at least a daily basis and the end caps removed and the arms flushed as required.
- The biofilters must be flushed periodically to prevent clogging with solids. This is done by taking one biofilter out of duty and then directing the entire flow through the other biofilter. At the same time the rotation of the biofilter arm must be slowed down manually to thoroughly flood the biofilter being flushed.
- If visible ponds of liquid appear on the surface of the biofilter then the biofilter must be flushed as described above until the blockage is cleared. If the ponding continues the biofilter must be taken out of duty and the media removed in the area of the ponding up to a depth of 1m and the material blocking the biofilter removed manually.

9.2 OPERATION OF THE PST'S AND ANAEROBIC DIGESTERS

The primary settling tanks should be desludged manually every 2-4 hours depending upon the weather and hence the inflow to the works. Generally high flows during wet weather will result in the desludging having to take place more frequently.

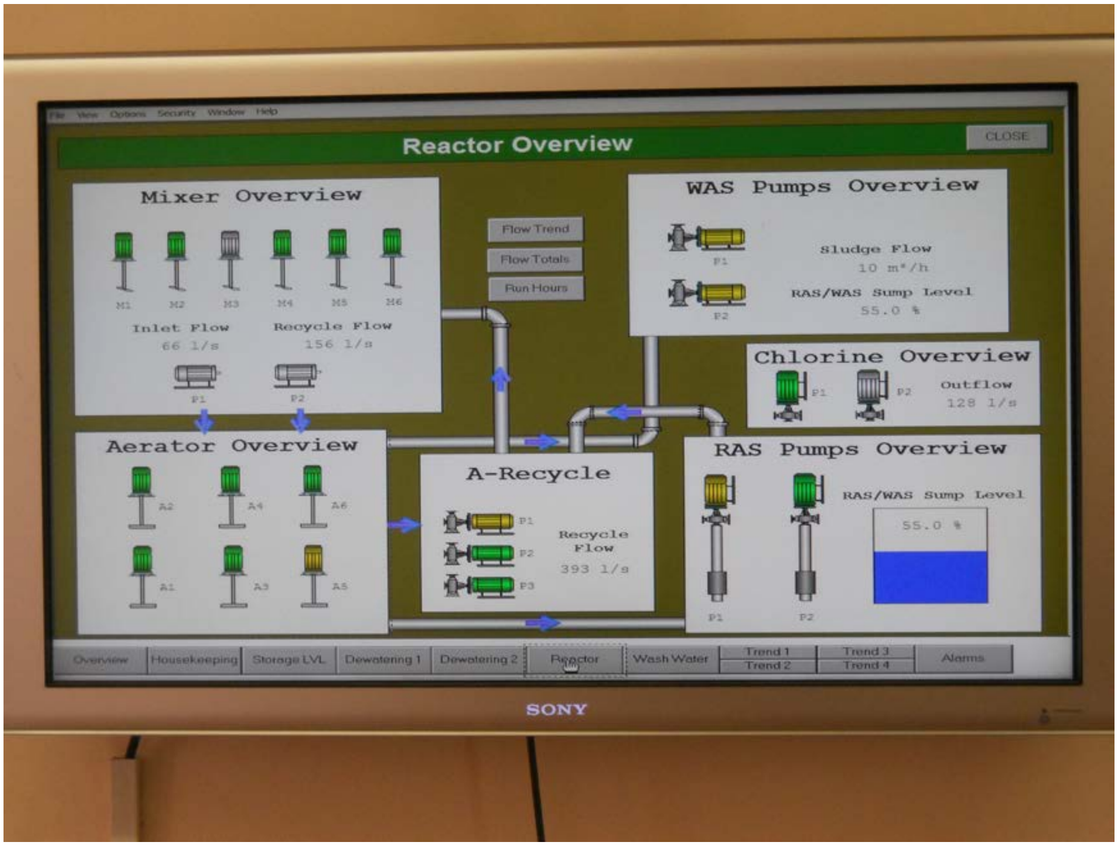
The raw sludge from the PST's is pumped up to the digester using the raw sludge pumps operated manually. This is performed every 4-8 hours

There are three supernatant valves on the digester. Samples should be taken from these and allowed to settle for 60 minutes to determine which contains the least solids. The supernatant is then withdrawn from the digester and flows to the inlet works.

Digested sludge is withdrawn from the anaerobic digester and flows to the drying beds. 1-6 drying beds of anaerobic sludge are withdrawn per month. The sludge drying period will very much depend on the weather, and once the sludge has dried (cracked and curled up a little) it should be removed from the bed and disposed of.

10 OPERATIONAL PROCEDURES – ACTIVATED SLUDGE PLANT

The activated sludge plant is largely automated, being controlled by the SCADA or HMI. For the purposes of testing during maintenance individual components can be run on "Manual" but it should be remembered that no interlocks apply in this mode.



The unit processes and installations related to the 7.3Ml/d modifications and the sludge thickening and dewatering facilities are described in this chapter.

10.1 FEED CHANNEL AND MEASURING FLUME

The 7.3Ml/d of division box no.1 outflow is passed on to the anaerobic basin of the bioreactor. A measuring flume with ultrasonic level detector is installed in the channel feeding the anaerobic basin.

10.2 ACTIVATED SLUDGE BIOREACTORS

The activated sludge plant should be started up using the start up sequence programmed into the SCADA.

Alternatively the plant can be started up according to the programme on the Human Machine Interface (HMI).

Should the plant be required to be started manually then the following sequence should be used:

- Start one RAS pump
- Start the clarifier bridges on the SST's
- Start the aerators
- Start the A and R recycles
- Start the mixers on the anaerobic and anoxic basins

The dimensions of the activated sludge basins are as follows (further data is supplied in Appendix B: Design Data):

Description	Volume (m^3)	Depth (m)
Anaerobic Basin	2940	4.7
Anoxic Basin	5090	4.7
Aerobic Basin	7514	4.45

Three recycles operate:

A- recycle – from the aerobic zone to the anoxic zone to provide denitrification (3 No axial flow pumps with a flowrate of 210 l/s with 2 pumps in operation and 1 on standby)
R- recycle – from the anoxic zone to the anaerobic zone to provide denitrified biomass for optimal P-release (3 No axial flow pumps with a flowrate of 170 l/s with 2 pumps in operation and 1 on standby)
S- recycle - from the SST underflow to the anoxic zone to provide denitrification (2 No. centrifugal pumps with a flowrate of 120 l/s with 1 pump in operation and 1 on standby)

10.2.1 ACTIVATED SLUDGE PROCESS SUMMARY

When the sludge in the anaerobic basin mixes with the raw sewage the sludge releases phosphate in order to provide energy for the uptake of VFA's.

The sludge in the anaerobic basin is passed on to the anoxic basin where the biodegradable COD is removed together with nitrate. This process is known as denitrification where nitrate is used as an electron acceptor instead of oxygen. The nitrate enters the anoxic basin via the A-recycle from the aerobic basin.

The A-recycle needs to be controlled to keep the anoxic basin underloaded with nitrate so that no nitrate is recycled to the anaerobic reactor.

Denitrified sludge is passed onto the aerobic reactor where nitrification of the ammonia takes place with oxygen.

The uptake of P in the aerobic reactor is greater than the release of phosphate in the anaerobic basin therefore excess uptake thus phosphate removal from the liquid phase to the solid phase [uptake of polyp by new cell mass]

Outflow from the aerobic basin is passed onto the secondary clarifier where the solids are separated from the liquid by settling. The settled sludge is discharged via the underflow where some of the sludge is removed as waste activated sludge and the remainder is recycled back to the anoxic reactor via the RAS recycle. Recycling to the anaerobic basin introduces nitrate, which would prevent formation of VFAs.

10.2.2 VERTICAL SHAFT MIXERS

The unaerated zones are equipped with 11KW vertical shaft mixers that keep solids in suspension. Two mixers are in the anaerobic zone and four in the anoxic zone. The contents of the basins are gently mixed without introducing oxygen through surface agitation or vortexing.

10.2.2.1 Operation

The mixers require minimal maintenance and are not prone to accumulation of rags or debris. They are also equipped with stop/start control.

10.2.2.2 Failure of shaft mixers

Failure of mixers to power failure may result in settling of sludge. Once restarted the scour velocities near the bottom of the basin will lift the sludge and bring it back into suspension.

10.2.3 VERTICAL SHAFT LOW SPEED AERATORS

The aerated zone is fitted with six low speed, bridge mounted mechanical aerators of the following size: 4 aerators 55kW motors and 2 aerators 45kW motors.

Due to the variable oxygen demand in the plant, the oxygen transfer rate of the aerators is controlled by means of switching the aerators on and off. The number of operating aerators at any one time is determined by the DO measured by a probe in the reactor basin.

A further means of control is by varying the immersion depth of the aerator turbines. A 3 m long overflow tilting weir is provided. The weir shall be set to give the optimum oxygen transfer efficiency of each aerator at peak loads.

Note: Due to abundance of reactor volume future increase of loads to the plant can be managed by upgrading the aerator oxygenation capacity by fitting pairs of 90kW, 75kW and 55kW aerators. This would increase the capacity of the bioreactor by up to 45% of its present capacity.

10.2.3.1 Switching aerators on and off as required

- Sludge entering the aerobic zone from the anoxic zone should be aerated immediately in order to maintain aerobic conditions where the flow enters the aerobic zone. In order to achieve this, the first two aerators will normally be operated continuously.
- The second and third row of aerators will be switched on and off under the control of the DO meter.
- Following a power failure, the aerators must be started in a staggered manner with at least 30 seconds between each motor.
- The controlling PLC is programmed to ensure the following:
    - One aerator per row will be switched off at a time.

- In order to prevent "hunting" the DO meter(s) will only be interrogated every quarter of an hour and the DO level will have to be out of the specified range (1.8mg/L to 2.2mg/L with a setpoint of 2 mg/L) for two consecutive interrogations before the status of the aerators is changed. The setpoint can be changed by the process controller.

- Aerators will not be allowed to switch on and off for more than four times an hour.

- After an aerator has been switched off for a continuous period of 45 minutes it will automatically be switched on and the other aerator in the row will be switched off in order to prevent deposition and stagnation of the sludge on the floor of the bioreactor.

The "Golden Rule" for aeration is:

- If the final effluent ammonia concentration approaches 3mg/l then the DO setpoint must be increased – i.e. provide more air.
- If the nitrate concentrations in the final effluent approach 5 mg/l then the DO setpoint should be lowered.

10.2.4 AXIAL FLOW PROPELLER PUMPS (A-MLR PUMPS)

Three a-MLR pumps capable of lifting 210 l/s (2 duty, 1 standby) against a low head (ranging between 400 and 600 mm) recycle mixed liquor from the end of the aerobic zone back to the anoxic zone. One or two will be duty pumps that will lift the flow into the recycle channel.

- Rags may accumulate on the impellors or these pumps which will result in vibration being observed. The pump should be taken out of duty immediately and serviced.

10.2.5 AXIAL FLOW PROPELLER PUMPS (R-MLR PUMPS)

Two r-MLR pumps with variable speed driven motors, one duty and one standby, recycle mixed liquor from the end of the anoxic zone back to the anaerobic zone. The pumps are capable of lifting 170 l/s (2 duty, 1 standby) against a low head (between 400 and 800mm).

- Rags may accumulate on the impellors or these pumps which will result in vibration being observed. The pump should be taken out of duty immediately and serviced.

10.2.6 SECONDARY SETTLING TANKS (SST)

From the aeration basin the mixed liquor passes on to the two secondary settling tanks that are equipped with scraper mechanisms. Each clarifier has a 25m internal diameter, side water depth of 3.5m and horizontal floors. Sludge is withdrawn through the sludge draw-off siphon pipes attached to the rotating bridge. The siphons should be adjusted such that more sludge is removed at the periphery of the bridge than the center.

10.2.6.1 Access Bridge drive arrangements

The access bridge is driven by an electric motor through a general speed reducer and drive wheel to give the required peripheral speed. The bridge assembly shall rotate at a constant speed of between 1.5 and 2m/min.

10.2.6.2 Sludge withdrawal

Settled sludge is removed from the entire tank floor surface area by a system incorporating collection scrapers with hydraulic suction devices that are suitably spaced along the full length of the bridge.

10.2.7 RETURN ACTIVATED SLUDGE (RAS) PUMPS

Two RAS pumps are housed in the RAS/WAS pump station. The discharge of underflow from the clarifiers into the sump is controlled by telescopic valves. The operator shall manually set the telescopic valves in such a way as to prevent frequent low levels in the sump. The RAS pump speed is coupled to the inflow into the reactor basin. This control will be based on the ratio of the instantaneous inflow to a corresponding speed of the RAS pump depending on the pump specific curve. The required ratio is 1:1. The feedback loop will be slow, which will allow for some integration over a time period of the instantaneous flow. The percentage ratio on the HMI can be changed by the process controller.

10.3 WASTE ACTIVATED SLUDGE (WAS) PUMPS

Waste activated sludge is pumped from the WAS sumps which fills with RAS sludge

The sludge concentration in the reactor will be measured manually by the operator and the measured concentration will be logged. The percentage of solids that will be wasted (expressed as sludge age in d^{-1}) will also be determined and logged. Based on these figures the PLC calculates the total quantity of sludge to be wasted according to the volume (15 544m^3) of the reactor.

The WAS pumps then run until this quantity of sludge has been wasted, as measured by the turbidity meter in the WAS sump, as well as the flow meter on the WAS discharge line. If the pump is interrupted prior to the total quantity being pumped, the cycle will cease into a "pause" situation until the limit has been reset. Pumping will stop due to:

(i) low level in WAS pump
(ii) high level in sludge tank at the dewatering plant and
(iii) low limit measured on turbidity meter in WAS sump (sludge not thick enough)

Once the WAS wasting has reached the total quantity and has stopped (not merely paused), the cycle will only commence again once the operator has "reset" the system by requesting sludge wasting again (via an HMI input).

10.3.1 SELECTION OF SLUDGE AGE

The initial design MLSS concentration is 2 500mg/l which is lower than the usually accepted 3 500mg/l. This is due to the large volumes of the reactors which were converted from a Petro pond system. With increased loads over time a more optimum sludge concentration will be reached.

By increasing or decreasing the sludge age the sludge concentration in the reactor can be increased or decreased respectively. Selection of the sludge age is the most fundamental and important decision. The sludge age of a plant will determine the stability of the process and influence the sludge settleability.

Generally phosphate removal is best at a lower sludge age, while nitrification is best at a longer sludge age which results in a trade-off in deciding the sludge age.

Short sludge ages (1-5 days) are for the purpose for COD removal only. Intermediate sludge ages (10-15 days) are obligatory when nitrification is required. Long sludge age (15-25 days) plants are more stable in operation. Although the oxygen demand per unit input is larger, it needs less supervision and the effluent COD remains low.

This plant has been designed for 20 days sludge age, but can be operated at a sludge age of as low as 13 days should the need arise as the COD load increases.

10.3.2 IMPORTANCE OF ALKALINITY

With low alkalinity wastewaters (like those encountered in the Western and Southern Cape), nitrification can cause a significant reduction in effluent pH. This not only causes problems with the nitrification process itself in that only partial nitrification is achieved (with the likelihood of non-compliance of the ammonia standard) but also tends to favour the development of poor settling sludges and to produce effluents which are aggressive towards concrete, removing the fines.

To reduce these problems deliberate biological denitrification has been incorporated in the process and this recovers approximately half the alkalinity used in nitrification. This results in a higher alkalinity and stable pH.

The alkalinity in the final effluent should always be maintained above 80mg/l to ensure good nitrification and prevent aggression towards concrete which results in fines removal.

11 OPERATIONAL PROCEDURES – TERTIARY TREATMENT

The chlorination plant is largely automated, being controlled by the SCADA. For the purposes of testing during maintenance individual components can be run on "Manual" but it should be remembered that no interlocks apply in this mode.

Tertiary treatment at the Gwaing WWTW consists of:

- Maturation ponds for the biofilter effluent
- Disinfection by chlorination for the activated sludge effluent and the pond effluent

11.1 MATURATION PONDS

The maturation ponds require little in the way of operational management. The chief problem that they are likely to experience is the build up of solids from carryover on the humus tanks and diversions of stormflows. The accumulation of solids can give rise to the release of ammonia in the ponds, which will affect the final effluent quality.

For this reason a monthly sample should be taken at the beginning and end of the maturation pond to check for ammonia release.

11.2 DISINFECTION BY CHLORINATION

WARNING: Chlorine gas is extremely poisonous. One full breath of chlorine is usually fatal. Utmost care must be exercised in handling chlorine gas and must be limited to personnel trained in the handling of chlorine gas

The gas chlorination unit installed at the works uses 990kg cylinders and is proportional to the flow, being controlled by the SCADA. The system has a start up sequence on the SCADA.

Any problems encountered with the chlorination system should be addressed according to the supplier's detailed manual in conjunction with the supplier.

The following instructions are general instructions for chlorination installations and are provided merely as a guideline.

11.2.1 CHLORINE HANDLING PROCEDURE

Chlorine is a highly toxic gas; it can kill or injure when inhaled. It is therefore important that the necessary precautions are observed when handling chlorine:

1. Employees must be trained correctly on how to handle chlorine
2. Only trained and certified operators should be allowed to work with chlorine
3. Self-contained breathing apparatus (SCBA) should be worn when working with chlorine; this is before opening valves or changing chlorine containers
4. SCBA should always be checked before wearing them
5. Always adhere to plant safety policy.
6. Never enter an area where there is gas alone
7. Notify the local emergency services

11.2.2 START-UP AND SHUTDOWN PROCEDURE

A specific sequence should be followed when starting or shutting the chlorination system:

1. The following steps should be followed when starting a chlorination system:
2. Position full chlorine container on the scale
3. Follow safety procedures
4. Always use new lead washers to prevent leaks
5. Open appropriate valves at the point of solution application
6. Activate water flow at the injector to create the required vacuum. A vacuum of at least 17 to 24 kPa is normally required at the chlorinator for proper operation
7. Activate the evaporator heat exchanger to attain the typical operating temperature of between 71 and 82°C (if applicable)
8. Open the evaporator inlet and outlet valves (if applicable)
9. Activate the chlorinator, alarm system and electric positioner where applicable
10. Activate chlorine gas leak detector
11. Open the chlorinator inlet and outlet valves
12. Activate the main changeover system (if applicable)

13. Check for leaks using fumes from the aqueous ammonia squeeze bottle. While doing this slowly open the main chlorine manifold and tank valve to no more than one turn. Repair any leaks immediately
14. Activate the chlorine residual analyser system (if applicable)
15. Monitor chlorination system devices for proper operation.

To close down the procedure should be reversed and carried out where applicable in the inverse order.

12 OPERATIONAL PROCEDURES – SLUDGE HANDLING

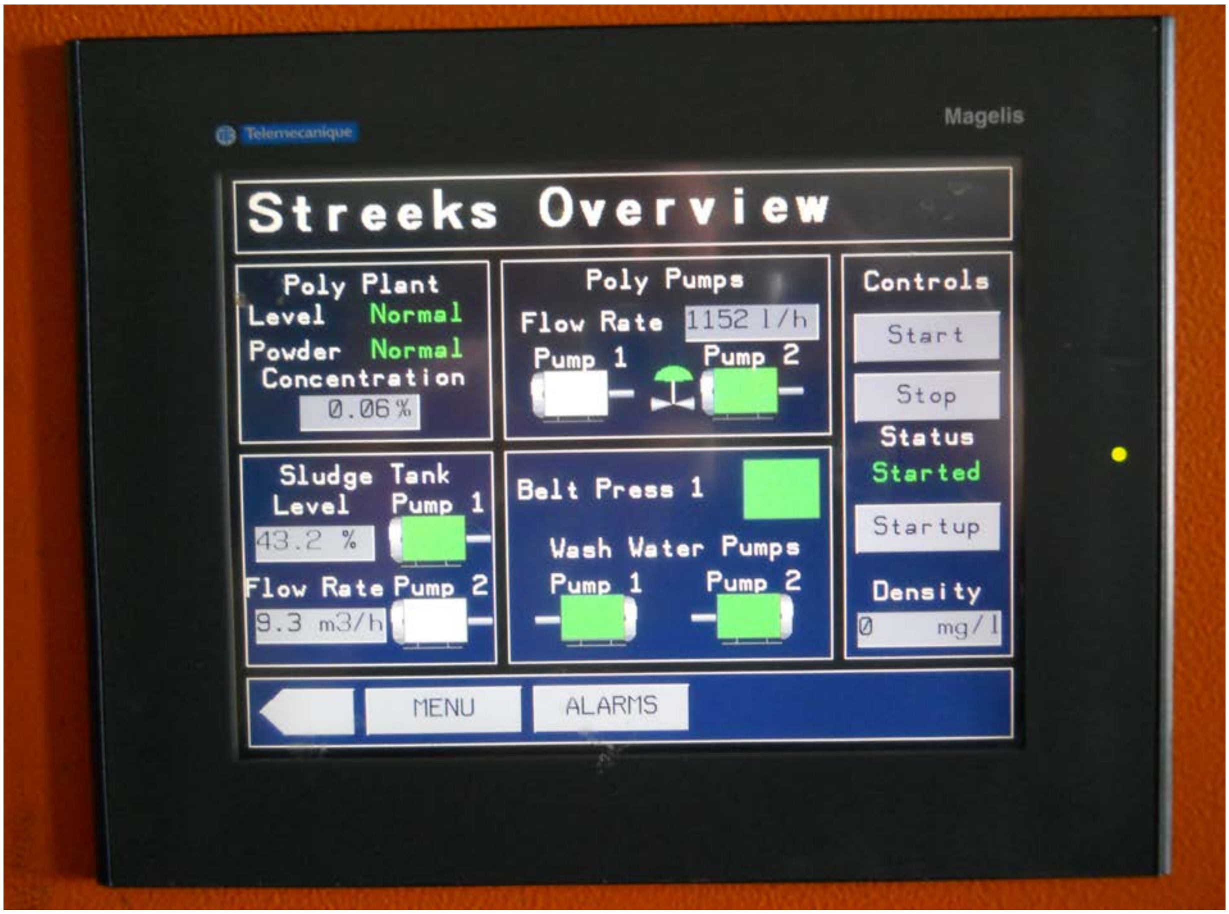
The beltpress plant is largely automated, being controlled by the SCADA or HMI. For the purposes of testing during maintenance individual components can be run on "Manual" but it should be remembered that no interlocks apply in this mode.

12.1 THICKENING AND DEWATERING OF GWAING WAS

The WAS is pumped by the WAS pumps to the sludge holding tank at the Beltpress Building, where it is mixed by aeration. From there the sludge is pumped by two variable speed progressive cavity pumps to a linear screen / belt press train for thickening and dewatering. The sludge feed pipeline is fitted with a flow meter, sludge solids density meter and sludge/poly mixing device.

There is an existing poly make-up system installed in the dewatering building, supplying polyelectrolyte both for the thickening/dewatering train and for the existing dewatering beltpress treating the Outeniqua WWTW sludge.

The beltpresses are generally operated using the HMI nearby.



The control philosophy of the system is described below.

12.1.1 POLY MAKE-UP

- ***Continuous batch make-up system with three tanks, overflowing into each other.***
- ***Low level in third (dosing) tank triggers make-up sequence.***
- ***Open solenoid valve for water feed into first (make-up) tank. After time delay, start screw feeder to measure preset quantity of dry poly into tank. This will be based on the rate of the feed of the screw feeder, and will be set by the operator on the HMI (in percentage poly solution required).***

12.1.2

12.1.3 DEWATERING CONTROL

- ***The belt speed will be adjusted by the operator depending on the quantity of sludge required to be dewatered.***
- ***The sludge feed pumps will vary their speed and hence pumping rate based on the sludge density to produce a defined solids sludge cake, up to the maximum capacity of the belt press at the speed set point. This will be a product of the density and flow as measured by turbidity meter in the sludge holding tank, and the flow meter in the sludge feed line***
- ***The poly dosing pumps will vary their speed according to the mass of sludge going to the belt press, based on the required poly dosing rate as set by the operator on the HMI***

12.1.4 DRAIN BELT/BELT PRESS START-UP SEQUENCE

- ***Perform safety check (E-stops, Limit Switches)***
- ***Check sufficient air pressure***
- ***If drain belt level low, open potable water solenoid for predetermined time***
- ***Wait 30 sec***
- ***Start belt***
- ***Wait 5 sec, if OK***
- ***Start conveyer***
- ***Wait 5 sec if OK***
- ***Start poly dosing pumps***
- ***Wait 10 sec, if OK***
- ***Start sludge feed pumps***
- ***Wait 10 sec, if OK***
- ***Start wash water meter***
- ***If any of the above fail, stop start –up sequence, identify problem step on HMI***

12.1.5 BELT PRESS SHUTDOWN SEQUENCE (NORMAL):

- ***Stop sludge feed pumps***
- ***Stop poly dosing pumps***
- ***Wait 5 min (adjustable 0-30min)***
- ***Stop wash water pumps***
- ***Wait 10 sec***
- ***Stop belt press***
- ***Stop conveyer***

12.1.6 EMERGENCY SHUTDOWN. THE FOLLOWING WILL STOP THE BELT PRESS AND ALL ASSOCIATED EQUIPMENT IMMEDIATELY:

- ***Any E-stop***
- ***Any Belt tracking limit switch***
- ***Low air pressure***

12.2 THICKENING AND DEWATERING OF REGIONAL/OUTENIQUA DAF THICKENED WAS

The waste activated sludge from the Outeniqua WWTW is DAF thickened at the Outeniqua WWTW and then pumped to the Gwaing WWTW where it is stored in a dedicated sump before dewatering on a dedicated beltpress.

The PLC control and poly makeup station is shared with the Gwaing WWTW beltpress.

The operation of the Regional/Outeniqua beltpress is similar to that described above and is selected on the same HMI.

As such it is unnecessary to repeat the detailed procedure.

13 MAINTENANCE

13.1 INTRODUCTION

Good maintenance practice saves money overall. Most of the failures experienced have been due to inadequate maintenance. There is always a difference in opinion between those advocating preventative maintenance and those who belief that equipment should be operated until something goes wrong. Preventative maintenance obviously costs money and too early replacement of wearing parts can be expensive. However good preventative maintenance can avoid costly and embarrassing breakdowns and prolong the service life of equipment considerably

In order to minimise mechanical equipment breakdowns, it is necessary to carry out preventative maintenance rather than corrective maintenance, which involves repairing and replacing damaged parts. This type of maintenance combines both the manufacturer's recommendations and the process controllers' experience acquired over a period of time. Preventative maintenance includes detailed inspection, reasonability checking cleaning, lubrication, replacement of defective parts and calibration where required Task schedules must be planned for maintenance that needs to be done by the process controllers or his assistants. Certain equipment must be checked daily, others at a set time intervals or during the actual running hours of the equipment. The efficiency of the process controllers can be maximised by keeping charts that show equipment maintenance requirements (i.e. what and when maintenance is to be done) thereby prioritising work to be done. A copy chart can be kept at a convenient spot for the process controller and his assistants.

Process controllers should be careful not to replace parts that are in good condition, just to carry out preventative maintenance. This implies that they must avoid replacing equipment parts without proper inspection.

13.2 MECHANICAL MAINTENANCE

Proper mechanical maintenance of equipment contributes to the efficiency and life span of the equipment. The process controller should do a routine check of mechanical plant for problems such as leaks, overheating, vibrations, noise or any other abnormalities. The process controller should check that equipment is free of obstruction, properly aligned and moving at normal speed. Mechanical maintenance of equipment must be according to the manufacturer's instructions. This could cover areas such as type and grade of oils and grease to be used, the frequency of greasing and oil changes, how much oil or grease must be used, and troubleshooting in case of problems, e.g. overheating, excessive vibrations.

13.3 PUMP MAINTENANCE

Pumps on a wastewater treatment plant are used for various duties depending on the material being pumped, for example, influent, sludge, effluent and grit. The maintenance programme of pumps depends on the type of duty the pump performs. All pumps should be checked for excessive noise, vibrations, overheating and leaks. Grit pumps are prone to rapid wear and should be opened up periodically for inspection and replacement of wearing parts. If more than one pump of the same size is used, they should be alternated in their duties to equalise their wear. This will also keep the motor windings dry, distribute lubricants in the bearings and avoid bearing failures which are common with standing machinery.

Pump packing glands must be checked for excessive leakage during operation. A slight seal leak should be allowed when pumps are running to keep the packing cool. However excessive leakage of the packing glands causes the water to enter the bearing housing thus leading to failure of the bearings.

Lubrication of the pumps should be in accordance with the manufacturer's instructions. The process controllers must be aware of the service frequency requirements of pumps in operation.

13.4 ELECTRICAL MAINTENANCE

1. The power should always be off when doing electrical maintenance
2. Electrical equipment should be kept free of dirt or moisture
3. Always check electrical equipment for loose leads
4. When the power is off, perform a sequenced start-up procedure
5. The motor control centre (MCC) should be checked periodically. Maintenance of MCCs should include cleaning the equipment, checking for damages and loose leads

Process controllers should check **electrical motors** for:

1. Unusual vibration and noise
2. Speed of the motor
3. Continuous sparking of brushes

13.4.1 STAND-BY GENERATORS:

1. Check the battery charge status monthly
2. Exercise the generator weekly
3. Check the warning light weekly to see if the generator energised
4. Carry out a diagnostic tune-up of the generator twice a year.

13.5 LUBRICATION

Lubrication forms part of preventative maintenance. Lubrication prevents metal-to-metal contact. Whether it is oiling or greasing the equipment, lubrication should always be in accordance with the manufacturer's instructions. A record of lubrication consisting of the frequency, type and amount of lubricant used should be kept for reference. A lubricant should be chosen according to the manufacturer's recommendations bearing in mind the operating conditions and material used.

13.6 PROTECTIVE COATING AND PAINTING

Plant facilities and equipment need to be protected from corrosion by maintenance painting. Process controllers are required to inspect facilities and equipment for possible repainting. A schedule should be provided outlining the structures to be inspected, frequency and type of inspection. When protective coating repair is necessary, the process controller should decide whether it is to be an immediate repair job or if complete repainting is required. Protective coating should be chosen according to the environment and application.

13.7 RECOMMENDED MAINTENANCE TASKS FOR MECHANICAL/ ELECTRICAL EQUIPMENT

Note that these tasks should be carried out in addition to any maintenance requirements specified in the manufacturer's operating manuals.

13.7.1 WEEKLY ITEMS

1. Visual inspection of all equipment for leaks, misalignment, excessive wear and breakages
2. Oil level check
3. Noise and vibration checks on all pumps and aerators

4. Grease all rotating elements
5. Clean floating debris and rags etc. from float switches
6. Check pump selection switches and record readings from hours run meters (where fitted)
7. Check aerator selection switches and record readings from hours run meters (where fitted)
8. Check operation of automatic flow meters and record readings (where fitted)
9. Check panel globes in MCC and replace as necessary
10. Check amperage draw for mechanical equipment against manufacturer's specifications
11. Check control circuits for pumps and dry run protection (where fitted)
12. Manual check of all auto systems and any interlocks
13. Check that all screenings/washings are collected in correct storage bins
14. Clean out all overflow weirs and launder channels around sedimentation tanks
15. Check status of sludge drying beds – rotate operation as required

13.7.2 MONTHLY ITEMS

1. Grease all motor bearings
2. Swap over duty/standby pumps and check impellors for any blockages
3. Manually operate all valves, and check for signs of leakage
4. Check gland packing to all valves and pumps, and replace as required
5. Top up oil levels, according to manufacturer's recommendations
6. Wash down sumps and clear all debris
7. Touch up and wire brush any corroded steelwork
8. Empty and clean out degritter sump

13.7.3 ANNUAL ITEMS

1. Change gearbox oil
2. Remove each pump, check for wear to impellor, renew gland packing, check for wear to cables
3. Strip all non-return valves, clean internally and repair as required
4. Recalibrate all flow meters
5. Re-align and undertake vibration tests for aerators, mixers and pumps

14 PUMPS

14.1 INTRODUCTION

The Egyptian "Wheel of pots" utilised manual or animal power to raise water from the river for the irrigation of crops and this was developed further into the water wheel or scoop wheel. Many hundreds of these were used in Holland and parts of England for land drainage until about 50 years ago. These were originally driven by windmills but were later converted to steam engine drives.

The best known of the early pumps, the Archimedean screw pump, was invented 2300 years ago and the same principle is still used today for large quantity, low head applications in wastewater plants and for land drainage and irrigation.

14.2 CLASSIFICATION OF PUMPS

In this manual, pumps have been broadly classified into the following groups:

- Rotodynamic, including centrifugal, axial flow and mixed flow
- Positive displacement, including reciprocating, progressive cavity and peristaltic Diaphragm pumps
- Air lift and ejector pumps Screw pumps.

14.2.1 ROTODYNAMIC PUMPS

These pumps incorporate a wheel or rotor of some kind whose rotating blades or vanes impart acceleration to the liquid passing through the pump. The speed of rotation will vary with the application and could be 500 rpm for a large raw sewage pump and up to 2950 rpm for a small high head clean water pump.

Of the pumps forming the group of rotodynamic pumps, the Centrifugal type is the most common. Each pump of this type comprises two principal components-

- The impeller, which forces the water into rotary motion

- The pump casing, which guides the water into the eye of the impeller and leads it away at a higher pressure.

The impeller is mounted on a shaft, supported in bearings and driven through a rigid or flexible coupling by a driver. This is usually an electric motor but could be an internal combustion engine, steam turbine or water turbine.

The pump casing includes the suction and discharge pipe connections, supports the bearings, and houses the rotor assembly. Sealing devices are included to prevent liquid escaping around the shaft and between the impeller and the casing. The detailed design of a centrifugal pump is influenced by the nature of the liquid to be pumped. When pumping clean water a closed impeller will be used and efficiencies of 80 to 95% can be achieved. For high pumping heads, multi-stage pumps can be constructed and for boiler feed duties, heads can be in excess of 300 Bar (30 000 kPa). For the pumping of raw sewage containing large solids, grit and stringy matter a different type of impeller is required. This requires large passages to allow solids to pass and may be of the closed design (with a plate each side of the vane) or the open design (with vanes mounted on a single rotating plate). Sewage pumps must always be specified to suit the maximum size of solids to be pumped and this may be called "freeway" with a capability of passing, say 80 mm diameter solids or "fullway" with a capacity of passing any solid coming down the suction pipe.

Fullway pumps are usually less efficient than freeway pumps but this disadvantage is offset by the lesser attention they require. There are many designs of impellers for handling raw sewage and these can be a simple S-shaped vane on a back plate, a single channel closed impeller, an open multi-vane impeller or even a vortex impeller. This last impeller type is recessed into the back cover of the casing and the impeller vanes do not protrude into the pump casing. They work by inducing a strong vortex in the liquid passing through the casing and are virtually un-chokeable. They have a low efficiency rate, around 35%, and can only generate low heads.

Other special types of pump incorporate cutting blades that cut or grind solid matter into pieces small enough to be handled by the pump. These are also less efficient and the cutting blades require regular replacement, especially where grit is present. Some pumps are provided with rubber linings to resist the abrasive effects of grit in the sewage.

It can be expected that any sewage pump will eventually become blocked from time to time and pipework should be arranged so that it is possible to quickly access the interior of the pump to clear a blockage Where possible, a solution is to purchase a pump having "Back-pull-out" construction, in conjunction with a spacer coupling In this design the spacer in the coupling is removed and the bearing bracket, back cover of the casing and rotating element is removed to give clear access to the interior of the pump casing without disturbing the pipework or the motor. Where the particular design of the pump does not provide this feature, adequate handholes with quickly removable covers should be provided on the pipework

The centrifugal pump is sometimes known as a "radial flow" pump and has some disadvantages. The freeway or fullway impeller tends to have a flat head/quantity curve so that a small change in operating head produces a large change in quantity pumped. Conversely if the head reduces, the quantity increases and the power requirement also increase so that larger sized motors become necessary to cater for this condition. Where several pumps run in parallel, this phenomenon is exaggerated and the selection of suitable motors must allow for this requirement.

In an axial flow pump, liquid approaches the impeller axially and the forward flow of liquid is parallel to the shaft axis. The impeller resembles a ship's propeller and these pumps are also known as propeller pumps. These pumps are suitable for handling large quantities at low heads but do not have good solids handling capabilities. They are suitable for recirculating effluents or similar duties. The axial flow pump has a steep head-quantity curve so that the quantity varies only slightly over a wide change in head and the power falls off as the flow increases. It does, however, absorb much more power as the flow is reduced towards zero and arrangements should be made to ensure that such pumps can never be run against a closed delivery valve.

All the rotodynamic pumps may be installed with the shafts horizontal, vertical or at an intermediate angle, although it is most usual for the horizontal arrangement to be adopted, with the driving motor on a single base plate. This has the advantage of easy access for cleaning and maintenance. The vertical arrangement is preferred when it is necessary to reduce the area of the pump station and the motors can be mounted directly on top of the pumps or located at a higher level, well above any possible flood level. Some designs can be suspended from a base plate at floor level to hang directly into the wet well or suction sump. This makes maintenance difficult and is not encountered often as the whole pump has to be pulled out of the sump.

All types of pump must be filled with water before starting and the easiest way is to arrange for the pump to be located in a dry well, below the level of the liquid to be pumped. This may not always be possible and several options are available. These include the provision of a small vacuum pump to evacuate the air from the pump casing before starting the pump. It is possible to provide a priming tank to allow the pump to fill itself with liquid during start-up but these tend to become clogged with solids on sewage duty. It is also possible to provide a foot valve on the suction pipe and to fill the pump with water before starting This arrangement has two serious disadvantages, in that these foot valves often leak and they present a high head loss to the suction Whatever the method of priming, there must always be an air release valve at the highest point on the pump casing to vent off any accumulated air or gas.

A further variation is the submersible pump, in which the pump is directly connected to a submersible electric motor and is positioned below the surface of the liquid. These are often used for small lift stations in remote areas and have the advantages of being installed in a manhole safe from vandalism and other damage. They are simple but can be expensive to repair.

14.2.2 POSITIVE DISPLACEMENT PUMPS

Theoretically, positive displacement pumps deliver a fixed quantity irrespective of the delivery head but in practice, the quantity does drop off as the head increases. The simplest type of positive displacement pump is the reciprocating or piston pump, with a piston moving forwards and backwards in a cylinder, to suck water into the cylinder and discharge it to a higher pressure. This type of pump has been in service for several hundreds of years for water supply and for pumping of water, sewage and other fluids. Many hundreds of farmers' borehole pumps are still of this type, often powered by windmills. They are also commonly used as hand pumps for water supply in small communities.

In the wastewater industry today, reciprocating pumps are usually used as specially designed high head pumps to handle sewage or sludge or in small sizes as chemical dosing or metering pumps, since every stroke delivers the measurable amount of fluid. The reciprocating type of pump cannot produce a steady rate of flow and it is advisable to provide an air vessel, on the discharge side, to control the pressure fluctuations. Although these pumps are self-priming, they should not be run dry as they will rapidly overheat and seize.

A number of rotary positive pumps are also found in wastewater plants and these include rotary lobe pumps and progressive cavity pumps. The rotary lobe pump is developed from the much older gear pump and comprises two elastomer-coated rotors connected together by an integral gear system with synchronised timing gears. The two rotors, which typically have two or more lobes, run without touching each other or the outer casing. The liquid is drawn into the inlet port and into the pockets between the lobes and chamber walls and is discharged in the direction of rotation of the outer lobes into the discharge nozzle. The discharge flow is continuous and smooth and is relatively non-agitating and non-shearing. The pump is self-priming and can be run dry for short periods. It is ideally suited to the pumping of a wide range of sludges.

A pump of similar capability, but different construction, in the progressive cavity pump, which comprises a hard steel rotor of helical spiral form which rotates in a stator of natural or artificial rubber with a similar internal helical spiral form. As the rotor turns, it contacts the stator, along a continuous sealing line, to create a series of sealed cavities that progress to the discharge end. The cavity fills with liquid as it opens at the suction end and this trapped liquid is transported along the rotor to the discharge and is gradually discharged in an axial direction. This type of pump is self-priming but must never be run dry. The initial starting load is high because of the dry contact between the rotor and the stator, but this drops off immediately once the pump starts to turn. Progressive cavity pumps are widely used for handling all types of slurries and sludges and can handle small solids. Where significant quantities of grit are present in the sludge, operating speeds must be kept below 350 rpm to minimise wear on the components.

A recent development in the pumping of sludges and slurries is the peristaltic pump. This is a simple design and comprises a semicircular chamber housing a rubber hose. A system of rotating rollers progressively squeezes the hose, pushing out any fluid in front of the rollers and sucking more fluid in behind it. A sufficient number of rollers are provided to maintain a constant flow through the hose. This type of pump is used in wastewater plants overseas but has not yet found general application in South Africa. It is self-priming, can be run dry and can handle a certain amount of solid matter. It is vulnerable to damage to the hose by sharp objects, although the hose can be easily and quickly replaced when necessary.

A variation of the reciprocating pump uses a flexible diaphragm in place of the piston. This form of construction eliminates the wear between the piston and cylinder but still has the problem of suction and delivery valves becoming fouled or jammed. Various patterns of diaphragm pump are in use and these include mechanically driven versions for dewatering excavations, compressed air operated versions for sludge handling and a diaphragm dosing pump for metering duties.

14.2.3 THE COMPRESSED AIR OPERATED TYPE PUMP

The compressed air operated type pump is of particular use in the pumping of sludges and has the advantage of being adjusted to suit the rate of sludge flow, by varying the length of stroke and the number of strokes per minute. The need to provide a supply of compressed air makes this pump expensive to purchase and to operate

Compressed air is also used to operate several other types of pump used in the wastewater industry. These include the airlift pump, which is comprised of a tube with a supply of compressed air, immersed in the liquid. The mixture of air and water is less dense and the pressure outside the tube forces this lighter mixture to the top of the tube where it is discharged. Airlift pumps can be used for activated sludge return where heads are lower than about 2.0 m and they have no moving parts requiring maintenance. They have limited flexibility in operation and are low in efficiency.

Another compressed air device is the air ejector lift station to lift fairly small quantities of raw sewage to the main outfall sewer. This device comprises a steel vessel arranged to collect the raw sewage. When the vessel is full, a supply of compressed air is blown into it to force the collected sewage up a rising main to the main sewer. These units were in regular use some years ago but have tended to be replaced by small submersible pumps in lift stations.

Compressed air can also be used to power ejectors for pump priming or for emptying sumps.

The Archimedes screw pump comprises a rotating torque tube, carrying one or more sets of spiral flights, located in a concrete or steel trough and supported by a combined thrust and radial bearing at the top and a sealed radial bearing at the bottom Pockets formed between the spiral flights and the trough, trap the liquid and move it up the incline in a continuous manner.

Screw pumps can handle large solids and high grit content and also have the facility of being able to pump the exact quantity entering the pump, from zero flow to full design flow, without any problems. The pump can be left running dry for an indefinite period.

The screw pump is rather restricted in terms of head, being limited to about 8.5 m in the larger sizes and reduced as the diameter decreases. This limitation can be overcome to an extent by arranging two pumps in series. It requires a large amount of space and the civil construction costs are high. The design of the bottom, submerged bearing is critical and must be given special attention.

14.3 PUMP DRIVERS

Most pumps found in a wastewater plant will be driven by electric motors but other types of drive can also be encountered. These include internal combustion engines, for temporary installations or for emergency service to back-up electric sets, and steam or water turbines. Wherever possible, the driver is connected directly to the pump through a flexible coupling but it may be preferable to incorporate a vee-belt drive or gearbox to change the speed.

In the case of self-priming sewage pumps, it is not possible to adjust the flow by reducing the impeller diameter and these pumps are regularly driven through a belt drive. Progressive cavity pumps are limited to low speeds when required to handle high grit loads and these can also be driven through belts or gearboxes.

The most common electric motor is the squirrel-cage induction type. This has a fixed stator, accommodating the stator winding, and an aluminium rotor, housing a number of rotor bars. The motor design provides a number of pairs of electrical poles and the rotational speed of a motor is given by the formula:

rpm = frequency of supply x 60 Number of pairs of poles

Thus a 2 pole motor would run at a speed of 3000 rpm.

This is the theoretical speed and in practise, the actual operating speed is slightly lower because of electrical "slip". The amount of slip is influenced by the size of the motor, larger motors having lower slip than smaller sized motors. A 10 kW 2 pole motor will run at 2800 rpm, whereas a 300 kW motor will run at 2981 rpm under full load conditions. At less than full load, the motor will run slightly faster.

A serious disadvantage of the induction motor was that the speed is fixed by the number of poles. This has now been overcome by the use of variable frequency drives, which enable a standard induction motor to run at any required speed between zero rpm and full rated speed, or even faster than full speed. This variable speed drive has another advantage in that starting is soft and gentle and acceleration can be controlled to reduce starting load on the electrical supply system It can easily be arranged for the motor speed to be controlled by a rate of flow device, so that a pump can match the change of flow of sewage influent to a pump station.

A much simpler version of this same device is the electronic "soft starter" which has the same features but without the variable speed facility. This gives the soft start capability that protects the motor and the supply system. It is possible to arrange for one soft starter to be shared between several motors of the same size and this can reduce initial costs considerably.

14.4 PROTECTIVE DEVICES

The current trend is increasingly towards full automatic control of pump stations and it is important to ensure that the plant is protected against abnormal operating conditions. The motors will always be provided with over-current protection and larger motors may also be fitted with devices to monitor winding temperature, bearing temperature and vibration levels.

Installations that run infrequently must be provided with electric heaters in motors and switch-gear panels to prevent any condensation of moisture. Where motors are not fitted with integral heaters, it is possible to arrange for a low voltage supply through the windings to keep them warm and dry when not in operation.

The pumps must be protected against dry running and this can be done by level switches in the suction sump, a limit switch on the non-return valve to sense that the valve is at least partly open or by actual flow measurement, or a combination of these. The control system must also monitor the discharge pressure and shut down the plant if the pumping head suddenly falls well below design levels. Other devices can be arranged to detect blocked screens, flooding of the pump house, abnormal gland leakage or even detect attempts to vandalise the installation.

Other control devices may be provided to protect the system against water hammer or pipeline surge. These may include special control valves or air-filled surge control vessels and will be specially designed to suit the individual system. The control system can be interfaced to a central control station by telephone or radio links. Every pump should be equipped with at least a pressure gauge on suction and delivery branches to provide an indication of its performance.

14.5 OPERATION OF THE PUMPING PLANT

14.5.1 PREPARATION FOR FIRST START

This section applies to the first start after the plant is initially installed or after a major overhaul. A competent person, whose name is clearly recorded on the form along with the date of inspection, should inspect the installation against a formal checklist. The inspection shall include the electrical and instrumentation systems, the entire mechanical plant, including sump pumps and ventilation equipment.

1. The suction intake system, including influent flumes, screens and wet well, must be checked for cleanliness and all debris removed. It is a wise precaution to install temporary strainers to the pump suctions during initial commissioning All level measuring equipment must be checked and calibrated, if necessary.

2. The piping system should be pressure tested during installation and thoroughly checked for the tightness of all bolts, including restraints on flexible couplings and anchor points. Check all air release valves and small-bore piping to pressure gauges and safety devices.

3. Check that all valves have been installed correctly, especially non-return valves, and are fully operational. Check operation of all valve limit switches.

4. Ensure all valves are closed.

5. Ensure pump and motor are disconnected. Check and record coupling alignment Check pump and motor are both free to turn.

6. Check lubrication of pump bearings and seals. Check motor lubrication. Check rotation arrow on pump and check actual rotation required against volute casing.

7. "Bump" start motor by energising and immediately tripping to check motor rotation. Whilst motor is running down listen to bearing noises with a stethoscope or long screwdriver to check for abnormal noise.

8. Reconnect pump-motor coupling and replace guard.

9. With belt driven units, remove belts, check pulley alignment, check motor rotation and replace belts to correct tension and replace guard.

10. Check operation of any auxiliary services, such as flushing water to glands or cooling water to bearings.

11. Fill suction sump or wet well, preferably with clean water for the first start. Check operation of level sensors. Check for leaks through civil structure.

12. Slowly open suction valve and charge pump with water, ensuring all air is discharged Check pump gland or mechanical seal. Open suction valve fully.

13. Crack-open discharge valve and start pump. Check for leaks and check suction and discharge pressure gauges and the motor ammeter. As the rising main has not been charged with water, the line pressure will be low and the pumping rate must be restricted so as not to overload the motor. Check all bearings and glands/seals and continue pumping at a slow rate, whilst monitoring pump and pipeline pressure gauges

As the line fills with water, the line pressure will increase and the pump discharge valve can be gradually opened until the line pressure is roughly equal to the pump pressure, when the discharge valve can then be fully opened.

In the case of a self-priming pump, it will be necessary to first fill the pump casing with water after which the procedure is similar. A non-self priming pump must also be charged with water, either by a vacuum exhauster, which may be hand operated or powered, or by filling the suction system with water against a foot valve. The use of foot valves is not favoured as they present a restriction to flow and cannot be relied on to be leak tight, especially when handling sewage.

After the pump has run for a sufficient time for bearing temperatures to stabilise and glands to settle down, the pump may be stopped. For the very first stop, it is recommended that the flow be reduced by closing the discharge valve partially and then tripping the motor. This will reduce the possibility of water hammer or surge If no surge is present, this procedure should be repeated a few times until the pump is tripped with a fully opened valve, without mishap.

This procedure will only apply in the case of a new installation.

In the case of a multiple pump installation, each pump will be started in turn until all have been set to work. After that, several pumps can be run together to establish the performance of the overall system.

Records should be maintained during all of these commissioning tests, as these will form the baseline for future reference. After all pumps have been run on manual control, the automatic control system may be selected and the tests repeated. The operation of all safety devices must be checked during these tests, including any interface links to central control.

14.5.2 NORMAL STARTING AND STOPPING

In most installations, normal operation will be under automatic control. Where manual control is required, this will generally be simply pressing the "Start" or "Stop" button. All valves will normally remain fully open.

14.5.3 OPERATING CHECKS

Even if full automatic control is provided, it is essential that the installation be regularly checked for correct operation. This should ideally be on a daily basis but may be extended to once per week. A log sheet should be maintained of record operating pressures, motor currents and flow rates. A record should also be kept of noise and vibration, gland leakage, bearing temperatures, etc. In the case of a manually controlled pump station, the log sheet should be more detailed with a record of when pumps were started and stopped, and flow meter and level readings.

The operating and maintenance instruction manual provided by the pump manufacturer will give the process controller or service technician detailed instruction for the maintenance of the pumps. Where this information is not available, maintenance must be based on observation by operating staff supplemented by regular inspections at three monthly intervals.

Problem	Possible Reason
No liquid delivered	Delivery valve closed. Suction valve closed
Pump not primed	System head too high
No water in sump	Impeller blocked
Insufficient liquid delivered	Valves partially closed
System head too high	Impeller partially blocked
Water in sump low	Wear in pump
Insufficient pressure, system head low	Air or gas in system. Wear in pump. Fractured Rising Main
Vibration and noise	Partially blocked impeller. Misalignment or damaged bearing

The most significant element of successful maintenance is quite simply "Good Housekeeping" This starts with keeping the plant clean, so that minor leaks can be detected and attended to before they become serious. A minor oil leak can be readily seen on a clean machine and can be fixed before the bearing fails. A leaking gland can be adjusted before it fails and releases a torrent of dirty water into the pump bearing, washing away all the lubricant and resulting in a major failure.

One aspect, not often realised, is that flying insects are attracted into the pump house by the lights and they often finish up in the gland drainage basins and block the free outlet of gland water. This then builds up to the extent where it overflows into the pump bearing Regular attention to all drainage piping is essential.

The two most vulnerable items on any pump are the bearings and the glands/shaft seals.

14.6 BEARINGS

Many modern pumps and motors are now being fitted with "Sealed for life" bearings, which require no routine maintenance and are replaced after a predetermined period. Other types require replacement of the grease after a stated period, whereas other makers specify small regular injections of grease.

It is important to clearly identify the specific requirements of each pump. It is most important that grease be kept clean and that bearings not be overcharged with grease, as this will result in overheating and possible breakdown. Some manufacturers use oil-lubricated bearings and these should be checked at regular intervals and drained and refilled at annual intervals. Ball bearings will always run slightly warm and may be operated at up to 70°C. Any sudden increase in temperature should always be investigated immediately. A grease-lubricated bearing may be given one shot of grease but if this does not immediately improve the condition, no further grease is to be added. Instead, the pump must be stopped and the cause investigated.

Some large pumps are fitted with oil-lubricated bearings in which the oil is distributed by an oil ring running on the shaft. These rings should be regularly inspected to ensure that they are rotating correctly. These larger bearings are often water-cooled and it should be ensured that the cooling water is circulating.

The Archimedean screw pump has a bottom bearing submerged below the liquid and a mechanical lubricator, often with its own electric motor, usually keeps this charged with grease. It is essential that this bearing be kept charged with grease at all times, not only to provide lubrication but also to exclude dirty water and grit

It is imperative that the grease filled into the lubricator is absolutely clean, as many failures have been traced to grease pipes blocked by cotton waste used to clean the grease container. The preferred method is to use a large grease container fitted with a charging pump, which is taken to the grease lubricator and connected by a flexible charging connector. Some screw pumps use a grease circulating system that returns excess grease to a container. The condition of this returned grease will give an indication of the bearing condition The returned grease must not be reused in the lubricator.

14.7 SHAFT SEALS

The item requiring the most attention and service on any pump is the shaft-sealing device. This can be a simple soft-packed gland or a sophisticated mechanical seal. The soft-packed gland or stuffing box seal comprises a number of rings of a square section packing material compressed between the end of the stuffing box and an adjustable gland follower. The packing is manufactured in many different materials, including animal fibres, vegetable fibres, asbestos, metal and graphite fibres, many synthetic fibres and other metals. These are provided with suitable lubricants that can include animal, vegetable and mineral oils and greases, synthetic lubricants and also dry lubricants such as graphite and teflon. Just to add further complication, packings are made in many grades of hardness and some glands use a mixture of hard and soft packings. The pump manufacturer will normally select the packing material and this should not be changed without referring to him. Many problems in service occur because of incorrect adjustment of glands and incorrect re-packing procedures.

Many modern packing materials require "bedding-in" and must be allowed to leak initially, and be gradually loaded. This is unacceptable for raw sewage pumps as grit particles will penetrate the gland, become embedded in the packing and rapidly score the shaft Good practise for this type of pump is for the gland to be provided with a grease seal to exclude the actual liquid from the packing and this grease seal must be maintained at all times.

When the gland is re-packed, all old packing must be removed and the stuffing box thoroughly cleaned. The shaft sleeve must be inspected to ensure that it is smooth and not scored. The packing must be cut to fit the shaft and each ring must be individually tamped to place in the stuffing box. Each ring must be compressed, by tamping or preferably by packing bushes, to expand in working condition. Each ring has to function as a pressure break device. Successive rings of packing must be tamped home, care being taken to ensure that joints in the rings are staggered to prevent leakage. Where glands incorporate lantern rings for supply of lubricant or flushing water, the position of these must be noted so that they can be reinstalled in the correct position

Mechanical seals are becoming more common and are imperative for certain types of pump, such as submersible sewage pumps. A mechanical seal comprises a rotating ring on the pump shaft in contact with a fixed ring in the casing. The materials of the rings are selected to suit the individual application and can include various combinations of carbon, metal-filled carbon, tungsten carbide, silicon carbide, siliconised carbon and bronze for the primary rotating ring and ceramic cast iron, tungsten carbide and silicon carbide for the fixed mating ring. These rings have to be manufactured to stringent standards of flatness and highly polished to eliminate leakage. Seals are classified as single seals or double /multiple seals. A double seal could be used on a sewage pump, with a neutral clean water or light oil circulating between the two seals, to provide cooling and lubrication and to exclude any penetration of grit.

The seals on submersible pumps run in an oil bath and on the larger sizes of pumps. an electrical device monitors for any leakage of water past the seal. Oil-filled seals are also used on self-priming sewage pumps and the oil in these seal chambers should be changed at regular intervals.

14.8 OVERHAUL OF PUMPS

It is difficult to make general rules regarding the frequency of complete pump overhauls as so many different factors are involved. It is considered that a pump should not be opened for inspection unless there is real evidence that this is necessary. This may be that performance has fallen off significantly or vibration, noise, overheating or overloading indicates that trouble is present. It is for this reason that the establishment of baseline data at initial start-up and keeping of log sheets is important.

Pumps have many different types of construction, even from the same manufacturer. For example, a raw sewage pump may have an open or a closed impeller, which may be secured on the shaft by a screwed thread or may have a key and a securing nut. With the open type of impeller, internal clearances may be adjusted by the adjustment of the thrust bearing position or the suction wear plate and these adjustments may be by screws or studs, by inserting or removing shims, or by adjusting the number of gaskets between components. It is always preferable to make use of manufacturers maintenance manuals and drawings when carrying out any overhaul to a pump.

Particular care must be taken when handling ball/roller bearings, which must be carefully cleaned, inspected and relubricated. In many cases special tools may be required for dismantling and reassembly to avoid damage. In any case of doubt as to the integrity of the bearing, it should be replaced, as the replacement cost is a fraction of the cost of a failure at a later stage.

Similar remarks apply in the case of a mechanical seal, where the manufacturer's instructions must be followed implicitly. In the case of a major overhaul, consideration should be given to returning the pump to the manufacturer who has the specialist knowledge, equipment and facilities to test the pump after the overhaul.

A special note of caution would be sounded against the use of spares from manufacturers other than the original supplier, as these parts may not restore original performance and, in extreme cases, may even result in further damage to the pump.

15 RECORDS

15.1 INTRODUCTION

Record keeping and reporting is a tiresome activity, but failure to do so may result in circumstances that might have been easily avoided had proper records been kept. Accurate and full records of all aspects of the construction, operation and maintenance of a wastewater works are vitally important for several reasons:

15.1.1 OPERATION

Only when the layout, process flow, size, characteristics and history of all parts of the works are known, can the process controller hope to be able to run his plant correctly. These records also reflect overall efficiency of the treatment process. Records of effluent quality will show if the treatment works is complying with regulations.

15.1.2 PLANNING

It is important to keep track of sewage flows and strengths and of the behaviour of the works in relation to changing loads. These records will assist the authority to plan properly for future sewers or works. Problems can also be detected well before they reach serious proportions.

15.1.3 MAINTENANCE

Proper maintenance records assist greatly in the timely servicing and repair of plant equipment. This minimises mechanical breakdowns and down time.

15.1.4 COSTING

For controlling and budgeting of expenses, it is important to have records of what work was done, by whom and how much was spent or materials Financial records can be useful when setting rates for customers.

15.1.5 RESEARCH

Full, accurate records are invaluable to a researcher studying aspects of the operation of a wastewater works. In many instances, long-term operating records are far more valuable than laboratory studies.

15.2 WHAT RECORDS SHOULD BE KEPT

The following is a brief guide to the type of records that should be kept on wastewater treatment works. Some process controllers may keep more and others less. Unless it takes up too much working time, though, more record keeping is better than less.

15.2.1 PLANS

There should be a full set of the final 'as built' drawings of the works showing the-layout, size, shape and details of all components, particularly for buried items such as pipelines and cables. These plans provide the plant personnel with records of the plant equipment regarding their location and their relationship with other plant equipment. The drawings are classified under the following categories: Plant layout, process flow and instrumentation, mechanical and electrical The drawings can be obtained from the designers of the works and must be carefully filed. The drawings should be updated when there are modifications to the plant because, when repairs or modifications are planned, they will be a most valuable source of information. Plant plans should be available to the operating personnel at all times and should be in good usable condition.

15.2.2 DESIGN PARAMETERS

The works process controller must know how his plant is expected to operate and the operating conditions. This will enable him to understand the plant and to know when certain components are under or overloaded. The design engineer should provide a report detailing the basis of design, design capacities and parameters The manufactures' handbook, outlining recommended operating guidelines, installation procedure and maintenance instructions, must be obtained.

15.2.3 DAILY LOG

A large, page-a-day diary or logbook will serve for this purpose and any information that does not logically fit in other records must be entered in the diary. Typical examples are staff movements, visitors, appointments, weather conditions and any deliveries made. Every process controller should keep a pocket book in which he should note any significant event on the works, such as a peculiar colour of the water, failure of equipment, or a strange smell, recording the date and time at which this occurs. These notes should be transferred to the Daily Log at the end of each shift.

15.2.4 WEEKLY AND MONTHLY RECORDS

These records will contain operating data of the wastewater treatment for example, aeration, disinfection, sludge digestion as well as the information mentioned in the daily logs. The monthly report should contain a summary of all the data collected during the month. From this data, operating parameters reflecting performance of the works can be calculated which will assist in process control. Analysis of data on a monthly basis will also show any deviations from previously established operation. Sampling or data collection points should be placed such that they are easily accessible to process controllers.

15.2.5 LABORATORY RECORDS

For purposes of presentation experimental readings are often collected together and presented in tabular form. The data can either be presented on sheets or notebooks. Laboratory data sheets may be developed for recording test results and calculations. The records of laboratory data should be prepared in such a way that recording, reviewing, or recovering of data is possible when necessary. These days it is often easier to store records via computers. However care should be taken to backup files onto other machines or CD's so that permanent records are preserved.

A copy of testing procedures should be provided in case there are staff changes so that procedures are consistent. Also original readings when performing a test should always be recorded not just the calculated values.

15.2.6 FLOW RECORDS

Depending upon the size and complexity of the works, this could vary from a few entries on a chart each day to a page full of figures. All flow meters on the works should be fitted with integrators. These can then be read at a fixed time each day and the figures recorded. If possible the main incoming flow rate should also be recorded continuously on a chart or SCADA system so the exact variations in flow rate can be studied. The strips or discs from such a recorder must be carefully labelled and filed. These records are essential for planning purposes and often for trouble-shooting on the works. It can also be useful to plot daily flows on a wall chart as this can give a clue to trends in flow. A record of the maximum and minimum instantaneous flows that occurred during each month may be kept. This can assist the planners to assess how much of the sewage flow is groundwater or rainwater infiltration.

15.2.7 PERFORMANCE RECORDS

All analyses made on the sewage must be properly recorded. A log sheet for this purpose can, in some cases, be combined with the flow record sheet. The following is a guideline, where applicable, of the sort of information that might be kept to evaluate the performance of the wastewater treatment work:

1. Influent flow Hydraulic loading
2. Organic loading Sludge age
3. Sludge blanket level
4. Sludge settleability
5. Suspended solids
6. Return sludge flow

7. Waste sludge quantity
8. Chemical dosages
9. Digester gas production.

In addition, information such as sewage temperature (inlet and outlet) and details of plant running times should be kept on the same log.

It is a good idea to make the log sheet flexible in layout for the first year of operation. This allows for more data to be added or for a better layout to be selected as the staff becomes used to working with the records. It may also be useful to get the process controllers to fill in a log sheet for each shift and then to transfer the important information for each day to the main log sheet.

15.2.8 EMERGENCY RECORDS

Documentation of emergency events and actions taken in response to these events will help plan future emergency responses. A record of all significant emergency events should be kept.

This report should include the following points:

1. Description and time of event
2. How the event affected the process
3. Length of time it took to get the process back to normal
4. Location where event first occurred
5. Action taken by process controllers/personnel in response to the emergency
6. Process equipment and structure affected
7. Description of repairs and replacements required
8. Costs of repairs and replacements
9. Emergency response plan in case of re-occurrence of similar event.

15.2.9 MAINTENANCE

Maintenance records are of vital importance and are discussed in a separate section.

15.2.10 ACCOUNTING

Although it is unlikely that a wastewater works process controller would be expected to keep his own books, he must nevertheless have some record of and control over costs. The costs of labour, materials, spare parts, new equipment, electricity and hired plant should all be recorded if possible. Delivery notes and invoices paid should be recorded so that any problems can be simply and quickly cleared up. If good information on quotes is available it can help the process controller to make the cheapest decision for future jobs. For example, it may be cheaper to buy a new pump than to have the various components overhauled and reassembled.

15.3 FILING

Records are only of use if they can be found easily and reliably. A piece of paper with a row of numbers on it may mean something on the day it is written but, when examined a year later, it will convey nothing. It is therefore essential that a systematic filing system be developed for each wastewater works.

Some records can be kept in books, which are stored away when full. Other information is best kept on loose leaves in lever-arch or suspended files. A box of small file cards can also be a most useful place for keeping multiple bits of brief information, such as equipment records. On the larger works, a computer system may be used to keep electronic records. Books and manuals should be stored in shelves. Drawings should be kept in drawers or filing cabinets.

16 SAFETY

16.1 INTRODUCTION

The formulation of, and adherence to, safe-working procedures is in the best interests of everyone concerned with the operation and maintenance of wastewater works plants. It should be remembered that a wastewater works has operating machinery, which requires the same care and precautions as would be required in any factory. In fact the provisions of the Factories, Machinery & Building Work Act, 1941 and the Machinery and Occupational Safety Act, 1983 and the current Occupational Health and Safety Act are applicable to wastewater works In addition; a sewage treatment installation has the additional hazard of disease infection.

On large plants, it is the responsibility of management to formulate and implement safety procedures. The operating and maintenance staff must actively support these. On small plants the process controller himself may have to take the initiative.

16.2 SAFETY COMMITTEES

In terms of regulations framed under the Occupational Health and Safety Act, Act No 85, one safety representative must be appointed in writing at any workplace for every 50 persons employed, except where there are less than 20 employees (farm labourers are excluded). It is mandatory for this safety officer to carry out at least one inspection per month of the workplace to which he has been designated. He must report any threat or potential threat to the health and safety of any employee to his employer or any safety committee established in terms of the Act.

In large undertakings, the various safety representatives would form a safety committee. At smaller installations it is suggested that such a committee should include the engineer or responsible person duly delegated by the Chief Executive Officer, the works manager, the maintenance foreman, a senior process controller, a labour representative and the safety officer.

Small works should at least be served by the engineer or responsible person, the superintendent or process controller, and representatives from maintenance and the labour force.

Meetings should be held on a routine basis or the entire purpose of the committee is lost. The committee's functions are to promote awareness of safety, investigate accidents, recommend safe practices and procedures, and to ensure compliance with statutory requirements.

16.3 INSPECTIONS

On the basis that prevention is better than cure, it is suggested that arrangements be made with the factories, or safety inspector to visit the Works occasionally and report any shortcomings. These can then be rectified before any problems occur.

16.3.1 BASIC RULES

All persons visiting or employed on a wastewater works should observe the following basic rules at all times:

1. Do not smoke or use an open flame on the works except in those areas that have been designated as safe
2. Wash hands well with soap and warm water after working with sewage or sludge and especially before eating
3. Do not touch electrical equipment or switches and treat all equipment that has not been isolated and locked as live
4. Do not touch moving machinery
5. Do not enter a sewage manhole or deep sump without testing for hydrogen sulphide (H_2S) and wearing a harness attached to a rope held by a man at the surface
6. Do not enter a digester unless it has been emptied, purged with air, tested and certified safe
7. Take care when standing near or working over tanks and channels where there may be deep or swiftly moving water
8. Ensure all moving machinery parts are adequately guarded

16.4 SAFETY EQUIPMENT

Each works should be equipped with the following items - quantities of each item depend on the number of people employed on the works:

1. Full parachute-type harness complete with a sufficient length of 12 diameter nylon rope.

2. Explosion-proof portable blower, lighting and extension cord.
3. Self-contained compressed air breathing apparatus consisting of a parachute harness and lifeline, full facemask, air supply hoses, a cylinder with a minimum of 30 minutes air supply and a pressure gauge. Note that certain types of respirator (gas mask) are unsuitable for wastewater works applications as they protect only against poisonous gases when these are in limited quantities and can only be used where there is no deficiency in oxygen.
4. In many manholes and sumps there will be a deficiency in oxygen, or the gas present will be methane (earth gas) that penetrates the ordinary respirator and will cause suffocation. The only suitable respirators are those connected to a supply of fresh air, or those generating there own oxygen from containers of appropriate chemicals.
5. An interchangeable compressed air cylinder to last for 10 minutes.
6. Portable oxygen deficiency explosive gas mixture meter, complete with alarm system.
7. Lead acetate paper.
8. Spark-proof tools.
9. Symbolic safety signs.
10. First aid kit.
11. Barricades, traffic cones, flashers and warning signs.
12. Fire-fighting equipment to suit each area.

16.5 PROTECTIVE CLOTHING

The items listed below make up the necessary basic clothing for all those employed on a wastewater works: (Records of the issues must be kept and signed for by the worker):

1. Hardhat - made of high-density polyethylene
2. Overall - elastic in cuffs and in the waist and having a zip front
3. Gumboots - lightweight with built-in toe protection and non-slip soles
4. Boots, leather, ankle protection type with toe protection and non-slip soles
5. Gloves made of strong flexible PVC with roughened palm

6. Oilskins
7. Earmuffs - if working in a blower room or similar noisy area.

In addition to the above, those who are involved in workshop activities should have:

1. Earmuffs
2. Appropriate goggles, gauntlets, etc, for use during welding, grinding and cutting operations
3. Workshop gloves - made of soft, flexible leather or pigskin with fingertip and knuckle protection.

Those involved in laboratory work require:

1. Acid-resistant dustcoats
2. Unlined neoprene gloves.

16.6 SUPERVISION

There is no point in equipping a works with all the recommended safety equipment and the personnel with protective clothing, if the equipment is not maintained and is allowed to deteriorate. A fire extinguisher, which does not work, is worse than no extinguisher at all. The safety equipment should be stored in an accessible position, outside the hazardous area. Similarly, there is no point in drawing up a safety manual and recommended procedures if they are not followed. The works manager, superintendent or responsible person must therefore ensure that procedures are adhered to, that ladders, fire extinguishers and respirators are inspected and tested on a routine basis; and that certain protective equipment such as earmuffs and eye protection, which may be unpopular, is in fact worn when necessary.

16.7 SAFETY PROCEDURES

The following are presented as a guide only. They may require to be amended to some extent for the circumstances applying to a specific works.

16.7.1 WORK IN MANHOLES, SEWERS AND DEEP SUMPS

1. Protect the job site against traffic hazards
2. Never work in confined spaces/areas alone - two or more persons should always be present in case of an emergency
3. Test the atmosphere for oxygen deficiency, explosive or flammable gas and for hydrogen sulphide by inserting a probe through a hole in the cover. If there are no holes in the cover, then the cover must be removed very carefully without causing sparks. This is important because sparks created by removing the cover can cause an explosion. Once the cover is removed, the atmospheric tests are carried out near the bottom and also about one third down from the top of the sump
4. If the tests indicate a safe atmosphere, the two adjacent manhole covers are removed and the sewer is allowed to ventilate for 10 minutes before any person enters
5. If the tests indicate an unsafe condition, forced ventilation must be used. All blower equipment must be placed upwind from the manhole to prevent any possibility of gas ignition by the blower equipment. Any other potential ignition sources should be eliminated, such as smoking in or near a manhole
6. Under emergency conditions, self-contained air breathing apparatus and a safety harness with lifeline must be used with two persons in attendance at the manhole opening
7. Persons entering a manhole should not be permitted to carry objects in their hands. Tools, etc, may be passed down to them by rope after they have reached the bottom
8. Carbon dioxide, which causes suffocation, is heavier than air. It is therefore necessary to use forced ventilation under all conditions where upward displacement of gas by air is required. This applies to deep sumps even when the pump station may be equipped with its own ventilation fan
9. The use of a safety hat, overalls to prevent contamination of regular clothes gumboots with toe protection and waterproof gloves are considered to be minimum acceptable dress for this type of work
10. In addition to the above dress the following equipment must be used:

- Safety harness with lifeline
- Anti-spark tools
- Explosion-proof lighting and equipment
- A ladder is preferred for entering or leaving a manhole or sump even if stepirons are present.

11. A blowtorch should never be used to melt ice, paint or bitumen, etc, around a manhole or any other surface cover.

16.7.2 WORK IN DIGESTERS OR SLUDGE STORAGE TANKS

The digester should be filled to its highest level in order that the gas space is reduced to a minimum. The gas line from the digester should then be closed. The gas pressure should then be slowly reduced by venting to the atmosphere. After the pressure has been reduced to atmospheric pressure the cover plates on the gas dome can be removed, using non-spark tools and fresh air forced into the digester by blowers to purge the gas. The purged air must be sampled and tested until the explosive level is below the lower limits. Once this level is reached, the tank contents can be lowered. Continuous purging must then be maintained until the tank is emptied and completely cleaned. Note that even this procedure contains a hazard in that the gas mixture passes through the explosive range during the initial stage of purging with air.

1. Absolutely every care should be taken to ensure that no spark is generated during the initial stage of purging. Ideally the first purge should be carried out with an inert gas such as nitrogen or carbon dioxide. However, this is not practical in most cases
2. After the tank is empty and before any person enters the tank, the levels of the explosive atmosphere and oxygen deficiency must be obtained
3. During cleaning operations the atmosphere must be monitored continually with an oxygen deficiency indicator and explosive gas detector both of which incorporate alarm devices that are activated when unsafe levels are reached
4. A properly qualified person should make the necessary tests of the interior of the tank to monitor the level of explosive or flammable gas and oxygen deficiency
5. The air purge must operate continuously until work is completed and commissioning starts

6. The power supply to mechanical or gas mixing equipment must be disconnected and all piping leading into the tank for gas or sludge transfer should be valved-off for the duration of the work
7. At least two men should be stationed at the entrance. They should be trained in the use of self-contained breathing apparatus, safety and some first aid. They should also be wearing self-contained breathing apparatus
8. self-contained air breathing equipment, safety harness and respirators should be stationed at the entrance to the tank during the entire time that persons are working in there
9. All smoking equipment, i.e. cigars, cigarettes, pipes, tobacco, matches and lighters must be stored in lockers by all those working in the digester area
10. Floating cover digesters: The only difference in procedure between fixed and floating roofs is that the first step is to draw off the supernatant liquor until the roof rests firmly on the supports. The draw-off is then stopped until the gas space been purged to below the lower explosive level in the same manner as that for fixed roofed digesters
11. Low voltage explosion-proof lights are permitted inside a confined space

16.7.3 MACHINERY

1. When working on a piece of equipment, ensure that it cannot be started or operated either by isolating at the panel and/or the local stop and disconnecting the means of starting
2. Always use the correct tools for the job
3. Keep chisels in good condition
4. Wear visors or goggles when grinding
5. Use correct grade of protective visor or goggles when welding or brazing
6. Do not manhandle heavy objects. Use lifting gear
7. Always replace belt guards and other safety shields
8. Always read the instructions carefully before carrying out any maintenance operation on a specialised piece of equipment.

16.7.4 ELECTRICAL

1. No unauthorised person shall work on electrical equipment, open a panel or enter a substation.
2. All equipment that is to be worked on shall be properly isolated and locked so that it cannot be switched on. Suitable notices shall be placed at the switch panel and adjacent to the equipment.
3. All installations shall be properly tested by a competent person before being put back into service.

16.7.5 MATERIALS HANDLING

Care should be taken in handling heavy or bulky objects. In order to reduce the number of injuries caused by the use of incorrect material handling methods, the following points should be considered:

1. Use suitable lifting gear wherever possible
2. No person should attempt to lift more than can be handled comfortably
3. Wear protective gloves as a general rule. Otherwise ensure that the hands and the object are clean and not slippery, and that it is free of jagged edges, metal slivers, nails, burrs and splinters
4. Ensure firm footing and good visibility whilst manoeuvring.

16.7.6 LABORATORY SAFETY

1. ***Glassware***. Gloves should be worn when setting up glass apparatus; cutting tubing or attempting to open tightly stoppered bottles. Chipped and cracked glassware should be discarded. Bottles should never be carried by their necks. Use copper gauze when heating glass vessels using gas flames
2. ***Gas***. Gas cylinders should be stored in well-ventilated areas outside the laboratory, or well away from heat if in the laboratory. Always double check that the gas is properly closed off after use. If there is a smell of gas in the laboratory open all doors and windows and operate all ventilation equipment. Identify the cause of the leaks if

possible, and isolate. Otherwise evacuate the laboratory and obtain specialist assistance

3. ***Chemicals***. All chemicals should be clearly marked as to their contents and possible hazard. Solvents should be stored in explosion-proof containers in a suitably ventilated place. Acids should be separately stored in an area where spillage can be dealt with. Rubber aprons, face shields, gloves and acid-resistant dustcoats should be used when working with dangerous chemicals. There should be a shower with a valve that can be quickly operated by means of a pull on a chain or a short movement of a lever.
4. ***Electrical***. All electrical equipment should be explosion proof and earthed. Earth leakage equipment should be installed on the laboratory circuits.
5. ***Safety and Fire Hazards***. Certain chemicals such as ammonia, nitric and perchloric acids can react violently with some organic chemicals giving rise to the possibility of fire or explosion. Many volatile solvents are inflammable. When working with solvents the work should be carried out under a ventilated hood. Suitable fire extinguishers should be available at accessible points and a first-aid kit should be kept in the laboratory
6. ***Procedures***. Suction bulbs should be used on pipettes for dangerous chemicals. Tongs and asbestos gloves must be used when handling heavy samples. Spillage should be cleaned up immediately. Hands should be washed with soap and hot water before eating or smoking. No smoking or eating should be permitted in the laboratory.

16.8 SAFETY LEGISLATION

All wastewater works plants must comply with the provisions of the Occupational Health and Safety Act (Act No 85 of 1993) and any amendments and regulations relating thereto. The regulations amongst other things provide for the following:

1. Depending on the total size of machinery power installed, the works may be required to be under the responsibility of a certified engineer or a designated responsible competent person. Delegations will be made in terms of the Occupational Health and Safety Act

2. The engineer (or responsible person) is responsible to the Divisional Factories Inspector for all safety procedures at the works and can be held responsible for any accidents, which may occur through neglect of safe working procedures.

The engineer (or responsible person) must also keep all records required by the Act such as registers for lifting gear, elevators, pressure vessels and boilers. He shall also submit accident reports and ensure that any inspections required in terms of the Act on pressure vessels and boilers are carried out timeously.

17 APPENDIX A: PROCESS FLOW DIAGRAM

18 APPENDIX B: LIST OF MECHANICAL EQUIPMENT

GWAING WWTW

1 Inlet Works

1.1 General Data

Number of units .... 2 ....

Model number... ....

Country of origin ....

Model Name .... Huber Rotamat screens.................

Kilowatt rating .... 0.75 KW ....

General data gearbox.. Bauer motor/gearbox.....................

Drive end bearings and make ....

Non-drive end bearings and make ....

Bar spacing... ....

Drive sprocket shaft bearings size/make.................... ....

Bottom sprocket shaft bearings size/make................. ....

Width of screen ....

1.2 Conveyor.. :...

Drive unit .... Euro drive motor/gearbox……..

Kilowatt rating .... 1.1 KW…………………………..

Country of origin ....

Drive Bearings and make... ....

Non drive Bearings and make.................................... ....

Method of greasing .... …………………………………..

Length of belt /screw.. …………………………………..

1.3 Pista paddle drive gearbox

Make .... Bearingman...................................

Country of origin	
Power rating	1.1 KW
Power absorbed at Duty Point	
Maximum shaft power output	
Speed	
Frame size	
Greasing/oil	

1.4 Blowers

Make	Sutorbilt
Model	2LP
Kilowatt rating	4 KW
Number of units	1

1.5 Wash water pumps

Make	Franklin Electric booster pump
Model	
Country of origin	
Type	
Type of glands	
Drive end bearings and make	
Non-drive end bearings and make	
Greasing method	
Kilowatt rating	1.5 KW
Number of pumps	2
Valves inlet/outlet type	
Non return valves	

Lifting unit	....
Capacity of unit	....
Date tested	....

1.6 Classifier

Type of gearbox..	Bauer motor/gearbox.....................
Model\type	RoSF3 ....
Country of origin	....
Power rating	1.1 KW ....
Type of material bridge	steel ....
Drive end bearings and make	....
Non-drive bearings and make	....
Centre Bearing size	....
Scum removal mechanism.....................................	....
De-sludge valves	....
Condition of Bridge	....
Bridge Drive wheels type	....
Method of greasing..	....

2 BNR system

2.1 Aerators

Number of units	4 ....
Kilowatt rating	55 KW ....
Number of units	2 ....
Kilowatt rating	45 KW ....
Gearbox make	Flender...
Gearbox Power rating	....
Gearbox drive end bearing and make	....

Gearbox Non-drive end bearing and make ....

Coupling type ....

Coupling size ....

Rotor size ....

Type of oil and capacity ....

2.2 Mixers

Number of units .... 6..

Make... Motorelli industrial motor and Mixtec gearbox..............................

Model ....

Drive end bearing and make (Gearbox)..................... ....

Non-drive end bearing and Make.............................. ....

Coupling Type ....

Kilowatt rating .... 11 KW ....

Type of oil and capacity ....

2.3 "r" Recycling pumps

Number of units.. 6..

Type of pumps .... Vertical axial lift ....

Model ....

Country of origin.. ....

Sealing arrangement mechanical/gland ....

Size of mechanical seal.. ....

Make .... Engineered pump & systems.........

Suction size.. ....

Delivery size... ....

Delivery head ....

Capacity of pump	....
Kilowatt rating	11 KW ....
Valves inlet/outlet type	....
Non-return valves..	....

2.4 "a" Recycling pumps

Number of units	3..
Type of pumps	Vertical axial lift ....
Model	....
Country of origin..	....
Sealing arrangement mechanical/gland	....
Size of mechanical seal...	....
Make	Engineered pump & systems..........
Suction size...	....
Delivery size..	....
Delivery head	....
Capacity of pump	....
Kilowatt rating	11 KW ....
Valves inlet/outlet type	....
Non-return valves..	....

3 SST`s Clarifiers

Number of units	2..
Type of drive..	SEW eurodrive motor/gearbox ....
Make gearbox...	SEW...
Kilowatt rating	0.12 KW ....
Type of oil...	....
Capacity of oil	....

Centre bearing Type	....
Centre bearing size..	....
Type/method of lubrication...	....
Material type centre bearing	....
Make/type Bridge carrier wheels................................	....
Condition of Bridge walkway structure	....
Type of sludge discharge valves/sluice gates	....
Chlorination pipe work/type and schedule...................	....
Condition of weirs	....
Type of weirs	....
Condition of centre scum/baffle plates	....
Type of scum discharge...	....
Condition of scum removal mechanism	....
Condition of outlet V-Notch plates..............................	....

4 RAS/WAS Pump Station

Number of units	2..
Type of pumps **RAS**	Gorman Rupp................................
Type of drive...	....
Pulley sizes Drive end	....
Pulley sizes Non drive end...	....
Coupling guards material..	....
Taper lock bush sizes for coupling D/E.......................	....
Taper lock bush size for coupling Non D/E	....
V-Belt sizes...	....
Number of belts	....
Make of belts	....

Direct coupling Yes/No	....
Fennerflex coupling size	....
Type of pumps **WAS**..	Submersible ....
Number of units	2...
Size of pumps...	....
Make/Model..	....
Make/material of guide poles	....
Capacity of pump..	....
Delivery size of pump	....
Valves inlet/outlet type...	....
Non-return valves	....
Type of lifting equipment..	....
Capacity of unit...	....
Date of last testing..	....

5 CHLORINE BUILDING

Number of units (pumps)	2...
Type of pumps...	Grundfos booster pumps................
Model..	....
Country of origin	....
Type of Coupling	....
Coupling size..	....
Capacity of pumps...	....
Kilowatt rating...	1.1 KW ....
No of fans...	2...
Type of fans..	Woods electric................................
Kilowatt rating...	0.55 KW ....

Lifting unit ....

Capacity of unit ....

6 DEWATERING PLANT

6.1 Sludge pumps

Number of units	2..
Type	Seepex cavity pumps ....
Make...	Seepex...
Model..	....
Capacity	....
Kilowatt rating	4 KW ....
Type of coupling	....
Size of coupling	....
Type of drive..	....
V-belt drive Yes/No..	....
Pulley size drive end..	....
Pulley size Non-drive end	....
Number of belts	....
Type of belt..	....
V-Belt size	....
Lifting unit	....
Capacity of lifting unit...	....
Date tested	....
Valves inlet\outlet type	....
Non-return valves	....

6.2 Air Ejectors

Number of units	2..
Type	Flygt Flo-Get ....
Material type	....

6.3 Mixers

Number of units	2..
Type	Flygt ....
Country of origin	....
Model..	....
Kilowatt rating	....
Type of Gearbox..	....
Gearbox ratio/rpm...	....

6.4 Wash Water pump

Number of units	2..
Type	Booster pump................................
Make..	Franklin Electro ....
Model..	....
Capacity	....
Kilowatt rating	1.5 KW ....
Type of coupling	....
Size of coupling	....
Type of drive...	....
Valves inlet/outlet type..	....
Non-return valves	....

6.5 Pumps

Number of units	2..
Type	High pressure in line.......................
Make..	Movitec KSB..................................
Model..	....
Capacity	....

Kilowatt rating	7.5 KW ....
Type of coupling	....
Size of coupling	....
Type of drive..	....
Valves inlet/outlet type	....
Non-return valves	....

6.6 Conveyors

Number of units	2..
Drive unit	Bauer drive motor/gearbox ....
Kilowatt rating	1 KW & 0.75 KW ....
Country of origin	....
Drive end Bearings and make...................................	....
Non drive end Bearings and make............................	....
Method of greasing	....
Length of belt /screw..	....

6.7 Compressors

Number of units	2..
Model...	....
Make..	Kaeser Kompressoren...................
Maximum rated pressure	10 Bar ....
Kilowatt rating	1.1 KW ....
Type of oil	....
No of Cylinders	....
Operating Pressure...	....
Country of origin	....

Year of manufacture ....

Date tested ....

6.8 Belt wash effluent pump

Number of units	2..
Model..	....
Type	Submersible ....
Capacity	....
Size of unit..	....
Kilowatt rating	....
Valves inlet/outlet type	
Non-return valves	....

6.9 Belt presses

Number of units	2 ....
Model..	....
Make...	....
Country of origin	....
Year of manufacture	....
Gearbox make	Bauer motor/gearbox......................
Coupling size	....
Belt width..	....
Auxiliary equipment	....
Instrumentation..	....
Capacity	....
Kilowatt rating	2.2-2.6 KW ....

6.10 Strainer

Number of units	1 ....
Type of unit..	....

6.11 Drain Belt

Number of units	1 ....
Drive unit	Bauer drive motor/gearbox ....
Kilowatt rating	0.75 KW ....
Country of origin	....
Drive end Bearings and make....................................	....
Non drive end Bearings and make.............................	....
Method of greasing	....
Length of belt /screw...	....

6.12 Poly Pumps

Number of units	3..
Type	Centrifugal....................................
Make..	Seepex..
Model..	....
Capacity	....
Kilowatt rating	0.75 KW ....
Type of coupling	....
Size of coupling	....
Type of drive...	....
Valves inlet/outlet type	....

6.13 Polly Mixers

Number of units	2..
Type	....
Country of origin	....
Model..	....
Kilowatt rating	0.75 KW ....

Type of Gearbox.. ....

Gearbox ratio/rpm... ....

6.14 Poly Feeder

Number of units .... 1 ....

Type ....

Country of origin ....

Model.. ....

Kilowatt rating .... 0.18 KW ....

Type of Gearbox.. Elektrim motor/gearbox ....

Gearbox ratio/rpm... ....

Drive end bearing and make...................................... ....

Non-drive bearing and make..................................... ....

7 RAW PUMPSTATION

7.1 PUMPS

Make.. Gorman Rupp................................

Type .... Self priming ....

Size/model.. ....

Kilowatt rating .... 28 KW ....

Suction size ....

Delivery size ....

T-type of drive... ....

Pulley sizes Drive end ....

Pulley sizes Non drive end... ....

Coupling guards material... ....

Taper lock bush sizes for coupling D/E...................... ....

Taper lock bush size for coupling Non-D/E................. ....

V-Belt sizes..	....
Number of belts	....
Make of belts	....
Direct coupling Yes/No	....
Fennerflex coupling size	....
Valves inlet/outlet type...	....
Non-return valves type..	....

7.2 PST`S

Number of units	2..
Type of drive..	Flender motor/gearbox ....
Make gearbox...	Flender ....
Type of oil	....
Capacity of oil	....
Kilowatt rating	0.37 KW ....
Centre bearing Type	....
Centre bearing size...	....
Type/method of lubrication.....................................	....
Material type centre bearing	....
Make/type Bridge carrier wheels............................	....
Condition of Bridge walkway structure	....
Type of sludge discharge valves/sluice gates	....
Condition of outlet V-Notch plates..........................	....
Type of weirs	....
Condition of centre scum/baffle plates	....
Type of scum discharge...	....
Condition of scum removal mechanism	....

8 RETICULATION PUMP STATION

8.1 HUMUS

Number of units	2..
Make...	Gorman Rupp.................................
Type	Self priming ....
Size/model..	....
Kilowatt rating	4 KW ....
Suction size	....
Delivery size	....
T-type of drive..	....
Pulley sizes Drive end	....
Pulley sizes Non drive end...	....
Coupling guards material	....
Taper lock bush sizes for coupling D/E	....
Taper lock bush size for coupling Non D/E	....
V-Belt sizes..	....
Number of belts	....
Make of belts	....
Direct coupling Yes/No	....
Fennerflex coupling size	....
Valves inlet\outlet type	....
Non-return valves	....

8.2 RECYCLING PUMP No.1

Number of units	1 ....
Make...	KSB..
Type	....
Size/model..	....
Kilowatt rating	22 KW ....
Suction size	....
Delivery size	....
T-type of drive..	....
Pulley sizes Drive end	....
Pulley sizes Non-drive end	....
Coupling guards material..	....
Taper lock bush sizes for coupling D/E	....
Taper lock bush size for coupling Non-D/E	....
V-Belt sizes..	....
Number of belts	....
Make of belts	....
Direct coupling Yes/No	....
Fennerflex coupling size	....
Valves inlet\outlet type..	....
Non-return valves	....

8.3 RECYCLING PUMP No.2

Number of units	1 ....
Make..	KSB..
Type	....
Size/model...	....
Kilowatt rating	15 KW ....
Suction size	....
Delivery size	....
T-type of drive...	....
Pulley sizes Drive end	....
Pulley sizes Non-drive end	....
Coupling guards material..	....
Taper lock bush sizes for coupling D/E......................	....
Taper lock bush size for coupling Non-D/E................	....
V-Belt sizes...	....
Number of belts	....
Make of belts	....
Direct coupling Yes/No	....
Fennerflex coupling size	....
Valves inlet\outlet type..	....
Non-return valves	....

8.4 HUMUS TANK ROTATING BRIDGE No.1

Number of units	1 ....
Type of drive...	Femco motor/gearbox ....
Make gearbox...	Femco ....
Type of oil..	....
Kilowatt rating	....
Capacity of oil	....
Centre bearing Type	....
Centre bearing size...	....
Type/method of lubrication..	....
Material type centre bearing	....
Make/type Bridge carrier wheels................................	....
Condition of Bridge walkway structure	....
Type of sludge discharge valves/sluice gates	....
Condition of outlet V-Notch plates	....

8.5 HUMUS TANK ROTATING BRIDGE No.2

Number of units	1 ....
Type of drive...	WEG motor/gearbox.......................
Make gearbox...	WEG ....
Type of oil..	....
Capacity of oil	....
Kilowatt rating	....
Centre bearing Type	....
Centre bearing size...	....
Type/method of lubrication..	....
Material type centre bearing	....

Make/type Bridge carrier wheels ....

Condition of Bridge walkway structure ....

Type of sludge discharge valves/sluice gates ....

Condition of outlet V-Notch plates.............................. ....

9 FINAL EFFLUENT PUMP STATION

9.1 Submersible/ Recycle pumps

Number of units .... 2..

Model.. ....

Type .... Submersible ....

Capacity ....

Size of unit... ....

Kilowatt rating ....

Valves inlet/outlet type ....

Non-return valves ....

9.2 Booster pumps

Number of units .... 1..

Make... Franklin Electro ....

Type .... Booster...

Size/model... ....

Kilowatt rating .... 1.5 KW ....

Suction size ....

Delivery size ....

Type of drive.. ....

Pulley sizes Drive end ....

Pulley sizes Non-drive end ....

Coupling guards material.. ....

Taper lock bush sizes for coupling D/E	....
Taper lock bush size for coupling Non-D/E	....
V-Belt sizes..	....
Number of belts	....
Make of belts	....
Direct coupling Yes/No	....
Fennerflex coupling size	....
Valves inlet\outlet type	....
Non-return valves	....

10 ANAEROBIC DIGESTER

10.1 Mixer

Number of units	1 ....
Type	WEG ....
Country of origin	....
Model...	....
Kilowatt rating	15 KW ....
Type of Gearbox...	motor/gearbox ....
Gearbox ratio/rpm..	....

10.2 Lubricator

Number of units	1 ....
Type	WEG ....
Capacity	0.88 KW ....
Make...	....
Model...	....

11 NIGHTSOIL SYSTEM

11.1 Pump

Number of units	1 ....
Model..	....
Type	Submersible ....
Capacity	....
Size of unit..	....
Kilowatt rating	15-20 KW ....
Valves inlet/outlet type	....
Non-return valves	....

19 APPENDIX C: DESIGN DATA

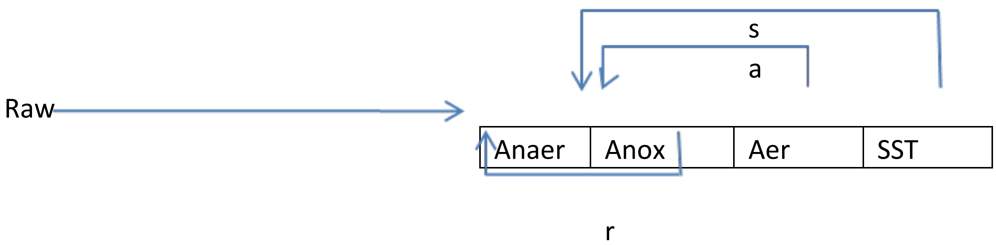
Design Data

Description	Value	Units
Design criteria		
Average dry weather flow	11	Ml/d
	127	l/s
Peak factor	3	
Peak wet weather flow	33	Ml/d
	1375	m3/h
	382	l/s
Raw sewage contribution (est.)	167	l/capita/d
Population equivalents (est.)	65868	
Influent sewage quality		
COD	950	mg/l
TKN	52	mg/l
P	15.3	mg/l
Suspended solids	320	mg/l
COD load	10450	kgCOD/d
TKN load	572	kgN/d
P load	168.3	kgP/d
Suspended solids load	3520	kg/d
Biofilter Plant		
ADWF	3.7	Ml/d
PST's	2	No
Diameter	15.5	m
Area (each)	188.72	m2
Upflow rate (ADWF)	0.4085	m/h
Upflow rate (PWWF)	1.2254	m/h
COD load	3515	kgCOD/d
COD removal	35	%
Suspended solids load	1184	kg/d
Suspended solids removal	67	%
Mass of primary sludge	793.28	kg/d
Mass of humus sludge	616.88	kg/d

Total sludge mass from PSTs	1410.2	kg/d
Biofilters	2	No
Diameter	30	m
Area (each)	706.95	m2
Depth	4	m
Volume (each)	2827.8	m3
Volume (total)	5656	m3
COD load	2285	kgCOD/d
Organic load	0.40	kgCOD/m3/d
Hydraulic load	2.62	m3/m2/d
Humus tanks	2	No
Diameter	20	m
Area (each)	314	m2
Upflow rate (ADWF)	0.25	m/h
Upflow rate (PWWF)	0.74	m/h
Humus sludge production	617	kg/d
Expected Effluent Quality Biofilters		
COD	72	
Ammonia	4	
Nitrate	25	
Soluble reactive P	11	
Suspended solids	15	
Activated Sludge		
ADWF	7.3	Ml/d
COD load	6935	kg/d
TKN load	379.6	kg/d
P load	111.69	kg/d
Anaerobic basin volume	2940	m3
Anoxic basin volume	5090	m3
Aerobic basin volume	7514	m3
Total volume	15544	m3
Retention time	2.1293	d
MLSS	2500	mg/l
Mass of activated sludge biomass	38860	kgMLSS
COD/MLSS ratio	0.1785	mgCOD/mgMLSS/d
Temperature (max)	22	C
Temperature (min)	17	C
Sludge age	20	days

A recycle	210	l/s
R recycle	170	l/s
S recycle	120	l/s

Inflow ADWF – Q	127	l/s
A/Q	1.6	
R/Q	1.3	
S/Q	0.9	



SSTs	2	No
Diameter	25	m
Area (each)	490.94	m2
Upflow rate (ADWF)	0.3098	m/h
Upflow rate (PWWF)	0.9293	m/h

Expected Effluent Quality Activated Sludge

COD	74
Ammonia	0.5
Nitrate	9.7
Soluble reactive P	0.3
Suspended solids	10

Anaerobic Digester

Total sludge mass	1410	kg/d
Sludge concentration	4	%
Volume of raw sludge produced	35	m3/d
Volume of digester	2750	m3
Retention time	78	d
Sludge mass after digestion	1128.1	kg/d
Sludge volume at 4% solids	28.203	m3/d

Sludge Drying Beds

Digested sludge volume	28.2	m3/d
Depth of sludge application	150.0	mm
Required area per day	188.0	m2/d

No of beds	20.0	
Bed length	35.0	m
Bed width	5.5	m
Total bed area	3850.0	m2
Drying period	20.5	d

20 APPENDIX D: TROUBLESHOOTING MATRIX

TROUBLESHOOTING MATRIX – PST'S, BIOFILTERS AND HUMUS TANKS

Problem/Symptom	Cause	Remedy
PST emits large bubbles with a bad smell	PST scraper mechanism stopped	Reset
	PST scraper mechanism rubber strips worn	Examine and replace
	Desludging frequency too low	Increase
Biofilter ponding	Media clogged	Rinse thoroughly
		Dig up affected area to 1m depth and clean media
		If fats are causing the problem find the source of the fats – industry responsible
Biofilter ammonias rise	COD overloading	Increase frequency of PST desludging
	Recycle pump not operating	Reset or repair
	Humus tank desludging too infrequent – solids breaking down	Increase frequency of desludging
	Scraper mechanism stopped	Reset or repair
	Scraper mechanism rubber strips worn	Inspect and replace

TROUBLESHOOTING MATRIX – DISINFECTION

Problem/Symptom	Cause	Remedy
High E coli	High ammonias	Biofilter problem – investigate further
		Activated sludge problem – too little aeration
		Accumulated solids in maturation river breaking down and releasing ammonia – measure ammonia before and after pond
	High suspended solids absorbing chlorine	Check suspended solids in effluent and determine cause – e.g. floc carryover on SST's
	Low chlorine dose	Check with chlorine comparator
	Chlorine cylinder empty	Replace
	Flow proportioning not working	Check if chlorine dose increases as flow increases

TROUBLESHOOTING MATRIX – ANAEROBIC DIGESTION

Problem/Symptom	Cause	Remedy
VFA's in excess of 200mg/l or pH less than 7.0 or no gas generated	Hydraulic overloading of digester	Reduce volumes pumped to digester
	Organic overload	Check if the strength of the sludge has increased (COD) or if high ammonia effluent has been fed to digester (blood from abattoir)
	Mixer not operating	Check and repair
If problems persist contact experienced operator to assist – methanogenisis fails below pH of 6.8 – to be avoided at all costs! Increase pH using sodium bicarbonate. Do not use lime to increase pH – it will block pipes		

TROUBLESHOOTING MATRIX – ACTIVATED SLUDGE

Problem/Symptom	Cause	Remedy
High phosphates	**R – recycle low or off**	**Check pumps for debris collection**
		Check that required number of pumps are operational
High nitrates	**A – recycle low or off**	**Check pumps for debris collection**
		Check that required number of pumps are operational
High ammonias	**Too little aeration**	**Increase DO setpoint**
		Check that outlet weir level has not been lowered by mistake
	Toxic effluent received – e.g. industrial effluent – ammonias rise very fast and wont go down	**Nitrifiers are slow growing and can take 10-14 days to recover**
	MLSS too low	**Measure and decrease wasting**
High COD	**High suspended solids carryover from SST's**	**See below**
High suspended solids carryover from SST's	**Worn RAS pump impeller**	**Check for wear and replace**
	RAS pump not operating	**Reset or repair**
	Excessive inflows into works	**Divert flow to maturation pond**
		Investigate cause of excessive flow – e.g. stormwater ingress
	Excessive MLSS concentration	**Measure and increase wasting volume**
	Scraper/siphon tripped	**Reset or repair**
	Scraper/siphon rubber strip worn	**Examine and replace**

TROUBLESHOOTING MATRIX – SLUDGE DEWATERING

Problem/Symptom	Cause	Remedy
Dewatered sludge solids low i.e. too wet	Poly incorrect	Check poly
	Poly makeup incorrect	Check an correct
	Solids measurement detector malfunction	Contact agents
	Feed sludge too thin	Investigate and correct

21 APPENDIX E: DRAWINGS