AQUARIUS CONSULT CC
Reg. No.: CC/2010/3052

OSHAKATI TOWN COUNCIL

SEWAGE TREATMENT PLANT

PRELIMINARY DESIGN REPORT

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REV	DATE	BY	COMMENTS
0	21 Aug 2019	TS	Preliminary Design - for Client's comments

Written & Compiled by: T. Seifart

Revision : 0

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OSHAKATI SEWAGE TREATMENT

SECTION 1: BACKGROUND, DESIGN PARAMETERS, TECHNICAL, OPERATIONAL AND HEALTH AND SAFETY ASPECTS

1. INTRODUCTION

A comprehensive assessment report (Seifart, 2018) regarding the condition of the existing sewage treatment plants at Oshakati East and West, which employ oxidation pond systems, has been undertaken in 2018. Figure 1 shows the location of these ponds.

Figure 1. Google™ Map indicating location of the East and West Ponds at Oshakati

In summary, this report concluded that:

- The oxidation ponds were provided many years ago and have been expanded as the population increased;
- Both plants are already highly overloaded with regards to sewage volumes and organic loading reaching the sewage works;
- Future population influx and above-average growth, coupled to an increase in households with flushing toilets being connected up to the reticulation system, will result in more discharge to the sewage works in the near future already.

Furthermore, the report pointed out that rain and flooding is routinely experienced during the rainy season, resulting in embankments overflowing and/or breaking, spilling raw or, at best, insufficiently treated sewage into the surrounding, lower lying, densely populated areas and oshanas. Not only does this cause dangerous health conditions for the people who largely commute by foot through the flooded areas, but also contributes towards contaminating fish that is caught in the oshanas and widely consumed. People develop diarrhoea during the rainy season in the affected areas and there have even been cases of cholera documented that could be linked to sewage spills. Even in times of drought, some of these overloaded ponds may still discharge into the surrounding environment where animals drink the insufficiently treated water. Figures 2 and 3 show typical problems encountered with the pond set-up at Oshakati West and East ponds, respectively.

a) Final water discharged outside of the fence b) Cattle grazing and drinking

Figure 2. Oshakati West Ponds – Final water health hazards at the ponds

a) Soil erosion at the final pond outlet b) Area adjacent to final pond outlet - previous ponding

Figure 3. Oshakati East Ponds – Final water health hazards at the ponds

The current legal framework and environmental impact of pond systems need also be taken into consideration: Ponds do **not** achieve a final water quality that conforms to the Namibian General Standard (DWAF, Vol 2, 2008), nor is the final, treated effluent safe for reuse.

Also, Namibia is an arid country that needs to exploit its water resources more optimally and reuse treated effluent. DWAF therefore does not encourage future use of ponds for larger communities any more. The *General Guidelines* for *Pond Systems* (DWAF, Vol. 2, July 2008) state: "Pond systems may only be considered if the ultimate load does not exceed 5 000 PE (population equivalents) or 800 kℓ/d", and latter Guideline also states: "Since water is a scarce commodity in Namibia, reuse thereof is strongly encouraged".

Since the people served by the both sewage treatment plants in Oshakati exceed 5 000 PE, extensions to the existing pond system is not an option anymore and an advanced treatment plant with reuse of the final effluent is required.

This report addresses the treatment capacity required and gives a preliminary design and cost estimate for a new sewage treatment plant (STP) for each community. Emphasis was placed on selecting advanced treatment technology that would be inexpensive, easy to operate and maintain and therefore most appropriate to incorporate at the town. Also, reuse of the final effluent in line with DWAF's policies, is addressed.

2. TECHNOLOGY OF CHOICE

Several advanced biological treatment processes that can treat raw sewage to a final effluent conforming to the Namibian General Standard and suitable for reuse in agriculture, are currently available on the market. The most familiar ones would be the activated sludge process, new-generation trickling filters, submerged membrane bioreactors and rotating disc reactors. We recommend trickling filter technology is chosen for the envisaged new plant at Oshakati, because we have found it most applicable to local conditions and especially because low-tech equipment is employed with no/minimal operator interference required. This will now be elucidated on.

2.1 New-Generation Trickling Filter Systems

New-Generation Trickling Filters (NGTF) effect advanced biological treatment of an effluent using attached-growth media technology to produce a high-quality final effluent. NGTF employ low-level mechanical technology in the form of submersible pumps, but latter require little service and maintenance. Generally, this technology is gaining increased acceptance throughout third world countries for the following reasons:

- Small footprint. To treat domestic effluent, NGTF need only ca 2-5% of the land area necessary for oxidation ponds (including evaporation);
- High quality final effluent. A final effluent exceeding the Namibian General Standard standards is produced. This will be safe for discharge even during periods of severe flooding of the area. Also, the final effluent can be reused for growing selected crops and aquaculture in line with DWAF guidelines (DWAF, Vol 6, 2012) or for gardening and lawns (e.g. sports fields and public parks) in the town.
- Simple technology. The only advanced mechanical equipment employed, are submersible pumps, which can be replaced without specific technical knowledge, and the drives for clarifier bridges. Once commissioned, no further process control or adjustment to the process is required.

- Minimal mechanical equipment that can break. Under the latter, only the service/recycle pumps would be of concern, but designers always allow for duty and standby pumps.
- Minimal inspection, service and maintenance required. Only submersible pumps and gearboxes, which require periodic inspection and maintenance, are employed. However, the town will also need other pump stations to transfer sewage to the treatment plant and submersible pumps can therefore be regarded as standard mechanical equipment once a full reticulation system has been provided for the town.
- Low power requirements. NGTF use approximately 35 to 40% less power than required by other advanced treatment processes giving a comparable treated effluent, such as oxidation ditches or activated sludge processes. Not only will the continuous power demand be low, but standby power in the form of a standby generator can be provided at minimal costs.

For the specific conditions encountered at Oshakati, Trickling Filter Technology was therefore considered as most appropriate and most reliable technology to be employed. The next section will deal with the most important design parameters on which our design was based on for both towns.

2.2 Basic Design Philosophy

The general and specific design aspects that have been taken into consideration when designing the new Oshakati STP include:

- Similar construction and lay-out of all structures. In order to allow for phase implementation (see later), the plant is designed in multiple trains, with each train looking and operating the same, so that operators will find exactly the same arrangement and equipment at all plant trains and will be familiar with the operation thereof.

- Operation and maintenance. Emphasis was placed on simple operation, ease of maintenance and minimal process adjustments, coupled to familiar processes as also currently used at the STP.

- General design aspects. The following aspects have been taken into account for choosing a specific unit treatment process:

    - Known, well-proven unit processes and equipment employed;
    - Availability of electricity is limited and power costs are expensive – energy-intensive unit processes were avoided;
    - Simplicity with regards to operation and maintenance;
    - Limited reliance based on skilled personnel;
    - Routine maintenance to be performed by locally trained personnel;
    - A standby pump is provided for each set of duty pumps;
    - Duplication of critical equipment such as pumps and valves will ensure limited stocks of spares can be kept on site.

- Specific design aspects. Specific attention was given to the following, area specific aspects:

    - Flooding. Large parts of northern Namibia are regularly flooded during the rainy season. There for, both plants were lifted approximately 1.5 m above natural ground level to ensure that they remain dry, even during times of severe flooding;

    - Tamper-resistant plant operation. Emphasis was placed on incorporating unit processes and equipment such that operators cannot simply bypass critical equipment unless really necessary for emergency maintenance purposes.

    - Plant location. The new plant will be constructed at the site of the current West Ponds (Figure 4). This will allow all sewage that is currently pumped from various pump stations throughout the town to the West Ponds to discharge into the new plant, with no modifications to the sewage collection and transfer network required. Sewage that is currently discharged into the East Ponds will be collected in one of the existing ponds and will be transferred by a set of pumps to the new plant. This means that all of the existing transfer pump stations throughout the town will remain in use as is, and no rerouting of existing pump lines will be required.

Figure 4. Proposed plant location at the Oshakati West ponds

3. DESIGN

3.1 Basic Design Figures

Our design relies on discharge figures currently observed plus expected growth due to more consumers installing flush toilets and being connected up to the sewer network, as well as future expected growth for the next ten years. Since it will take approximately three years to do a detail design, tendering, build and put into operation a new sewage treatment plant at the town, a ten year window is not far into the future. The plant is designed to be easily expanded and our overall design thus allows for additional treatment trains to be added, which may only be necessary in ten years' time or even thereafter.

Raw water treatment capacity. Design and construction of the now required capacity is termed Phase 1, whereas future capacity extensions are termed Phase 2. For Phase 1 basic flows (Table 1) as listed below were used for process design. The current and expected future population estimate was based on population estimates and expected growth figures for serviced erven in the near future, obtained from the Manager: Infrastructure & Technical Services of the Oshakati Town Council (T. Negongo, personal communication, 24 October 2017).

Table 1: Population and Wastewater Volumes for Oshakati

DESIGN PARAMETER	**UNITS**	**PLANT CAPACITY**		
		Phase 1 now	**Phase 2 future**	**TOTAL**
Population served	PE	45 000	15 000	60 000
Sewage Discharged	m³/d	4 500	1 500	6 000
Average Dry Weather Flow	m³/h	187.5	62.5	250
Peak Flow	m³/h	525	175	700

Main raw water design parameters. Envisaged organic loads, for raw sewage discharged to the new works that were used for design purposes are shown in Table 2.

Table 2: Average Daily Design Wastewater Loads for Oshakati

DESIGN PARAMETER		**Basis**	**PLANT CAPACITY**		
		Load (mg/l)	**Phase 1** (kg/d)	**Phase 2** (kg/d)	**TOTAL** (kg/d)
Chemical Oxygen Demand	(COD)	1 000	4 500	1 500	6 000
Biological Oxygen Demand	(COD)	500	2 250	750	3 000
Total Suspended Solids	(TSS)	400	1 800	600	2 400
Ammonia-Nitrogen	(NH_4-N as N)	60	270	90	360
Total Phosphates	(TP as P)	25	112.5	37.5	150

Final water quality. The plant will be designed such that the final effluent that is produced will conform to the Namibian General Standard (Appendix A) as per current Namibian legislation for final effluents (Water Act, 1956 (Act No. 54 of 1956) and will exceed European Standards (EC Directive 91/271/EHS) for plants of this size.

We are also aware that new effluent quality standards have been drawn up and are currently being circulated by the Department of Water Affairs and Forestry (DWAF). These are expected to be legalized soon and our current design therefore already includes for adhering to the future Namibian General Standard for Effluents (Appendix B) as well.

3.2 Selected Treatment Processes & Technology

Advanced biological treatment utilizing Trickling Filter (TF) technology as employed for Oshakati will incorporate the following unit treatment processes:

- Inlet works with screening and grit removal in a grit channel;
- Suspended solids removal in a primary clarifier
- Aerobic, biological carbonaceous material removal and nitrification in biofilters (trickling filters);
- Biomass removal in a secondary clarifier;
- Disinfection using chlorine gas

- Sludge digestion in a humus tank with desludging to and sludge drying in on-site drying beds.

Figure 5 depicts the proposed process schematics for the plant and unit processes. Latter are further elaborated on individually in this report.

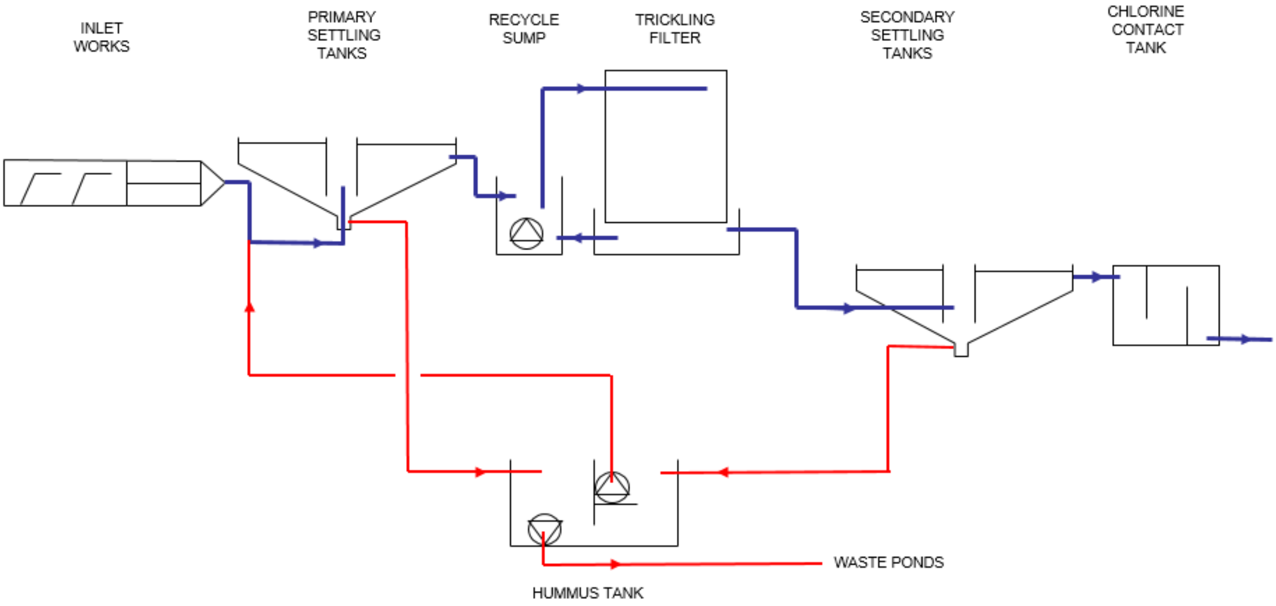

Figure 5: Process Schematic for Oshakati STP

The individual unit processes will now be discussed in a similar order as the raw sewage flows through the plant and needs treatment. The discussion is supported by a basic process/piping and instrumentation diagram (P&ID, Drawing No 1802.001.OSH-001), which should be referred to as well.

3.2.1 Inlet Works (CT01). A typical inlet works structure will serve two off trains, each sized for 1 500 m³/d ADWF. Large objects such as plastic bags, bottles, rags and other, generally non-biodegradable material will be caught by a set (two off) of screens in series at the inlet to the treatment plant. These screens consist of static, parallel bars at a 45° angle with spacing between the bars of 25 mm for the first screen, followed by 10 mm for the second screen. The screens will be manually cleaned (raked) and the screenings collected and disposed of in a waste-bin that will be placed next to the screens. Final disposal of the screenings will be to the municipal solid-waste dump site.

After screening a set of grit removal channels (see Figure 6) will ensure that the bulk of sand and grit can be removed from the sewage before further treatment. During normal operation both channels are in operation and heavy, mostly inorganic particles settle in these channels. During times of low inflow to the works, one channel is taken out of operation by inserting manual sluice gates on either side thereof and draining the water from it. The grit is then manually removed by an operator from the bottom of the channel and left to drip off and dry out on a ledge at the top of the channel.

Figure 6: Proposed inlet works with grit removal channel

Although requiring manual intervention to clean the screens and grit channels, we recommend that this method be used and that no electro-mechanical screen will be provided. This is because latter need frequent services and maintenance and, from practical experience, we found them to often break down due to a revolving chain employed. The necessary expertise to repair such a mechanical screen is not available in close proximity of the plant.

After passing through the grit channels, the inflow will be split to feed two trains, thus to the inlet of the primary clarifiers (CT02). A flowmeter (FM01/02) will be provided to measure inlet flows to each clarifier.

<u>3.2.2 Primary clarifier (CT02)</u>. Primary clarifiers are employed to remove 60% to 70% of total suspended solids (TSS) and 35 to 40% of COD/BOD in the raw sewage. To achieve this, a clarifier detention time of approximately 3 hours and a weir overflow rate not exceeding 30 $m^3/m^2.d$ is required (Figure 7 from Qasim, 1999).

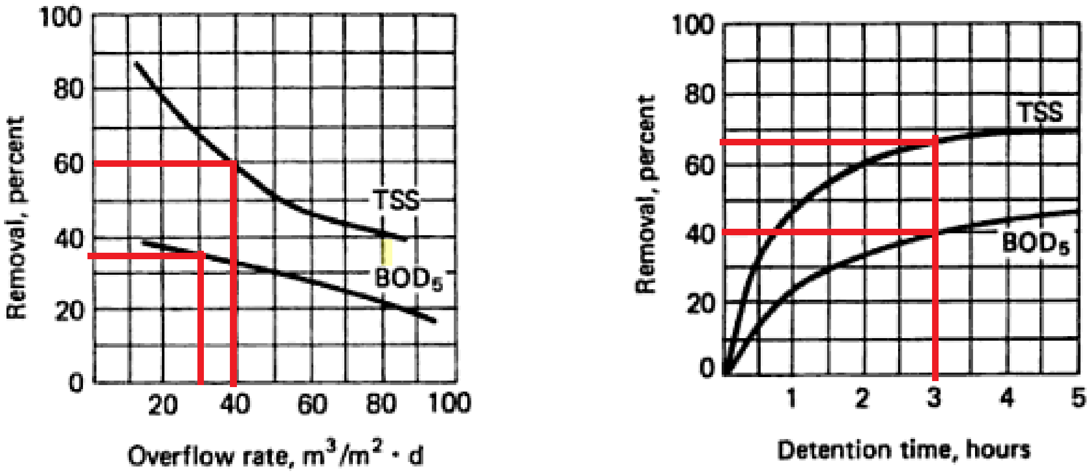

Figure 7: Primary Settling Tank Design Criteria (Qasim, 1999)

One primary clarifier will be therefore be provided per train, thus with capacity of 1 500 m^3/d ADWF and main dimensions as follows:

- Diameter = 16,0 m
- Water depth (sidewall) = 3,5 m

The settler will be fitted with a central, stilling well to equally distribute the inflow, with the following dimensions:

- Diameter = 1,2 m
- Water depth (sidewall) = 2,5 m

Peripheral overflow weirs (V-notch) with a 500 mm wide Stamford baffle will be provided in the clarifier to prevent density currents and ensure equal draw-off of clarified effluent.

Rotating bridge (Figure 8). The settler will be fitted with a rotating (travelling) bridge driven by a peripheral bridge-drive (MM01) and scum and sludge-scraping mechanism. The peripheral drive runs on the outside wall of the clarifier and the sludge is moved towards the central sludge hopper for periodic sludge withdrawal.

The clarifier is fitted with a desludge pipe with a manual valve so that the desludge process can be adjusted as required. Sludge and scum is withdrawn continuously by leaving the desludge valve open at a set position and the sludge is then discarded to the humus tank.

Figure 8. Clarifier with Rotating Bridge

Control system. The primary clarifiers will be equipped with a very basic control system. The motor controlling the rotating bridge will have an “ON/OFF” button at the clarifier, so that the bridge can be stopped for emergencies or maintenance. The desludge valve will be manually set during commissioning, allowing settled sludge from the bottom of the clarifier to be removed to the sludge humus tank. The hydraulics of the plant will be such that the water pressure in the clarifier will automatically push the sludge to the humus tank.

After primary clarification, the settled effluent is discharged into the trickling filter feed/recycle sump of the trickling filter system.

3.2.3 Trickling Filter System. The trickling filter system consists of a feed/recycle sump (CT03), which is sized for and acts as anoxic reactor for denitrification, the trickling filter tower (MT01) and trickling filter basin (CT04):

3.2.3.1 Trickling Filter Feed Sump (CT03). After primary treatment, the overflow from the primary settler, is discharged into a pump sump, from where it is recirculated by open impeller submersible pumps (2 duty, 1 standby) through the trickling filter. This sump is sized with a hydraulic retention time that allows anoxic conditions to prevail. The pumps will be sized as follows:

Number - 3 off (2 duty, 1 standby)
Tag Number - PS01 A/B/E
Type - Submersible pump
Capacity - 240 m^3/h
Head - 10 mWC
Motor - 18.5 kW (Inst); 380 V

Control System. The pumps will be fitted with a low-level protection switch. If the period of non-inflow to the plant is very long, it can be expected that water will be lost through evaporation and the level in this sump will drop. To then prevent the pump(s) from running dry, they will be switched off at a certain low-level. Should the plant receive inflow again, the level in the sump will rise and the level switch will switch the pump(s) on automatically. This also ensures that no operator will be required to ever switch the plant on or off.

3.2.3.2 Trickling Filter Tower (MT01). The trickling filter itself consists of a tower stacked with a bed of highly permeable medium (Figure 9a), which serves as host for micro-organisms to attach to and grow on, to form a biological film. Organic material in the wastewater is absorbed by micro-organisms growing as a biological film on the media. In the outer portion of the film, aerobic organisms degrade organic material, whereas anaerobic organisms exist deeper into the biological film, i.e. near the surface of the media (Figure 9 b).

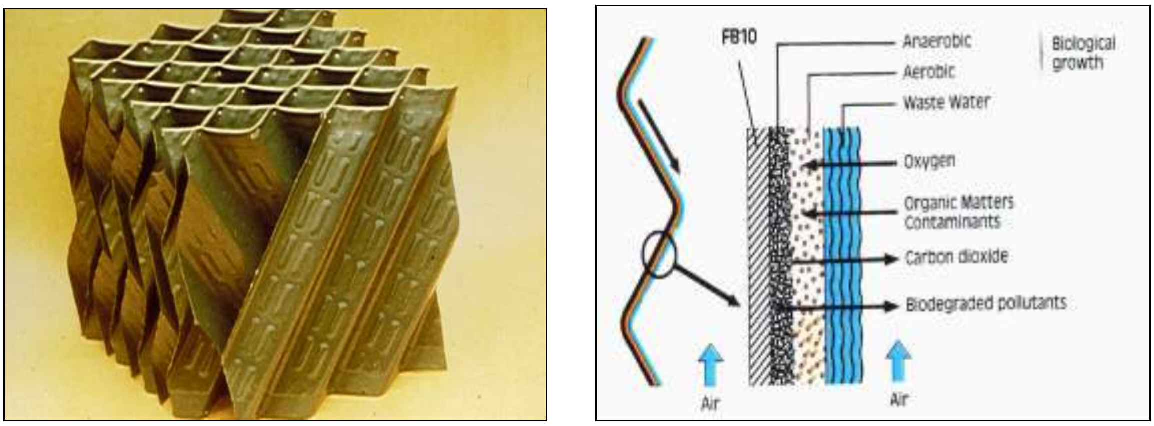

Figure 9a): Packing in trickling filter.

Figure 9b): Biofilm growth on media.

Figure 9: Trickling Filter Media and Wetting (Spray Nozzles)

The filter media will be manufactured from robust, weatherproof and UV-stabilised plastic material with self-supporting structure and is stacked inside a tower, 6 m high (Figure 10a). Wastewater is sprayed over and percolates through the media. A simple system of non-clogging, open nozzles will be used to distribute the water evenly over the top of the media (Figure 10b). The media will allow for carbonaceous material removal as well as nitrification to take place inside the trickling filter. The packing will have a high void ratio (>97%) to reduce the risk of clogging and to maximize ventilation throughout the filter. Efficient mixing and wetting is essential and media with a cross-flow pattern for the even distribution of water throughout the filter bed will be provided.

Figure 10a): Trickling filter tower

Figure 10b): Water distribution on top.

Figure 10: Trickling Tower with Wetting (Spray Nozzles) on Top

A trickling filter serving 15 000 PE (1 500 m^3/d) will be provided with overall design data as reflected in Table 3.

Table 3: Trickling filter design specifications (for 15 000 PE)

Quantity	1
Footprint area (internal)	15.5 m by 15.5 m
Packing height	6 m
Recycle Feed:	480 m^3/h
Raw inflow (ADWF)	62.5 m^3/h
Effluent BOD concentration	< 20 mg/l
Effluent Ammonia concentration	< 10 mg/l as N

Control. The trickling filter control system will be based on maintaining a constant water level in the recycle sump. The two duty pumps will each recirculate water at a constant rate of 240 m^3/h, totaling 480 m^3/h. An actuated valve on the recycle return line to the recycle sump will ensure that the level in this sump remains more or less stable. If there is low/no settled water inflow to the sump and the level drops, more or all of the 480 m^3/h pumped to the trickling filters will be returned to the sump. If the level is at a pre-determined high level, the valve will close progressively and will result in treated water overflowing to the secondary settler, which will ensure that the sump does not overflow. A constant level in the recycle sump ensures that the trickling filter feed (to top of media) remains constant, even during times of no or low raw sewage inflow to the plant, which is ideal for microbial biomass growth in the trickling filters required for aerobic digestion.

The water, after percolating through the media, is collected in the trickling filter basin. Biological solids that have become detached from the packing media have to be removed before the effluent is disinfected and can be finally discharged. Removal of the biomass is achieved in a conventional, secondary settler/clarifier.

3.2.4 Secondary Clarifier (CT05). Treated effluent from the trickling filter is discharged into the settling tank, where the suspended solids settle out and clear water is drawn off via V-notch weirs that discharge into a peripheral channel at the top of the clarifier. The sludge is scraped by a rotating bridge to the centre of the tank, where it is collected in a desludge hopper. The following minimum design criteria have to be met:

- Settling rate ≤ 1.0 $m^3/m^2/h$ at PF
- Retention time > 3 h

One secondary clarifier will be provided per train, thus with capacity of 1 500 m^3/d ADWF and main dimensions as follows:

- Diameter = 19,0 m
- Water depth (sidewall) = 3,5 m

The settler will be fitted with a central, stilling well to equally distribute the inflow, with the following dimensions:

- Diameter = 1,5 m
- Water depth (sidewall) = 2,5 m

Rotating bridge. As before (see primary clarifier), the settler will be fitted with a rotating (travelling) bridge driven by an electric motor (MM02) with speed reducer to obtain a peripheral speed between 1,5 and 2 m per minute, similarly as previously described for the primary clarifier. A sludge scraper is fitted to the bridge to scrape the sludge (bottom) into a central hopper, from where it is then periodically discharged into the humus tank (CT08).

Control. Will be the same as described under the primary clarifier (Section 3.2.2)

3.2.5 Sludge Handling - Humus Tank (CT08). All sludge discharged from the primary and secondary clarifiers is collected in the humus tank. The sludge will be anaerobic due to microbial degradation/decay taking place in an oxygen deficient environment in this tank.

Part of this sludge (the more dilute part) is continuously returned with a set of sludge return pumps (PS02 – 1 duty, 1 standby) to the inlet of the primary clarifier, where this return sludge also serves as seeding material for anaerobic microorganisms in the primary clarifier. The sludge return pumps will be mounted approx. half-way (down) in the sump, ensuring that only the more dilute sludge is returned to the primary settler, whereas the thicker sludge will settle to the bottom of the humus tank. The Sludge Return Pumps will be provided as follows:

Number - 2 off (duty, standby)
Tag Number - PS02 A/B
Type - Submersible sludge pump

Capacity - 32 m^3/h
Head - 4 mWC
Motor - 2,2 kW (Inst); 380 V

The thicker sludge that settles at the bottom of the humus tank will be discharged from time-to-time to the sludge drying beds (CT07) by a separate set of sludge pumps (PS01 – 1 duty, 1 standby). The Desludge Pumps will be provided the same as the sludge return pumps (for ease of maintenance etc.) as follows:

Number - 2 off (duty, standby)
Tag Number - PS01 A/B
Type - Submersible sludge pump
Capacity - 32 m^3/h
Head - 4 mWC
Motor - 2,2 kW (Inst); 380 V

Control. The Sludge Return Pumps will operate continuously and are only fitted with a low-level protection to prevent them from running dry, should the level in the humus tank drop.

Desludging is estimated to takes place ca once per week, for 5 min only and the switching of the Desludge Pumps will be timer controlled. However, the frequency and duration of desludging must be adjustable (password protected, by process specialist only). During commissioning, the operating times will be set by a process engineer and should not be changed by an operator. (Only a process engineer should adjust the settings, if required.)

3.2.6 Disinfection – Chlorine Contact Tank (CT06). It is a requirement by DWAF that all final effluent produced in sewage treatment plants **must** be disinfected properly, even if only discarded to the environment.

The effluent will be disinfected utilising chlorine gas. A chlorine gas dosing station will be supplied for each site/plant. This will consists of 2 off 68 kg chlorine gas cylinders (on hire by client), each of which is fitted with a gas chlorinator. The dosing rate of the chlorinator can be manually adjusted to provide the necessary dosage for disinfecting the final effluent before discharge. An automatic switch-over unit will ensure that, when the cylinder in operation is empty, the system will switch over to a new, full bottle.

Figure 11: Typical medium-scale chlorine gas disinfection system (Hydramet)

An ejector, which is driven by the chlorine booster pump sucks in and mixes chlorine gas into a recycle stream. The details of the chlorine booster pumps will be as follows:

Number	-	2 off (duty/standby)
Tag Number	-	PB01 A/B
Type	-	Self priming booster pump
Capacity	-	1,4 m³/h
Head	-	30 mWC
Motor	-	0,8 kW (Inst); 380 V; 2 Pole

Water for the booster pump stream is obtained from filtered final water. The chlorinated stream discharges into the inlet to the chlorine contact tank (CT06), which is sized to provide at least 20 min contact time at peak flow for proper disinfection.

3.2.7 Sludge Disposal – Sludge Drying Beds (CT07). 20 off Sludge drying beds, each with a surface area of 10 m², will be supplied per 15 000 PE train. Sludge is periodically (ca once per week) removed from the humus tank as described in Section 3.2.5 and pumped to the drying beds. The operators will select which drying bed to fill by switching the isolating valves such that these pumps discharge only into the selected sludge drying bed(s). The sludge is then left to dry and can then be manually removed from the sludge drying beds and reused as compost, typically for gardening purposes.

3.2.8 Final Water Reuse. The final water produced by these plants will be excellent for reuse in gardens, parks and even selected agricultural produce. It is therefore proposed to discharge the final water as follows:

- At Oshakati West ponds, final water will be discharged into one of the existing ponds, to be used as a final water irrigation pond. In addition a set of pumps will be provided to pump final water to the East ponds to be used for irrigation (see below).

- At Oshakati East ponds, one of the existing ponds will be used to store the treated final water pumped from the new plant (located at the West ponds) so that the water can be used for irrigation in the nearby area, including the golf course.

3.3 Power Supply, Electrical Board, Control and Monitoring

Total, continuous power consumption for one train serving 15 000 people will be not more than 45 kW (absorbed power). However, it is recommended that a feeder that also caters for future extensions to both plants should be installed now already. This will require provision made for:

- Phase 1 (3 x 1 500 m^3/d trains): 135 kW (absorbed), 380 V, 3-phase, continuous power to be drawn;

- Phase 2 (1 x 1 500 m^3/d train): 45 kW (absorbed), 380 V, 3-phase, continuous power to be drawn;

The plant will be fitted with very basic control:

- Automatic duty/standby rotation every 12 h of all pumps sets;
- Two indication lights (running/trip) for every pump are required;
- An alarm signal light (similar to a break-down truck) on top of the control board will be provided. Latter will be activated if any pump trips and will be switched off when all signals are healthy again. Thus, an operator will be able to already see from a considerable distance from the plant, if any motor has tripped.

Data logging/monitoring will include:

- Raw water inflow (FE01);
- Sludge wastage (FE03);
- Final water discharge (FE04).

4 OPERATION AND MAINTENANCE

Although the trickling filter technology as proposed for Oshakati is simple to operate, requires no seasonal adjustments and needs minimal maintenance, we recommend that two semi-skilled persons are employed to oversee proper operation at the site and to do all necessary routine service and maintenance functions. Theoretically, only one person would suffice, but for health and safety reasons, a minimum of two people must be present at any industrial site.

4.1 Operation and Maintenance

The STP will have a proper operating manual containing all the details necessary to successfully operate and understand processes and procedures of the plant. The manual will be properly bound and be available in the English language. The following information will be included in the manual, as a minimum:

- The commissioning procedure and plant settings after successful commissioning;
- All plant-related drawings and diagrams. This includes layout, mechanical, and piping and instrumentation drawings as well as electrical wiring diagrams and any other drawings which may be useful for plant operation and maintenance;
- Complete functional description of the process including the control philosophy;
- Illustrated operating instructions including start-up, shut-down, backwashing, regeneration and/or cleaning procedures and emergency actions to be taken in the case of possible equipment failures;
- Maintenance instructions to include the descriptions and required frequency of all maintenance tasks;
- Equipment data sheets and manufacturer's operation and maintenance instructions;

- Procedures for chemicals preparation with cautionary notes and clearly visible signage for hazardous chemicals. Clear instructions for emergency procedures to be followed in case of an accident involving chemicals must be easily visible and available;

- Chemicals suppliers contact details;

- Trouble shooting notes with contact details for emergency action;

- Suggested typical plant operating parameters, such as chlorine dosing, flow rates and head losses. After commissioning, such values that are fine-tuned during the commissioning process should be included in the commissioning report and included in the operation and maintenance manual;

- Sample calculations where applicable.

4.2 Routine Operation

4.2.1 Spares and Consumables. In addition to the regular checks and procedures to be followed, it is very important to keep stock of critical spares and consumables on the plant. In the event of failure of equipment that is crucial to the successful operation of the plant, a technician should be able to replace or repair such equipment with minimal or no plant shutdown. Stock levels of consumables and chemicals (e.g. chlorine) should also be managed carefully in order to ensure that sufficient time is allowed for re-ordering and delivering new supplies. Typical spares to be kept on site include pumps, valves, pipes and fittings, instrumentation and service kits for major equipment.

4.2.2 Asset inventory. An asset inventory helps plant managers to identify what assets they own, where these assets are located or stored and what their condition and service history is. This data needs to be catalogued in a logical, readable format such as a handwritten list, spreadsheet software, database software or even commercially available asset management database software for very large plants. These lists can be drawn up for installed equipment, chemical supplies as well as for general stock available at the plant.

4.2.3 Safe Operation. The main health and safety concern is that the STP produces a final water that complies with the prescribed wastewater quality standards at all times. Failure to comply with the required final water quality must result in immediate remedial action or even complete plant shut-down to rectify the factor(s) causing the non-compliance. During shut-down raw sewage will be diverted to the existing emergency storage pond. The STP needs to monitor its final water quality in order to ensure that the consumer receives a safe irrigation water supply at all times. This is done with regular sampling and testing in either on-site or an independent laboratory.

The STP will need to keep records of plant performance regarding final water quality achieved, with minimum sampling frequencies as set out in the applicable wastewater quality standards. The results of these analyses must be available at any time for auditing by the Department of Water Affairs in order to ensure the safe supply of treated wastewater for irrigation purposes. The following records need to be available and may be requested by DWA during a plant audit:

- Logs of final water quality, with minimum sampling frequencies as prescribed;
- Proof of valid wastewater discharge license. This license needs to be renewed as necessary;
- Proof of operator and process controller qualifications and attendance registers, as proof that the minimum operator and process control qualification requirements have been met.

4.3 Environmental, Safety and Health Aspects

Every STP needs to adhere to all relevant local Acts regarding the operation and environmental impacts of the plant. The plant must provide treated wastewater safe for irrigation purposes and conforming to the Namibian General Standard for Effluents at all times while having a minimum impact on the environment.

The following aspects are especially important for the environmental analysis:

- Quantities and nature of chemicals used at the WTW. Emergency preparedness plans, safety equipment and emergency clean-up procedures need to be in place in case of a spillage. Chlorine gas that is used for disinfection is a particular concern, as this is a highly toxic gas and can have severe health and environmental impacts if leakages occur. The chlorination equipment including the chlorine cylinders will be contained within a separate building, away from any other chemicals. All relevant safety notices and safety equipment will be available at this building.

- Waste material disposal. All waste produced by the plant, including waste sludge from the process, domestic waste and sewage needs to be disposed of or treated in a suitable manner. The most suitable disposal or reuse of sludge should be considered. Recommended options include the use of dried sludge for gardening, local farmers or residents for soil fertilisation. Other disposal options include land application or disposal at land fill sites.

- Safety. All open water structures that are on ground level will be fitted with hand railing to prevent the possibility of operators falling into these structures, especially during night shifts when visibility is poor.

- Construction. The construction process for the sewage treatment plant will take the best part of 2 – 3 years. During this time, care must be taken to ensure minimal impact on the environment and to ensure that all construction works comply with the relevant Acts regarding health and safety.

Oshakati Town Council will be the owner of the new plant. They will therefore be responsible to obtain all applicable permits and licenses required for the operation of the wastewater treatment plant and disposal of associated waste products. However the Consultants will assist OTC in preparing documentation required for these permits.

SECTION 2: COST ESTIMATE, PROJECT DURATION AND BENEFITS

A budget cost estimate of capital as well as operating costs was made for an envisaged plant for Oshakati based on the above-described design. Whereas total costs for a complete plant that includes also future extensions is given, only Phase 1 is relevant currently for construction purposes. Phase 2 will be an extension to be implemented when need arises, but is foreseen to be required within 10 years' time. We have also allowed for an irrigation ring mains of 22 km to be provided with Phase 2 to allow other consumers throughout the town to also connect to the system and benefit from the final treated effluent for irrigation use.

1 CAPITAL COSTS AND PROJECT REALISATION

Project Costs. It is estimated that the Total Project Costs for Phase 1, *viz*. to provide a new sewage treatment plant for Oshakati to serve 45 000 people and treat approximately 4 500 m³/d of domestic effluent, will be approximately **N$148.5 m** (incl. V.A.T.), as reflected in Table 4 below.

Table 4. Estimated Project Cost for 4 500 m³/d WWTP - Phase 1 only

ITEM	DESCRIPTION	COSTS (N$)
1	Professional Fees (Consultant)	13 300 000
2	Treatment Plant Cost:	
	• Civil Works	53 300 000
	• Mechanical Works	44 150 000
	• Electrical/Control	2 300 000
3	Peripheral Services Upgrade:	
	• Transformer and Electrical Feeder Upgrade	2 200 000
	• Boundary Wall, Gate & Guard Cubicle	2 100 000
	Sub-Total	117 350 000
	Add 10% Contingency	11 735 000
	Sub-Total	129 085 000
	Add 15% V.A.T.	19 362 750
	TOTAL	**148 447 750**

Implementation. Detail design, tendering and construction of Phase 1 of this project will be scheduled over three years for completion for cash flow purposes, with another year that will be required to add Phase 2, thus in total a period of three years should be allowed for.

The cash flow projections for the proposed implementation over four years are shown in Table 5 below. The phasing will be as follows:

- Year 1: Engineering, design & tendering up to tender award;
- Year 2: Construction of first treatment train of Phase 1 (= 1 500 m^3/d);
- Year 3: Construction of two additional trains for Phase 1 (= 3 000 m^3/d additional, 4 500 m^3/d total);
- Year 4: Construction of one additional train for Phase 2 (= 1 500 m^3/d additional, 6 000 m^3/d total) and reuse pipeline for irrigation water;

Note that the entire project including Phase 2 and the reuse pipeline could even be completed within two years should sufficient funding be available.

Table 5. Estimated Project Phasing and Cash Flow Projections

			PHASE 1 = 45 000 PEOPLE				PHASE 2 = 15 000 ADDITIONAL PEOPLE		
	DESCRIPTION		**YEAR 1**	**YEAR 2**	**YEAR 3**	**TOTAL**	**YEAR 4**		**TOTAL**
	Financial Year:		**Jul '19 - Jun '20**	**Jul '20 - Jun '21**	**Jul '21 - Jun '22**	**PHASE 1 ONLY**	**Jul '22 - Jun '23**		**PHASE 1 & 2**
	Scheduled progress		**Design**	**Train 1**	**Trains 2 and 3**		**Train 4**		
	Available Treatment Capacity to serve			**15 000 People**	**45 000 People**		**60 000 People**		
1	**PROFESSIONAL FEES (Consultant)**		Phase 1			13,300,000	3,350,000	Phase 2	16,650,000
	- Prelim Design, Feasability, Report	20%	2,660,000						2,660,000
	- Detail Design (up to Tender Award)	40%	5,320,000						5,320,000
	- Construction (progressively)	40%		1,773,333	3,546,667				5,320,000
2	**TREATMENT PLANT COSTS:**								
2.1	PHASE 1 - 3 Trains, each serving 15 000 PE - total = 45 000 PE:								
	- Scheduled Installation			1 Train compl.	Add 2 Trains = 3 Trains compl.				
	Civil Works			23,300,000	30,000,000	53,300,000			53,300,000
	Mechanical Works			16,150,000	28,000,000	44,150,000			44,150,000
	Electrical/Control			1,500,000	800,000	2,300,000			2,300,000
2.2	PHASE 2 - 1 add. Train serving 15 000 PE - total plant capacity = 60 000 PE:						Add 1 Train, 4 Trains compl.		
	Civil Works						22,500,000		22,500,000
	Mechanical Works						20,000,000		20,000,000
	Electrical/Control						850,000		850,000
3	**PERIPHIRAL SERVICES:**								
	Transformer and Electrical Feeder Upgrade			2,200,000		2,200,000			2,200,000
	Boundary Wall, Gate & Guard Cubicle			2,100,000		2,100,000			2,100,000
4	**22 km Reuse Pipeline**						22,000,000		22,000,000
	Sub-Total		7,980,000	47,023,333	62,346,667	117,350,000	68,700,000		199,350,000
	Add 10% Contingency	10%	798,000	4,702,333	6,234,667	11,735,000	6,870,000		19,935,000
	Sub-Total		8,778,000	51,725,667	68,581,333	129,085,000	75,570,000		219,285,000
	Add 15% V.A.T.	15%	1,316,700	7,758,850	10,287,200	19,362,750	11,335,500		32,892,750
	TOTAL		**10,094,700**	**59,484,517**	**78,868,533**	**148,447,750**	**86,905,500**		**235,353,250**

2 OPERATIONAL COSTS

The main annual operating costs for the trickling filter plants under consideration, includes the following major items:

- Electricity (Power) Consumption and Demand;
- Personnel – this includes workers and their supervisor;
- Chemicals – mainly chlorine for disinfection is required;
- General Service and Maintenance Costs.

These will now be discussed in more detail and will be given for **Phase 1 only**.

2.1 Power Consumption

The total estimated power consumption is shown in Table 5 below, with corresponding power costs shown in Table 6. Some components are operated for less than 24 hours a day to keep the consumption to a minimum.

Installed power is based only on duty units, even if additional standby units are given. Absorbed power was calculated for each component individually according to the operating hours and component's efficiency.

We have again assumed that the average daily flow will be maintained at the plant throughout the year. Average power consumption will be approximately 40 kW (continuous, 24 h/day = 960 kWh/day) per 1 500 m^3/d train and is reflected in more detail for all major components in Table 6.

Table 6: Estimate of total daily power consumption

Process/Activity	Power Per 1 500 m^3/d Train		Phase 1 4 500 m^3/d
	Installed, Duty [kW]	**Absorbed [kWh/day]**	**Absorbed [kWh/day]**
Primary clarification			
Scraper bridge motor	1 x 0.75	16.2	48.6
Trickling filters			
TF feed pump	2 x 18.5	754.8	2 264.4
Actuated desludge valves	2 x 0.75	3	9
Secondary clarification			
Scraper bridge motor	1 x 0.75	16.2	48.6
Chlorine contact tank			
Booster pumps	1 x 2.2	44.9	89.8
Sludge recirculation and waste:			
Recirculation pumps	1 x 2.2	44.9	134.7
Waste sludge pumps	1 x 2.2	0.4	0.8
Ancillaries including instrumentation, flood lighting at site, and control room, and change rooms (sum)	6.5	88	176
TOTAL	**52.6**	**968.4**	**2 771.9**

The estimated annual power costs consist of a passive power cost and an active usage cost. Time of use periods were taken as per Nored’s pricing structure and total power costs are reflected in Table 7.

Table 7: Estimate of total annual power costs

	Phase 1 (4 500 m^3/d)
Total duty installed power [kW]	157.8
Total absorbed power demand [kWh/day]	2 772
Passive power costs [N$/annum]	79 761
Active power costs [N$/annum]	1 508 443
TOTAL [N$/annum]	**1 588 204**

2.2 Personnel Costs

Theoretically, only one operator is required per each plant to daily clean the linear screen, ensure chlorination is properly functioning, replace the chlorine cylinder when empty and ensure all pumps are functioning. However, due to safety regulations, a minimum of 2 persons must be provided at an industrial site to ensure that there is help available if one person has an accident. This second person need not be an operator as such, but can also be, for example, a security guard. Additional workers may be required periodically to empty the sludge drying beds.

Also, a semi-skilled person should be available to check up on the workers from time-to-time. In our unit cost calculation we have therefore allowed for:

- 2 off Workers for for a period of only 9 h/d;
- 2 off Security guards (2 off 8 h shifts) – 16 h/d ;

The estimated costs for salaries of personnel directly associated with the operation of the plant have been considered and are summarised in Table 8.

Table 8: Estimate of total annual personnel costs

Job Description	Monthly Salary [N$]	No	Annual Salary [N$]
Operations supervisor (part-time)	15 000	1	180 000
Operator/worker	6 000	2	144 000
Security Guards	5 000	2	120 000
TOTAL			**444 000**

2.3 Chemical Costs – Disinfection

Chlorination of the final effluent is an environmental requirement (and mandatory by DWAF) irrespective of reuse of the final effluent or discharge to the environment. We have allowed for 2 mg/l chlorination, based on the capacity for each plant.

Table 9: Estimate of total annual chemical costs for disinfection (Phase 1 – 4500 m^3/d)

Chemical	Average Dosage [mg/l]	Unit Cost [N$/kg]	Annual Cost [N$/annum]
Chlorine (final water disinfection)	2 mg/l	36,00	**118 260**

2.4 Maintenance Costs

The total annual cost associated with the service and maintenance of a water treatment plant is typically expressed in industry as a percentage of capital costs that need to be maintained. Trickling Filter technology need very little service and maintenance costs and are typically 2% of total installed mechanical and electrical costs. Routine general and preventative maintenance costs were taken as a percentage of the capital costs as reflected in Table 10 below:

Table 10: Estimate of total annual service and maintenance costs

Component	% OF CAPTITAL COST	Capital, N$	Annual, N$
Civil works	0.5	53 300 000	266 500
M & E	2	46 450 000	929 000
TOTAL [N$/annum]			**1 195 500**

2.5 TOTAL ANNUAL COSTS

The total **annual operating costs** based on typical Namibian costs for power, personnel, chemicals and service and maintenance costs as per Tables 7 - 10 have been calculated and are summarized in Table 11.

A unit cost (N$ per m^3 effluent treated) was then calculated based on full plant capacity for Phase 1 for 4 500 m^3/d of sewage that has to be treated. The resultant unit cost is also reflected in Table 11.

Table 11. Estimated Annual Operational Cost (excl. V.A.T.) – Phase 1 (4 500 m^3/d)

Item No.	DESCRIPTION	ANNUAL PLANT OPERATING COSTS (N$)
1	Power (Table 5)	1 588 204
2	Manpower (Table 6)	444 000
3	Chemicals (Table 7)	118 260
4	Service and Maintenance	1 195 500
	TOTAL (excl V.A.T.)	**3 345 964**
	UNIT PRODUCTION COST:	
	Wastewater Treated (m^3/annum)	1 642 500
	80% Recovery for reuse (m^3/annum)	1 314 000
	Unit operating costs (N$ per m^3 effluent)	**N$2,55/$m^3$**

The above unit operating costs make it very attractive to reuse this final effluent, which will be highly nutritious for plants, for selected agricultural production, if compared to current potable water unit prices. Also, when sports facilities with grass fields need to be provided with irrigation water, this reclaimed water will be at a fraction of the cost of potable water as currently provided by NamWater.

3 JOB CREATION AND LONG TERM BENEFITS

This project will greatly benefit the community, not only during the construction phase when many local workers will be required for the building works, but long thereafter as well. This is due to the fact that a good quality of final effluent will be produced that can/should be reused for agricultural purposes, and latter aspect will be promoted. With the final, reusable effluent estimated at 3 600 m³/d for Phase 1 and an additional 1 200 m³/d for Phase 2 on a sustainable basis, large agricultural developments can be undertaken and will be encouraged by the Oshakati Town Council to be undertaken by the local communities in the adjacent areas. Table 12 indicates the envisaged short and long term jobs that this project will create for the two communities respectively.

Table 12 – Estimated Jobs Created by these Projects

DESCRIPTION	**Temporary** (construct.)	**Permanent** (agriculture)
During Construction Phase	120	
After Construction (agriculture)		85

Thus, there will be in total 120 temporary employed persons during the construction phase and afterwards 85 permanently employed people that will benefit from this project.

SECTION 3: CONCLUSIONS

A conceptual design for a new sewage treatment plant for Oshakati Town Council was undertaken, based on most appropriate technology for the Oshana Region:

- New-Generation Trickling Filter technology was selected as most appropriate process for sewage treatment at Oshakati;
- The respective design capacities for Phase 1 (urgent) are 4 500 m³/d and 1 500 m³/d for Phase 2 (within next 10 years);
- The final water will be of a standard that conforms to the current and future Namibian General Standard and will be suitable for reuse in gardens, lawns (e.g. sports fields) and selective agricultural growth;
- The approximate capital costs for the new plant will be N$148.5 m for Phase 1 (contingencies & V.A.T. included, reuse pipeline throughout the town excluded);
- The project can be undertaken over three financial years;
- The annual operating costs will be N$2.55 per m³, which makes the final water attractive for reuse, especially if it can be used to replace fresh water, where latter would have to be supplied by NamWater;
- The project will result in at least 120 temporary jobs created and 85 permanent jobs.

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APPENDICES

Appendix A: Current Water Quality Standards for Effluents

Appendix B: Envisaged Future Water Quality Standards for Effluents

DRAWINGS (PRELIMINARY):

Piping and Instrumentation

General Layout

Sections

APPENDIX A: Currently Applicable Standards for Wastewater Discharge

Parameter	Unit	General*	Special*
Colour, odor, taste		No substance that will produce color, odor, taste	No substance that will produce color, odor, taste
Faecal coliforms	per 100 mL	Nil	Nil
Chemical Oxygen Demand (mg/L)	mg/L	75	30
pH		5.5 - 9.5	5.5 - 7.5
Dissolved Oxygen	% satur.	75	75
Temperature	°C	≤ 35	≤ 35
Oxygen Absorbed (N/80/4h)	mg/L	10	5
TDS	mg/L	increase in TDS ≤ 500 over intake water conc.	increase in TDS ≤ 15% over intake water conc.
Ammonia as N	mg/L	10	1
Nitrate/Nitrite as N	mg/L	NS	1.5
Chlorine as Free Chlorine	mg/L	0.1	Nil
Suspended Solids	mg/L	25	10
Electrical Conductivity	mS/m	NS	≤70 mS/m above, max 150 mS/m
Soap, oil or grease	mg/L	≤ 2.5	Nil
Arsenic (as As)	mg/L	0.5	0.1
Boron (as B)	mg/L	1	0.5
Cadmium (as Cd)	mg/L	NS	0.05
Hexavalent chromium (as Cr)	mg/L	0.05	NS
Total chromium (as Cr)	mg/L	0.5	0.05
Copper (as Cu)	mg/L	1	0.02
Cyanide (as CN)	mg/L	0.5	0.5
Fluoride (as F)	mg/L	1	1
Iron (as Fe)	mg/L	NS	0.3
Lead (as Pb)	mg/L	1	0.1
Manganese (as Mn)	mg/L	NS	0.1
Ortho-Phosphate (as P)	mg/L	NS	1.0
Total Phosphates (asP)	mg/L	NS	2.0
Sodium (as Na)	mg/L	≤ 50 over intake conc.	≤ 50 over intake water conc.
Sulphides (as S)	mg/L	1	0.05
Zinc (as Zn)	mg/L	5	0.3

* as per Regional Effluent Standard: R553 of 15 April 1962 and amendments (Water Act, 1956)
NS = not specified

APPENDIX B: Envisaged Future Standards for Wastewater Discharge

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	**General Standard**
DETERMINANTS	**UNIT**	**FORMAT**	**95 percentile requirements**	
PHYSICAL REQUIREMENTS				
Temperature	° C		Not more than 10^{0}C higher than the recipient water body	
Turbidity	NTU		< 5	< 12
pH			6.5-9.5	6.5-9.5
Colour	mg/litre Pt		< 10	< 15
Smell			No offensive smell	
Electric conductivity 25 °C	mS/m		< 75 mS/m above the intake potable water quality	
Total Dissolved Solids	mg/litre		< 500 mg/litre above the intake potable water quality	
Total Suspended Solids	mg/litre		< 40	< 100
Dissolved oxygen	% saturation		>75	>75
Radioactivity	units		below ambient water quality of the recipient water body	
ORGANIC REQUIREMENTS				
Biological Oxygen Demand	mg/litre	BOD	< 10	< 30
Chemical Oxygen Demand	mg/litre	COD	< 55	< 100
Detergents (soap)	mg/litre		< 0.2	< 3
Fat, oil & grease, individual	mg/litre	FOG	< 1.0	< 3.0
Phenolic compounds	mg/litre	as phenol	< 0.01	< 0.10
Aldehyde	µg/litre		< 50	< 100
Adsorbable Organic Halogen	µg/litre	AOX	< 50	< 100
INORGANIC MACRO DETERMINANTS				
Ammonia (NH_4 – N)	mg/litre	N	< 1	< 10
Nitrate (NO_3 - N)	mg/litre	N	< 15	< 20
Nitrite (NO_2 - N)	mg/litre	N	< 2	< 3
Total Kjeldahl Nitrogen (TKN)	mg/litre	N	< 5.0	< 33
Chloride	mg/litre	Cl	< 40 mg/litre above the intake potable water quality	< 70 mg/litre above the intake potable water quality
Sodium	mg/litre	N	< 50 mg/litre above the intake potable water quality	<90 mg/litre above the intake potable water quality
Sulphate	mg/litre	SO_4	< 20 mg/litre above the intake potable water quality	< 40 mg/litre above the intake potable water quality
Sulphide	mg/litre	S	< 0.05	< 0.5
Fluoride	mg/litre	F	1.0	2.0
Cyanide (Free)	µg/litre	CN	< 30	< 100

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	General Standard
DETERMINANTS	**UNIT**	**FORMAT**	**95 percentile requirements**	
Cyanide (recoverable)	µg/litre	CN	< 70	< 200
Soluble Ortho phosphate	mg/litre	P	< 1.0	< 15
Zinc*	mg/litre	Zn	1	5

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	General Standard
DETERMINANTS	**UNIT**	**FORMAT**	**95 percentile requirements**	
INORGANIC MICRO DETERMINANTS				
Aluminium	µg/litre	Al	< 25	< 200
Antimony	µg/litre	Sb	< 5	< 50
Arsenic	µg/litre	As	< 50	< 150
Barium	µg/litre	Ba	< 50	< 200
Boron	µg/litre	B	< 500	< 1000
Cadmium*	µg/litre	Cd	< 5	< 50
Chromium, (hexavalent)	µg/litre	Cr	< 10	< 50
Chromium, Total*	µg/litre	Cr	< 50	< 1000
Copper*	µg/litre	Cu	< 500	< 2000
Iron	µg/litre	Fe	< 200	< 1000
Lead*	µg/litre	Pb	< 10	< 100
Manganese	µg/litre	Mn	< 100	< 400
Mercury*	µg/litre	Hg	< 1	< 2
Nickel	µg/litre	Ni	< 100	< 300
Selenium	µg/litre	Se	< 10	< 50
Strontium*	µg/litre	Sr	< 100	< 100
Thallium	µg/litre	Ti	< 5	< 10
Tin*	µg/litre	Sn	< 100	< 400
Titanium	µg/litre	Ti	< 100	< 300
Uranium*	µg/litre	U	< 15	< 500
*Total for Heavy Metals (Sum of Cd,Cr,Cu,Hg,Pb	µg/litre	Cd,Cr,Cu, Hg & Pb	< 200	< 500
UNSPECIFIED COMPOUNDS FROM ANTHROPOGENIC ACTIVITIES				
Agricultural chemical compounds	µg/litre		Any in-/organic compound recognized as an agro-chemical is to be avoided or reduced as far as possible. Maximum acceptable contaminant levels will be site specific, dependent on chemical usage and based the water quality of the recipient water body	
Industrial and mining chemical compounds, including unlisted metals	µg/litre		Any in-/ organic compound recognized as an industrial chemical including unlisted metals is to	

and persistent organic pollutants			be avoided or reduced as far as possible. Maximum acceptable contaminant levels will be site specific dependent on chemical usage and based the water quality of the recipient water body	
Endocrine Disruptive Compounds (EDC)	µg/litre		Any chemical compound that is suspected of having endocrine disruptive effects is to be avoided as far as is possible. Maximum acceptable contaminant levels will be site specific dependent on chemical usage and based the water quality of the recipient water body.	
Hydrocarbons (Benzene, Ethyl Benzene, Toluene and Xylene	µg/litre		Below detection level	Below detection level
Organo-metallic compounds: methyl mercury, tributyl tin (TBT), etc.	µg/litre		Below detection level	Below detection level
DISINFECTION				
Residual chlorine	mg/litre		1 Dependent on recipient water body (at retention time 3 hours)	3 Dependent on recipient water body (at retention time 5 hours)

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	**General Standard**
DETERMINANTS	**UNIT**	**FORMAT**		
BIOLOGICAL REQUIREMENTS (Algae and parasites)				
Further treatment of the effluent dependent on: 1. the water quality of the recipient water body if any 2. the distance from any point of potable water abstraction 3. an acceptable maximum contaminant level downstream of the point of discharge 4. the exposure to human and animal consumption downstream of the point of discharge 5. any reuse option that may be implemented.				
MICROBIOLOGY				
Further treatment of the effluent are dependent on: 1. the water quality of the recipient water body if any 2. the distance from any point of potable water abstraction 3. an acceptable maximum contaminant level downstream of the point of discharge 4. the exposure to human and animal consumption downstream of the point of discharge 5 any water reuse option that may be implemented.				