DEPARTMENT OF WATER AFFAIRS & FORESTRY

OPERATIONAL GUIDELINES FOR DRINKING WATER TREATMENT PLANTS

(July 2014 - Rev 4)

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DEFINITIONS

General:

Aesthetic:	A characteristic of drinking water that does not affect human health but impairs the quality thereof. Typically relates to taste, smell, look, or a tendency to build up scale in the water.
Aquifer:	A water-bearing geological formation from which water can be abstracted;
Brine:	Term commonly used to describe highly concentrated saline waste streams, typically waste streams from desalination and demineralisation processes.
Cyst:	Environmentally resistant infective parasitic life stage (e.g. *Giardia lamblia, Taenia*);
Contaminant:	Constituent found in water (including microorganisms, minerals, chemicals, radionuclides, etc.) which may be harmful to human health, environment and infrastructure;
Cryptosporidium:	Protozoa highly resistant to disinfection, can cause outbreaks of gastrointestinal illness and commonly found in dams and rivers;
Dam:	(a) A barrier or structure constructed across or next to a water course that impounds or holds back water flowing in that water course; or (b) A structure that stores or impounds effluent, and includes the water impounded and held back or the effluent stored or impounded and the area covered by that water or effluent;
Disinfection:	Inactivation of pathogenic organisms using chemicals, radiation, heat or physical separation processes (e.g. membranes);
Disinfectant byproducts:	Chemicals that may form when disinfectants (such as chlorine) react with contaminants in the water;
Distribution system:	A network of pipes leading from a treatment plant to consumers;
Effluent:	Wastewater, treated or untreated, that flows out of a treatment plant, sewer or industrial outfall;
Giardia lamblia:	A protozoa frequently found in rivers and dams, which, if not treated properly, may cause diarrhoea, fatigue, and cramps after ingestion;
Groundwater:	Water - (a) occurring naturally below the surface of the ground; or (b) pumped, diverted or released into a cavity for storage underground;
Inorganic contaminants:	Mineral-based compounds such as metals, anions and cations. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities;
Meteoric water:	Water that precipitates from the atmosphere;

Multiple-barrier approach:	A treatment process that is designed with more than one removal process for any problem contaminant;
Organic contaminants:	Undesirable concentrations of chemical compounds made up of mostly carbon and hydrogen;
Pathogens:	Disease-causing microorganisms such bacteria, viruses and protozoa.
Potable water:	A water supply which is considered safe and fit for human consumption;
Raw water:	Water in its natural state, prior to any treatment;
Surface water:	Waters that occur in a source open to the atmosphere, such as rivers, dams and reservoirs;
Turbidity:	The cloudy appearance of water caused by the presence of tiny particles, mostly of colloidal nature;
Waste:	Includes sewage and any matter or substance, whether wholly or partly in solid, liquid or gaseous state, which if added to water and may cause the water to be polluted;
Wastewater:	Water containing waste;
Watercourse:	a) A river or spring, including the base flow of an ephemeral river when there is no surface flow;
	b) A natural channel in which water flows regularly or intermittently;
	c) An estuary, wetland, lake or dam into which, or from which, water flows;
	(d) Any collection or body of water declared under section 5(s) of the Water Resources Management Act (Act 11 of 2013) to be a watercourse,
	And includes the water in, and the bed and the banks of, the watercourse;
Water resource:	The whole or any part of a watercourse or an aquifer and includes the sea and meteoric water;
Water services provider:	A person or an entity that provides or manages water services to end consumers;

Chemical:

GAC:	Granular Activated Carbon = particulate activated carbon used for adsorption of dissolved organic matter in filters
IX:	Ion Exchange = treatment process for removing undesirable dissolved ions
MSDS:	Material Safety Data Sheet = document that outlines information and procedures for handling and working with chemicals
NTU:	Nephelometric Turbidity Units = unit for quantifying turbidity

PAC:	Powder Activated Carbon = fine activated carbon used for adsorption of dissolved organic matter
TDS:	Total Dissolved Solids = measurement of the combined content of all dissolved inorganic and organic substances contained in a liquid
THM:	Trihalomethanes = a disinfection by-product formed when organic carbon reacts with a halogen (e.g. chlorine, bromine) to form a constituent which is believed to be carcinogenic and harmful to living organisms
TSS:	Total Suspended Solids = measurement of the combined content of all non-dissolved substances contained in a liquid
WTR:	Water Treatment Residue = particles and grit that are removed during treatment processes such as clarification and filtration

ACRONYMS

Bq/l	Becquerel per litre
Ca	Calcium
DAF	Dissolved air flotation
DWAF	Department of Water Affairs and Forestry
Fe	Iron
m^3/a	Cubic metres per annum
Mg	Magnesium
Mg/l	Milligrams per litre
m/h	Unit of filtration rate – metres per hour
Mn	Manganese
mS/m	Unit of Conductivity – millisiemens per metre
MAWF	Ministry of Agriculture, Water and Forestry
O_3	Ozone
PoU	Point-of-use
RO	Reverse Osmosis
s^{-1}	Unit for velocity gradient (mixing intensity) – units per second
UV	Ultraviolet
WWTP	Wastewater treatment plant

1. INTRODUCTION

Namibia is a hot and dry country with a sparse and erratic rainfall pattern and mean annual rainfall estimated at 285 mm (AQUASTAT, 2005). Of the total rainfall it has been estimated that only 2% becomes runoff water that can be collected and stored in surface storage facilities, 83% evaporates, 14% is used up by vegetation and 1% infiltrates to recharge underground aquifers.

Despite this low annual rainfall figure, Namibia's average renewable water availability amounts to 3 100 m³ per person annually, which is classified as "relatively sufficient" according to the United Nations Environment Program (Global Water Intelligence, 2005). However, unevenly distributed raw water sources across the country and a general lack of water infrastructure have resulted in water availability in most regions being rather low. Also, the country regularly experiences droughts, which place a further uncertainty on the actual water availability in future years.

There is therefore a need to closely manage, control, monitor and extract, on a sustainable basis, all reliably available raw water and treat this to a potable water standard in order to ensure that end-users can drink the water safely. In Namibia, in accordance with the Water Resources Management Act (Act 11 of 2013), the Ministry of Agriculture, Water and Forestry (MAWF) is in charge of water management and consists of two departments: the Department of Agriculture and the Department of Water Affairs and Forestry (DWAF). The Namibia Water Corporation (NamWater), which is a parastatal responsible for bulk water supply throughout the country, is closely linked to DWAF. All water services providers in Namibia need to obtain a license to supply drinking water from DWAF (see Section 7.2).

All reliable, sustainable raw water sources that are available to the country and can be used economically are currently being exploited (Van der Merwe, 2013). Irrespective of the source, all raw water needs some form of treatment before it can be deemed safe to be consumed by the end-user. Depending on the source, treatment can be very simple, ranging from a cartridge filter with disinfection, to very complicated and elaborate if, for example, reclamation or desalination needs to be employed.

This document addresses water treatment specifically related to typical Namibian conditions with a requirement on the supplier to provide a final water that can be safely consumed by the end-user(s). This includes dealing with the main raw water sources available in the country, major contaminants, possible problem constituents and major treatment processes currently being applied. Also, basic regulatory requirements for suppliers and operators of water treatment facilities are addressed in this document. This includes operational issues such as the number and capacity of operators, quality monitoring, control, maintenance and reporting activities.

2. MAIN WATER SOURCES IN NAMIBIA

Rivers, underground aquifers and, to a lesser extent, seawater constitute the bulk of raw water sources that are currently readily available, developed and suitably treated to provide potable water for the population of Namibia.

Of these, by far the largest supply is river water, whether from perennial or ephemeral rivers. The only three perennial rivers border the north and south of Namibia, with ephemeral river systems found in the rest of the country. These perennial and ephemeral river systems provide potable water to the largest number of people in Namibia and serve pre-dominantly communities, towns and cities.

Since a river constitutes a surface or "open water system" that can easily be contaminated at any time, the water abstracted from such a system needs to be properly treated first before it can be safely distributed to end-user(s). This applies to water directly abstracted from a perennial river or indirectly *via* abstraction from a surface storage facility, such as a dam, which was built in a perennial or ephemeral river system. Groundwater aquifers also often serve as a single source of potable water for smaller towns and rural communities, and pre-dominantly provide farms and lodges with sufficient potable water. Groundwater is also the most dominant source of drinking water in rural areas that do not have easy access to a perennial river water supply. Also many larger communities, including towns and cities, even if provided with bulk water from an open water system, use groundwater sources as well to augment their potable water supplies and serve as back-up in times of drought.

2.1 Perennial River Runoff

The Orange River in the south and the Kunene, Okavango and Zambezi Rivers in the north constitute perennial river systems that carry water all year and sustain substantial numbers of the Namibian population throughout the year.

Whereas water taken from a slow-flowing, pristine river system would only need disinfection to make it safe for human consumption, surface waters are generally rich in particles, which have to be removed before the water can be safely consumed. Also, rivers become contaminated, even severely polluted, due to excessive human activity along their river banks. During times of heavy rains, these rivers become murky and the water becomes aesthetically unacceptable to drink. Water treatment is required to ensure that safe, aesthetically pleasing water can be provided to consumers at all times. The basic unit processes employed for river water treatment are described in Section 5 of this Guideline.

2.2 Ephemeral River Runoff

Many of the larger towns receive their drinking water from surface dams that have been built in these ephemeral river systems and serve as surface storage facilities, despite having high evaporation losses. The most well-known surface storage dams in Namibia include the Hardap, Von Bach, Swakoppoort, Omatako, Naute, Oanob, Daan Viljoen, Tilda Viljoen, and Otjivero Dam. These dams are only augmented during the rainfall season, when the rivers flow, which may not happen every year.

Whereas water collected in a surface dam is normally of good quality, it is still not fit for direct human consumption and needs to be suitably treated for intended use, before it can be distributed and used by the end-user(s). As an absolute minimum, disinfection is required to ensure that the water is safe to use. However, water stored in a dam is, during most parts of the year, aesthetically not acceptable because it does not appear clear and, especially when these dams receive fresh runoff water during the rainy season, the water becomes "muddy" and needs additional treatment besides disinfection.

Many dams in Namibia have been provided with a conventional water treatment facility that is designed to improve the aesthetic parameters of the raw water and apply disinfection to ensure that safe drinking water is delivered to the end-users. Conventional water treatment plants in Namibia employ chemical-physical unit processes, which are described in Section 5 of this Guideline.

2.3 Groundwater Aquifers

Surface water that seeps into porous soils and eventually finds its way into groundwater aquifers and/or sub-surface groundwater storage reservoirs is generally low in suspended solids and of a good potable quality. Good quality groundwater needs no further treatment other than disinfection to prevent any transfer or distribution system from contaminating the pristine water. Fig. 1 shows main productive aquifers occurring in Namibia.

Often, soft soil formations in contact with groundwater result in minerals leaching into the groundwater and latter then becomes contaminated and needs treatment before the water can be safely used for human consumption again. Typically, many groundwater aquifers in Namibia show high levels of salts, fluorides, nitrates, sulphates, iron and manganese and the removal in simple treatment processes have been addressed in this document.

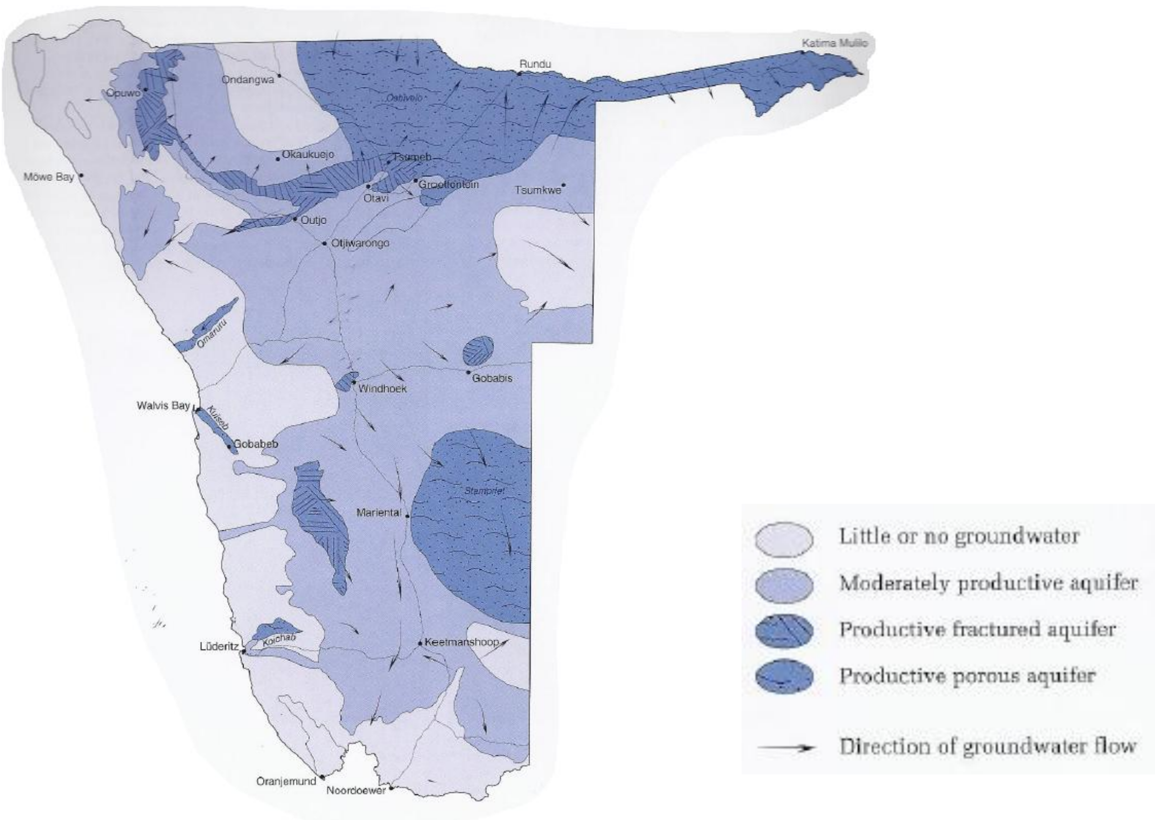


Figure 1: Types of aquifers in Namibia and their overall productivity (Mendelsohn et al., 2009)

Many groundwater aquifers in Namibia are found in regions where the rainwater must first penetrate limestone formations, resulting in calcium (Ca) and magnesium (Mg) ions leaching into the water. These ions when present in the water at higher concentrations, cause permanent hardness and the potable water is then deemed to be a “hard water”, which causes pipes and heating elements to scale-up. Whereas hardness (Ca and Mg ions) does not constitute a health hazard *per se*, it is a nuisance substance and water treatment is widely applied in these areas to remove excessive hardness from the raw water. The Karst Area around Outjo, Otjiwarongo, Otavi, Grootfontein and Tsumeb is only one example where groundwater high in total hardness occurs in Namibia and users are plagued with scaling problems. Softening using ion exchange resins is the most common form of treatment for hardness removal and is discussed in Section 5 of this Guideline. Hardness caused by limestone formations is only one example of effects of primary aquifer formations on the water quality. Many different types of primary aquifer formations exist and each can have a different effect on various parameters of the water quality.

2.4 Seawater

Seawater as raw water source to produce potable water *via* desalination was previously not commonly used in Namibia, mainly due to high capital and operating costs and higher skilled operators required to operate desalination plants. However, overexploitation of other, limited ground water resources supplying the coastal hub of Swakopmund and Walvis Bay has necessitated increased usage of seawater as the only remaining reliable raw water source to produce sufficient potable water supplies for that area.

At the end of 2013 a substantial amount (5 million m^3/a) of potable water for Swakopmund is already obtained *via* seawater desalination by reverse osmosis (RO) (Tjipangandjara, 2014). This amount is expected to increase continually, as the demand for potable water, driven by mining in the coastal area, increases.

Whereas seawater desalination is an expensive treatment process, seawater itself is a vast and reliable source of raw water along the Namibian coastline and the lack of other potable water sources will leave MAWF with no choice but to continue to exploit this. Therefore, seawater desalination will play an increasingly important role in meeting the future demand for water supplies in Namibia and this process is also described in Section 5 of this document.

2.5 Reclamation

When domestic wastewater (sewage) is treated to a potable water supply standard, this is known as potable water reclamation. Reclamation relies on advanced treatment technologies, which includes providing more than one distinct treatment process for each problem contaminant. This is referred to as “multiple-barrier approach” to plant design: If one unit process malfunctions, at least one more unit process must be available that will perform the same function and serve as back-up for removal of a specific problem contaminant.

Treatment processes employed for reclamation are complex and highly specialised. The process technology involved requires high levels of expertise, specialist water treatment engineers, highly experienced and conscientious operating personnel and continuous, expert monitoring and control to ensure that a water safe for human consumption is produced at all times all of which in a very expensive treatment process. Since such specialised, expert capacity is not readily available in the public sector, the operation of reclamation plants should be contracted out to an experienced operator in the private sector with proven track record.

Typically, a reclamation plant would include all of the following unit processes to treat secondary effluent, after biological treatment, to potable water quality (Olivier, 2013):

- Physical-Chemical Treatment: Enhanced coagulation and flocculation, followed by dissolved air flotation, dual media filtration and granular activated carbon filtration;
- Membrane Treatment: Reverse osmosis;
- Polishing: Advanced oxidation (usually with hydrogen peroxide and UV) followed disinfection.

3. OBJECTIVES OF DRINKING WATER TREATMENT

In Namibia, water supplied to the public for drinking purposes by a water services provider must adhere to national drinking water quality standards (see Section 4.1). It is of the utmost importance that these standards are adhered to in order to ensure that drinking water supplied to communities is safe for human consumption and aesthetically pleasing at all times. The objectives of water treatment need to meet the requirements of the Water Resources Management Act (Act 11 of 2013), Part 9 Sections 35 and 36.

Whenever a new water source is considered for the provision of drinking water, an in-depth investigation needs to be performed in order to determine the quality and viability of the source. Such an investigation must be sufficiently detailed in order to determine all possible problem constituents and whether the water can be treated economically to the required physical, chemical and bacteriological standards in order to ensure a consistently safe drinking water supply.

Additional factors such as the future demand by residential and industrial developments in the vicinity of the source as well as possible pollution by nearby wastewater treatment plants need to be taken into account when determining the viability of a new source. The investigation should be performed by a suitably qualified water supply and treatment expert and must also include detailed water quality analyses.

The investigation will determine what the optimum treatment process should be taking account of the cost-effectiveness, the appropriate level of technology suitable for the local community and the likely skill level of the operators. Fig. 2 gives a broad outline of the most important factors in the decision-making process involved in determining the viability of a new water source.

Note that the methodology described in Fig. 2 should be used only as an indication of the decision-making process. If it is found that the water cannot be treated economically or that the technology required for the treatment of the water source is too advanced for the locally available expertise, an alternative source will need to be considered. Other options include outsourcing the operation of a complicated treatment plant to a skilled private operating company. As a matter of principle, the most effective technology (even if it is less technologically advanced) should always be the first choice. Any other environmental, social, economic or water quality factors specific to a potentially new source need to be considered by the water supply and treatment expert in the investigation.

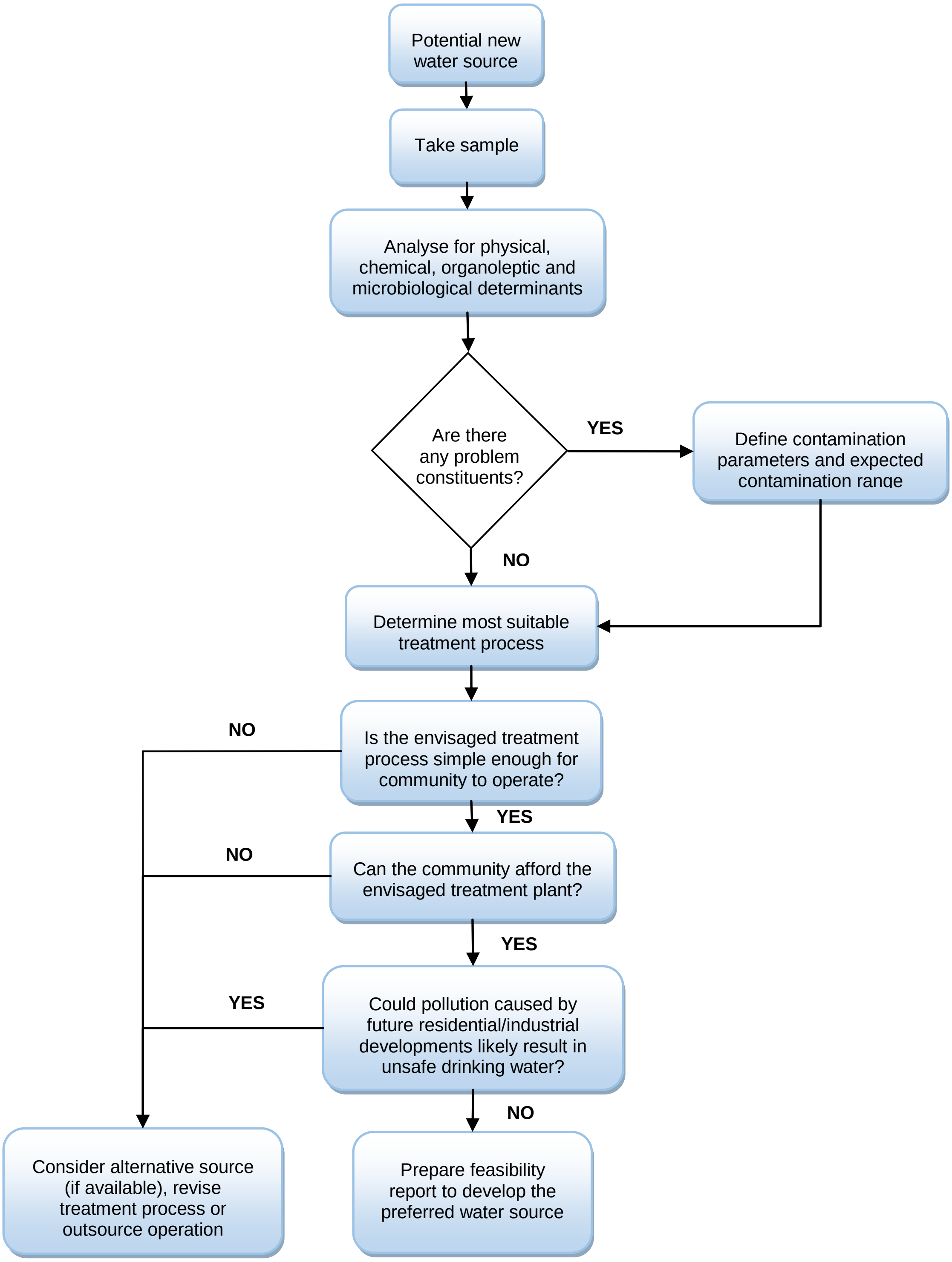


Figure 2: Basic Decision-Making Flowchart for a New Water Source

Drinking water treatment plants should be designed to be fit-for-purpose whilst employing the simplest and most cost-effective technologies possible. Each treatment plant design will be case-specific as there is no generic treatment method that will work for all types of source waters and for all client and community requirements.

In cases where a plant is situated in rural areas with very little technical expertise and far from industrial centres such as Windhoek or Walvis Bay, the design philosophy should focus on equipment that is easy to maintain and is robust as possible. Processes, equipment and instrumentation should be chosen to be as reliable as possible, taking into consideration that technical support may be very scarce in these areas. The more advanced electrical and mechanical equipment that is installed on a plant, the higher the likelihood that something will eventually malfunction. Also, plants should be designed in such a way to keep capital costs to a minimum. In rural areas, equipment employing advanced technologies that are not strictly essential for the operation of a plant should be replaced with simpler and more cost-effective solutions, or even omitted entirely.

The best solution for a plant in a rural area is not necessarily the same as would be a standard solution in an urban area. For example, a large private company in Windhoek might need to continuously sample and log the final water turbidity of their plant for prescribed quality control checks whilst for a plant in a rural area supplying drinking water to a school, the requirement to install continuous sampling is not necessary. Only if the process knowledge and technical expertise are locally available should more advanced and maintenance intensive treatment technologies be considered.

4. DRINKING WATER QUALITY PARAMETERS

4.1 Namibian Water Quality Standards

The Ministry of Agriculture, Water and Forestry has developed Namibian Water Quality Standards and Guidelines for Potable Water as part of Part 9 (Water Supply, Abstraction and Use) and Part 10 (Water Service Providers) of the Water Resources Management Act (Act 11 of 2013). This document specifies and quantifies the ideal and acceptable limits for a large range of water quality parameters. The "acceptable standard" limits have to be adhered to by law when providing drinking water supply for human consumption, whilst the "ideal guideline" indicates the preferred limits if these can be achieved economically. The entire document can be found in Appendix C. It is an extensive summary of water quality parameters to be adhered to including physical and organoleptic requirements, inorganic determinants, organic determinants, disinfection by-products, radioactivity, and microbiological requirements as well as sampling frequencies. Some of the more common and important quality parameters in the Namibian context are discussed in the following sections.

4.2 Water Quality Parameters in Namibian Waters

Pure water is an excellent medium for minerals, salts and even gases contained in soil or geological formations to easily dissolve into. Salts consist of a cationic (metallic) part and an anionic (non-metallic) part. Common cations include sodium, potassium, copper, magnesium, calcium, iron and manganese while common anions include chloride, sulphate, fluoride, nitrate, phosphate, carbonate and bicarbonate.

The presence of certain ions in high concentrations can lead to aesthetically unpleasant taste, smell or colour and can even cause the water to be unfit for human consumption. A brief discussion of some of the most common problem ions found in Namibian waters and their effects is found in the discussion below. The presence or absence of specific quality parameters cannot be assumed to be based solely on the location and general area of the source, even if past analysis results of similar sources in the area are available. For example, high nitrate concentration in a specific borehole does not necessarily indicate high nitrate concentration in an adjacent borehole a few kilometres away. Specific treatment methods for addressing each of these contaminants are discussed in Section 5.

Microbiological contamination is also an important consideration for Namibian waters and disinfection needs to be included in the treatment process in order to ensure safe drinking water. Microbiological contaminants and proper sampling methods are discussed in Section 4.4, while disinfection for removal or inactivation of such contaminants is discussed in Section 5.7.

Sections 4.2.1 to 4.2.5 discuss some of the more commonly found contaminants in Namibian waters. It should be noted that this is only a discussion of the most prevalent contaminants in Namibian waters and isolated cases of other problem contaminants can also occur. For example, arsenic contamination of groundwater in the Tsumeb area and cyanide contamination in the Kombat area have been known to occur and need to be monitored in these specific instances.

Contaminants are not limited to any specific type of water source or geographical area of the source. Therefore, whenever a new water source is considered for drinking water purposes water quality sampling and analysis has to be performed. The sample should preferably be taken by an expert in the water treatment field and needs to be analysed in an approved, recognised laboratory for water analysis purposes. The sampling, storage and handling procedure must be carefully controlled. The following procedure should be followed for sampling:

For the analysis of major inorganic and physio-chemical parameters use bottles of approximately 1L capacity with close-fitting clean stoppers. Avoid use of metal-lined caps.

- Clean bottles thoroughly before use (if not supplied by the laboratory);
- Collect samples that are representative of the water that is to be tested;
- A representative sample is one that typifies (represents) in time and space that part of the aqueous system to be examined;
- The choice of technique for collecting a homogenous sample must be defined in the sampling plan;
- Fix sampling points by detailed description in the sampling plan, by maps or with the aid of landmarks in a manner that will permit their identification by other persons;
- Pump the water from a new borehole or well for at least 24h before taking a sample; borehole drilling, - completion and – development methods can have long term effects on sample chemistry;
- Before collecting samples from distribution systems, flush lines with tap fully open for 2 to 3 min before sampling;
- Rinse the bottle with the water being sampled before starting to collect the sample, unless the bottle contains a preservative;
- Fill container full;
- Make a record of every sample collected and identify every bottle;
- Submit samples in clearly labelled bottles. Include on the label all sample details that should appear on the final report, i.e. when and where the sample was taken;
- Deliver samples to the laboratory as soon as practicable after collection, typically within 2 days. Where shorter holding times are required (to be confirmed with the laboratory before sample collection), make special arrangements to insure timely delivery to the laboratory.

4.2.1 Nitrate

Nitrate deposits occur naturally in arid and semi-arid regions of Namibia, typically (but not exclusively) in Kalkfeld in the Otjozondjupa region and towns in the Karas region. These can cause a high concentration of nitrates in groundwater which exceed the maximum allowable limit for human consumption as stipulated by the latest Namibian Water Quality Standards and Guidelines. Nitrate levels in water supplies should ideally be below 6 mg/l (as N) but not exceed 11 mg/l (as N) for human consumption (latest Namibian Water Quality Standards and Guidelines) and, for livestock watering, be below 110 mg/l (as N) (Tredoux *et al*, 2009). Fig. 3 shows those areas with naturally high nitrate occurrence in groundwater throughout Southern Africa.

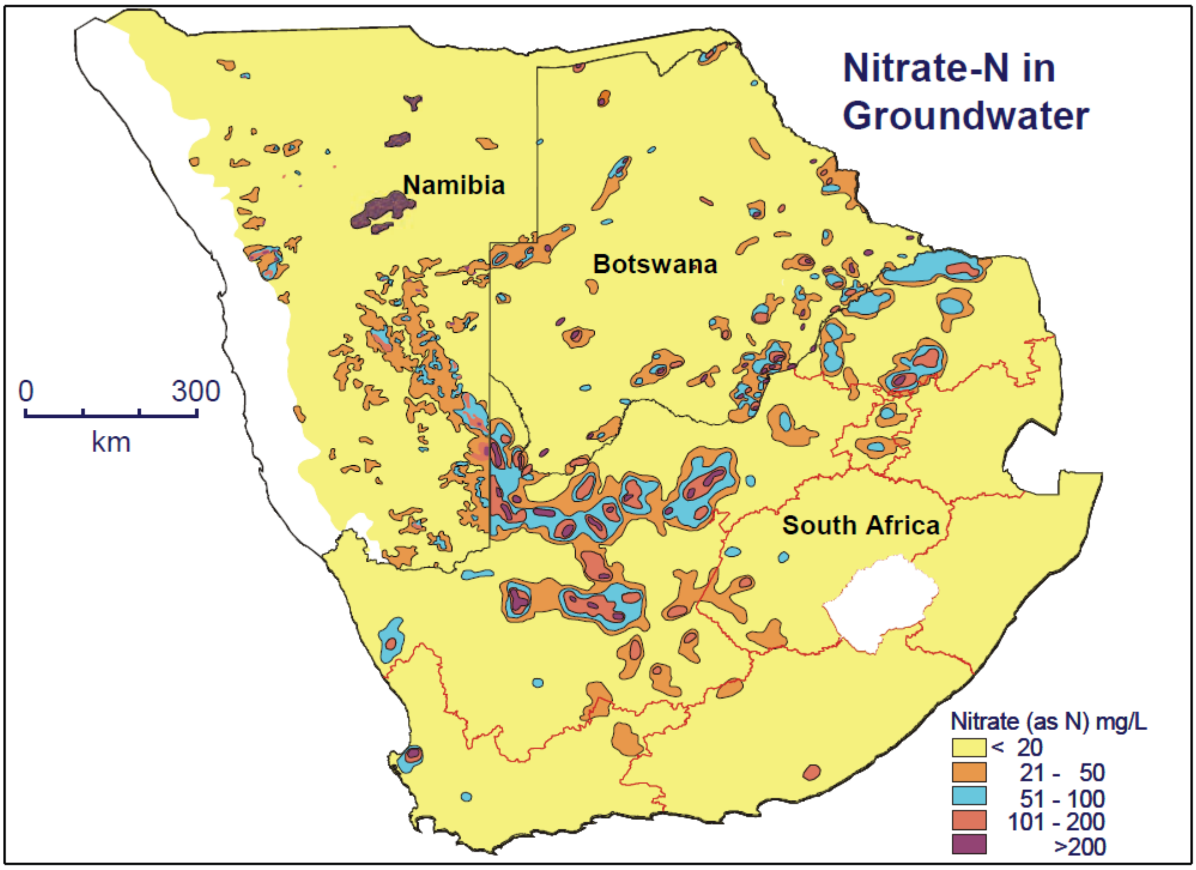


Figure 3: Groundwater Nitrate Distribution in Southern Africa (Tredoux et al, 2009)

Nitrates are reduced to nitrites when ingested by humans. These nitrites enter the bloodstream and compete with and reduce the body's ability to carry oxygen. Adults may drink water with relatively high nitrate concentration without negative effects but infants are much more susceptible to nitrate poisoning, which can cause the fatal condition methaemoglobinaemia, commonly known as "blue baby syndrome" (WHO, 2014). Nitrates can also lead to livestock deaths when animals consume large quantities of water with high nitrate concentration.

In addition, nitrate pollution can occur due to agricultural activities near a water source. During heavy rains, products with high concentrations of nitrates such as animal waste, fertilisers and compost seep into the groundwater. This can cause significant increases in nitrate concentrations of water sources, even where natural nitrate deposits do not occur. Namibia, in recent years has increasingly seen previously good groundwater aquifers becoming unsuitable even for livestock watering, due to sharp increases in nitrate levels. This has predominantly been experienced on farms, where farmers have built their cattle pens next to production boreholes. Over many decades, rainwater seepage through animal waste has slowly leached high nitrates from the waste into the underground aquifer rendering this source eventually unsuitable for water supplies.

4.2.2 Fluoride

High fluoride concentrations in groundwater usually occur in granitic environments and are specifically problematic in the Orange-Fish River Basin and the Cuvelai-Etosha Basin. Towns in the Orange-Fish River Basin such as Ai-Ais, Ariamsvlei, Gabis, Grünau, Kalkrand and Warmbad (Tordiffe, 2010) and towns in the Cuvelai-Etosha Basin such as Ongwediva, Okankolo and Oshakati (BWC, 2010) have all been reported to contain high levels of fluoride in the groundwater. Fig. 4 reflects fluoride occurrence in groundwater specifically in the Cuvelai-Etosha Basin.

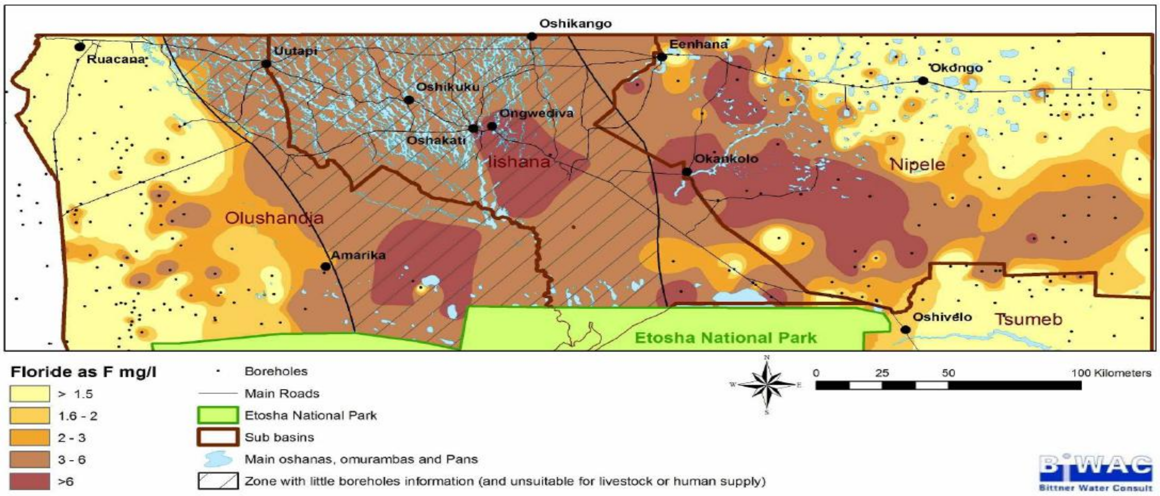


Figure 4: Groundwater Fluoride Distribution in the Cuvelai-Etosha Basin (BWC, 2010)

While fluorides are beneficial to human health at concentrations between 0.7 and 1.2 mg/l because they prevent tooth decay and strengthen bone structures, they become harmful at slightly higher concentrations and acute toxic to humans at concentrations above 4 mg/l (AWWA, 1999). Typical symptoms of fluoride poisoning are tooth decay, brittle bone structures and skeletal fluorosis, which causes pain in the back and/or extremities (WHO, 2006). As per the National Water Quality Standards and Guidelines fluoride concentrations in drinking water should be kept below 1.5 mg/l, with preferable limits below 0.7 mg/l, while livestock should not ingest water with fluorides exceeding 2 mg/l (Ayers & Westcot, 1985). Calcium ingestion through drinking water or diet can significantly reduce the effects of fluoride on the body by forming calcium fluoride.

4.2.3 Sulphate

High sulphate concentrations in groundwater can be caused by the presence of weathered sulphide minerals in the water environment or by decomposed organic material in sedimentary rocks surrounding the groundwater. Sulphates are known to be present in high concentrations in areas such as the Cuvelai-Etosha Basin and towns such as Ai-Ais and Ariamsvlei, and a detailed analysis should be performed whenever a new water source is considered for drinking water purposes. Sulphate levels in water should ideally be below 100 mg/l (as SO_4) but not exceed 300 mg/l (as SO_4) for human consumption (latest Namibian Water Quality Standards and Guidelines) and for livestock watering should be below 1 200 mg/l (as SO_4) (NamWater Quality Guidelines, 1998).

Sulphates can have a laxative effect if ingested in high concentrations, causing dehydration and diarrhoea. It is thus recommended that water containing sulphates in concentrations exceeding the Namibian Drinking Water Standards and Guidelines maximum limit of 300 mg/l should not be ingested by infants and the elderly, as these population groups are more sensitive to sulphate ingestion than healthy adults (EPA, 1999b,c). Older children and adults become sensitised to high sulphate levels after a few days. Fig. 5 shows a detailed sulphate concentration map of the Cuvelai-Etosha Basin based on a recent groundwater study performed by Bittner Water Consult (2010).

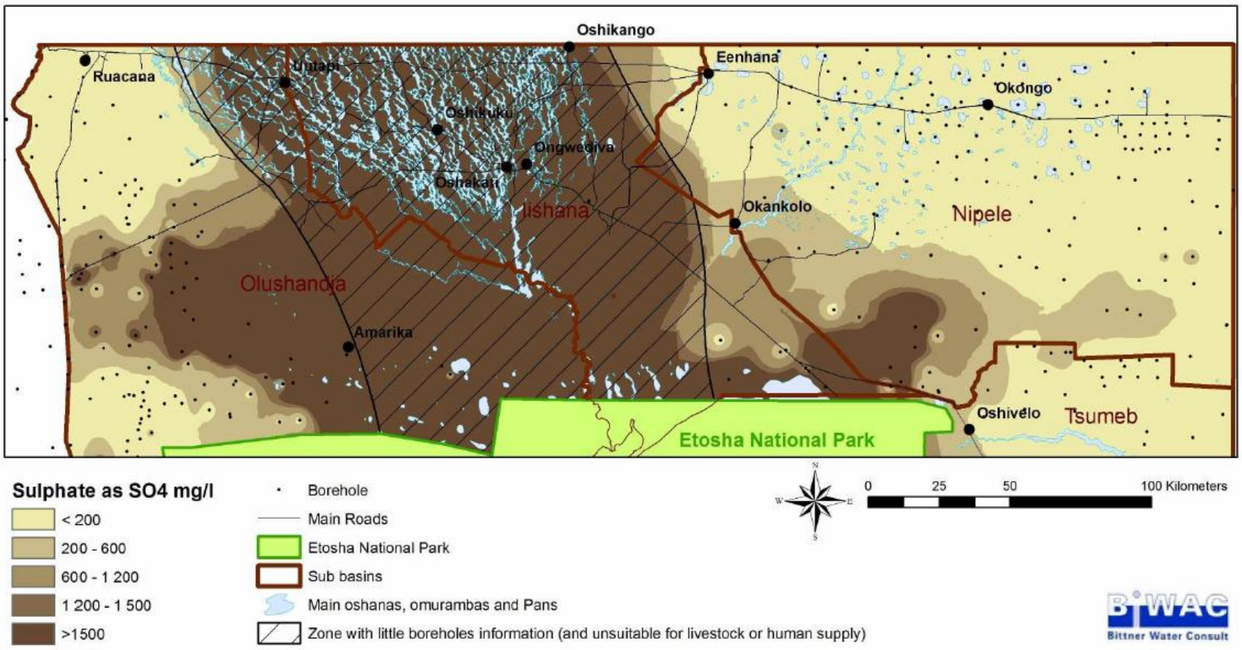


Figure 5: Groundwater Sulphate Distribution in the Cuvelai-Etosha Basin (BWC, 2010)

4.2.4 Iron and Manganese

Iron (Fe) and manganese (Mn) occur naturally in groundwater due to minerals and rocks containing these ions. Acid mine drainage, landfill leachate and industrial effluents may significantly increase these concentration in the groundwater. Fe and Mn often occur together as nuisance constituents, thus if excessive concentrations of one om them are found in a groundwater source, the other one will also be high. As per the latest Namibian Water Quality Standards and Guidelines, Fe and Mn concentrations in drinking water should be kept below 0.3 mg/l as Fe (ideally below 0.2 mg/l as Fe) and below 0.1 mg/l as Mn (ideally below 0.05 mg/l as Mn), respectively. At concentrations above 0.3 mg/l for Fe and above 0.1 mg/l for Mn these constituents can cause an aesthetically unpleasant smell and metallic taste in drinking water (AWWA, 1999). At higher concentrations the water may have a reddish-brown colour which can cause staining in plumbing fixtures and especially washing machine. Fe and Mn precipitates may form deposits in pipes and may appear as rust flakes in the drinking water. The growth of unwanted bacteria proliferating on Fe and Mn can also cause a slimy coating in water pipes.

4.2.5 Total Dissolved Solids

The total dissolved solids (TDS) concentration in water is an indication of the total combined concentration of all dissolved ions and particles which is often called dissolved salts. Dissolved solids are measured in order to ascertain the total mineral content in water including minerals that are present in very low concentrations but are not measured individually. TDS concentration can also be referred to as salinity and indicates the degree of saltiness of the water.

Salinity is measured as the conductivity of the water and is then expressed typically in mS/m. However, there is an empirical relationship between salinity and conductivity, which may differ slightly for different potable water sources, but is generally fairly constant here in Namibia and is widely used to calculate the TDS from conductivity results as follows:

TDS (in mg/l) = Conductivity (in mS/m) x 6.7

As per the latest Namibian Water Quality Standards and Guidelines the conductivity in drinking water should ideally be below 1 000 mg/l TDS but may be acceptable up to a maximum limit of 2 000 mg/l TDS for drinking water and 6 000 mg/l TDS for livestock watering (Namwater Water Quality Guidelines) . Note that this is just an indication of the total mineral content of the water and limits for individual constituents take precedence over the total dissolved solids limit.

Boreholes often contain brackish water which has a salty taste, indicating TDS higher than 1 000 mg/l (Water Quality Association, 1999). Although the acceptable limit is 2 000 mg/l, a salty taste may be present in the water from 1 000 mg/l upwards. Further investigation into the individual ions that cause this high TDS concentration would then be required to determine the appropriate treatment method. Seawater has a TDS of approximately 35 000 mg/l. Fig. 6 shows the pattern of readings from boreholes throughout Namibia with varying TDS concentrations. Towns such as Gochas, Aranos, Koes, Stampriet and Aroab typically have boreholes with high TDS concentrations.

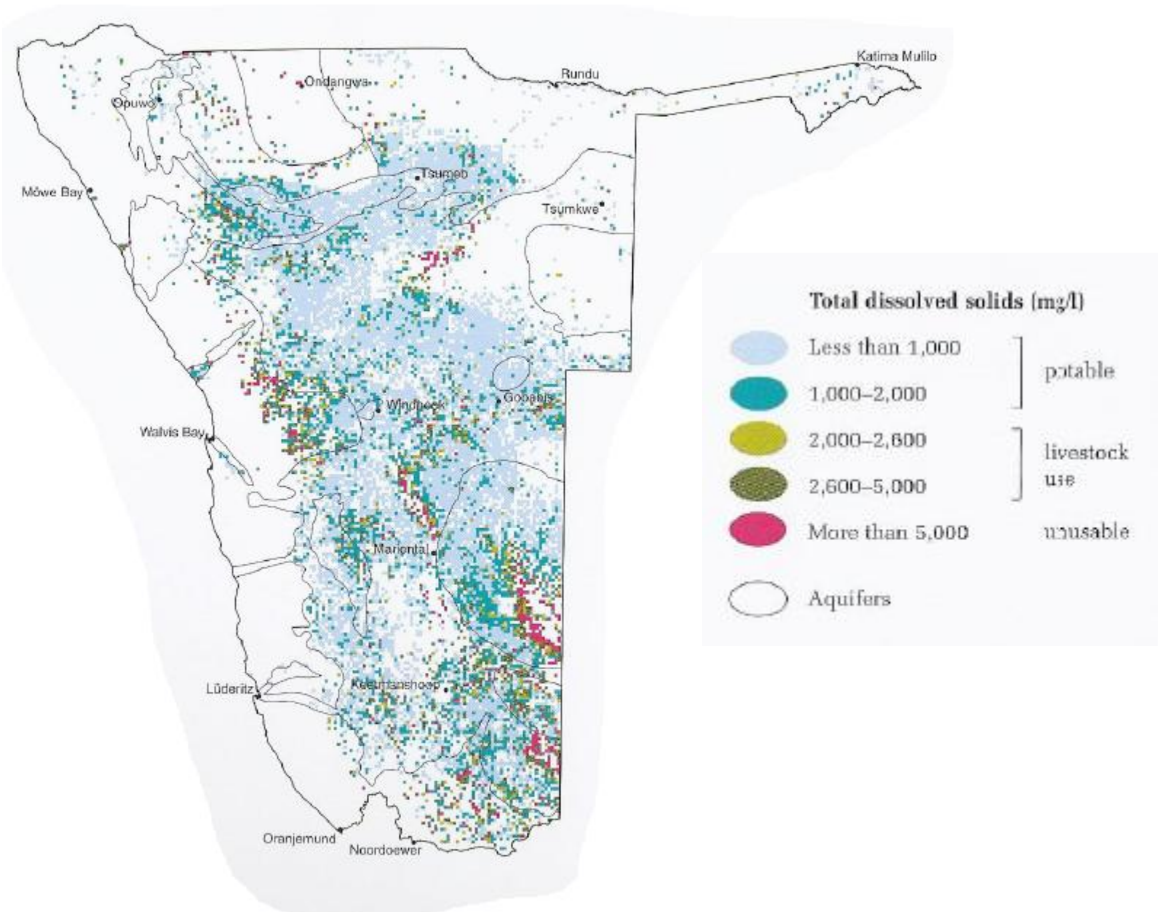


Figure 6: Total dissolved solids concentration of boreholes throughout Namibia (Mendelsohn *et al.,* 2009)

Table 1 lists some of the most commonly known or used salts in water treatment with their commonly known name.

Table 1: Common salts found in water and used in water treatment

Formula	**Chemical Name**	**Commonly Used Name**
$Al_2(SO_4)_3.14H_2O$	Aluminium sulphate	Alum
$CaCO_3$	Calcium carbonate	Limestone
$Ca(OH)_2$	Calcium hydroxide	Lime
$CaSO_4$	Calcium sulphate	Gypsum
$FeCl_3$	Ferric chloride	Ferric
$KMnO_4$	Potassium permanganate	Condy's crystals
$MgSO_4$	Magnesium sulphate	Epsom salt
$NaHCO_3$	Sodium bicarbonate	Bicarbonate of soda
Na_2SO_4	Sodium sulphate	Glauber's salt
NaCl	Sodium chloride	Table salt, coarse salt
Na(OH)	Sodium hydroxide	Caustic soda, caustic

When a salt dissolves in water it separates into the cationic and anionic parts. It can then no longer be distinguished from which salt a certain ion it originated from. For example, sodium ions dissolved in water could have originated from sodium chloride, sodium bicarbonate or sodium sulphate and it is simply not possible to determine from which salt the cation was derived. Therefore, chemical analyses quantify the presence of specific anions or cations and do not consider individual salt concentrations.

4.3 Radioactive Elements

Certain rock types have naturally occurring trace levels of radioactive elements, which can accumulate in drinking water sources. Radionuclides in these elements are unstable nuclei that emit energy in the form of high speed particles, alpha or beta, in order to stabilise themselves. This is termed ionising radiation, which can be measured and quantified. Radioactivity can also be influenced by human activity such as uranium mining, if proper precautions are not met when dealing with radioactive waste. In Namibia, there is significant uranium mining activity in the region between Usakos and Swakopmund. Some of the more common radioactive radionuclides occurring in water include radium-226 and radium-228, uranium-234, uranium-235, uranium-238, iodine-131, tritium and radon-222 (USGS, 2014).

The high speed particles emitted by radionuclides can displace electrons in the body, thereby disrupting the original function of the affected cells. Both alpha and beta particles ingested with drinking water over many years can increase the risk of developing cancer. The Namibian Drinking Water Quality Standards and Guidelines stipulate maximum levels of both alpha and beta radioactivity (measured in units of Becquerel per liter) in drinking water sources in order to ensure minimal health risks:

- Gross alpha activity. Ideal: <0.2 Bq/l, Acceptable: <0.5 Bq/l
- Gross beta activity: Ideal: <0.4 Bq/l, Acceptable: <1.0 Bq/l

Radioactivity can be removed from drinking water using ion exchange processes and care must be taken to dispose of the resulting radioactive sludge at a suitable radioactive waste disposal facility.

Conventional water treatment processes such as lime softening, ion exchange and activated charcoal used for the removal of other contaminants can also remove some radioactive material from a water source. If the raw water source contains excessive levels of radioactivity, the sludge produced by these conventional processes will almost likely also contain radioactive material. The degree of contamination depends on the treatment methods used and the natural abundance of radionuclides in the raw water. Drinking water sludge is often used for applications such as soil conditioning for agricultural purposes or is disposed of in lagoons or landfills. Care must be taken to ensure that radioactive material is not concentrated in the sludge to an extent that it can cause contamination when disposed of or reused. Disposal of radioactive material should only be carried out at a suitably advanced disposal facility.

4.4 Microbiological Contaminants

Water intended for human consumption must adhere to certain microbiological standards in order to ensure that the water is in fact safe for the intended use. Bacteria, viruses and protozoa can cause serious illness and even death when ingested by humans and the maximum limits for specific contaminants as per Table 2 of the latest Namibian Water Quality Standards and Guidelines for Potable Water (see Appendix B) must be adhered to at all times. Microbiological contaminants can be removed or inactivated with disinfection processes (see Section 5.7) which must form part of any water treatment plant.

Samples for microbiological tests are only accepted in laboratory supplied sterile bottles. The volume should be sufficient to carry out all tests required, preferably not less than 100ml.

- Wash your hands carefully with soap and water before collecting the sample;
- Collect the sample from the drinking water outlet (not a hydrant, hose or faucet located outside of the building). Remove the aeration screen from tap .Disinfect the end of the faucet with a bleach solution (mix 1 part bleach to 4 parts water);
- Allow the water to run for two minutes, before adjusting the flow to a stream about the width of a pencil. Take the cap off the bottle and hold the cap in one hand and the bottle in the other. Never rinse the bottle. The bottle contains a neutralizing agent to neutralize any chlorine. Carefully fill the bottle within 6-7 mm of the top. Replace the cap to the bottle without touching the inside of the cap or the mouth of the bottle;
- Fill in all areas of the sample request form;
- Clearly print sample description, date and time on the sample bottle(s);
- Place the sample bottle(s) with the correct requisition form in an insulated cooler. The cooler should contain absorbent material in the event a sample bottle leaks or is broken in transit. Place enough ice packs in the cooler so the sample will stay cool but will not freeze during transportation to the laboratory;
- Samples that are more than 24h old will be tested only for the presence or absence of indicator bacteria. Samples older than 48h will not be tested. In the case of any examination commenced more than 6h (24h for cooled samples) after sampling, the results obtained are not to be used to assess compliance or non-compliance with the requirements of the specification. Such results may be used only for purposes of information.

If a sample needs to be tested for both chemical and microbiological tests, send two samples. Microbial indicators are necessary if the possible source carries a high organics content and/or if contamination from human or animal activity is suspected.

5. TREATMENT TECHNOLOGIES

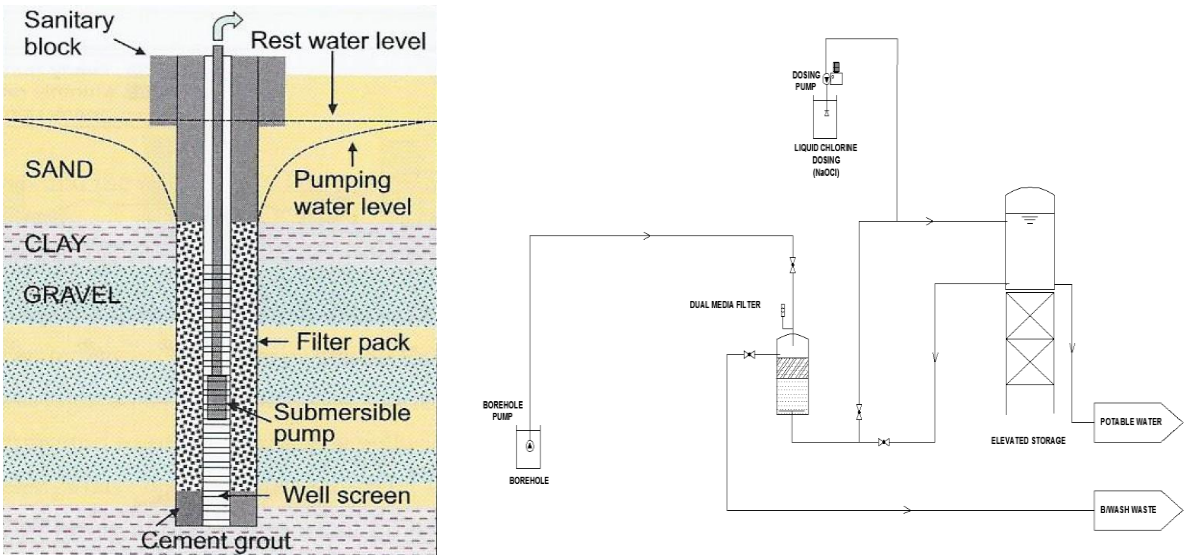
Treatment of raw water sources to potable water quality standards is a complex and case-specific process which requires in-depth analyses to be carried out by suitably qualified specialists. This section will briefly summarise some of the commonly used Namibian water sources used for drinking water purposes as well as the generic treatment processes employed to treat these sources.

This Section describes different treatment options for alternative water sources in Namibia but a case-specific approach still needs to be conducted to select the most appropriate treatment technology for a specific water source. Irrespective of the treatment technology used, disinfection always has to be the final treatment step to ensure that the water is microbiologically safe for human consumption. Disinfection is treated separately at the end of this Section.

5.1 Borehole Water Treatment

In general, boreholes in Namibia can have an excellent water quality and only minimal treatment is required to obtain potable quality water. If a water analysis reveals that the TDS is relatively low (< 1 000 mg/l) and none of the individual quality parameter limits are exceeded for determinants such as nitrates and sodium, this water can be treated relatively easily using sand filtration and disinfection.

Water is pumped from the borehole through a sand filter after which it is disinfected using chlorination or any other disinfection method as discussed in Section 5.7. Sand filters mechanically filter the water by removing particles and impurities that become trapped in the sand. Even though the borehole water may be of such a high quality that sand filtration is technically not required, it is still recommended to remove fine sand and grit particles that may be transported along with the water during the pumping process. Minimal equipment is therefore necessary for borehole water treatment, provided that it is already within potable water quality limits. Fig. 7a) shows a typical section through a borehole and Fig. 7b) illustrates a typical borehole water treatment process.



a) Typical borehole installation (Christelis & Struckmeier, 2001) **b) Basic borehole treatment process schematics**

Figure 7: Typical borehole water installation and basic treatment

Often, particles from the borehole can find their way into the drinking water supply and filters are then used to ensure that these particles are removed before final discharge to the end user. These filters are provided with various different media types such as silica sand, anthracite, garnet and magnetite, depending on the application. Dual-media filters are often used with two types of media with varying effective particle size such as sand and anthracite. Dual-media filtration results in longer filter runs before backwashing is required. Higher filtration rates and less backwash water are required for each cycle.

For single households the use of small, point-of-use (PoU) water treatment devices is a very cost-effective way of treating water before consumption. These small treatment devices are also often referred to as “under-counter” treatment systems due to their small size and installation directly at the location where the water is used, such as under the sink. PoU treatment systems can consist of various process units such as cartridge filters, carbon filters, softeners (ion exchange), Ultraviolet (UV) filtration and even RO units for various types of treatment capabilities and many different manufacturers are available for these systems. Carbon filtration, ion exchange and RO treatment technologies are discussed in Section 5.6.2, 5.6.3 and 5.5, respectively. Fig. 8 shows some typical PoU water treatment systems.

a) Dual media filter (Triangular Wave)

b)Reverse Osmosis (Applied Membranes Inc)

c) Three-stage UV filtration (Overstock)

Figure 8: Typical Point-of-Use small-scale water treatment devices

5.2 River Water Treatment

Continuously flowing rivers carry water that, for most of the year, is of a very good quality and treatment processes can be very similar as those used for borehole water treatment. However, during times of increased runoff, such as during the rainy season, the water picks up additional rocks, sand, mud, colloidal particles and plant material, which increases the turbidity and requires additional treatment.

Therefore, for river water the sand filtration step is often preceded by an additional chemical dosing unit using a metal salt or poly-electrolyte coupled with coagulation, flocculation and sedimentation steps depending on the river water turbidity. This is further discussed in Section 5.3 below. During the rainy season, flooding of rivers can cause a sharp increase in river water turbidity and care must be when designing a treatment plant. Often, the plant will be designed to handle a worst-case, high turbidity water and then the pre-treatment steps preceding sand filtration are then by-passed during the dry season when the river water turbidity is low. As a rule of thumb the following treatment processes are required as a minimum to deal with water turbidity:

Table 2: Recommended treatment processes required for river water based on raw water turbidity

Approximate River Water Turbidity [NTU]	Minimum Treatment Steps Required
<15-20	Straight, single-stage sand filtration, disinfection
20-80	Chemical addition, coagulation, flocculation, single-stage sand filtration, disinfection
80-150	Chemical addition, coagulation, flocculation, double-stage sand filtration in series, disinfection
>150	Chemical addition, coagulation, flocculation, sedimentation (or dissolved air flotation), sand filtration, disinfection

Running water generally contains very little microbiological and organic contamination, provided that there are no external factors contributing to such pollution. Towns or cities located on river banks often cause significant pollution of the river. People bathing, doing their laundry and possibly urinating and defecating in rivers can cause an otherwise potable water source to become unsafe for human consumption. Industrial and domestic wastewater (sewage) discharges into rivers also cause significant pollution problems. It is therefore recommended that treatment plants downstream of river-side settlements and towns are also fitted with activated carbon filtration units directly following the sand filtration step, in order to remove organic material in the water. Fig. 9 illustrates a typical river water treatment process dealing with low turbidity water, with a flocculation unit and single-stage sand filtration but excluding activated carbon filtration.

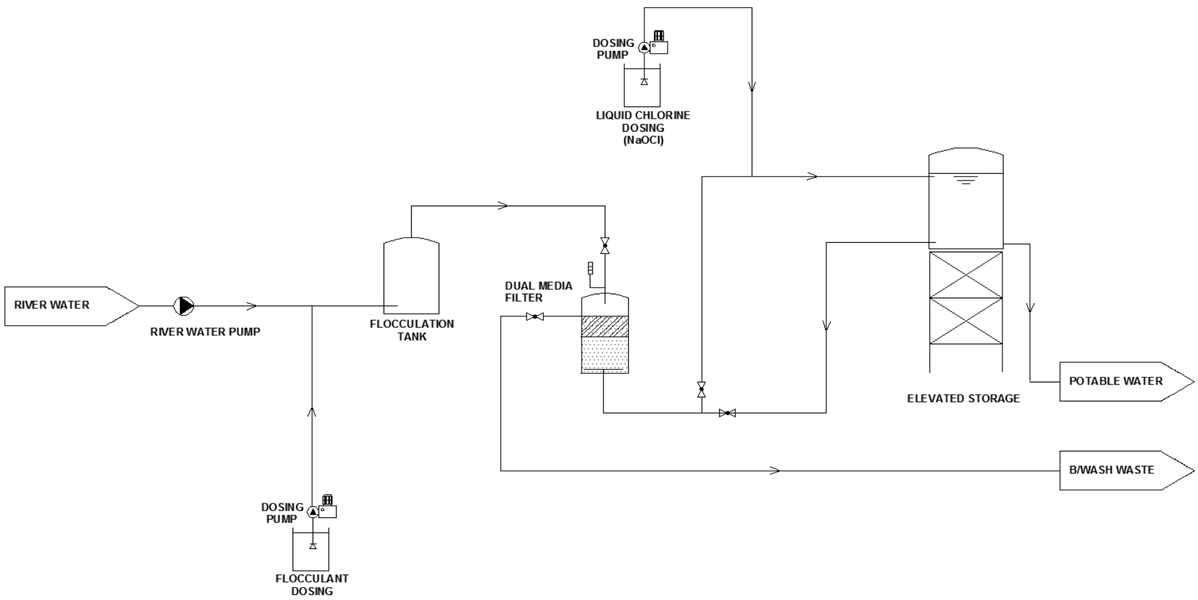


Figure 9: Typical river water treatment plant schematics for low-turbidity waters

5.3 Chemical Addition for Coagulation and Flocculation

5.3.1 Chemical Dosing and Coagulation

Chemical dosing is used in water treatment processes to destabilise suspended material such as colloidal particles so that it can be agglomerated to form settleable flocs. The efficiency of this destabilisation process depends on the chemical(s) used, the mixing or agitation intensity and the control of dosing flow rate. The chemicals can be added using equipment such as dosing pumps, drip feeders, siphons, mechanical screw-feeders and saturators (WRC, 1997).

Although there is a vast array of different chemicals that can be used for suspended material destabilisation, the most commonly used chemicals are metal salts such as aluminium sulphate (alum), ferric chloride and poly-electrolytes. The selection of the most suitable chemicals and the optimum dosage requirement are obtained by performing beaker tests on the raw water to be treated (see Section 5.3.3 for details). This is a case-specific procedure and each raw water will have its specific optimum chemical and dosing rate.

Aluminium sulphate (alum). Alum undergoes hydrolysis when dissolved in water and requires the presence of alkalinity to form a floc forming precipitate in the form of aluminium hydroxide. The optimum coagulation efficiency of alum occurs at pH of 6 to 7. pH adjustments are thus often required in conjunction with alum coagulation. The destabilisation of suspended material occurs via two distinct mechanisms:

- Adsorption-destabilisation. Alum forms a number of intermediate hydrolysis products, which attach themselves to the surface of clay particles. Interparticle bridging then takes place and clay particles coagulate to form flocs.
- Sweep coagulation. Aluminum hydroxide precipitate captures and encloses clay particles in the precipitation process. These form into floc particles which settle and allow the clay particles to be removed.

The main coagulation reaction that occurs with alum coagulation is as follows:

$$Al_2(SO_4)_3 + 6(HCO_3)^- \rightarrow 2Al(OH)_3\downarrow + 3SO_4^{2-} + 6CO_2\uparrow$$

Ferric chloride. Ferric chloride also undergoes hydrolysis in water depending on the nature of hydrolysis products and on the pH to form ferric hydroxide that results in coagulation of particles. The mechanism of suspended material destabilisation is similar to alum, with either adsorption-destabilisation or sweep coagulation occurring. The main coagulation reactions that occur with ferric chloride are as follows:

$$FeCl_3 + 3(HCO_3)^- \rightarrow Fe(OH)_3\downarrow + 3Cl^- + 3\ CO_2$$

$$2FeCl_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3\downarrow + 3CaCl_2$$

Poly-electrolytes. Poly-electrolytes are water soluble organic compounds that can be used as a primary coagulation chemical or as a flocculant in conjunction with a metal salt in order to aid floc formation. Various different types and manufacturers of polyelectrolytes exist and the selection needs be made by performing case-specific beaker tests (see Section 5.3.3).

The coagulation chemical(s) need to be mixed with the raw water in order for uniform particle destabilisation to occur. The mixing intensity is quantified with the so-called velocity gradient, or G-value. The first step in the coagulation process requires rapid or flash mixing in order for the chemicals to be brought into contact with suspended particles. Typical G-values for flash mixing are between 300 and 5 000 s^{-1} (WRC, 1997). The optimum

G-value for a specific application will depend on the coagulant used, the type of mixer and the characteristics of the water.

5.3.2 Flocculation

After coagulation with alum the destabilisation of clay particles is completed through flocculation, whereby optimal conditions are created for contact between small flocs and individual clay particles to agglomerate into large settleable flocs. The control of mixing intensities, quantified by the G-value, is of very great importance during flocculation as there are two opposing phenomena to consider:

- Increasing the mixing intensity increases inter-particle contact, which results in floc growth;
- Increasing the mixing intensity too much results in disintegration of previously formed larger flocs.

Therefore, there is a very narrow range of mixing intensities that will result in optimal floc formation and clay particle destabilisation. The flocculation process usually consists of an initial rapid mixing stage followed by a reduction in mixing intensity to allow for floc growth without disintegration of already formed larger flocs. Typically, G-values for flocculation can range from 15 s^{-1} to 100 s^{-1} (CSIR 1985). Various different types of flocculators can be used, depending on the specific requirements, for example:

- Baffled channels, which cause mixing due to frictional head loss around 180° bends;
- Mechanical flocculator, which imparts energy through electrically driven mixers;
- Rotor/stator flocculator, which consists of a slowly rotating bridge in a circular basin with mixer blades suspended in the water.

5.3.3 Beaker Tests

Beaker tests, or jar tests, need to be performed on a case-specific basis for each plant where coagulation and flocculation is required for the destabilisation of suspended material. This is done using a standardised test method, which uses a trial-and-error approach and visual inspection of the floc formation in order to determine the optimum coagulation/flocculation chemical and the optimum dosage. The jar testing procedure is described in detail in Appendix A.

5.4 Dam or High-Turbidity River Water Treatment

High-turbidity raw water treatment, typically required for dam water or river water when it carries high-turbidities, requires the chemical addition of a metal salt or poly-electrolyte coupled with the conventional treatment steps of coagulation, flocculation, sand filtration, activated carbon filtration and disinfection. The same methodology as for river water treatment applies. If the turbidity is high then pre-treatment before sand filtration is necessary. During seasonal fluctuations thermal stratification (dam turnover) can occur when differences in water temperature and associated water density can cause water layers to turn over. This results in sediments at the bottom of the dam to be liberated and results in elevated turbidity as well as increased heavy metals concentration (if applicable). Although not all dams experience thermal stratification, it is recommended to keep this phenomenon in mind when designing dam water treatment plants.

Also if the inflows are high in nutrients the dam can become mesotrophic or eutrophic, i.e. seasonally or permanently enriched with nutrients, respectively, which will result in the growth of nuisance algal species. In such cases the plant will need to be able to remove high concentrations of organic carbon and microbial by-products, which can be achieved using activated carbon filtration following sand filtration. For dam water containing algae, proper coagulation, flocculation and a clarification process such as dissolved air flotation (DAF) or sedimentation needs to be incorporated in the plant design. Dissolved air flotation, discussed in more detail in Section 5.6.1, is especially effective in removing lighter particles such as algae and colour-causing organics that are difficult to remove using conventional sedimentation. The treatment process depicted in Fig. 9 above for river water treatment is therefore also applicable for dam water treatment, with additional sedimentation following flocculation as well as activated carbon filtration, if necessary. A treatment process that consists of coagulation, flocculation, sedimentation, filtration and disinfection is often referred to as "conventional treatment" and is described in Fig. 10 below.

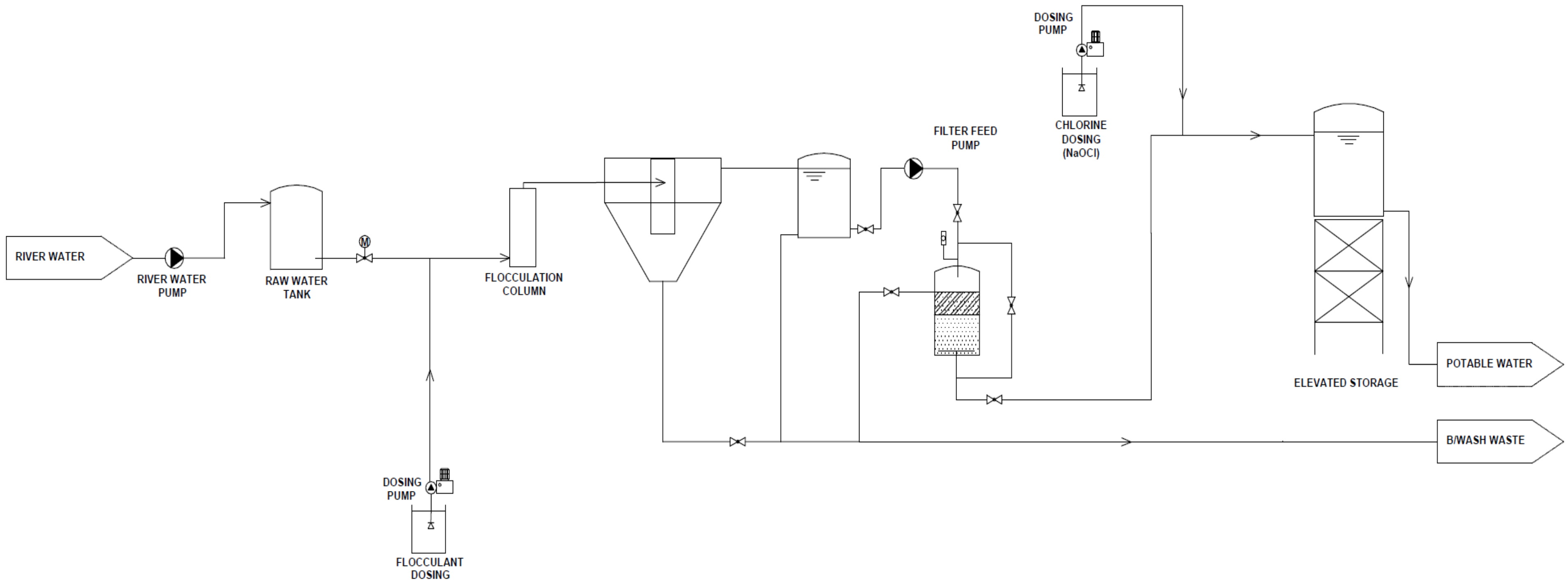


Figure 10: Typical conventional treatment plant schematic with elevated final water storage tank

5.5 High-salinity Waters and Seawater Desalination

Waters with TDS concentrations exceeding aesthetically acceptable limits such as brackish borehole water or seawater can be treated to drinking water quality using desalination processes such as thermal processes (distillation), electrodialysis and RO. Distillation is often used in the mining and power generation sectors with boilers generating water vapour that is then condensed to form very pure water. The most commonly used technology in Namibia for producing drinking water from high-salinity raw water is RO technology.

The RO process uses a semi-permeable membrane to remove dissolved minerals and particles. The feed water is pumped through the membrane at a high pressure, causing pure water molecules to pass through while larger salt molecules and particles are unable to pass through. Fig. 11 illustrates the principle of RO, whereby high pressure is used to counter-act the natural tendency for particles to migrate from high concentration areas to low concentration areas.

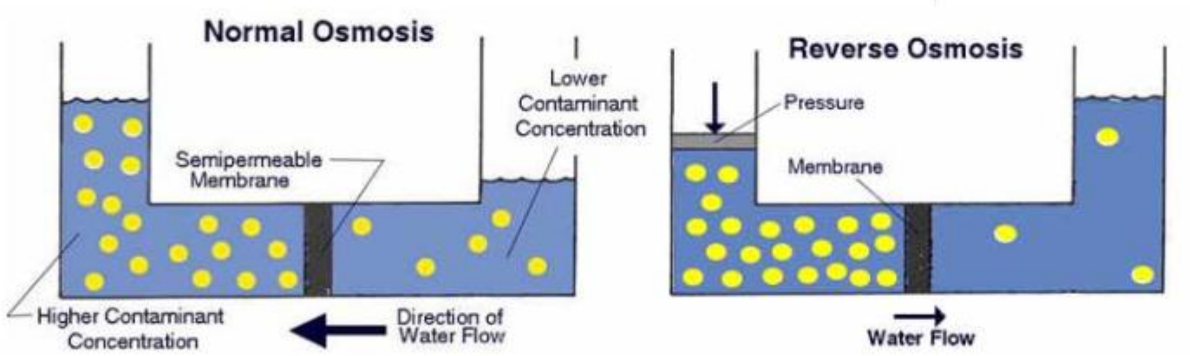
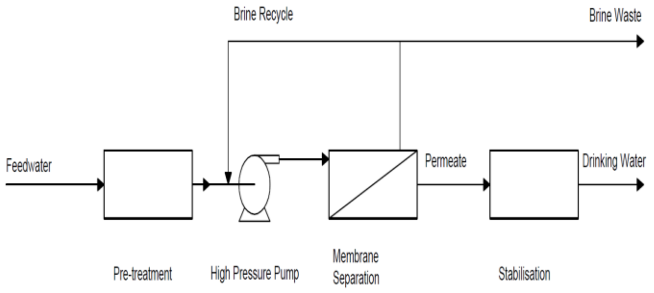


Figure 11: Illustration depicting normal osmosis versus reverse osmosis (Water Quality Association, 2014)

As feed water continues to pass through the membrane, the concentration of salts on the pressurised side of the membrane keeps increasing. A portion of the brine solution is therefore continually removed in order to keep the membrane pores from being blocked by too many salt particles. A common practise is to then recycle a portion of the brine solution back to the inlet of the membrane and wasting a smaller portion. This will increase the concentration of the waste brine stream which reduces the overall volume of brine produced. There are different types of membranes for various different feed water applications and a suitably qualified water treatment specialist should be consulted before a type of membrane is chosen for a new RO plant.

Fig. 12 is a simplified schematic illustrating a typical RO desalination process:



a) Simplified RO process schematics **b) Typical RO Membrane Skid** (Lenntech)

Figure 12: Reverse osmosis treatment process

- Pre-treatment. RO membranes are very sensitive to certain feed water constituents and care must be taken to ensure that the membrane does not become damaged due to unfavourable feed water conditions. Pre-treatment can include removing suspended solids, pH adjustments, anti-scalant addition to control scaling caused by constituents such as calcium sulphate, as well as removal of constituents such as chlorine that can damage the membranes.
- Pressurisation. The pressure of the pre-treated water is then raised to a level appropriate for the salinity of the water and the type of membrane. In general, the higher the salinity of the water the higher the pressure required for successful separation.
- Separation. The pressurised water is passed through a semi-permeable membrane, with clean water passing through and salt molecules and particles being rejected to a brine stream. Depending on the type of membrane and feed water composition, a small amount of salt particles will pass through the membrane along with the clean water.
- Stabilisation. The water that has passed through the membrane (permeate) has a very low concentration of dissolved salts. This makes the water unstable and aggressive towards any minerals that can increase its stability. The water will attack metal pipes by dissolving metal ions in the mineral-poor water. This will cause corrosion of metal pipes and fittings used for distribution of the drinking water. The water is therefore often stabilised before it is distributed to end users using remineralisation processes such adding lime. In cases when the water is supplied for industrial processes where a very low salt concentration is specifically required, care must be taken to ensure that pipes and fittings used in the distribution system are corrosion proof.

The main advantages and disadvantages of RO technology for drinking water production are summarised in Table 3.

Table 3: Advantages and disadvantages of desalination using RO technology

Advantages	**Disadvantages**
Simple processing system	Membranes are very sensitive and easily damaged or contaminated
Low installation costs	Highly trained personnel needed for design, construction and operation
Modular, existing plant capacity can easily be expanded	Pre-treatment of feed water usually required
Small plant footprint versus production capacity	Brine must be carefully disposed of
Able desalinate seawater, an extremely stable and abundant feed water source	High energy consumption for pressurisation
Able to remove inorganic and organic contaminants	High cost compared to groundwater or surface water sources, if such sources are available and suitable
Negligible environmental impact apart from brine disposal	
Minimal use of chemicals	

It should be noted that other membrane processes are also available that operate on principles similar to RO, but with larger pore sizes in the membranes. Microfiltration, ultrafiltration and nanofiltration (in order of decreasing pore size) can be used to remove various constituents from water, depending on the application. As the pore sizes in the membrane become smaller, the pressure required to force water through the membrane becomes higher. For example, if salt removal is not required for a specific application, the use of ultrafiltration for instance could be sufficient and would require less pressure and energy to operate. Fig. 23 in Section 5.7.4 illustrates the various membrane treatment technologies and the respective pore sizes.

5.6 Special Applications

The treatment methods discussed in Sections 5.1 - 5.4 are all generic methods for best case conditions used for sources where the water quality does not contain any unusual contaminants. The borehole water treatment method discussed in Section 5.1 is not applicable if it found that the water contains unacceptably high concentration of fluoride, for example. This Section discusses some of the treatment methods that can be used on their own or in conjunction with any of the previously discussed methods for removing specific contaminants.

5.6.1 Dissolved Air Flotation

Dissolved air flotation (DAF) is a clarification process that uses micro air bubbles to attach to suspended solids and flocculated particles to float them to the water surface. This is presented in Figure 13, where the influent is flocculated water and the effluent is the final clarified water. A scum layer is formed on the water surface which can then be easily removed using scrapers or overflow channels. In contrast, conventional sedimentation requires particles to settle toward the bottom of the chamber. DAF is therefore the preferred method for removing lighter particles that settle only slowly or not at all. Common applications include the removal of oil, grease and fat, as well as removing light organic particles and algae from dam water.

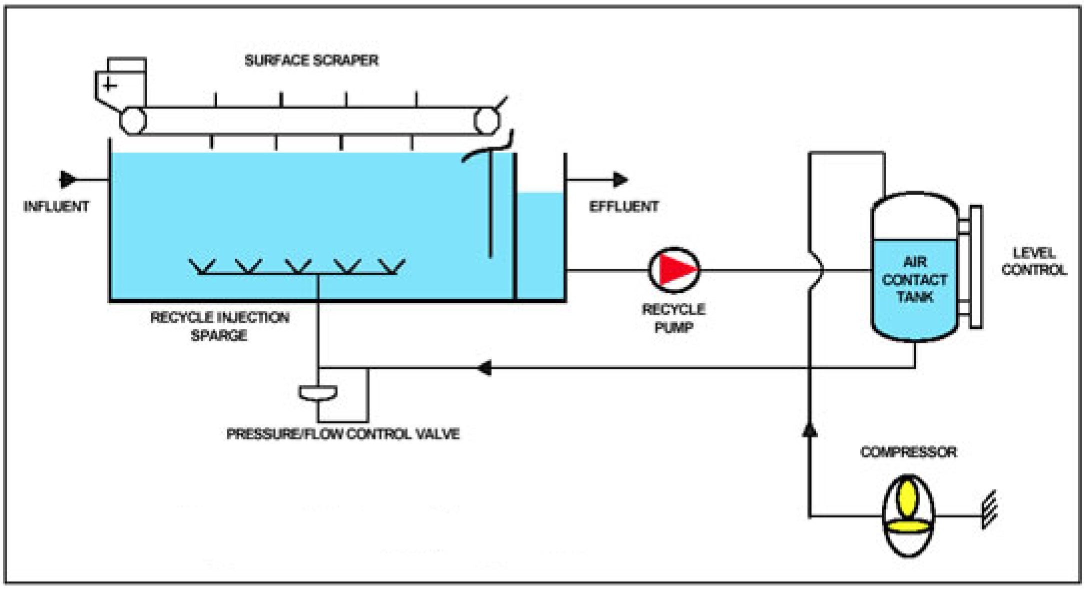


Figure 13: Typical dissolved air flotation schematic (Stetfield Separators, 2014)

DAF clarifiers are sensitive to raw water flow rate and quality. They are most widely used in applications where the raw water quality remains reasonably constant such as seawater clarification for process water in fish factories or for clarification of dam water containing algal blooms or colour-causing organic material. DAF clarifiers are also used as pre-treatment to seawater desalination plants to combat red tide or algal bloom problems. They are not recommended for river water treatment plants where the turbidity increases above 80-100 NTU.

DAF clarifiers can typically achieve loading rates of approximately 8 to 10 m/h as opposed to conventional sedimentation clarifiers which typically operate at 1 m/h. Furthermore, DAF clarifiers do not require the formation of heavy floc for sedimentation purposes and thus the consumption of coagulation and flocculation chemicals is significantly reduced.

5.6.2 High-rate clarification

Another clarification process that can be used as an alternative to conventional settling or dissolved air flotation is the process of high-rate clarification. High-rate clarifiers typically use ballasting agents such as micro sand or bentonite to enable particles and floc to settle more rapidly, or alternatively make use of sludge recirculation to enable more rapid particle settling. In addition, poly-electrolyte flocculant aids (see Section 5.3.1) are used to enable more rapid settling of particles. Angled lamella are also used to reduce the distance that particles need to settle downwards. High-rate clarifiers can typically achieve settling rates of up to 40 - 80 m/h, while conventional sedimentation clarifiers typically operate at 1 m/h. High-rate clarifiers are currently available as proprietary systems from various manufacturers. Fig. 14 shows an “Actiflo” system, which is a proprietary high-rate clarifier manufactured by Veolia.

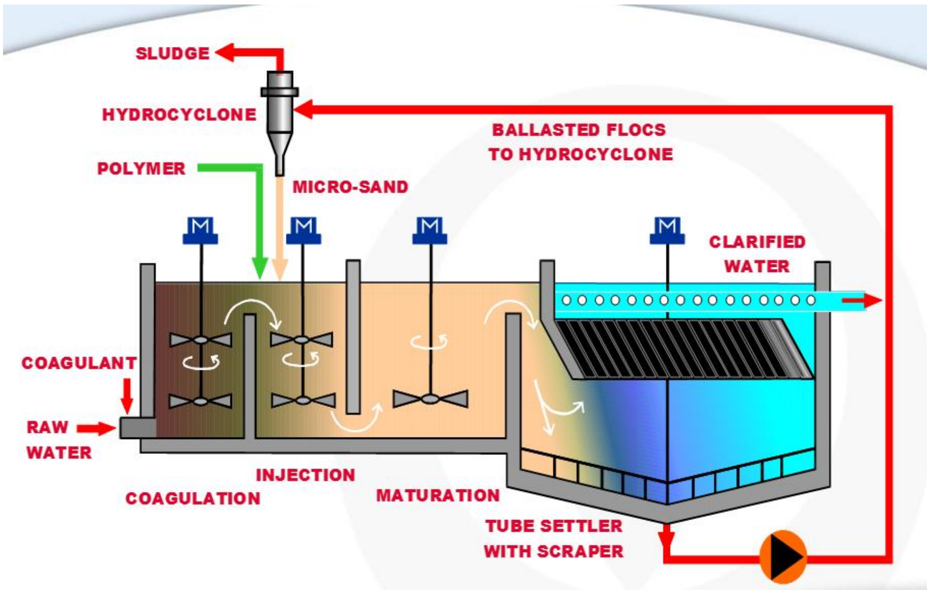


Figure 14: "Actiflo" high-rate clarifier (Veolia, 2005)

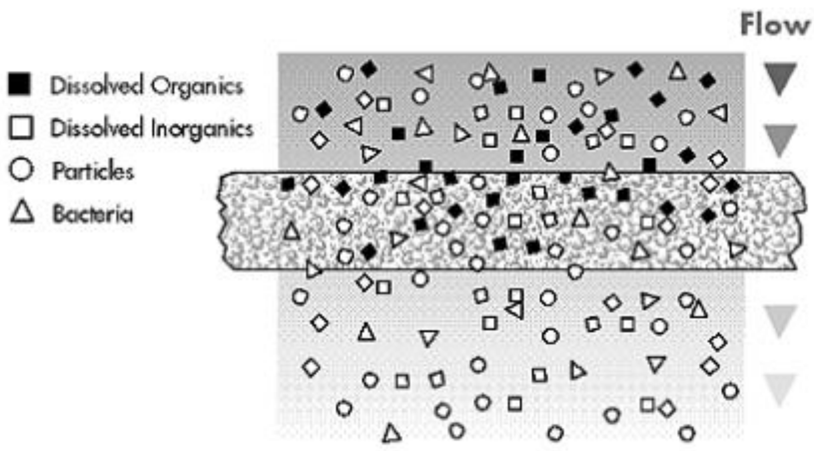
5.6.3 Activated Carbon Filtration

Activated carbon is used in drinking water plants for removing organic constituents, which can cause aesthetic problems such as unpleasant smell, taste and colour. Activated carbon works mainly through the process of adsorption, by which soluble material in the water physically attaches to the surface of carbon particles (Fig. 15). Activated carbon also removes chlorine and chlorine-based byproducts. Chlorine-based compounds are usually adsorbed more easily and strongly than organic constituents and chlorination is thus performed after carbon filtration. However, due to this property, activated carbon is often used as a polishing filter or at point-of-use systems (see Fig. 8) following chlorination in order to remove excess chlorine and chlorination byproducts. As material is adsorbed onto the carbon it becomes saturated and its ability to remove further organic material or disinfection byproducts becomes diminished.

Activated carbon is available in two different forms: Powder Activated Carbon (PAC) and Granular Activated Carbon (GAC).

PAC is used mainly for pre-treatment to remove organic material and suspended solids prior to downstream processes to reduce organic loading. It is typically dosed in powder form directly into the water stream near the inlet of the treatment plant to allow sufficient contact time for adsorption onto the carbon particles to occur (typically 15 minutes). The PAC along with the adsorbed organics are then removed by sedimentation and/or filtration.

GAC is used in either gravity or pressure filters so that the carbon is immobile and water passes over the carbon for adsorption to occur. As soon as the GAC is near to saturation, the filter bed is replaced with new carbon. Depending on the water contamination, GAC beds need to be replaced approximately every 6 to 24 months. The spent PAC or GAC needs to be disposed of at a suitable waste disposal facility.



a) **Carbon Adsorption Diagram** (Filterfast) b) **Typical extended bed GAC Filter vessel**

Figure 15: Activated carbon process and equipment

5.6.4 Ion Exchange

Ion Exchange (IX) processes use reversible chemical reactions that remove dissolved ions of undesirable salts from the water and replace them with similarly charged ions. Various specifically designed resins exist in order to remove specific dissolved substances from the water. Cationic resins remove cations from the water and replace them with another cation, typically sodium. The most common application of cationic ion exchange is softening, which is the removal of calcium and magnesium ions from the water, by replacing them with sodium ions. Fig. 16 depicts the reactions for calcium and magnesium removal (where R is a resin compound), as well as a typical softener installation. The reaction is fully reversible and when the system is regenerated using brine (salt) solution containing sodium, the resin will once again be able to react with calcium and magnesium.

$2\ RNa + Ca^{2+} \rightarrow R_2Ca + 2Na^+$

$2\ RNa + Mg^{2+} \rightarrow R_2Mg + 2Na^+$

a) **Hardness reducing reactions** b) **Typical softener installation** (Veolia)

Figure 16: Softening reactions and typical installation

Similarly, anionic resins can remove anionic contaminants such as nitrate, fluoride, sulphate and arsenic amongst others, by replacing them with a negatively charged ion, typically chloride.

When the resin's capacity to absorb specific ions is exhausted, it needs to be regenerated in order to return to its original condition. Sodium chloride (brine) is most commonly used for this although other regeneration chemicals can be used, depending on the application and availability of the chemicals. If IX reactors are regenerated properly and diligently, the resin can be used for many years without needing to be replaced. However, as with membrane processes, IX resins may experience fouling due to surface clogging or scaling of minerals on the resin. Therefore, pre-treatment to reduce suspended solids concentration and to prevent scaling is often performed.

IX reactors can also contain more than one type of resin for the removal of multiple contaminants in one reactor. This is called mixed bed polishing. However, these reactors are usually difficult to regenerate as the different resins need to be separated before regeneration can occur and they usually require higher amounts of chemicals for regeneration.

An additional use of ion exchange processes is the removal of radioactive material from drinking water supplies. Radioactive cations can be adsorbed onto specific resins in the same way that any other contaminant is removed. However, regeneration has to be performed with extreme care in such cases as the waste water produced during regenerations will contain concentrated amounts of radioactive materials. This wastewater will then need to be disposed of at a suitable radioactive waste disposal facility. Suitable qualified specialists should be consulted for the removal of radioactive contamination from water as well as the subsequent disposal of the resultant radioactive waste.

The most common applications of IX processes in Namibia are as follows:

- Drinking water softening for removal of magnesium and calcium hardness. Hardness can cause scaling of household taps and fittings, especially when the water is heated. Geysers, shower heads and kettles are particular prone to scaling;
- Nitrate removal to prevent nitrate poisoning of infants and livestock;
- Fluoride removal to prevent fluoride poisoning;
- Sulphate removal to prevent dehydration and diarrhoea;
- Boiler feed water demineralisation to prevent damage to equipment. The evaporation process causes concentration of minerals in the boiler which can cause equipment damage if the feed water is not demineralised.;
- Radioactive material removal in order to conform to the latest Namibian Water Quality Standards and Guidelines.

5.7 Disinfection

As mentioned previously, disinfection <u>must</u> be the final treatment step in any drinking water treatment process. This is to ensure that the final water conforms with the Namibian Drinking Water Quality Standards and Guidelines so that the water is safe for human consumption at all times. Disinfection removes bacteria, viruses, cysts and other pathogens that can be harmful if ingested by humans. There are many disinfection technologies available, with some being more effective than others for certain applications. It is widely accepted that there is no single disinfection technology that can achieve all the treatment objectives.

5.7.1 Chlorination

Chlorination is by far the most widely used and acceptable disinfection method currently in use in Namibia, as well as globally. Chlorine can be used in various forms for disinfection, including chlorine gas (Cl_2), chlorine dioxide (ClO_2), sodium hypochlorite ($NaOCl$) and calcium hypochlorite [$Ca(OCl)_2$]. Chlorination can result in the formation of undesirable disinfection by-products (DPBs), that can be removed using treatment methods such as activated carbon filtration (see Section 5.6.3).

Chlorine gas. Chlorine gas is usually used for larger plants (Fig. 17) as the chlorine content is 100%, which allows for the minimum dosage rate to be applied. For the other chemicals mentioned above, the available chlorine content used for disinfection is only a fraction of the entire chemical composition and thus requires much higher dosing rates than for pure chlorine gas. However, for small and medium-sized plants, the high capital costs of a chlorine gas disinfection system results in a dosing system with very low capital costs such as sodium hypochlorite being the preferred option. Chlorine gas systems can be set up to inject into various streams from the same cylinder (Fig. 20).

It is generally understood that the active constituent in chlorine disinfection is hypochlorous acid, which forms when chlorine dissolves in water:

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$

a) 1 tonne cylinder on cradle **b) 70 kg cylinder**

Figure 17: Chlorine gas dosing cylinders

Chlorine dioxide. Chlorine dioxide (Fig. 18) is an unstable gas that must be generated at the point-of-use. It is a viable alternative to chlorine gas due to the following factors (WRC, 1997):

- It does not react with ammonia to form chloramines;
- A minimal amount of chlorinated organics (including trihalomethanes) are formed after disinfection with chlorine dioxide;
- It is effective for removing taste and odour from the water, especially those caused by phenol;
- Iron and manganese (including organically bound Fe and Mn) are removed by chlorine dioxide.

Figure 18: Typical chlorine dioxide installation (Grundfos)

Sodium hypochlorite and calcium hypochlorite. NaOCl (Liquid) and $Ca(OCl)_2$ (solid) can provide simple solutions to disinfection at smaller treatment plants. A simple dosing plant with low capital costs can be installed (see Fig. 19), which will be much more cost-effective than using a chlorine gas system for a small plant. However, the available chlorine for disinfection is significantly lower than for pure chlorine gas. The dosing pumps can be installed directly onto the chemicals tank, in order to provide a neat and compact installation.

a) Mounted directly onto tank **b) Wall-mounted**

Figure 19: Liquid chlorine dosing installations with dosing pump

Note that for the purposes of this discussion the use of the terms “chlorine addition” and “chlorination” is meant to include any of the above disinfection chemicals that are chlorine based and does not just refer to pure chlorine gas.

Chlorine disinfection should be seen as the final polishing step in a treatment process to ensure that pathogenic organisms are destroyed prior to distribution of the drinking water and not as a singular treatment step against heavily polluted water. Chlorine can also be used for other applications at various stages of a treatment process such as oxidation of low concentrations of iron and manganese, removal of constituents that can cause taste and odour problems, destruction of algae during pre-chlorination and as a flocculation aid. However, during disinfection the sole purpose of chlorine should be the destruction of pathogens. Colloidal and organic material that was not removed in the treatment plant and that is still present in the water at the chlorination unit will react with the chlorine to form chlorination by-products before pathogen destruction can take place. This means that a higher dosage of chlorine must be applied in order to achieve actual disinfection. Therefore, care must be taken to monitor the treatment units upstream of the disinfection unit to ensure proper removal of such materials. The required chlorine dosage to achieve disinfection will therefore also depend on the water quality at disinfection and regular monitoring and dosing rate adjustments need to be made in order to achieve proper disinfection. The free chlorine concentration following adequate reaction time is generally used in order to ascertain whether sufficient chlorine was added to react with any organic material that might still be present as well as to destroy pathogenic organisms.

Figure 20: Typical gas chlorination board with multiple injectors

The following factors regarding the chlorination efficiency need to be taken into consideration:

- Colloidal and organic material can shield pathogenic organisms against the effects of chlorine;
- Chlorination is less effective for low alkalinity water and for water with a pH greater than 7.2;

- Chlorine can react with naturally-occurring materials in the water to form chlorination by-products which may be harmful to humans such as trihalomethanes (THMs) and haloacetic acids, which are believed to increase the risk of cancer in humans;
- Increased water temperature will increase the chlorination efficiency;
- The contact or reaction time for chlorination to be effective is very important. The minimum contact time before free chlorine concentration is measured should be 20 minutes. If after such time the free chlorine concentration is zero or very low, the chlorine dosage needs to be increased;
- Proper mixing of the chlorine and the water needs to occur in order for the disinfection reaction to occur successfully. This is usually done with baffles (with minimum 5 off 180° hydraulic turns) or by dosing the chlorine upstream of turbulence causing features such as hydraulic jumps or pump stations;
- One of the major advantages of chlorination is that it achieves residual disinfection. If there is a remaining free chlorine concentration in the water after all pathogenic organisms have been destroyed, the water will have the ability to remain disinfected even after distribution through pipe networks and reservoirs that may be microbiologically contaminated. This is not the case with disinfection methods such as ozonation and UV as these are instantaneous methods that do not protect the water downstream of the disinfection unit. If the pipeline downstream of an ozonation or UV system is contaminated, the water will not remain disinfected.

Due to the fact that disinfection is such a vital step in drinking water treatment, utmost care must be taken to ensure that an uninterrupted chlorine supply and dosing are readily available. The dosing rate needs to be monitored and adjusted according to the free chlorine concentration following an adequate reaction time. The dosing rate should be adjusted to produce a safe water at all times but at the same time should not be excessively high. Too much chlorine application will cause an unpleasant taste in the water and will result in chlorine (and money) being wasted unnecessarily. All equipment that comes into contact with chlorination chemicals needs to be constructed of suitably resistant materials.

5.7.2 Ozonation

Ozone (O_3) is a very powerful oxidising agent that is able to oxidise (destroy) pathogenic organisms with less contact time and concentration than chlorine based disinfection agents. However, it is an instantaneous oxidation method and no residual disinfection will be provided. Similar to chlorine based compounds, ozone can also be used for different treatment processes of a water treatment plant such as the oxidation of iron and manganese, removal of constituents that can cause taste and odour problems, destruction of algae during pre-chlorination and as a flocculation aid. Ozone is often used as a primary disinfectant followed by chlorination in order to provide residual disinfection in the distribution system.

Ozone is usually generated at the treatment plant itself, due to its very aggressive and reactive nature. Air, dry air or pure oxygen is drawn into an ozone generator, which produces a very high voltage that splits the diatomic oxygen (O_2) molecule to form atomic oxygen (O). These particles are highly unstable and quickly react with diatomic oxygen to form ozone (O_3) molecules. After the ozonation process has been completed, excess ozone needs to be destroyed as it is fatally toxic to humans. This is done in an off-gas destruction system, where ozone is converted back to normal oxygen at high temperatures.

A complete ozonation system consists of a gas feed system to draw in air or oxygen, an ozone generator to split O_2 particles for the production of O_3 particles, an ozone contactor where the ozone gas is able to react with the water to be disinfected, and an off-gas destruction system. Fig. 21 depicts a typical ozonation process:

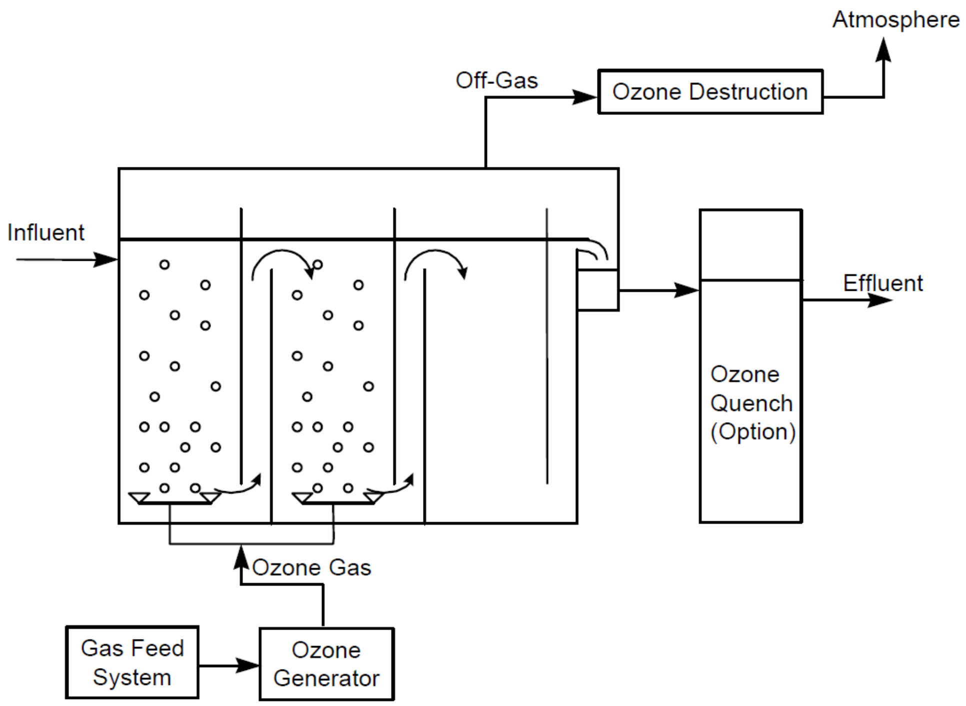
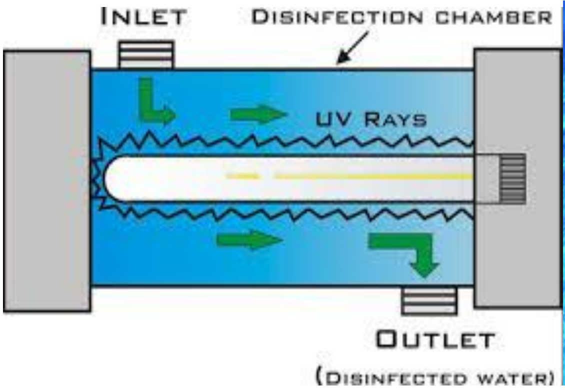


Figure 21: Simplified ozone system schematic (Environmental Protection Agency, 1999a)

Ozonation can also produce disinfection byproducts such as aldehydes, bromate and bromomethanes. Especially problematic are toxic brominated by-products formed by ozonation if bromide is present in the water, which can pose a health hazard to humans. Ozone does not form trihalomethanes and haloacetic acid that can be formed with chlorine disinfection, but it does form a variety of inorganic and organic by-products.

5.7.3 Ultraviolet Radiation

UV light is a commonly used disinfection method that does not add any chemicals to the water and therefore does not negatively affect the taste or colour of the final water. Disinfection is achieved by simply placing a suitably sized bulb radiating UV light in the pipe or vessel containing the water (Fig. 22). Whereas chlorine and ozonation destroy pathogens by rupturing the organisms' cell walls, UV light damages the microrganisms' DNA, thereby deactivating it from performing its pathogenic functions and ability to reproduce.



a) **Inline UV system process diagram** (Farnham&Associates)

b) **Typical submerged UV tubes** (Wedeco)

Figure 22: UV disinfection system

One of the major advantages of UV disinfection is that it does not cause a chemical reaction in the water and thus no disinfection by-products are formed. However, UV disinfection is very sensitive to the quality of the water. Even low concentrations of iron and manganese, and turbidity exceeding 1.0 NTU can shield microorganisms from the UV rays, causing incomplete disinfection. Any particles that block the UV light will cause problems when this method of disinfection is used. Also, UV does not provide residual disinfection and is thus often used as a primary disinfection method followed by chlorination. When using UV lamps, care must be taken to ensure that they are cleaned regularly to guarantee that the maximum amount of UV light can be radiated. UV is a very popular disinfection option if disinfection by-products need to be strictly avoided. In general, however, it is more costly than providing chlorine-based disinfection systems.

5.7.4 Ultrafiltration

Ultrafiltration is a purely physical disinfection method that does not involve the destruction or inactivation of pathogenic organisms. Similar to the RO process described in Section 5.5, ultrafiltration happens water passes through membranes with very small pore sizes. These pore sizes are smaller than the bacteria, viruses and protozoa and therefore retain these organisms while allowing clean water to pass through the membrane. The organisms are then discharged along with the backwash water.

Ultrafiltration is more commonly used for clarification purposes but can also be used solely for disinfection. Fig. 23 shows the size relation of various contaminants in relation to filtration processes. It can clearly be seen that viruses, bacteria and cysts are larger than the pore sizes used in ultrafiltration and thus these pathogens will be removed from the water using this type of filtration method.

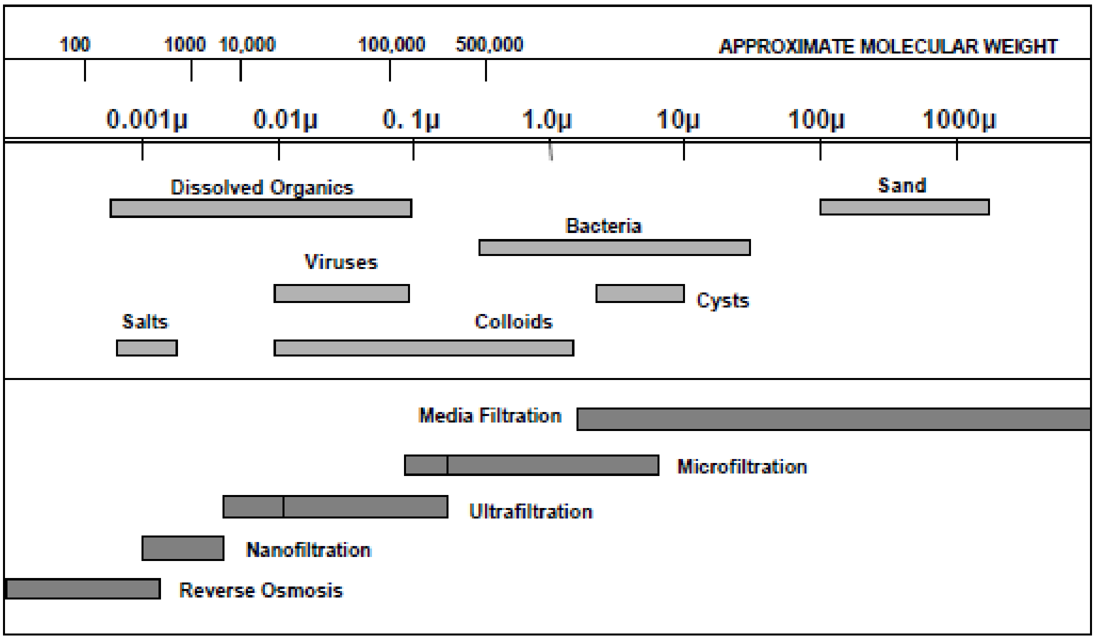


Figure 23: Membrane process removal classification (Environmental Protection Agency, 2001)

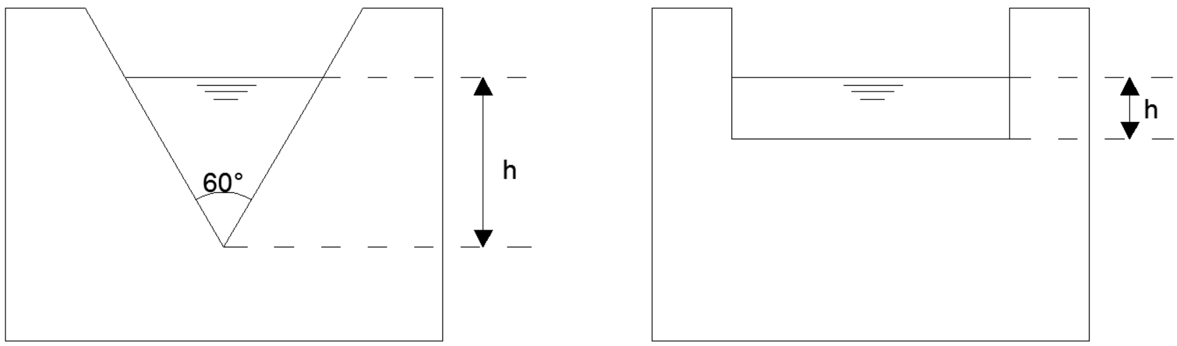
5.8 Flow Measurement

Although not a treatment technology, flow measurement forms an integral part of most drinking water treatment plants and is thus briefly discussed in this guideline. There are many different types of equipment for flow measurement, ranging from simple hydraulic devices such as overflow weirs to sophisticated electronic equipment. As discussed in Section 3.2, the level of sophistication of equipment selected for water treatment plants should correspond to the client's needs and expertise of personnel operating the plant. Some popular flow measurement devices are briefly described below:

5.8.1 Hydraulic Flow Measuring Devices

Weirs are one of the simplest and most cost-effective type of flow measurement devices available and are very popular for applications where very precise digital measurements are not necessary. Also, the flow rate is measured hydraulically, meaning that no electricity is required and measurements can be taken in even the most remote areas of Namibia where electricity supply is unreliable or unavailable.

Flow rates using this method are determined by measuring the height of water flowing over the weir with a known angle or known shape. Common overflow weir shapes are V-shaped and rectangular (Fig. 24), but others such as the Cipoletti weir and Sutro weir are also available. Only the V-notch and rectangular weirs are discussed in this Guideline, as they are the most commonly used in Namibia. Empirical equations for various weir types and angles are available and can then be used to determine the flow rate.



a) 60° V-Notch Weir **b) Sharp-crested rectangular weir**

Figure 24: Height measurement for flow calculations over typical weirs

Sharp-crested weirs do not have a notch or cut-out through which the water flows and only consist of a straight, sharp edge over which the water passes. These are often used in distribution towers, where the incoming flow is split into multiple trains using sharp-crested weirs. Weirs are often fitted with some form of height measurement that makes it easier to read off the water level above the crest of the weir. Using this height, the flow rate can then be calculated using the correct equation for the specific weir type. If desired and necessary for control and automation purposes, weirs can be fitted with ultrasonic level sensors in order to indicate the flow rate over the weir in real-time and for totalisation purposes. The general equation for flow measurement over a weir is based on the Bernoulli Equation and can be expressed as:

Rectangular weir:

$$q = 2/3\ c_d\ b\ (2\ g)^{1/2}\ h^{3/2} \qquad (1)$$

where

q = flow rate (m^3/s)

h = head on the weir (m)

b = width of the weir (m)

g = 9.81 (m/s^2) - gravity

c_d= discharge constant for the weir - must be determined for each weir type

V-Notch weir:

$$q = 8/15\ c_d\ (2\ g)^{1/2}\ \tan(\theta/2)\ h^{5/2} \qquad (2)$$

where

θ = v-notch angle

Flumes are often used in flow channels in order to determine the volumetric flow rate of the water. A flume constricts channel flow and thus creates a hydraulic pressure drop over the device. This pressure drop causes the water upstream of the channel to “dam up”. The height of water build-up upstream of the channel, together with the channel dimensions and known flume type, can then be used to determine the flow rate of water in the channel. This can be done manually by measuring the water depth, but is normally automated using ultrasonic level sensors that correlate with the water depth and flume type in order to compute the flow rate. Care should be taken to install flumes exactly according to the manufacturer's specifications, especially regarding upstream and downstream flow requirements.

Many different types of flumes with different constriction and hydraulic jump designs have been developed for specific applications such as flow measurement in pipes and channels. Some of the more well-known types of flumes include the Venturi flume, Parshall flume (Fig. 25), Palmer-Bowlus and Cutthroat flume.

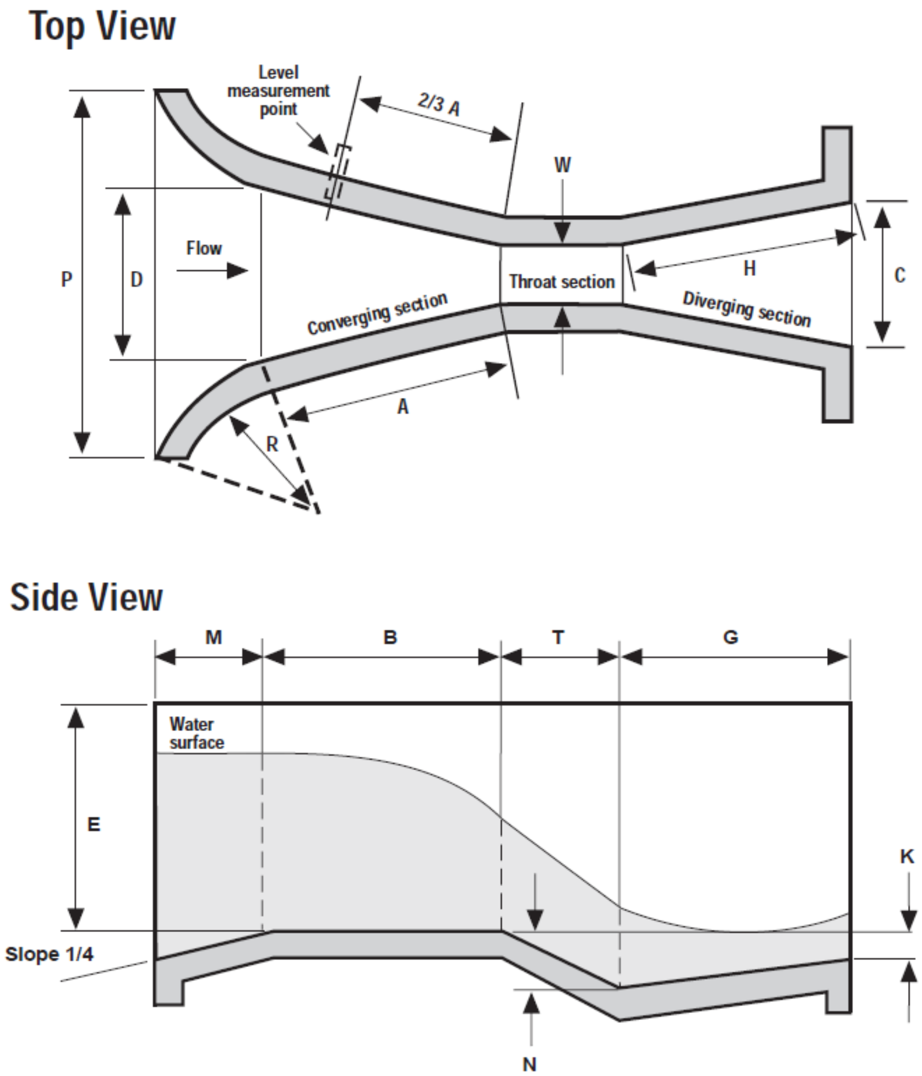


Figure 25: Parshall flumes are self-cleaning and can measure a wide range of flow rates (Grant & Dawson, 2001)

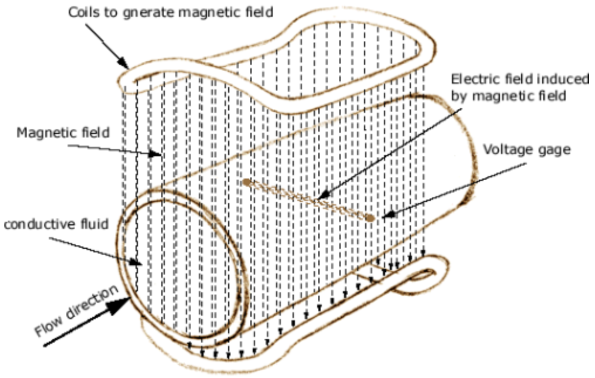
5.8.2 Mechanical Flowmeters

Mechanical flow meters are in-line measuring devices that are installed in pipelines to measure the flow rate passing through the pipe. They operate on a mechanical friction principle whereby the force of the water flowing through the flow meter physically rotates a measuring wheel. The flow rate is then displayed on a mechanical dial of the flow meter. These flow meters often contain several dials including a totaliser in order for instantaneous flow to be calculated more easily. Mechanical flow meters are most commonly used by municipalities for water consumption measurement and billing purposes of residential and industrial water accounts. They are a very cost-effective measuring technology, where very precise digital measurements are not required.

5.8.3 Electronic Flow meters

Electronic flow meters are much more precise than any of the measuring devices discussed above and are thus usually also more expensive. Various different types of flow meters are available and a brief summary of each technology applicable to water treatment plants is given below:

- Electronic flow switches. These do not measure the flow rate, but merely detect whether there is flow or not. They are often used for pump systems in order to automatically shut down a pump during no-flow conditions to prevent damage to the pump.
- Electromagnetic flow meters (Fig. 26). This is the most common and popular electronic flow meter currently in use in Namibia due to its reliability and accuracy. A magnetic field is induced by two field coils over the water flowing through the pipe. The water acts as a conductor and generates a voltage when passing through the magnetic field. The strength of the generated voltage is used to determine the flow velocity and thus the volumetric flow rate. These flow meters can also measure flow rates of fluids with high solids content, such as water treatment residue produced at a water treatment plant.
- Ultrasonic flow meters. These use the so called time-of-flight principle, whereby an ultrasonic signal is sent through the water by a transmitter and is then detected by a receiver. The time taken for the signal to be detected after transmission is then correlated to the velocity of the water. With a known pipe diameter, the flow rate is then determined and displayed. A major advantage of ultrasonic flow meters is that they can be used with very low conductivity water, such as the final water of RO plants. An electromagnetic flow meter would not function correctly in such circumstances due to the lack of electrically conductive particles in the water. Another advantage is the fact that ultrasonic flow meters are available in a clamp-on version, which means that it can be fitted onto an existing pipe without the need to cut the pipe and install an inline flow meter. This is especially useful if only temporary flow measurements are required for purposes such as commissioning or trouble shooting.
- Other electronic flow meters include the thermal, vortex and Coriolis types, which are most commonly used for specialised applications in the mining, gas and petrochemical industries but are not often used on water treatment plants. An instrumentation specialist should be consulted if any more complex flow measurements are required at a plant.



a) Magnetic field generated in an electromagnetic flow meter (Efunda)

b) Typical flow meter (Endress+Hauser)

Figure 26: Magnetic field generated in an electromagnetic flow meter

6. WATER TREATMENT RESIDUE HANDLING AND DISPOSAL

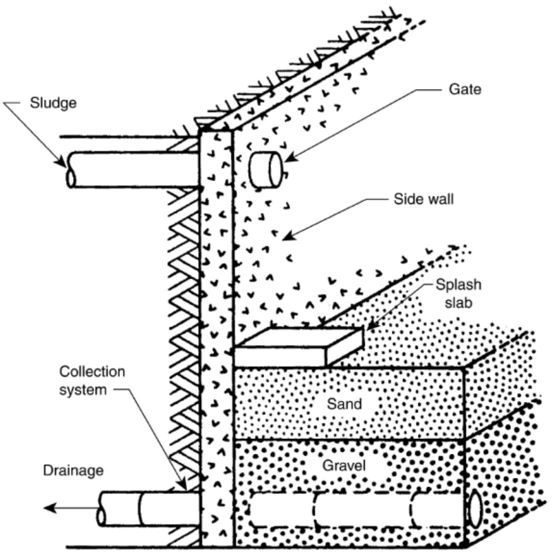
6.1 Conventional Water Treatment Residues

Treatment processes such as dissolved air flotation, clarification, sand filtration and activated carbon filtration all produce solid waste products, collectively termed water treatment residues (WTR). In order to minimize the use of water and to reduce the volume and related costs of disposal, WTR is usually collected and concentrated on site before removal to a suitable disposal site or reuse facility.

WTR can be handled through a variety of processes such as:

- Thickening. This is a process whereby the solids content in the residue is concentrated, typically from 0.5% to about 5% (w/w) dry solids (DS).
- Dewatering. Similar to thickening - also a liquid-solid separation process, but dewatering refers to a final solids concentration of 10-20 % (w/w) DS.
- Drying. An extension of the dewatering process to solids concentrations exceeding 35% (w/w) DS.
- Conditioning. The WTR is often modified or stabilised by the addition of chemicals in order to improve the dewatering characteristics, which can reduce the time required for dewatering by up to 50% (Wang, Shammas & Hung, 2007)
- Disposal and reuse. Once concentrated to the required solids content, the residue can then be disposed of at a suitable waste disposal site or reused for applications such as fertilisation of agricultural land. WTR disposal and reuse is discussed in great detail in the Guideline for Disposal of Solids from Water and Wastewater Treatment Processes (MAWF, 2012) and this document should be referred to for more detail regarding WTR disposal and further reuse for purposes such as agricultural land application.
- Liquid recycling. The concentration process produces both a concentrated solids component, as well as a liquid component. If possible, this liquid component should be returned to the inlet works of the drinking water treatment plant, provided that it will not negatively affect the final water quality of the plant. In particular, residual metal concentrations, disinfectant by-products and the use of conditioning polymers in the residuals handling process need to be carefully monitored when determining the suitability of returning the liquid waste component to the water treatment plant. In addition, pathogenic organisms may be concentrated during the thickening, dewatering and drying process and the return water should be disinfected with UV (see Section 5.7.3), as this is a particularly effective method for the destruction of *Cryptosporidium*, *Giardia* and *Listeria*. These are all organisms that are becoming increasingly chlorine-tolerant and that are harmful to humans.

The aim of WTR concentration processes should therefore be to remove solid waste while wasting as little water as possible. This is most commonly done using drying beds. Conventional sand drying beds are the most commonly used type of drying process for small to medium sized plants. The drying beds consist of a drainage system such as a perforated pipe, which is covered with sand. WTR is then applied on top of the sand layer and left to dry out. Drying occurs by water flowing out through the drainage system while solids are left behind on the sand layer, as well as by evaporation from the surface. The resulting dry residual typically has a moisture content of up to 60% (w/w) solids. It is a very effective way of drying residue and is much more cost-effective than mechanical means of residue concentration. However, some of the sand is usually removed with the dried residue after the drying process in complete and large areas are required to allow for evaporation of liquid from the residue. This makes this method less effective for larger plants. The method is very simple and requires minimal operator input, other than managing which beds are to receive fresh residue and which are to be emptied. The beds can be covered in areas where high rainfall is experienced. Fig 27 shows a typical section through a sand drying bed. Note that for drinking water treatment plants, the term “sludge” has been replaced with “water treatment residue” to avoid confusion with the two types of solid waste. The principles of drying bed construction remain exactly the same for both types of solid waste though.



a) Typical sand drying bed construction **b) Typical drying bed array**

(Wang, Shammas & Hung, 2007)

Figure 27: Typical sand drying bed construction

Drainage can also be achieved without a sand layer and perforated drainage pipes. The residue inlet pipe is installed somewhere in the bottom half of the bed and the bed is filled to just below the outlet pipe with WTR. This is then left to settle and after some time, a clear water layer forms at the top and a solids residue layer forms at the bottom. The bed is then filled again (from the bottom) which forces the top clear water to overflow into a draw-off channel, to be pumped back to the treatment plant inlet works. The bed is then filled again and left to settle, after which time the bottom residual layer will now be higher than the first fill level. This process is repeated until the solid residual layer at the bottom takes up the entire bed and virtually no clear water remains in the top layer. The bed is then left to dry out even more and is eventually emptied to the residue disposal or reuse facility. Water treatment residues can often smell and care must be taken to ensure that the construction of drying beds at the water treatment plant site will not cause odour problems for nearby towns and settlements.

WTR can also be discharged to an existing waste water treatment plant (WWTP), provided that this transfer is economically feasible and that the WWTP has sufficient capacity to handle the additional solids loading. Care must be taken to ensure that the WTR does not contain any significant concentrations of toxins that may be harmful to the biological processes at the WWTP and that the additional solids loading will not result in final effluent quality parameters exceeding the allowable limits.

For very large water treatment plants producing significant quantities of WTR, concentration using centrifugation would be another option. However, this requires very intensive maintenance of the centrifuges and highly skilled operator teams and are therefore only considered for use at very large plants. The use of centrifuges in Namibia is not recommended, as the relatively small treatment plants currently in operation do not warrant the use of centrifuges for WTR handling.

Dried WTR can be reused for land application for agricultural purposes, as well as for fertilisation of residential gardens. Care must be taken to ensure that the receiving soil conditions and maximum application rates are compatible with the WTR and that all requirements as per the “Guideline for Disposal of Solids from Water and Wastewater Treatment Processes” (MAWF, 2012) are adhered to. Where this is not possible or feasible, WTR can be disposed of at a suitable land fill site.

Waste streams from drinking water treatment plants can also be reused for irrigation purposes or discharged into nature, depending on the nature of the waste stream. All the requirements as per the “Code of Practice, Volume 6: Wastewater Reuse” (MAWF, 2012) and the Namibian Water Quality Standards for Effluent (Appendix B) shall be adhered to.

6.2 Brine

Brine is the highly concentrated waste stream, which results from desalination processes. Salts and other particles removed from the water are concentrated into a single stream that must then be disposed of. An environmental impact assessment (EIA) is required to determine suitable disposal of the brine.

Seawater. A very common practice for brine disposal for seawater desalination plants is to return the brine to the sea via a brine discharge pipe. The highly concentrated salt stream is denser than normal sea water and the brine therefore tends to accumulate on the sea floor around the discharge pipe outlet. This creates a very salty layer which can have negative impacts on the flora, the marine life and any related human activities. Care must therefore be taken to ensure that proper mixing of the discharged brine with the seawater occurs, to prevent build up of salty material. An environmental impact assessment needs to be performed by a suitably qualified specialist to ascertain if and how brine should be safely discharged into the sea. Build up of brine on the ocean floor can be prevented or mitigated as follows:

- Discharging directly into a strong current, which ensures that brine is immediately mixed with seawater;
- Providing a perforated discharge pipe with nozzles or diffusers to ensure that the brine is discharged evenly over a larger area. This allows for better mixing with seawater and prevents build up of high salinity effluent;
- Diluting the brine before discharging into the sea to ensure that the final brine concentration is only slightly higher than the seawater concentration (typically 10%). The brine can be diluted with fresh water sources available near the plant such as a river discharging into the sea or with additional seawater intake.

Inland. When brine is produced at a site where seawater disposal is not an option, proper disposal thereof, without impacting negatively on the environment, is required. Possible disposal would include:

- Evaporation ponds. Ponds must be designed large enough to ensure all brine will be evaporated, also during the rainy season. These ponds, when full, must be cleaned and the solids (salt) disposed of in a solid waste disposal site that is specifically built to receive solid waste without later contaminating the area surrounding it.
- Re-injection into the ground. When a dry borehole with subsoil that is suitable for infiltration but not in the vicinity of a potable water aquifer, the brine can be re-injected into the ground again. A detailed EIA, including geo-hydrological tests and

establishing subsoil conditions, is required to determine the depth of injection and maximum discharge per day.

- Thermal evaporation/crystallization. Brine can be concentrated up using thermal and mechanical processes to leave a solid waste product. Latter must be disposed of in a suitable solid waste disposal site. These processes are expensive, both capital-wise and operationally, and require skilled operators to operate and maintain.

7. ROLES, RESPONSIBILITIES AND QUALIFICATIONS OF WATER TREATMENT PLANT OPERATORS

Drinking water treatment plants require skilled personnel for successful operation and maintenance. The more complex the treatment processes and technologies employed at the plant, the more skilled the process controller and operator(s) need to be. The minimum requirements regarding quantity of personnel required as well as their respective minimum qualifications are discussed in Terms of Part 9 (Water Supply, Abstraction and Use) and Part 10 (Water Service Providers) of the Water Resources Management Act (Act 11 of 2013). The entire Drinking Water Regulation pertaining to this Act as well as the applicable Schedules are reproduced in Appendix C.

All the requirements specified in the Regulation need to be adhered to when employing operators in order to ensure that they are suitably qualified for the operation of a water treatment plant. This ensures that safe drinking water can be provided at all times. **Note that the requirements of the Drinking Water Regulation are lawfully enforceable, and <u>must</u> be adhered to.**

7.1 Basic Training for Waterworks Operators

There are various water treatment and operator training short courses available throughout Namibia and South Africa, although no formal fixed schedule for these is available. Organisations that offer courses on demand typically include:

- Namwater's Human Resources Development Centre (HRDC) in Okahandja;
- Private water treatment companies. In Namibia, most training courses are driven and organized by the private sector due to the specific demand for operator training by companies in the water treatment field. Companies such as Aqua Services & Engineering (Pty) Ltd have previously organised specialised training courses on both wastewater and drinking water treatment processes, which are advertised to the public with the aim of achieving the highest possible attendance figures from other private companies as well as municipal organisations;
- The Water Institute of Southern Africa (WISA);
- National Community Water and Sanitation Training Institute (NCWSTI) in South Africa
- Private training facilitators such as Alusani in South Africa;

7.2 Licensing of Water Services Providers

The licensing and compliance conditions for water treatment works are also discussed in detail in Part 9 (Water Supply, Abstraction and Use) and Part 10 (Water Service Providers) of the Water Resources Management Act (Act 11 of 2013).

A plant-specific license needs to be obtained for each existing and new plant by the owner/operator that provides drinking water for human consumption. The plant will then be classified according to the following parameters and minimum operator requirements are then prescribed according to the specific plant requirements:

- <u>Population supplied</u>. For a plant supplying large numbers of people it is more critical to keep operating smoothly and without interruption than for a very small plant.

- Quality of intake water. If the plant inflow quality varies significantly over time, as skilled operator is required to adapt the treatment process accordingly.
- Process. The more complex and technologically advanced the process the more skilled the operator(s) have to be.
- Design capacity. A large plant requires more operators of a higher skill level than a small plant.

The following Sections in the above mentioned Regulation deal in detail with the applicable requirements:

- Water Services Providers
- Water Quality, Control and Compliance Monitoring
- Registration, Licensing and Operation of a Waterworks
- Tariffs, Fees, Penalties and Fines

The above Sections in the Drinking Water Regulations and the corresponding Appendices discuss the requirements surrounding licensing and compliance, including penalties for non-compliance are reproduced in Appendix C. All of the required license application forms and details are contained in that document and are available from MAWF. **Note that the requirements of the Drinking Water Regulation are lawfully enforceable, and must be adhered to.**

It is of utmost importance that a drinking water treatment plant is properly operated and maintained, in order to ensure uninterrupted and safe drinking water supply. Plant operators need to be suitably qualified according to the complexity of the plant and to the minimum qualifications specified in the Regulations (see Appendix C).

7.3 Plant Operating Manual

Each drinking water treatment plant must have a proper operating manual, regardless of its size or complexity. This manual must contain all the details necessary to successfully operate and understand processes and procedures of the plant. The manual should be properly bound and be available in the English language. The following information needs to be included in the manual, as a minimum:

- Instructions for the assembly, installation and commissioning of the plant (where applicable and particularly when a packaged plant is supplied in an un-assembled state). If the plant is supplied fully assembled and installed only the commissioning procedure should be included;
- 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 and material safety data sheets (MSDS) of all chemicals used 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 chemical 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.

7.4 Maintenance Requirements

As a general guideline, certain types of equipment should be considered for maintenance purposes. Specific manufacturer's instructions should always take preference and be adhered to. This list serves only as a general indication of tasks to be performed.

- General Housekeeping. The plant must be kept neat and tidy at all times: The fenced-in area and a 1 m wide strip outside of the fence must always be kept free from grass and bushes; any spillages must be cleaned immediately; floors must be swept and all dust wiped at least once a week.
- Pipework. PVC pipework and fittings should be painted with UV resistant paint. All pipework should be checked at least once a month to see if there are any leaks or if there is any obvious damage.
- Pumps. Different types of pumps require different maintenance procedures and the manufacturer's operation and maintenance manual should be followed. In addition to this, pumps should be regularly checked for leaks, unusual noises which might indicate cavitation or bearing problems, and for integrity of electrical connections.
- Dosing pumps. Dosing pumps require regular cleaning and servicing according to the manufacturer's instructions in order to prevent a reduction in pump performance. Service kits are usually available for this purpose.
- Valves. All valves should be checked at least once a month to see whether they still function properly and whether a tight seal is obtained upon closing the valve. Spindles and hand wheels should also be greased, where necessary.
- Tanks and Reservoirs. Any vessels in which water is stored should be inspected regularly for algal growth. Clarifiers, filters and final water reservoirs may accumulate algae over time and these will need to be removed via shock disinfection and tank cleaning.
- Filters. The filter medium in both sand and carbon filters will need to be replaced from time to time. Care must be taken to follow the proper shut-down procedures when bed replacements are performed.
- Instrumentation. Any electrical or mechanical measuring instruments should be regularly checked, calibrated and maintained for proper operation. A suitably qualified instrumentation technician may be required for troubleshooting.

7.5 Asset Management

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, an operator should be able to replace or repair such equipment with minimal or no plant shutdown. Stock levels of consumables and chemicals 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 small pumps, valves, pipes and fittings, instrumentation and service kits for major equipment.

An asset inventory helps water services providers 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.

A typical example of a simple asset management table for plant equipment is illustrated in Table 4 below.

Table 4: Simplified example of an equipment asset management list

Equipment Tag Nr	Description	Date Installed	Condition	Expected Year of Replacement	Comments
PS-201 A	Submersible Drainage Pump	2004	Fair	2019	Coil repaired Aug 2007
MV-708	Actuator	2009	Good	2024	
LE-1305	Ultrasonic Level Sensor	2013	Bad	Needs replacement	Electrical damage
TK-212	HCl Tank	2002	Fair	2022	Corrosion on bolts

8. QUALITY CONTROL AND REPORTING

8.1 Quality Control and Assurance

All drinking water plants need to monitor their final water quality in order to ensure that the consumer receives a safe drinking water supply at all times. This is done with regular sampling and testing in either an on-site or independent laboratory. The frequency of sampling depends on the population size served by the plant and is specified in the Water Quality Standards and Guidelines for Potable Water and given in Appendix B.

Table 5: Microbiological sampling frequency based on size of population served

Size of population served	Frequency of sampling
> 250 000	**Thrice weekly ** **
100 001 – 250 000	**Twice weekly**
50 001 – 100 000	**Once weekly**
10 001 – 50 000	**Three times every month**
< 10 000 reticulated	**Once every 1 month***
< 10 000 non-reticulated	**Once every 1 month***

* Upon complaints by the consumers or of medical practitioners and after incidents such as pipe breaks, the frequency should be increased until the situation has returned to original counts and been declared safe;

** The frequency should be stepped up by one extra sampling per week for every 100 000 residents (including the estimated number of visitors residing within the area at any time) in the area served, over and above 250 000.

Section 3.1 of the Regulations for Drinking Water Quality and Supply in Terms of Part 9 (Water Supply, Abstraction and Use) and Part 10 (Water Service Providers) of the Water Resources Management Act (Act 11 of 2013 is reproduced here to highlight the quality control and assurance requirements of these Regulations:

1 Water Quality Standards for Potable Water.

[Part X, Sections 70 & 71 of the Water Act].

To ensure that water supplied for human consumption is always safe to drink, the water must adhere to certain water quality standards, be monitored regularly and samples analysed by suitably registered laboratories:

1.1 The producer of potable water is responsible for his/her own monitoring of final product quality, which includes quality control procedures and standards;

1.2 The quality control procedures and standards introduced by the producer are subject to inspection and approval by the Minister;

1.3 The producer of potable water must comply with the Water Quality Standards for Potable Water as included in Appendix A herein and applicable Water Safety Plans (WSP) at all times;

1.4 Any supplier of potable water shall, as a minimum, have his/her raw and product water monitored, sampled and analysed for microbial monitoring in accordance with Appendix A, Tables 2 and 4, but not less than once per year;

1.5 Any supplier of potable water shall, as a minimum, have his/her raw and product water monitored, sampled and analysed for physical and organoleptic requirements and for inorganic macro and micro determinants, in accordance with Appendix A, Table 1, but not less than once per year;

1.6 A report regarding the water quality and quantity, with all relevant supporting data shall be submitted to the Ministry not less than once per year or as specified by the Minister;

1.7 The Minister may, at his/her own discretion, order the producer to include for additional tests or increase the frequency of sampling;

1.8 Only suitably registered laboratories may be used for analysing water samples;

1.9 The Minister shall at least once per year inspect all registered laboratories and keep and make available an updated register of suitable laboratories at all times.

1.10 In the application of the measures and provisions contained in these Regulations, the Minister shall appoint staff for the administration of the Regulations and associated inspections and reporting, normally referred to as the Inspectorate.

From the excerpt above taken from the Namibian Drinking Water Regulation, it is apparent that drinking water suppliers need to have the water tested regularly to ensure it is safe for human consumption and within the legal limits as per the latest Namibian Water Quality Standards for Potable Water (Appendix B). The analysis results need to be recorded and safely stored so that reporting to and auditing by MAWF can be performed.

8.2 Auditing and Reporting

As mentioned in Section 8.1, drinking water suppliers need to keep records of plant performance regarding final water quality achieved, with minimum sampling frequencies as set out in the Regulation and in the Water Quality Standards and Guidelines for Potable Water. The results of these analyses must be available at any time for auditing by MAWF in order to ensure the safe supply of drinking water. The following records need to be available and may be requested by MAWF during a plant audit:

- Logs of final water quality, with minimum sampling frequency as per Table 5;
- Proof of valid license, which may be valid between 6 months and 5 years. 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, as outlined in Section 7 have been met;

Failure to be able to present the above information may result in deregistration of a water treatment plant and may also lead to penalties and fines as per Section 6 of the Drinking Water Regulations (Appendix C).

REFERENCES

Applied Membranes Inc. Viewed 30 March 2014. http://www.appliedmembranes.com/assembled_systems.htm

Aquastat, 2005. *Water report 29, 2009*. Viewed 27 March 2014. http://www.fao.org/nr/water/aquastat/countries_regions/NAM/index.stm

Ayers, R.S. and Westcot, D.W. 1985. *Water quality for agriculture*. Food and Agriculture Organization Irrigation and Drainage Paper 29 Rev 1. Rome.

AWWA, 1999. *Water Quality and Treatment*, Fifth Edition. A Handbook of Community Water Supplies. American Water Works Association. McGraw Hill, New York. ISBN 0-07-001659.

Bittner Water Consult 2010. *Regional rural water supply development plant for the Cuvelai-Etosha Basin, Namiba*. Groundwater specialist input report no: 2010-G17-V1.

Brunt, R., Vasak, L. and Griffioen, J. 2004. *Fluoride in groundwater: Probability of occurrence of excessive concentration on global scale*. International Groundwater Resources Assessment Centre (IGRAC) Report Nr SP 2004-2. IGRAC. Utrecht.

Christelis. G. and Struckmeier, W. Groundwater in Namibia: an explanation to the hydrogeological map. Ministry of Agriculture, Water and Rural Development. Windhoek.

Council for Scientific and Industrial Research (CSIR) 1985. *Technical guide K73: Manual on water purification technology*. National Institute for Water Research. Pretoria.

Efunda. Visited 31 March 2014. https://www.efunda.com/designstandards/sensors/flowmeters/flowmeter_mag.cfm

Endress+Hauser. Visited 31 March 2014. http://www.endress.com/eh/home.nsf/#products/promag_w

Environmental Protection Agency (EPA) 1999a. *Alternative disinfectants and oxidants guidance manual*. EPA 815-R-99-014. Washington.

Environmental Protection Agency (EPA) 1999b. *Health effects from exposure to high levels of sulphate in drinking water study*. EPA 815-R-99-001. Washington.

Environmental Protection Agency (EPA) 1999c. *Health effects from exposure to high levels of sulphate in drinking water workshop*. EPA 815-R-99-002. Washington.

Environmental Protection Agency (EPA) 2001. *Low-pressure membrane filtration for pathogen removal: Application, implementation, and regulatory issues*. EPA 815-C-01-001. Washington.

Farnham&Asscociates Inc. Viewed 31 March 2014. http://www.farnhaminc.com/residential-and-commercial-water-filitration-systems/

Filterfast. Viewed 31 March 2014. http://www.filtersfast.com/articles/Guide-to-Water-Purification.php

Global Water Intelligence 2005. *Report on water reuse markets 2005-2015, a global assessment & forecast*. First Edition: June 2005

Grundfos. Visited 31 March 2014.
http://wt.grundfos.com/gb/products/chlorine-dioxide-disinfection/

Grant, D.M., Dawson, B.D. 2001. *Isco open channel flow measurement handbook*. Fifth Edition. Isco. Lincoln, Nebraska.

Lenntech Water Treatment Solutions. Visited 31 March 2014.
http://www.lenntech.com/systems/reverse-osmosis/ro/rosmosis.htm

Mendelsohn, J., Jarvis, A., Roberts, C. and Robertson, T. 2009. *Atlas of Namibia: A portrait of the land and its people*. Third Edition. Sunbird Publishers. Cape Town

Ministry of Agriculture, Water & Forestry (MAWF) 2012. *Guideline for disposal of solids from water and wastewater treatment processes*. MAWF. Windhoek.

Ministry of Agriculture, Water & Forestry (MAWF) 2012. *Code of practice, Volume 6: Wastewater reuse.* MAWF. Windhoek.

Olivier, C. 2013. *Removal of Emerging Pollutants from Wastewater in a Southern African Context.* Paper presented at the IWA Reuse Conference, October 2013, Windhoek, Namibia.

Overstock. Viewed 31 March 2014. http://www.overstock.com/Home-Garden/Three-stage-Under-counter-UV-Filtration-System/3276497/product.html

Stetfield Separators. 2014. *Stetfloat: Dissolved air flotation (DAF) for oil/solids separation*. Stetfield Separators Limited. Visited 1 August 2014.
http://www.stetfield.com/Media/DATASHEETS/Stetfloat_web.pdf

Tjipangandjara, 2014. Personal conversation. Operations Director: Namibia Water Company.

Tordiffe, EAW. 2010. *Groundwater monitoring in the Orange-Fish River Basin, Namibia: Recommendations towards establishing a monitoring system*. Report produced by GeoHydro Consultants Namibia and Karst Hydrogeological Consultants Namibia for the Ephemeral River Basins in Southern Africa (ERB) Project, Desert Research Foundation of Namibia (DRFN). Windhoek.

Tredoux, G., Engelbrecht, P. and Israel, S. 2009. *Nitrate in groundwater: Why is it a hazard and how to control it?* Water Research Commission Report No. TT 410/09. WRC. ISBN 978-1-77005-873-6. Stellenbosch

Triangular Wave Technologies. Viewed 30 March 2014.
http://www.triangularwave.com/e4c.htm

USGS 2014. *Naturally occurring radionuclides in ground water of Southeastern Pensyllvania*. USGS Fact Sheet 012-00. Visited 29 April 2014.
http://pa.water.usgs.gov/reports/fs012-00.html

Van der Merwe, B. 2013. *Securing Water Supply to Windhoek through Unconventional Water Resources.* Paper presented at the IWA Reuse Conference, October 2013, Windhoek, Namibia.

Veolia 2005. *Drinking Water Treatment 2005*. PowerPoint Slides for Internal Training.

Veolia. Viewed 31 March 2014.
http://www.veoliawaterst.com/berkoion/en/simplex_industrial_water_softeners.htm

Wang, L.K., Shammas, N.K., Hung, Y-T (Eds.) 2007. 'Drying Beds', in *Handbook of environmental engineering, volume 6: Biosolids treatment processes*. Humana Press Inc. Totowa

Water Quality Association. 1999. *The WQA Glossary of Terms*. Viewed 28 March 2014.
http://www.wqa.org/glossary.cfm?gl=1874

Water Quality Association. Viewed 27 March 2014.
http://www.wqa.org/sitelogic.cfm?ID=872

Water Research Commission (WRC) 1997. *Package water treatment plant selection part 1 guidelines*. WRC Report No. 450/1/97. ISBN 1 86845 301 4.

Wedeco. Viewed 31 March 2014.
http://www.wedeco.com/us/expertise/uv-technology/uv-disinfection.html

World Health Organisation (WHO) 2006. *Fluoride in drinking-water*. IWA Publishing. London

World Health Organisation (WHO). Viewed 7 May 2014.
http://www.who.int/water_sanitation_health/diseases/methaemoglob/en/

APPENDIX A: Jar Testing Procedure

Jar Testing Procedure

1. Purpose

1.1 Characteristics of raw water continually change, therefore the optimum dose of coagulant cannot be determined from the results of a water analysis, but must be based on tests on the condition of the water at the time. The Jar Test has been widely used to evaluate the coagulation – flocculation component of the water treatment process.

1.2 This standard operating procedure describes the process of performing a standard coagulant jar test to determine the optimum dosage of coagulants, flocculation aids and pH correction chemicals.

1.3 To find the required chemical dosage, coagulant Jar Tests are required if the raw water quality is changing.

2. Scope

This procedure is applicable to all, but not limited to Water Treatment Plants.

3. Responsibility

3.1 Operations Manager – shall ensure that staff adheres to this procedure.

3.2 Coordinator Water Quality Team - shall ensure that:

- Adequate chemical stocks are available; and
- All Plant Equipment is available, in good working order and used in accordance with the manufacturer's instructions.

3.3 Water Quality Team Member – shall:

- Prepare standard solutions
- Ensure the accuracy of the final solutions;
- Comply with all OHS requirements; and
- Cleanup the work area ensuring all equipment is washed and ready for next use.

4. Procedure

4.1 Preliminaries

4.1.1 Preparation

- Rinse all containers and pipettes to be used to avoid possible impurities and contamination.
- Ensure there is enough room on the laboratory workbench.
- Read and adhere to chemical MSDS's.

4.1.2 Dosing Solution Strengths

- Coagulants – 1% (w/v) Alum or Ferric Chloride
- Flocculation Aid – 0.01% (w/v) Polyelectrolyte
- pH Correction – 1% (w/v) Lime.

4.1.3 All dosing solutions must be prepared from the actual chemicals used in the treatment process of each individual plant.

4.2 Activity

4.2.1 Take Sample

- Use raw water sample tap in laboratory to fill six beakers with raw water using graduated cylinder.
- Tip out excess water so each beaker contains exactly 500 ml.

4.2.2 Add Coagulant Dose

- Place on flocculator and start stirrer on maximum speed (100 rpm).
- Add different (increasing) dosages of Alum to each beaker (jar) while stirring
- To begin with try 10 mg/l, 20 mg/l, 30 mg/l, 40 mg/l, 50 mg/l, 60 mg/l (see Annex A1)
- Stir rapidly for 120 seconds.

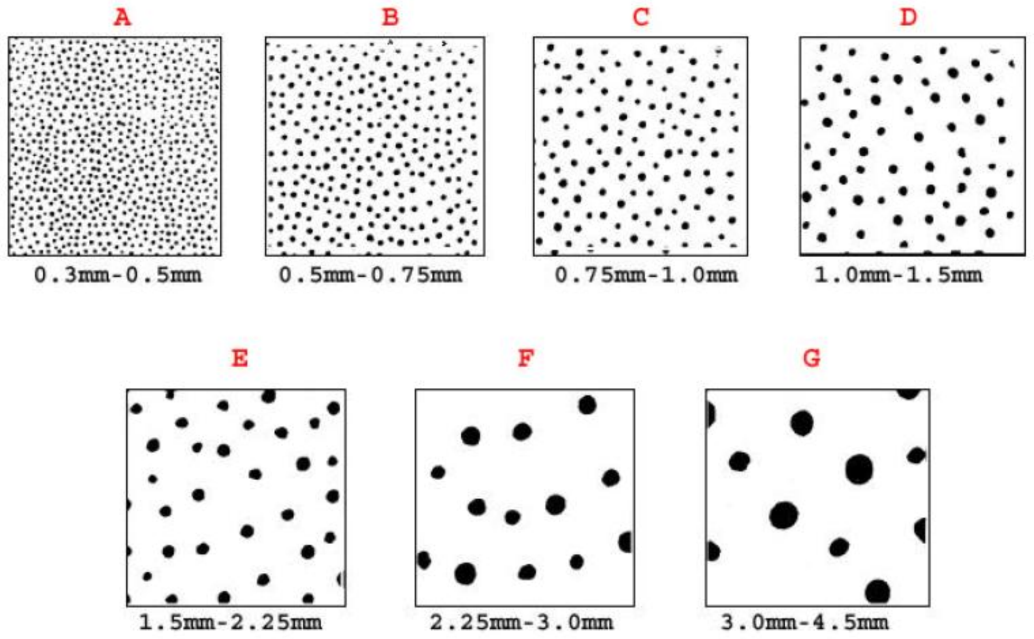
4.2.3 Gentle Mix for Flocculation

- Reduce stirring speed to 40 rpm and continue stirring for 8 minutes.
- Observe the results and record
- Stop the stirrers and let stand for 10 min
- Observe the results and record

A successful trial will generally result in the initial formation of very fine floc particles, which gradually increase in size to large heavy floc with clear water between them. If no floc has formed, the trial is probably a failure and other dosages should be tried. The stirrer speed and flocculation time should be based on the actual plant operating conditions.

4.2.4 Selection of Required Dose

- After stirring, remove the beakers from the flocculator, allow to settle and look for the following characteristics:
  - Largest floc
  - Toughest floc
  - Fastest settling floc
  - Supernatant with minimum of fines.



- Measure turbidity, colour and pH after 10 minutes.
- Select optimum alum dosage i.e. lowest turbidity and colour and pH between 5.8 - 6.5.
- Record results

4.2.5 Correction For pH

If addition, if alum solution causes significant changes in sample pH, it may be necessary to check for optimum coagulation pH 5.8 - 6.5.

- Prepare six raw water samples as above (500 ml).
- Inject lime solution and start stirrer (100 rpm).
- To begin with try 10 mg/l, 20 mg/l, 30 mg/l, 40 mg/l, 50 mg/l, 60 mg/l (see Annex A1)
- Inject optimum alum solution
- Stir for 120 seconds.
- Proceed with 4.2.3 Gentle Mix for Flocculation.

4.2.6 Selection of Required Lime

- Measure pH.
- Select Lime dosage i.e. pH between 5.8 - 6.5.
- Record results on OM 002.1 – Coagulant Jar Test Log Sheet.
- Repeat test above for varying alum doses but in each case correct to optimum pH for coagulation by addition of lime solution.

NOTE: The pH of the optimum Jar Test can be used as a quick routine check on the plant to determine if the correct dosages are being applied. The pH of the settled water in the clarifier should agree with the jar sample.

4.2.7 Addition of Polyelectrolyte

If floc formation is slow it may be necessary to add a small amount of polyelectrolyte solution.

- Prepare six raw water samples as above (500 ml).
- Inject optimum alum dose, pH corrected if necessary and start stirrer (100rpm).
- To begin with try 0.05 mg/l, 0.1 mg/l, 0.15 mg/l, 0.2 mg/l, 0.25 mg/l, 0.3 mg/l (see Annex A1).
- Stir for 120 seconds.
- Proceed with 4.2.3 Gentle Mix for Flocculation.

4.2.8 Selection of Required Polyelectrolyte Dose

· After 10 minute's measure turbidity and colour.
- Select optimum poly dosage i.e. lowest turbidity and colour.
- Record results

NOTE: Polyelectrolyte overdosing should be avoided at all times as it will bind the filter media and reduce performance, causing more frequent backwashing.

4.2.9 Selection of Required Chemical Dose

If a wide range of coagulant doses were used in the first Jar Test, then repeat the test using a narrower range centred on the best dose already achieved. The optimum dose is that which gives the best result using the least amount of coagulant.

- After 10 minutes of settling, take 150 ml sample of the settled water.
- If a fixed sampling point is not available, use a pipette and sample from about the top 4cm of each beaker.
- Filter the sampled water using the laboratory filtering system (Gravity or Vacuum), this will give the operator a sample of filtered water.
- If no filtering system is available then colour can only be recorded as apparent colour.
- Perform Turbidity, pH and Colour tests on the filtered sample.

The filtration step should be omitted if your plant is sedimentation – clarification only. i.e. no filtration.

The Jar Test is not difficult to perform but unless the operator records the date and all observations made, the results may be of little use.

4.3 Monitoring Requirements

Monitor all stages of Jar Test as specified in section 4.2.

4.4 Cleanup

Wash all used laboratory equipment and put away.

5.0 Documentation

5.1 Document 1: Jar Test Dose Rate Sheet

6.0 Definitions and Acronyms

7.1 Bench top Flocculator

ANNEX A1: PREPARATION OF STOCK FLOCCULANT SOLUTIONS

Stock solutions for the following flocculants can be prepared as follows: (Denysschen, 1985):

Aluminium sulphate. Dissolve 5 g in 1 l distilled water. One ml added to 500 ml sample equals a dosage of 10 mg/l.

Calcium hydroxide (slaked lime). Commercial quality $Ca(OH)_2$ may vary between 70% and 97% purity. 1 mg of aluminium sulphate will react with 0.39 mg calcium hydroxide (based on 95% pure product). A suspension of 1 g/l in distilled water is prepared. It should be shaken thoroughly each time before withdrawing a quantity for treating a water sample. Close to the minimum quantity should be withdrawn to prevent settling of the suspension in the pipette. One ml added to 500 ml is equivalent to a dosage of 2 mg/l.

Ferric chloride. 8 ml of the commercial solution (43% m/m or 62.5% m/v) is diluted to 1 l with distilled water. 1 ml of this solution added to 500 ml water equals a dosage of 10 mg/l.

Polyelectrolytes. These reagents are supplied in either powder or liquid form. The manufacturer's instructions regarding dissolving or diluting should be followed. A solution containing 0.10 g powder per liter is prepared. 1 ml added to a 500 ml sample equals a dosage of 0.2 mg/l. Liquid reagents should be diluted in 2 steps; e.g. tenfold dilution, followed by 1 ml to 1 l distilled water, to give the same strength solution as above.

Test series should be carried out to assess the effects of a number of flocculants; for example Al2(SO4)3, FeCl3 and two or three polyelectrolytes. The latter should be confined to products that have health clearance for drinking water and should, preferably, be manufactured locally.

APPENDIX B: Namibian Water Quality Standards

- **Water Quality Standards and Guidelines for Potable Water**
- **Water Quality Standards for Effluent**

Table 1: CHEMICAL AND BIOLOGICAL REQUIREMENTS

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
PHYSICAL AND ORGANOLEPTIC REQUIREMENTS					
Temperature	° C		E	Ambient temperature	
Colour	PTU	or mg/litre	E	10	<15
Taste			O,E	No objectionable taste	
Odour			O,E	No objectionable odour	
Turbidity (treated surface water)	NTU	or TU	H,I	< 0.3	< 0.5
Turbidity (groundwater)	NTU	or TU	H,I	< 0,5	<2
pH @ 20 °C	pH		I	6.0 to 8.5	6 to 9
Electric Conductivity @ 25 °C	mS/m***	E.C.	H,I	< 80	< 300
Total Dissolved Solids (treated surface water)	mg/litre		H,I	< 500	< 2 000
Total Dissolved Solids (groundwater)	mg/litre		H,I	< 1000	< 2 000
INORGANIC MACRO DETERMINANTS					
Ammonia	mg/litre	N	H	< 0.2	< 0.5
Barium	mg/litre	Ba	H	0.5	< 2
Calcium	mg/litre	Ca	I	< 80	< 150
Chloride	mg/litre	Cl	H,I	< 100	< 300
Fluoride	mg/litre	F	H	< 0.7	< 1.5
Magnesium	mg/litre	Mg	H	< 30	< 70
Nitrate	mg/litre	N	H	< 6	< 11
Nitrite	mg/litre	N	H	< 0.1	< 0.15
Potassium	mg/litre	K	H	< 25	< 100
Sodium	mg/litre	Na	H.I	< 100	< 300
Sulphate	mg/litre	SO_4	H,O	100	< 300
Asbestos (fibres longer than 10 μm)	Fibres/litre		H	<500 000	< 1000 000
INORGANIC MICRO DETERMINANTS					
Aluminium	μg/litre	Al	H	< 25	< 100
Antimony	μg/litre	Sb	H	< 5	< 50
Arsenic	μg/litre	As	H	<10	< 50
Beryllium	μg/litre	Be	H	< 2	< 5
Bismuth	μg/litre	Bi	H	< 250	< 500
Boron	μg/litre	B	H	< 300	< 500
Bromide	μg/litre	Br	H	< 500	< 1 000
Cadmium	μg/litre	Cd	H	< 5	< 10
Cerium	μg/litre	Ce	H	<1 000	<2 000
Cesium	μg/litre	Cs	H	< 1 000	< 2 000
Chromium Total	μg/litre	Cr	H	< 50	< 100
Cobalt	μg/litre	Co	H	< 250	< 500
Copper	μg/litre	Cu	H	< 500	< 2 000
Radon	Bq/L	Ra		< 200	< 1 000

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
INORGANIC MICRO DETERMINANTS					
Cyanide (free)	µg/litre	CN^-	H	< 20	< 50
Cyanide (recoverable)	µg/litre	CN^-	H	< 70	< 200
Iron	µg/litre	Fe	H,E	< 200	< 300
Lead	µg/litre	Pb	H	<10	< 50
Manganese	µg/litre	Mn	H	< 50	< 100
Mercury	µg/litre	Hg	H	< 1	<2
Nickel	µg/litre	Ni	H	< 50	< 150
Selenium	µg/litre	Se	H	< 10	< 50
Thallium	µg/litre	Ti	H	< 5	< 10
Tin	µg/litre	Sn	H	<100	<200
Titanium	µg/litre	Ti	H	< 100	< 300
Uranium	µg/litre	U	H	< 3	< 15
Vanadium	µg/litre	V	H	< 100	< 500
Zinc	µg/litre	Zn	H	< 1 000	< 5 000
Organo-metallic compounds (as organo or industrial chemicals or others)	µg/litre	Polymer	H	below detection limit (in accordance with WHO and EPA requirements)	below detection limit (in accordance with WHO and EPA requirements)
ORGANIC DETERMINANTS					
Dissolved Organic Carbon	mg/litre	DOC-C	H	< 5	<10
Phenol compounds	µg/litre	phenol	H	< 5	< 10
DISINFECTION AND DISINFECTION BY-PRODUCTS					
Bromodichloromethane (Part of THM)	µg/litre		H	< 20	< 50
Bromoform (Part of THM)	µg/litre		H	< 40	< 40
Chloroform (Part of THM)	µg/litre		H	< 20	< 100
Dibromomonochloro-methane (Part of THM)	µg/litre		H	< 20	< 100
Trihalomethanes (Total)	µg/litre	THM	H	< 100	< 150
Bromate	µg/litre		H	< 5	< 10
Chloramines	mg/litre	Cl_2	H	< 2	< 4
Chlorine dioxide after 30 min. GENERAL	µg/litre		H	200 - 500	< 800
Chlorine dioxide after 30 min. SPECIFIC	µg/litre		Turbidity > 0.3 NTU	200	200 - 400
Chlorine dioxide after 60 min. SPECIFIC	µg/litre		Turbidity > 1.0 NTU	< 200	200 - 500
Chlorite	µg/litre		H	< 400	< 800
Chlorate	µg/litre		H	< 200	< 700
Haloacetic acids	µg/litre		H	not detected	< 60
Chlorine, free, after 30 min; GENERAL	mg/litre	Cl_2	H,I	0.3 – 0.5	0.1 – 1.5

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
Chlorine, free, after 30 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: < 0.3 NTU**	**0.3**	**0.1 – 1.5**
Chlorine, free, after 30 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: > 0.3 NTU**	**0.5**	**0.1 – 1.5**
Chlorine, free, after 60 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: >1.0 NTU**	**1.0**	**0.1 – 1.5**

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
BIOLOGICAL REQUIREMENTS					
Algae					
Chlorophyll α	**μg/litre**		**E,O**	**< 1**	**< 2**
Total algae cell count		**/ml**	**H,O**	**< 200**	**<5 000**
Blue-green algae	**cells**	**/ml**	**H,O**	**< 200**	**<2 000**
Mycrocystin	**μg/litre**		**H**	**< 0.1**	**< 1**
Geosmin	**ηg/litre**		**E, H**	**< 15**	**< 30**
2-Methyl Iso Borneal (2 MIB)	**ηg/litre**		**E, H**	**< 15**	**< 30**
OTHER DETERMINANTS					
Agricultural chemical compounds			**H**	**Any organic compound recognized as an agro-chemical shall be in accordance with the WHO and EPA requirements.**	
Industrial chemical compounds			**H**	**Any organic compound recognized as an industrial chemical shall be in accordance with the WHO and EPA requirements.**	
Endocrine disruptive chemicals			**H**	**Any chemical compound that is suspected of having endocrine disruptive effects shall be in accordance with the WHO and EPA requirements.**	
RADIOACTIVITY				**95 Percentile Requirement**	
Gross alpha activity	**Bq/litre**		**H**	**< 0.2**	**< 0.5**
Gross beta activity	**Bq/litre**		**H**	**< 0.4**	**< 1.0**
If Gross alpha and beta is above specification calculate Dose based on individual radionuclide concentrations	**mSv/a**		**H**	**≤ 0.04**	**≤ 0.1**

"Concern" refers to impact if the limit is transgressed: H = health concern; O = organoleptic effect;
I = effect on infrastructure, structural; E = aesthetic effect
* Based on a viral cell culture-dependent method and not on cell culture-independent methods (e.g. PCR)
** Indicative of faecal pollution having occurred, even when the residual disinfectant levels are safe.
*** Comply with SANAS Guidelines

Table 2: Standards for Microbiological and Biological Requirements

MICROBIOLOGICAL REQUIREMENTS APPLICABLE TO ALL POTABLE WATER					
Microbiology	**cfu**			**95 percentile**	**1 of samples maximum**
Heterotrophic bacteria HPC or TCC	counts	/ml		100	1 000
Total Coliform	counts	/100 ml	H	0	5
E.Coli	counts	/100 ml	H	0	1
Entrerococci	counts	/100 ml	H	0	1
Somatic Coliphage	counts	/100 ml	H	0	1
Clostridium perfrigens inclusive spores	counts	/100 ml	H	0	1
Enteric viruses	viral count*	/10 L	H	0	1
Parasites (Protozoa) applicable to all potable water				**95 percentile**	**99 percentile**
Giardia lamblia	cysts	/100 litre	H	0	1
Cryptosporidium	oocysts	/100 litre	H	0	1
Giardia lamblia and Giardia lamblia (Grab sample)	cysts or oocysts	/10 L	H	0	0

Table 3: Special Requirements for the Protection of Infrastructure

Specifications for water quality intended for human consumption from the source and piped water supply for the protection of infrastructure against corrosion					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile requirement**	
CORROSIVE AND SCALING PROPERTIES (treated surface water)					
Calcium Carbonate Precipitation Potential	mg/litre	CCPP	I	4 - 5	1 - 6
Alkalinity/Sulphate/ Chloride Ratio	Equi-valents	Corrosivety Ratio	I	With SO_4 and Cl above 50 mg/litre Ratio=(Alk/50)/(SO_4/48+Cl/35.5) > 5.0 Water is Stable Ratio= (SO_4/48+Cl/35.5)/(Alk/50) > 0.2 Water is Corrosive	
Total Hardness (Ca & Mg)	mg/litre	$CaCO_3$	I	<200	< 400
CORROSIVE AND SCALING PROPERTIES (ground water)					
Calcium Carbonate Precipitation Potential	mg/litre	CCPP	I	4 - 5	3 - 15
Alkalinity/Sulphate/ Chloride Ratio	Equi-valents	Corrosivety Ratio	I	With SO_4 and Cl above 50 mg/litre Ratio=(Alk/50)/(SO_4/48+Cl/35.5) > 5.0 Water is Stable Ratio= (SO_4/48+Cl/35.5)/(Alk/50) > 0.2 Water is Corrosive	
Total Hardness (Ca & Mg)	mg/litre	$CaCO_3$	I	<400	< 1000

Table 4: Frequency of Microbiological Monitoring (including Turbidity values) for Water Supply and Distribution

Size of population served	Turbidity 95%**	Frequency of sampling
> 250 000	< 0,5 NTU	**Thrice weekly *****
100 001 – 250 000	< 1,0 NTU	**Twice weekly**
50 001 – 100 000	< 1,0 NTU	**Once weekly**
10 001 – 50 000	< 1,0 NTU	**Three times every month**
< 10 000 reticulated	< 1,0 NTU	**Once every 1 month***
< 10 000 non-reticulated	**1 – 2 NTU**	**Once every 1 month***

* Upon complaints by the consumers or of medical practitioners and after incidents such as pipe breaks, the frequency should be increased until the situation has returned to original counts and been declared safe;

** Average or 95 percentile turbidity of the water supplied

*** The frequency should be stepped up by one extra sampling per week for every 100 000 residents (including the estimated number of visitors residing within the area at any time) in the area served, over and above 250 000.

WATER QUALITY STANDARDS FOR EFFLUENT

Table 1: Water Quality Standards for Effluent

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

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**	
Fluoride	mg/litre	F	1.0	2.0
Cyanide (Free)	µg/litre	CN	< 30	< 100
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 and persistent organic pollutants	µg/litre		Any in-/ organic compound recognized as an industrial chemical including unlisted metals 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	
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.				

APPENDIX C: Regulations for Drinking Water

DEPARTMENT OF WATER AFFAIRS & FORESTRY

FAX: (061) 208 7160
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REFERENCE NO: ……………………….. NAMIBIA

REGULATIONS FOR DRINKING WATER QUALITY AND SUPPLY IN TERMS OF PART 9 (WATER SUPPLY, ABSTRACTION AND USE) AND PART 10 (WATER SERVICE PROVIDERS) OF THE WATER RESOURCES MANAGEMENT ACT (ACT 11 of 2013)

(Act No. 11 of 2013 - as published in the Government Gazette of the Republic of Namibia, No. 5367, of 19 December 2013, Government Notice No. 332)

Revision 8 – July 2012

CONTENTS

DEFINITIONS

In these Regulations any expression to which meaning has been assigned in the Water Act bears that meaning and, unless the context indicates otherwise:

"**Acceptable**" means acceptable to the Water Regulator or authority administering these regulations.

"**Control, controlling"** for the purposes of these Regulations, can be associated with or equalled to regulation (by law), limitation (by standards), guidance (by guidelines), checking or monitoring.

"**Drinking water**" is synonymous to 'potable water'

"**Minister**" means the Minister responsible for water affairs.

"Ministry" means the Ministry responsible for the administration of water affairs.

"**Operator**" is any natural person employed at a Waterworks, who has achieved the relevant competencies required to effectively undertake the duties assigned to that person to ensure that the Waterworks as a whole operate properly at all times.

"**Potable water**" means water that is or is made suitable for human consumption.

"**Process Controller**" is any natural person employed at a Waterworks, who has achieved the relevant competencies required to effectively operate all unit processes installed at the Waterworks, or a person authorised to design, construct, install, operate and maintain all unit process installed at the Waterworks to ensure that the Waterworks as a whole operate in accordance with the design at all times.

"**Producer, production of potable water**" means any national, regional or local authority, entrepreneur or commercial enterprise, who abstracts or collects water from a natural source, or reclaims 'used' water, purifies it, distributes it (by pipeline, tanker or as bottled water) and sells it to an intermediate retailer or consumer. For the purpose of these Regulations this includes any employer who produces potable water and makes it available to anyone else for a fee, free of charge or as part of the fringe benefits related to employment.

"**Product water**" means, for the purposes of these regulations and if not otherwise defined any natural or reclaimed water that is purified or processed to a quality of final water, in compliance with the water quality standards and guidelines for potable water as set out in these regulations.

"**Recycled water**" also means reclaimed sewage that has been treated and purified or processed to a quality of final water, in compliance with the water quality standards and guidelines for potable water as set out in these regulations.

"**Regulation(s)**" means the Regulations for Drinking Water Supply in terms of Part X: Water Supply, Abstraction and Use and Part XI: Water Services Providers of the Water Act.

"**Supplier, supply of potable water**" is synonymous to "Producer, production of potable water".

"**Water Act**" means the Water Resources Management Act (Act 11 of 2013) or any subsequent amendments to this act.

"**Water Regulator**" means within the context of this regulation any authority, body or organisation, that by appointment of the Minister, by line function or commensurate to its statutes, is authorised to compile and enforce regulations governing the activities within the water industry or the quality of the water or effluents.

“**Waterworks**” means within the context of this regulation any potable water treatment plant, which includes any works or plant or part thereof that is or will be provided for treating any water source to potable water standards.

1. WATER SUPPLY, ABSTRACTION AND USE (PART X)

The purpose of the Regulations for Drinking Water Quality and Supply is to ensure that the drinking water supplied to the end-user is safe for human consumption and conforms to the Water Quality Standards for Potable Water at all times. The Regulation must also protect the water source being tapped to ensure sustained utilisation of the source. This Regulation is an extension to the Water Resources Management Act, 2013 (“Water Act”) and all subsequent amendments.

1. Safety of Water Supply.
   [Refers to Part X, Section 70 of the Water Act]
   The Water Act holds the Minister, in concurrence with the Minister responsible for health, responsible for ensuring that water for drinking is healthy and safe for all Namibians at all times. This requires in particular that:

   1.1 Water quality standards are prescribed. Water quality standards for healthy and safe drinking water have to be developed and enforced as prescribed [Section 70 (a)], including maximum levels of contamination for waterborne contaminants, and shall adhere to the Water Quality Standards and Guidelines for Potable Water as further set out in Section 3 and Appendix A herein;

   1.2 Establish and maintain laboratories and other facilities and measures for the capacity to monitor, test and verify the quality of any water supply. The capacity to test, monitor, verify and maintain the quality of any water supply must be developed within the Ministry [Section 70 (b)] and requirements for the licensing of privately owned laboratories must be established [Section 70 (c)] . This includes developing own facilities and prescribing requirements for private facilities such as laboratories and competent personnel and for the latter to be certified and licensed as further set out in Section 3 herein;

   1.3 Prescribe criteria for the quality of recycled water. The quality of recycled water shall be such as to ensure that this water is safe and suitable for its intended use [Section 70 (d)] at all times as further set out in Section 3 herein.

   1.4 A national programme for testing and monitoring of water quality in Namibia is developed and maintained by the Ministry as per Section 70 (e). Such a programme shall be introduced and maintained as per Section 3 herein.

   1.5 The capacity to evaluate and approve processes and designs for the treatment of potable water before issuing of a licence [Section 70 (f)] for a water treatment plant by the Ministry for the treatment of potable water shall be developed as per Section 3 herein.

   1.6 A specialist, outside (private) person may be used if the Ministry cannot find suitably specialised personnel to do this.

2. Reliability of Water Supply.
   [Refers to Part X, Section 71 of the Water Act]
   The Act holds the Minister responsible for ensuring that all Namibians have access to an affordable and reliable water supply and that latter is adequate for basic human needs. This requires in particular that:

2.1 Exemption from compliance may be given by the Minister, provided that such exemption does not affect the health of water users and that users are informed adequately of such non-compliance [Section 71 (2)(a)(i)];

2.2 The Minister shall address the water quality requirements of non-compliant water with the service provider and affected community and specifically address the affect on the health of such water users [Section 71 (2)(a)(ii)];

2.3 Reliable standards as set out in Section 3 and the performance of water service providers and treatment facilities as set out in Section 4 shall be maintained, periodically reviewed, be enforced and corrective action taken as per Section 6 against any water supplier who fails to meet the standards of performance [Sections 71 (2)(b), (3)(a) and (3)(b)];

2.4 Only a person who abstracts water from a water resource for own domestic use, which may not exceed 10 m^3/d, is exempted from a licence to extract and use water [Section 73 (1)];

2.5 Every person who supplies water for domestic, commercial, industrial and/or agricultural use is registered and licensed and operates a Waterworks in compliance with the standards of performance [Part XI, Section 76 (1) – (4)] as further set out in Point A.3. below and Section 4 herein.

2.6 Any person who supplies any type of bottled water, be it for commercial gain or not, must do so in adherence with the latest Namibian Standard for BOTTLED WATER that applies to Bottled Natural Water, Processed Water, Mineral Water and Flavoured Water as laid down by the Department of Water Affairs and Forestry.

3. Abstraction and Use of Water.
[Refers to Part X, Sections 72, 73 and 74]
The Water Act specifies the abstraction and use of water as follows:

3.1 All water belongs to the Minister who may reserve part or all of the flow of a watercourse, including any groundwater resource and water stored in a dam or lake can be reserved by notice in the Government Gazette [Section 72 (1) & (3)].

3.2 The reservation under Point A. 3.1 above of part or all of the flow must take into account licensing and conditions for abstraction as further set out in Sections 4 & E herein [Part X, Section 72 (1) & (2) and Part XI, Section 76 (1) to (5)];

3.3 Sustainability (long term) of the raw water source reserved under Section 1.3.1 above must be ensured in accordance with Section 5 herein.

3.4 A person/body that abstracts water from a water resource for own domestic use, is exempted from the requirement for a licence to abstract and use water [Section 73 (1)] as long as such abstraction is not exceeding 10 m^3/d and is done to ensure the long-term sustainability of the resource;

3.5 A person/body that abstracts water from a water resource and supplies it to others for domestic use is subject to all conditions for licensing an abstraction as further set out in Sections 1, 2, 3, 4 and 5 herein.

2. WATER SERVICES PROVIDERS (PART XI)

The Water Act specifies that all water service providers must be licensed and must comply strictly with licence conditions. [Refers to Part XI, Section 76 to 78 of the Water Act].

1. Licensing of Water Service Providers.

[Refers to Part XI, Section 76 of the Water Act]

The Water Act specifies that every service provider needs a licence from the Minister to operate a Waterworks and/or for the distribution of water to end-consumers. This requires in particular that:

1.1 Service providers must apply for and obtain a licence to operate a Waterworks and/or distribution system from the Minister [Section 76 (1)] as set out in Section 4 herein;

1.2 The format and information required for such and application must be on an official application form [Section 76 (2) & (3)] as drawn up by the Minister and given in Appendix B;

1.3 The Minister may take any action he/she considers necessary for deciding the application [Section 76 (4)];

1.4 The licence must be issued in a form determined by the Minister and is subjected to licence conditions as set out by the Minister and further specified in Section 4 herein [Section 76 (6)].

2. Issue of Combined Licence to Water Service Provider.

[Refers to Part XI, Section 77 of the Water Act]

The Minister can issue a combined licence to abstract, treat and distribute potable water to a service provider provided that the service provider has complied with all requirements individually for the abstraction, treatment and distribution of potable water. Such licence shall be issued only if all requirements as provided in Sections 3 and 4 and 5 herein have been met.

3. Failure of a Water Services Provider to comply with Licence Conditions and/or adherence to these Regulations.

[Refers to Part XI, Section 78 of the Water Act]

The Ministry sees a failure by the water services provider to comply with licence conditions in a serious light. The Minister, in particular:

3.1 Requires the service provider to immediately verbally notify its consumers followed by a written statement setting out the nature of the failure [Section 78(1) and (2)(a)] and proposed remedial action;

3.2 Requires the service provider to notify the Minister in writing within 48 hours and set out the nature of the failure [Section 78(1) and (2)(a)];

3.3 Requires the service provider to immediately take remedial action as defined in Sections 78(2)(b) and (c) and remedy the failure in a reasonable time and further set out in Section 6 herein;

3.4 If the water service provider fails to remedy the failure and take the measures specified in Section 2.3.2 above, he/she shall be directed to cease operations as per Sections 78(3)(a). His/her functions shall then be taken over subject to the provisions made in Sections 78(4), (5) and (6).

3.5 Shall impose penalties and fines as further set out in Section 6 herein.

3. WATER QUALITY, CONTROL AND COMPLIANCE MONITORING

1 Water Quality Standards for Potable Water.

[Part X, Sections 70 & 71 of the Water Act].
To ensure that water supplied for human consumption is always safe to drink, the water must adhere to certain water quality standards, be monitored regularly and samples analysed by suitably registered laboratories:

1.11 The producer of potable water is responsible for his/her own monitoring of final product quality, which includes quality control procedures and standards;

1.12 The quality control procedures and standards introduced by the producer are subject to inspection and approval by the Minister;

1.13 The producer of potable water must comply with the Water Quality Standards for Potable Water as included in Appendix A herein and applicable Water Safety Plans (WSP) at all times;

1.14 Any supplier of potable water shall, as a minimum, have his/her raw and product water monitored, sampled and analysed for microbial monitoring in accordance with Appendix A, Tables 2 and 4, but not less than once per year;

1.15 Any supplier of potable water shall, as a minimum, have his/her raw and product water monitored, sampled and analysed for physical and organoleptic requirements and for inorganic macro and micro determinants, in accordance with Appendix A, Table 1, but not less than once per year;

1.16 A report regarding the water quality and quantity, with all relevant supporting data shall be submitted to the Ministry not less than once per year or as specified by the Minister;

1.17 The Minister may, at his/her own discretion, order the producer to include for additional tests or increase the frequency of sampling;

1.18 Only suitably registered laboratories may be used for analysing water samples;

1.19 The Minister shall at least once per year inspect all registered laboratories and keep and make available an updated register of suitable laboratories at all times.

1.20 In the application of the measures and provisions contained in these Regulations, the Minister shall appoint staff for the administration of the Regulations and associated inspections and reporting, normally referred to as the Inspectorate.

2 Inspectorate.

2.1 The inspectorate shall consist of suitably trained and experienced staff, responsible for the following activities, applicable country-wide:

- Attend to and supervise the handling of issues and applications concerning resource evaluation, potable water production, wastewater treatment and disposal, wastewater re-use/recycling/reclamation, disposal of solid waste produced by a waterworks.

- Administration of applications for licences;
- Site inspections with regards to applications and gathering of information;
- Evaluation and interpretation of information, documentation and analyses;
- Inspection, evaluation and approval of laboratories conducting water, wastewater and biosolids analyses;
- Compilation of reports;
- Issuance of licences;
- Routine inspections for compliance monitoring;
- Procedural handling of cases of non-compliance;
- Supervision of spill removal;
- Maintain intra- and inter-ministerial liaisons;
- Perform basic laboratory operations.

2.2 The rank and minimum educational qualifications required for a career in the inspectorate shall, in agreement with the rules and regulations of the Public Service Commission (PSC), for members of the Inspectorate be as follows:

2.2.1 Inspector: Bachelor of Technology (B.Tech.) – diploma obtained at the Polytechnic of Namibia or equivalent diploma obtained at an institution for higher technical education abroad, in the field of water engineering plus at least 3 years appropriate technical experience in the field of environmental law administration, with emphasis on water engineering, supply and treatment ;

2.2.2 Senior Inspector: Bachelor of Science (B.Sc.) – degree obtained at the University of Namibia or equivalent degree obtained at a university abroad, in the fields of water engineering, environmental engineering, chemistry plus at least 3 years appropriate technical experience in the field of environmental law administration, with emphasis on water engineering, supply and treatment;

2.2.3 Principal Inspector: Qualifications equal to or higher than that of an Inspector or Senior Inspector plus at least 10 years appropriate technical experience in the field of environmental law administration, with emphasis on water engineering, supply and treatment.

2.2.4 Chief Inspector: Qualifications equal to or higher than that of a Principal Inspector plus an advanced educational degree such as an Honours-degree obtained at the University of Namibia or equivalent degree obtained at a university abroad, in the fields of water engineering, environmental engineering or chemistry plus at least 15 years appropriate technical experience in the field of environmental law administration, with emphasis on water engineering, supply and treatment.

2.3 The members of the Inspectorate shall be prepared to take a compulsory “oath of integrity” at the time of their appointment and renewable every five years of their career.

2.4 The Inspectorate shall be part of the Division responsible for Law Administration and/or Water Quality.

2.5 The Minister shall provide continuous training to keep the members abreast of developments in their field of activity:

- By providing training both in-house and extra-mural;
- By providing opportunities to attend relevant conferences and exhibitions;
- By arranging internal drill meetings and exercises.

2.6 The Minister shall provide all the support the Inspectorate needs, which is necessary to perform tasks to the best of its ability by providing:

- Adequate office space;
- Access to adequate office equipment, including personal computers;
- Adequate means of transport, e.g. one sedan vehicle and two 4wd-vehicles; portable laboratory equipment for measurements in the field; cameras and GPS instruments;
- Adequate equipment and facilities for sampling, transport and in-transit storage of samples, storage of samples at suitably equipped central facilities;
- Minimal laboratory facilities for the calibration of field equipment;
- Adequate budget to allow payment of DSA, transport, analyses, vehicle maintenance, fuel, protective clothing.

3 Initial inspection concerning application for a licence.

3.1 Every premises or locality considered for an application for a licence shall be inspected prior to the finalization of the application.

3.2 The provisions referred to under Section 3.3.1 shall apply for first applications as well as existing operations not served by licences before.

3.3 The provisions referred to under Section 3.3.1 shall apply for all applications for renewal of licences.

3.4 A licence is issued against the background of conditions prevailing at the time of application. Any change to these conditions shall be liable to applications for a new licence or an addendum to the existing licence.

3.5 It is at the discretion of the Minister to decide whether technical inspections are necessary subsequent to the initial inspection related to first or renewal applications.

3.6 The provisions referred to under Section 3.3.1 shall apply equally to subsequent inspections referred to under Section 3.3.5.

4 Routine inspection and compliance monitoring.

4.1 The Minister shall issue a licence as follows:

- A Licence with a maximum validity of five years;
- A Temporary Licence with a minimum validity of six months and a maximum validity of twenty-four months, which can be extended to a maximum of another twelve months.
- A Licence not made out for five years is considered a Temporary Licence.

4.2 The premises of the holder of a Licence are subject to annual inspection for compliance monitoring.

4.3 The premises of the holder of a Temporary Licence are subject to inspection at a frequency as required by circumstances or as defined by the Licence document.

5 Powers and duties of the Inspectorate.

5.1 Inspectors shall have access to any sector of the premises for inspection whenever and wherever this is deemed necessary and/or appropriate. No prior notification of a visit to the owner or occupant of such premises needs to be given.

5.2 Upon entry, the inspector shall identify himself/herself as an employee of the Ministry and a member of the Inspectorate by showing his/her Ministerial Identity Card.

5.3 The Ministerial Inspectorate identification card, the format of which is given in Appendix E, shall have the size and format of the Namibian ID card or driver's licence and contain the following information:

- Name, surname and Namibian identity number,
- Ministerial ID code of the holder;
- ID Photograph of the holder of the card;
- Name of the Ministry, Department / Agency, Division / Inspectorate;
- Postal address of the Ministry;
- Telephone and Fax number of the office of the Chief Inspector;
- Declaration of authority and of right of entry upon lands;
- Signature of the cardholder and of the accounting officer of the Ministry.

5.4 The inspector shall have the right and duty to gather and remove from site any evidential material proving that the premises visited are in compliance or non-compliance with the Regulations:

- Samples of water bodies and soil, relevant to the case on hand;
- Photographs of relevant objects or land;

- Objects, where there is suspicion that such may be removed without the inspector’s permission, as may be the case;
- Documents as may be considered essential to the case on hand;
- Supply the holder of the Licence with a written statement confirming the removal of any objects and documents.

5.5 The inspector shall be vested with the following powers during the execution of his/her task:

- To take whatever measures deemed necessary to complete the task;
- In addition to Section 3.5.4, wherever damage to property will be a consequence, the presence of an officer of the Namibian Police shall be solicited and such officer shall be requested to write an affidavit concerning the event;
- To switch off an apparatus or instrument, close down a plant, wherever this is deemed necessary;
- In addition to Section 3.5.4, wherever a switch or a place need to be sealed or damage to a process or property will be a consequence, the presence of an officer of the Namibian Police shall be solicited and such officer shall be requested to seal such switch or place and to write an affidavit concerning the event;
- To recommend to the Minister and motivate that the activities, process or operations of an enterprise, plant or business be interrupted or stopped altogether for a specified time, wherever or whenever this is deemed necessary;
- In addition to Section 3.5.4, should the cessation or interruptions of normal operations concerning water supply or wastewater treatment lead to unnecessary hardship to the population concerned or undesirable consequences to the environment, he/she shall recommend and/or arrange for the Minister to take over the supervision of the activities, process or operations of an enterprise, plant or business, for a well-defined time.

5.6 Whenever the owner of the premises to be inspected or the holder of a licence willingly and knowingly prevents the inspector from entering the premises:

- The owner or the holder shall be issued with a first, verbal warning stating the consequences of this behaviour;
- A written warning shall be posted if this behaviour is repeated at a second visit;
- If this behaviour is maintained at a third visit, the entry may be forced, preferably in the presence of an officer of the Namibian Police, applying whatever means are considered reasonable and cause the least damage to the premises;
- Any costs originating from a forced entry shall be for the account of the owner or holder, whoever caused the event.

6 Laboratory analyses.

6.1 Sample analysis is necessary for:

- Monitoring to prove compliance with Water Quality Standards and licence conditions;
- Monitoring progress with remedying a non-compliance case;
- Collecting data during investigations, studies, projects and for planning purposes;
- Establishing the level of concentration of suspected pollutants;
- Calibration of field equipment;
- Testing plant processes and technologies.

6.2 Methods of sampling and analyses will be further defined in the Water Quality Standards as per Appendix A.

6.3 In accordance with Section 3, 3.1.8 and 3.1.9, the Minister shall nominate, inspect and keep an updated register of suitably registered laboratories in the country for the monitoring of the quality of potable water and wastewater generated in the country.

6.4 The Minister shall provide minimum laboratory equipment and facilities for essential, basic measurements, such as:

- pH
- Electric conductivity;
- Turbidity;
- Free chlorine and chlorine demand;
- Temperature;
- Simple tests and make-up of chemicals for these;
- Provision of sterile sampling bottles and samples;
- The laboratory may use any method of analysis, the performance of which with regard to trueness, precision and limit of detection, can offer the necessary limit of quantification in order to comply with the requirements of SANS 241:2006 (edition 6.1) or subsequent revision thereof. Recommended test methods as per SANS 241 are the SANS methods and the “Standard methods on the examination of water and wastewater” by the American Public Health Association (APHA), American Water Works Association (AWWA) and the Water Environment Federation (WEF).

6.5 For all other analyses that cannot be performed by the Minister, the Minister may outsource by entering into an agreement/contract with an external laboratory for undertaking these analyses. For emergency and/or non-routine analyses the normal tender procedures may be bypassed.

6.6 The agreement between the Minister and the laboratory shall:

- State the validity/duration of the contract;
- Specify the agreed price list for the services rendered and the validity of same for the duration of the contract;
- Detail the analyses (methodology, detection limit);
- State a minimum number of samples to be submitted by the Inspectorate;
- State the conditions and procedures for unilateral termination of contract, including a penalty for early termination or non-performance;
- State preparedness to handle all information and results confidentially;

6.7 To qualify as external laboratory for routine analyses, the laboratory shall:

- Have sufficient capacity to deal with a larger number of samples within reasonable time;
- Show a positive track record, preferentially with the Ministry, of satisfied capacity and consistent quality (accuracy);
- Be registered or in the process of acquiring registration and accreditation for most of the methods, or alternatively, show ISO Standard compliancy.

6.8 The contracted laboratory shall accept analysis requests submitted by Divisions within the Ministry other than that of the Inspectorate, for routine analysis.

6.9 The laboratory may also be requested, by contract, to collect routine samples for analysis (e.g. for microbiological analysis) within Windhoek or elsewhere.

7 Monitoring and data management.

7.1 The Inspectorate shall establish an electronic and hard-copy database containing detailed information concerning all licence applicants.

7.2 The Inspectorate shall formulate and institute a proper data management plan and system.

7.3 Quality data for selected determinants shall be presented graphically for better monitoring and trend analysis.

7.4 The electronic database shall be conceived in such manner that transgression of preset limits is ‘flagged’.

7.5 The purpose of monitoring and trending is to indicate and highlight deteriorating quality parameters so that relevant authorities can be warned or informed early to allow for remedial action to be instituted well in time.

4. REGISTRATION, LICENSING AND OPERATION OF A WATERWORKS

The abstraction, production and supply of potable water are subject to an application and licensing by the Minister.

1 Applying for registration and licensing of a Waterworks.

It is mandatory for every owner of an existing Waterworks or a new Waterworks that is still under construction and will be put into operation to, within 30 days of these regulations coming into effect:

1.1 Apply for registration and licensing of the Waterworks at the Department of Water Affairs and Forestry on the official application form, *viz* APPENDIX C: APPLICATION AND REGISTRATION FOR A WATERWORKS AND OPERATING PERSONNEL;

1.2 Classify the Waterworks in terms of Class A to D in accordance with Schedule I of the attached Appendix C;

1.3 List the number and class of operators that need to be employed to operate the Waterworks as per III in the attached Appendix C;

1.4 Prove that the number of operators employed with their relevant experience will be sufficient to properly operate, control and maintain the Waterworks in accordance with Schedules II and III in the attached Appendix C to provide the final quality of potable water or effluent for which the Waterworks has been designed;

1.5 Nominate and give all contact details and experience of the owner of the Waterworks and of the Process Controller ultimately responsible for ensuring that the Waterworks will operate in accordance with the design parameters;

1.6 Regularly update all information given under the above Points 1.4 and 1.5 and submit this to the Regulator, but not less than once per year.

2 Registering and Licensing a Waterworks.

Upon receipt of an application for registration of a Waterworks with all particulars as specified in Section 3.1 above, the Minister must, within 6 months:

2.1 Classify the Waterworks in accordance with Schedule I, Appendix C;

2.2 Verify the number and competency of employees as proposed by the applicant in accordance with III of Appendix C;

2.3 Verify the competency of the Process Controller that will be in charge of the Waterworks;

2.4 Issue a certificate of registration in respect of such Waterworks;

2.5 Issue a certificate of registration in respect of the nominated Process Controller;

2.6 Issue a Licence for the Waterworks under review with a validity period not less than six months but no longer than five years (refer to Appendix C);

2.7 The Minister must keep a register of particulars of every Waterworks, including its location and contact details of the owner and responsible Process Controller.

3 Operating a Waterworks.

It is mandatory for every owner of an existing Waterworks or a new Waterworks that is still under construction and will be put into operation to, within 30 days of these regulations coming into effect:

3.1 Employ a suitably qualified Process Controller, who will be in charge of the Waterworks;

3.2 Provide and keep in his/her employment, as an absolute minimum, the number of personnel as laid down in Appendix C, III with relevant training for each employee as laid down in Schedule II;

3.3 Keep a register, which is updated monthly, of all employees with their qualifications, that are employed on the Waterworks;

3.4 Keep an incident book where all important incidences related to the operation of the plant are conscientiously logged;

3.5 Monitor, as a minimum, raw water abstraction, wastewater discharge and final water production figures;

3.6 Ensure that the necessary quality control of the final water is undertaken to ensure that the Waterworks produce a final water in accordance with the design at all times;

3.7 Keep a register, which is updated monthly, of all chemicals acquired, quantity used and stock remaining on the plant;

3.8 The register, incident book and proof that the final water quality is in accordance with the design and is maintained within the design parameters, must be kept by the owner of a Waterworks and must be made available for inspection by the Regulator or responsible authority at all times;

3.9 Display the registration certificate for the Waterworks in a prominent place on that Waterworks, once he/she has received such certificate from the relevant authority;

3.10 Display a valid licence for the Waterworks in a prominent place on that Waterworks. This licence must be renewed dutifully before expiry thereof;

3.11 Each Waterworks must have its own specific operational manual and procedures under which the Waterworks will be operated. These manuals and procedures should be in line with the Minister's Regulations for Drinking Water Quality and Supply and must adhere to conditions as described in the Operational Guidelines for Drinking Water Treatment Plants.

5. SUSTAINABILITY OF THE RAW WATER SOURCE

The abstraction of raw water from an aquifer, river, dam or other raw water source must be sustainable and the raw water source may not be in danger of being over-exploited or contaminated:

1. The abstraction of raw water, regardless of the source, is subject to an application and licence to utilize a controlled water source, issued by the Minister [Part XII, Section 79 (1) & (2) of the Water Act] as per Appendix B herein.
2. Where the abstraction of raw water is followed by a treatment facility such as a water treatment plant, the licence application for Registering, Licensing and Operation of a Waterworks as per Appendix C will also serve as application for the abstraction licence (Part XI, Section 77 of the Water Act) and the Minister must address the sustainability of the raw water source as described in Point E.3. hereinafter;
3. The Minister may only issue an abstraction licence if he/she is sure that the raw water source will not be over-exploited or depleted over time (Part IX, Sections 66 to 69 of the Water Act). To assess and support the latter, the Minister shall:
   - 3.1 Base his/her decision and the amount of water to be extracted on a scientific study, such as an environmental impact assessment study and/or geohydrological data, which must be available to support his/her decision. The scientific study must include baseline data which must be sufficient to trend any possible changes in water quality over time;
   - 3.2 Consider the Integrated Water Resources Management Plan and any reservation of water;
   - 3.3 Clearly specify the maximum allowable volume of water to be extracted at any particular day and also on average over any specific year;
   - 3.4 Shall take into account the distance of the nearest wastewater discharge point and quality of final effluent being discharged if an aquifer, river, dam or other open source of raw water is used;
   - 3.5 The minimum distance from the extraction point to the nearest houses or animal grazing/sheltering areas will not be less than 500 m.

6. TARIFFS, FEES, PENALTIES AND FINES

1 Fees.

The Minister shall develop and enforce the following fees, which may be revised annually. The following will apply:

1.1 Application processing fees:

1.1.2 People treating under 10 m^3/d of raw water will be exempted from fees (but not an application);

1.1.3 Application processing fees, revised annually and made available by the Ministry at the beginning of a new year, will be charged for the following:

1.1.3.1 Potable Water Abstraction Licence

1.1.3.2 Potable Water Distribution Licence

1.1.3.3 Potable Water Abstraction and Distribution Licence

1.1.3.4 Waterworks Licence

1.1.4 In cases of non-payment the applicant shall be considered as not having been issued with a licence and the provisions of non-compliance will apply as set out under Sections 6.2.1 to 6.2.9.

1.1.5 The proceeds of selling and processing licences shall be paid into the Emergency Services Fund referred to under Section 6.3.

2 Penalties for Non-compliance.

2.1 If an operator is found to be non-compliant with these Regulations a member of the Inspectorate will inform him/her verbally of the findings. He/she will be informed of the consequences of non-compliance and a period for rectification will be mutually agreed upon. A written confirmation of the verbal warning will be sent to him/her.

2.2 If, after the agreed period, the condition of non-compliance has not been rectified the operator will receive a maximum of two written warnings with a maximum of three moths in-between the written warnings.

2.3 The operator has a right of appeal explaining why the situation referred to has/had not been attended to as agreed. The Minister shall reply to the appeal within one month of receipt of the appeal.

2.4 Should his/her appeal and the reasons given by the operator be rejected, the operator will be informed of the penalty to be paid within the period of three months of the date of notification. He/she will be instructed to cease the operation(s) referring to the process or plant under scrutiny, with immediate effect.

2.5 Repeated refusal to follow up and refusal to cease operations will lead to

- The Minister referring the matter to the courts;
- The Minister confiscating the installations, under the powers vested in his/her office;

- The Minister may decide on ways and means to close down or continue operations by effecting the rectifying action that was required in the first place. Depending on the case on hand, the Minister may close the facilities or institute measures to treat and/or upgrade the operations to produce a final water that adheres to the Water Quality Standards as per Appendix A;
- For the duration of the Ministerial supervision of the operations of a process or plant the staff in the employ of the operator before the Ministerial actions referred to above have been instituted, shall continue to be employed and remunerated by the operator as before;
- However their employment status shall be that of civil servants with all duties and benefits applicable to members of the Public Service;
- The duration of such action as well as the future development of the process or plant and the employees dealt with as described above shall be at the discretion of the Minister, in consultation with the Public Services Commission and Ministry of Justice.
- No fixed amount for penalties or fines is given as these may vary from case to case.
- Applicable penalties shall be defined and revised by the Minister at his/her discretion.

2.6 The cost incurred by the actions referred to under Section 6.2.5 shall initially be covered from the Emergency Serves Fund referred to under Section 6.3 below but will be reclaimed from the operator in full.

2.7 Delays in submitting applications for licences lasting longer than six months, after a third written warning was issued, and for which delay no reasons are given that are acceptable to the Minister, a penalty of N$10 000.00 is charged, payable within one month of date of penalization.

2.8 Refusal or delay of more than three months in attending to issues of non-compliance after a Temporary Licence has lapsed and for which refusal or delay no reasons are given that are acceptable to the Minister a penalty of N$10 000.00 is charged, payable within one month of date of penalization.

2.9 Refusal or delay of more than three months to attend to issues of non-compliance with the provisions of these Regulations and/or the conditions spelled out in a licence and for which refusal or delay no reasons are given that are acceptable to the Minister a penalty of N$50 000.00 is charged, payable within one month of date of penalization.

3 The Emergency Services Fund.

This will be in conjunction with the Minister's Regulation for Water Pollution Control.

7. ENACTMENT OF THE REGULATIONS

The Minister shall at his/her own discretion declare these Regulations enacted. Such action shall be published in the *Government Gazette.*

APPENDIX A: WATER QUALITY STANDARDS AND GUIDELINES FOR POTABLE WATER

Table 1: CHEMICAL AND BIOLOGICAL REQUIREMENTS

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
PHYSICAL AND ORGANOLEPTIC REQUIREMENTS					
Temperature	° C		E	Ambient temperature	
Colour	PTU	or mg/litre	E	10	<15
Taste			O,E	No objectionable taste	
Odour			O,E	No objectionable odour	
Turbidity (treated surface water)	NTU	or TU	H,I	< 0.3	< 0.5
Turbidity (groundwater)	NTU	or TU	H,I	< 0,5	<2
pH @ 20 °C	pH		I	6.0 to 8.5	6 to 9
Electric Conductivity @ 25 °C	mS/m***	E.C.	H,I	< 80	< 300
Total Dissolved Solids (treated surface water)	mg/litre		H,I	< 500	< 2 000
Total Dissolved Solids (groundwater)	mg/litre		H,I	< 1000	< 2 000
INORGANIC MACRO DETERMINANTS					
Ammonia	mg/litre	N	H	< 0.2	< 0.5
Barium	mg/litre	Ba	H	0.5	< 2
Calcium	mg/litre	Ca	I	< 80	< 150
Chloride	mg/litre	Cl	H,I	< 100	< 300
Fluoride	mg/litre	F	H	< 0.7	< 1.5
Magnesium	mg/litre	Mg	H	< 30	< 70
Nitrate	mg/litre	N	H	< 6	< 11
Nitrite	mg/litre	N	H	< 0.1	< 0.15
Potassium	mg/litre	K	H	< 25	< 100
Sodium	mg/litre	Na	H.I	< 100	< 300
Sulphate	mg/litre	SO_4	H,O	100	< 300
Asbestos (fibres longer than 10 μm)	Fibres/litre		H	<500 000	< 1000 000
INORGANIC MICRO DETERMINANTS					
Aluminium	μg/litre	Al	H	< 25	< 100
Antimony	μg/litre	Sb	H	< 5	< 50
Arsenic	μg/litre	As	H	<10	< 50
Beryllium	μg/litre	Be	H	< 2	< 5
Bismuth	μg/litre	Bi	H	< 250	< 500
Boron	μg/litre	B	H	< 300	< 500
Bromide	μg/litre	Br	H	< 500	< 1 000
Cadmium	μg/litre	Cd	H	< 5	< 10
Cerium	μg/litre	Ce	H	<1 000	<2 000
Cesium	μg/litre	Cs	H	< 1 000	< 2 000
Chromium Total	μg/litre	Cr	H	< 50	< 100

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
Cobalt	**μg/litre**	**Co**	**H**	**< 250**	**< 500**
Copper	**μg/litre**	**Cu**	**H**	**< 500**	**< 2 000**
Radon	**Bq/L**	**Ra**		**< 200**	**< 1 000**

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
INORGANIC MICRO DETERMINANTS					
Cyanide (free)	µg/litre	CN^-	H	< 20	< 50
Cyanide (recoverable)	µg/litre	CN^-	H	< 70	< 200
Iron	µg/litre	Fe	H,E	< 200	< 300
Lead	µg/litre	Pb	H	<10	< 50
Manganese	µg/litre	Mn	H	< 50	< 100
Mercury	µg/litre	Hg	H	< 1	<2
Nickel	µg/litre	Ni	H	< 50	< 150
Selenium	µg/litre	Se	H	< 10	< 50
Thallium	µg/litre	Ti	H	< 5	< 10
Tin	µg/litre	Sn	H	<100	<200
Titanium	µg/litre	Ti	H	< 100	< 300
Uranium	µg/litre	U	H	< 3	< 15
Vanadium	µg/litre	V	H	< 100	< 500
Zinc	µg/litre	Zn	H	< 1 000	< 5 000
Organo-metallic compounds (as organo or industrial chemicals or others)	µg/litre	Polymer	H	below detection limit (in accordance with WHO and EPA requirements)	below detection limit (in accordance with WHO and EPA requirements)
ORGANIC DETERMINANTS					
Dissolved Organic Carbon	mg/litre	DOC-C	H	< 5	<10
Phenol compounds	µg/litre	phenol	H	< 5	< 10
DISINFECTION AND DISINFECTION BY-PRODUCTS					
Bromodichloromethane (Part of THM)	µg/litre		H	< 20	< 50
Bromoform (Part of THM)	µg/litre		H	< 40	< 40
Chloroform (Part of THM)	µg/litre		H	< 20	< 100
Dibromomonochloro-methane (Part of THM)	µg/litre		H	< 20	< 100
Trihalomethanes (Total)	µg/litre	THM	H	< 100	< 150
Bromate	µg/litre		H	< 5	< 10
Chloramines	mg/litre	Cl_2	H	< 2	< 4
Chlorine dioxide after 30 min. GENERAL	µg/litre		H	200 - 500	< 800
Chlorine dioxide after 30 min. SPECIFIC	µg/litre		Turbidity > 0.3 NTU	200	200 - 400
Chlorine dioxide after 60 min. SPECIFIC	µg/litre		Turbidity > 1.0 NTU	< 200	200 - 500
Chlorite	µg/litre		H	< 400	< 800
Chlorate	µg/litre		H	< 200	< 700
Haloacetic acids	µg/litre		H	not detected	< 60
Chlorine, free, after 30 min; GENERAL	mg/litre	Cl_2	H,I	0.3 – 0.5	0.1 – 1.5

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
Chlorine, free, after 30 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: < 0.3 NTU**	**0.3**	**0.1 – 1.5**
Chlorine, free, after 30 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: > 0.3 NTU**	**0.5**	**0.1 – 1.5**
Chlorine, free, after 60 min; SPECIFIC	**mg/litre**	**Cl_2**	**Turbidity: >1.0 NTU**	**1.0**	**0.1 – 1.5**

Specifications for water quality intended for human consumption from the source and piped water supply					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile Requirement**	
BIOLOGICAL REQUIREMENTS					
Algae					
Chlorophyll α	**µg/litre**		**E,O**	**< 1**	**< 2**
Total algae cell count		**/ml**	**H,O**	**< 200**	**<5 000**
Blue-green algae	**cells**	**/ml**	**H,O**	**< 200**	**<2 000**
Mycrocystin	**µg/litre**		**H**	**< 0.1**	**< 1**
Geosmin	**ηg/litre**		**E, H**	**< 15**	**< 30**
2-Methyl Iso Borneal (2 MIB)	**ηg/litre**		**E, H**	**< 15**	**< 30**
OTHER DETERMINANTS					
Agricultural chemical compounds			**H**	**Any organic compound recognized as an agro-chemical shall be in accordance with the WHO and EPA requirements.**	
Industrial chemical compounds			**H**	**Any organic compound recognized as an industrial chemical shall be in accordance with the WHO and EPA requirements.**	
Endocrine disruptive chemicals			**H**	**Any chemical compound that is suspected of having endocrine disruptive effects shall be in accordance with the WHO and EPA requirements.**	
RADIOACTIVITY				**95 Percentile Requirement**	
Gross alpha activity	**Bq/litre**		**H**	**< 0.2**	**< 0.5**
Gross beta activity	**Bq/litre**		**H**	**< 0.4**	**< 1.0**
If Gross alpha and beta is above specification calculate Dose based on individual radionuclide concentrations	**mSv/a**		**H**	**≤ 0.04**	**≤ 0.1**

"Concern" refers to impact if the limit is transgressed: H = health concern; O = organoleptic effect;
I = effect on infrastructure, structural; E = aesthetic effect
* Based on a viral cell culture-dependent method and not on cell culture-independent methods (e.g. PCR)
** Indicative of faecal pollution having occurred, even when the residual disinfectant levels are safe.
*** Comply with SANAS Guidelines

Table 2: Standards for Microbiological and Biological Requirements

MICROBIOLOGICAL REQUIREMENTS APPLICABLE TO ALL POTABLE WATER					
Microbiology	**cfu**			**95 percentile**	**1 of samples maximum**
Heterotrophic bacteria HPC or TCC	counts	/ml		100	1 000
Total Coliform	counts	/100 ml	H	0	5
E.Coli	counts	/100 ml	H	0	1
Entrerococci	counts	/100 ml	H	0	1
Somatic Coliphage	counts	/100 ml	H	0	1
Clostridium perfrigens inclusive spores	counts	/100 ml	H	0	1
Enteric viruses	viral count*	/10 L	H	0	1
Parasites (Protozoa) applicable to all potable water				**95 percentile**	**99 percentile**
Giardia lamblia	cysts	/100 litre	H	0	1
Cryptosporidium	oocysts	/100 litre	H	0	1
Giardia lamblia and Giardia lamblia (Grab sample)	cysts or oocysts	/10 L	H	0	0

Table 3: Special Requirements for the Protection of Infrastructure

Specifications for water quality intended for human consumption from the source and piped water supply for the protection of infrastructure against corrosion					
Status				**Ranges and upper limits**	
Interpretation				**(Ideal guideline)**	**(Acceptable Standard)**
DETERMINANTS	**Unit**	**Format**	**Concern**	**95 Percentile requirement**	
CORROSIVE AND SCALING PROPERTIES (treated surface water)					
Calcium Carbonate Precipitation Potential	mg/litre	CCPP	I	4 - 5	1 - 6
Alkalinity/Sulphate/ Chloride Ratio	Equi-valents	Corrosivety Ratio	I	With SO_4 and Cl above 50 mg/litre Ratio=(Alk/50)/(SO_4/48+Cl/35.5) > 5.0 Water is Stable Ratio= (SO_4/48+Cl/35.5)/(Alk/50) > 0.2 Water is Corrosive	
Total Hardness (Ca & Mg)	mg/litre	$CaCO_3$	I	<200	< 400
CORROSIVE AND SCALING PROPERTIES (ground water)					
Calcium Carbonate Precipitation Potential	mg/litre	CCPP	I	4 - 5	3 - 15
Alkalinity/Sulphate/ Chloride Ratio	Equi-valents	Corrosivety Ratio	I	With SO_4 and Cl above 50 mg/litre Ratio=(Alk/50)/(SO_4/48+Cl/35.5) > 5.0 Water is Stable Ratio= (SO_4/48+Cl/35.5)/(Alk/50) > 0.2 Water is Corrosive	
Total Hardness (Ca & Mg)	mg/litre	$CaCO_3$	I	<400	< 1000

Table 4: Frequency of Microbiological Monitoring (including Turbidity values) for Water Supply and Distribution

Size of population served	Turbidity 95%**	Frequency of sampling
> 250 000	< 0,5 NTU	**Thrice weekly *** **
100 001 – 250 000	< 1,0 NTU	**Twice weekly**

50 001 – 100 000	< 1,0 NTU	**Once weekly**
10 001 – 50 000	< 1,0 NTU	**Three times every month**
< 10 000 reticulated	< 1,0 NTU	**Once every 1 month***
< 10 000 non-reticulated	**1 – 2 NTU**	**Once every 1 month***

* Upon complaints by the consumers or of medical practitioners and after incidents such as pipe breaks, the frequency should be increased until the situation has returned to original counts and been declared safe;

** Average or 95 percentile turbidity of the water supplied

*** The frequency should be stepped up by one extra sampling per week for every 100 000 residents (including the estimated number of visitors residing within the area at any time) in the area served, over and above 250 000.

General Information

1. The area being monitored shall be defined by the Minister in consultation with the Minister responsible for health and, where applicable, relevant officials from the Regional and Local Authorities;
2. At the time of sampling the operator shall also take a “free chlorine” reading of the same water under examination but prior to sampling for microbiological sampling, whilst using a portable device designed for that purpose and accepted by the Minister; this ‘reading’ is to be recorded and reported together with the results from the microbiological analyses;
3. As for field ‘screening’ of water supplies for microbiological contamination there exist portable devices designed for that purpose and accepted by the Minister; these ‘readings’ are to be recorded and reported together with the results from the microbiological analyses;
4. The results of the microbiological monitoring together with the free chlorine readings is to be reported as per mutual agreement to the ultimate supplier (bulk water supplier, Local Authority, or any other supplier) for remedial action where required, and to the Minister for record and monitoring purposes and follow up actions;
5. The costs of routine monitoring shall be borne by the authority commissioning the monitoring;
6. The US-EPA 2012 (update) Drinking Water Standards and Health Advisories shall be used to prescribe the maximum disinfection dosages when deemed necessary by the Minister.
7. Biological monitoring of invertebrates shall be conducted using the NASS method as prescribed in the guidelines by the Minister.

Methodology for Sampling and Analyses

The methodologies followed for sampling and during transit and storage of samples prior to analysis shall be as prescribed.

1. Preferably samples are to be taken in borosilicate glass bottles with a glass or polypropylene screw-cap lid;
2. Where this is not feasible or practical polyethylene bottles with internal seal and with screw-lid can be used;
3. Samples shall, as far as practical, be analysed within 24 hours of sampling;
4. Where there are special requirements for the period between sampling and analysis to be less than 24 hours, such requirement should be attended to as far as is practical;
5. Samples are to be kept and stored, even during transit, at as low a temperature as is practically manageable, whilst preventing the risk of the sample freezing;
6. The sample shall be kept away from light and shielded from sunlight, to reduce chances of micro-/biological growth to a minimum;
7. The use of preservation chemicals should be considered, planned and executed with extreme care;
8. Where sample preservation is appropriate or required an extra smaller volume sample should be taken so as to not upset any other analyses that are affected by the preservation chemical(s);
9. Certain determinants may be monitored ‘in the field’ at the time of sampling; such field-data are to be measured in a receptacle or container different from the sample container; data so obtained shall be recorded as “field measurement” and cannot replace laboratory analysis for the parameters concerned;
10. The methodologies followed for physical, chemical and microbiological analysis shall be in agreement with the specifications listed in the latest edition of the SANS 241, Drinking Water Standards, published by the SABS.
11. The cost of routine, regulatory inspections and monitoring, for the purpose of fulfilling the provisions of this regulation shall borne by the service provider.

APPENDIX B: APPLICATION FOR A LICENCE TO UTILIZE A CONTROLLED WATER SOURCE

DEPARTMENT OF WATER AFFAIRS & FORESTRY

FAX: (061) 208 7160 PRIVATE BAG 13184

TEL: (061) 208 7111 WINDHOEK

REFERENCE NO: ……………………….. NAMIBIA

APPLICATION FOR A LICENCE TO ABSTRACT AND/OR USE AND/OR DISTRIBUTE WATER, IN TERMS OF PART 9 OF THE WATER RESOURCES MANAGEMENT ACT, 2013 (Act No. 11 of 2013 - as published in the Government Gazette of the Republic of Namibia, No. 5367 of 19 December 2013, Government Notice No. 332)

NAME OF CONTROLLED WATER SOURCE, WATERWORKS AND/OR DISTRIBUTION SYSTEM: ______________________________

PLACE: ______________________ **GPS Coordinates:** ____________________
(e.g. town, settlement)

A. GENERAL INFORMATION

- Please note that failure to complete this application form properly may result in unnecessary delays. A farm/area map must be attached.
- The applicant must please furnish all the information requested, complete all items and indicate where the information is not relevant or unavailable.
- Failure to complete the application form properly may result in unnecessary delays.

6. B.

GENERAL INFORMATION

1. Name of applicant: ______________________

2. Address - Contact Person: ______________________

   - Postal: ______________________

   - Physical: ______________________

   - Tel No.: ______________________

   - Fax No.: ______________________

   - E-mail: ______________________

3. Region in which source is situated: ______________________

4. Constituency: ______________________

5. Type of establishment: (e.g. farm, school, town, industry) ______________________

6. Source of water supply: (e.g. borehole, river, sea) ______________________

7. Total water consumption: ______________________ m^3/day ADWF*

   (*ADWF = Average Dry Weather Flow) ______________________ m^3/day ADWF*

   - Consumption based on the average usage over a 12-month period. ______________________ m^3/day ADWF*
   - List different sources separately ______________________ m^3/day ADWF*

8. Application:

   - Prepared by: Name : ______________ Position: ______________

     (e.g. Consultant) Signature: ______________ Date: ______________

   - Responsible Executive: Name : ______________ Position: ______________

     Signature: ______________ Date: ______________

C. PARTICULARS OF PROPERTY

(a) Registered name and number of property: ………………………………………………
(b) Name of registered owner: …………………………………………………………..……..
(c) Region: ………………………………………………………………………………..……
(d) Title Deed Number: ………………………………………………………….……………
(e) Surface area of property: ……………………………………….……….…………(ha)
(f) Information on current water allocation limits must be given in **TABLE 1**.

TABLE 1: CURRENT WATER ALLOCATION LICENCE(S)

LICENCE NUMBER	QUANTITY OF WATER ALLOCATED (m^3/annum)
1.	
2.	
3.	
TOTAL ALLOCATION:	

D. CURRENT WATER USE ON THE PROPERTY

The existing water use on the property is reflected in **TABLE 2**.

TABLE 2: PRESENT UTILIZATION OF WATER

TYPE OF USE	QUANTITY (m^3/annum)
Domestic	……………
Stock drinking	……………
Irrigation	……………
Industrial	……………
Other uses	……………
	……………
TOTAL	

E. PARTICULARS OF EXISTING WATER SOURCES

Give details of all the existing sources of water on the property and what the water is used for. **TABLE 3** must be accompanied by a map of the farm or a diagram of the property on which the location of the sources of water are indicated by using symbols. The location of boreholes (give WW number if available), wells and dams must be shown as EB1 or EW1 or ED1 for existing boreholes, wells or dams

TABLE 3: PRESENT UTILIZATION OF WATER SOURCES

SOURCE		SYMBOL ON MAP	SOURCE YIELD (m^3/annum)	WATER USE (ha)	AREA IRRIGATED (ha)
Boreholes	(Number)				
	……………				
	…………..				
	…………..				
	…………..				
	…………..				
	…………..				
Wells					
	…………..				
	…………..				
	…………..				
Dams					
	…………..				
	…………..				
Rivers	…………..				

F. PARTICULARS OF EXISTING AREA UNDER IRRIGATION

The position and size of the existing and proposed area to be irrigated must also be clearly indicated on the farm map where the water sources are indicated, as well as the direction and distance of the farm from the nearest town.

TABLE 4: AREA UNDER IRRIGATION

CROPS CULTIVATED	AREA (ha)	DATE OF SOIL SAMPLE ANALYSIS	SOIL SAMPLE ANALYSIS RESULTS
……………..………………			
…………..…………………			
………..……………………			
……..………………………			
…..…………………………			
TOTAL			

G. PARTICULARS OF THE NEW WATER SOURCE(S)

TABLE 5: NEW WATER SOURCES

SOURCE	SYMBOL ON MAP	SOURCE 7. IELD (m^3/a)	DEPTH DRILLED (m)	DEPTH TO WATER TABLE (m)	TYPE OF INSTALLATION
Boreholes (Number)					
…………..					
…………..					
…………..					
Dams …………..					
…………..					
…………..					
…………..					
Wells					
…………..					
…………..					
Rivers …………..					

Particulars of Dam(s)

Name of watercourse as indicated on map ..…….………………………….

Embankment type ………….……………………………………………..

Height of embankment …. m   Full storage capacity of dam ………. m^3

If the full capacity of the dam is more than 20 000 m^3, has the dam been authorised by the Department of Water Affairs ?   Yes/No

Number of Licence …………………………..…….. Date ………………

H. PARTICULARS OF EXISTING AND PLANNED WATER INSTALLATIONS

Please provide particulars about the water installations in use.

TABLE 6: INFORMATION ABOUT WATER INSTALLATIONS

SOURCE		IN RIVER (Yes or No)	DISTANCE FROM BANK OF RIVER (m)
SYMBOL(S) ON MAP	TYPE OF INSTALLATION		
……………………..…	…………………...….….	……..…….……	……………………..…
…………..………..	………..……….………..	….…..…..……	…………..………..
…..…………………	……………………..……	……….….…..	…..…………………
…..…………………	…………………………. ….	………………..	…..…………………

- What is the planned annual water consumption ………………..….…….m³/annum
- What is the planned daily water demand during peak periods …………….m³/day
- During what period of the year is the peak demand …………………………………
- If a borehole or well is situated in a river bed or on a river bank, indicate the name of the river :………………………………..………………………………

I. PARTICULARS OF AREA EARMARKED FOR IRRIGATION

(a) Intended date to start with irrigation: ……………………….………………
(b) Total area to be irrigated: ..…………………………………………... hectares
(c) Will the whole area be irrigated right from the start? Yes/No
(d) If not, indicate area that will be irrigated initially: ……………………. hectares
(e) Water requirement for the initial area to be irrigated: ………..……. m³/annum
(f) Water requirement for the total area to be irrigated: ……………… m³/annum
(g) Crops to be cultivated: ……………………………………………………………
(h) Confirmation that a copy of the soil analyses is attached: Yes/No

J. PARTICULARS OF SOIL CLASSIFICATION

(a) Date when the soil samples were analysed: ………………………………….

(b) Indicate soil classification as per the analysis, with regard to the following:

(i)	Type of soil …………………….	(ii)	Series …………………………..
(iii)	Percentage clay ……………….	(iv)	Effective Soil depth …….… cm
(v)	Texture ………………………….	(vi)	Colour ………………………….

(c) Indicate the irrigability of the soil and any restrictions on the compatibility of the soil and the water. (Irrigation classification). …………………………………
..……………………..…………………………………………………………………..
…..………………………………………………………………………………………

K. CROPS TO BE CULTIVATED

Detail of the type of crops and the respective areas planned to be irrigated.

TABLE 7: CROP CULTIVATION DETAIL

TYPE OF CROP	AREA (ha)
…………………………………………………………………………	…………
…………………………………………………………………………	…………
…………………………………………………………………………	…………
…………………………………………………………………………	…………
…………………………………………………………………………	…………
	…………

L. FEASIBILITY STUDY AND ENVIRONMENTAL STUDY

In order to authorise new licences to utilize controlled water sources to irrigate more than five hectares, it is required that an appropriate feasibility study is done to show that the proposed irrigation project is economically feasible. An environmental impact assessment of the proposed project must be provided to show how the impact of the development on the environment will be managed.

11.1 It is confirmed that a feasibility study for the project has been done and is submitted.
Yes/No

11.2 It is confirmed that an environmental impact assessment has been done for the project and is submitted. Yes/No

11.3 It is confirmed that a proper method statement for the envisaged decommissioning has been drawn up and is hereby attached. Yes/No

M. FOR OFFICIAL USE

1. Department of Agriculture

Comments and recommendations by the Department of Agriculture. (In respect of the type of soil, the compatibility of soil and water, the suitability of the crops to be cultivated under irrigation on that type of soil, the reasonable water demand for the irrigation of those crops and the general viability of the project):

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2. Department of Water Affairs and Forestry

Comments and recommendations by the Department of Water Affairs and Forestry:

2.1 Hydrology Division (In respect of surface water sources)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2.2 Geohydrology Division (In respect of groundwater sources)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2.3 Water Environment Division (In respect of the environment)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2.4 Planning Division (In respect of economic and water use)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2.5 Advisory Water Board/Water Committee

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

3. Recommendation

The application is supported/not supported.

UNDER SECRETARY FOR WATER AFFAIRS
DATE:

The application is approved/rejected.

PERMANENT SECRETARY
DATE:

/mm/msw/form wa 002 application for a licence

APPENDIX C: APPLICATION AND REGISTRATION FOR A WATERWORKS AND OPERATING PERSONNEL

DEPARTMENT OF WATER AFFAIRS & FORESTRY

FAX: (061) 208 7160 PRIVATE BAG 13184

TEL: (061) 208 7111 WINDHOEK

REFERENCE NO: ……………………….. NAMIBIA

REGISTRATION OF A WATERWORKS AND OPERATING PERSONNEL, IN TERMS OF PART 10 OF THE WATER RESOURCES MANAGEMENT ACT, 2013

(Act No. 11 of 2013 - as published in the Government Gazette of the Republic of Namibia, No. 5367, of 19 December 2013, Government Notice No. 332)

1. Applications must be submitted in duplicate to:

   The Permanent Secretary
   Attn.: Law Administration
   Ministry of Agriculture, Water and Forestry
   Private Bag 13184
   WINDHOEK

2. Application Fee (to accompany this document): N$_____________

3. A separate application needs to be filled in for each different plant/works.

NAME OF WATERWORKS: ____

PLACE: _________________________ **GPS Coordinates:** _________________
(e.g. town, settlement)

A. GENERAL INFORMATION

1. Name of applicant: ______________________________

2. Address
   - Contact Person: ______________________________
   - Postal: ______________________________
   - Physical: ______________________________
   - Tel No.: ______________________________
   - Fax No.: ______________________________
   - E-mail: ______________________________

3. Region in which plant is situated: ______________________________

4. Constituency in which plant falls: ______________________________

5. Type of establishment: ______________________________
   (e.g. school, town, industry)

6. Source of water supply: ______________________________
   (e.g. borehole, river, sea)

7. Total water consumption: ______________________________ m^3/day ADWF*

   (*ADWF = Average Dry Weather Flow) ______________________________ m^3/day ADWF*

   - Consumption based on the average usage over a 12-month period. ______________________________ m^3/day ADWF*
   - List different sources separately ______________________________ m^3/day ADWF*

8. Application:

   - Process Controller: Name : ______________ Position: ______________

     Signature: ______________ Date: ______________

   - Owner/Responsible Executive: Name : ______________ Position: ______________

     Signature: ______________ Date: ______________

B. DEFINITIONS

1. A “**Waterworks**” is any water treatment plant, which includes any works, plant and/or system that is or will be provided for treating potable and/or wastewater;
2. An “**Operator**” is any person employed at a Waterworks, who has achieved the relevant competencies required to effectively undertake the duties assigned to that person to ensure that the Waterworks as a whole operate properly at all times;
3. A “**Process Controller**” is any person employed or contracted by a Waterworks, who has achieved the relevant competencies and experience required to effectively operate all unit processes installed at the Waterworks, or a person authorised to design, construct, install, operate and maintain all unit process installed at the Waterworks to ensure that the Waterworks as a whole operate in accordance with the design at all times;
4. The “**Act**” means the Water Resources Management Act, 2004 or any subsequent amendments to this act.

C. APPLICATION FOR REGISTRATION

It is mandatory for every owner of an existing Waterworks or a new Waterworks that is still under construction and will be put into operation to, within 18 months of these regulations coming into effect:

1. Apply for registration of the Waterworks at the Department of Water Affairs and Forestry;
2. List the number and class of operators that are or will be employed to operate the Waterworks;
3. Prove that the number of operators employed with their relevant experience will be sufficient to properly operate, control and maintain the Waterworks to provide the final quality of potable water or effluent for which the Waterworks has been designed;
4. Nominate and give all contact details and experience of the owner of the Waterworks and of the Process Controller ultimately responsible for ensuring that the Waterworks will operate in accordance with the design parameters.

D. REGISTRATION AND DEREGISTRATION

Upon receipt of the particulars contemplated in Section 2 above, the Minister must, within 6 months:

1. Classify the Waterworks in accordance with Schedule I or II, as the case may be;
2. Verify the competency of the Process Controller that will be in charge of the Waterworks;
3. Issue a certificate of registration in respect of such Waterworks;
4. Issue a certificate in respect of the nominated Process Controller.

The responsible authority must keep a register of particulars of every Waterworks, including its location and contact details of the owner and responsible Process Controller.

When a waterworks is to be decommissioned, the application form “Application for Deregistering a Waterworks”, as contained in Appendix D of this document must be submitted to MAWF.

E. OPERATING A WATERWORKS

It is mandatory for every owner of an existing Waterworks or a new Waterworks that is still under construction and will be put into operation to, within 18 months of these regulations coming into effect:

1. Employ or contract a suitably qualified Process Controller, who will be in charge of the Waterworks;
2. Provide and keep in his employment, as an absolute minimum, the number of personnel as laid down in Schedule IV with relevant training for each employee as laid down in Schedule III;
3. Keep a register, which is updated monthly, of all employees with their qualifications, that are employed on the Waterworks;
4. Keep an incident book where all important incidences related to the operation of the plant are conscientiously logged;
5. Ensure that the necessary quality control of the final water is undertaken to ensure that the Waterworks produce a final water in accordance with the design at all times;
6. Keep a register of all chemicals used and quantity thereof consumed on the plant;
7. The register, incident book and proof that the final water quality is in accordance with the design and is maintained within the design parameters, must be kept by the owner of a Waterworks and must be made available for inspection by the responsible authority at all times;

8. Display the registration certificate for the Waterworks in a prominent place on that Waterworks, once such a certificate has been received from the relevant authority.

NOTE: It should be noted that the conditions of any licence that may be issued by the Department of Water Affairs and Forestry are specified according to the information that has been supplied by the applicant in this questionnaire. The applicant must therefore ensure that his Waterworks are constructed and operated in accordance with the details that have been submitted!

SCHEDULE I

CLASSIFICATION OF WATER CARE WORKS FOR THE PURIFICATION OR TREATMENT OF **WATER FOR HUMAN CONSUMPTION** OR FOOD PROCESSING

Rating:

Class of works……………………………… Range of points……………………………..	D 4 – 6	C 7 – 10	B 11 – 18	A Above 18

Points to be awarded in accordance with the following criteria:

Classification Parameter	Parameter Selection	Point Allocation	Plant Total
Population supplied	Up to 1 000 1 001 to 5 000 5 001 to 50 000 Over 50 000	1 2 4 8	
Quality of intake water	Fair, with little or no variation Seasonal variation Monthly variation Daily variation	1 2 4 8	
Process	(a) Pumping and/or chlorination (b) (a) plus filtration (c) (b) plus flocculation and clarification (a) or (b) or (c) plus special treatment*	1 2 4 8	
Design capacity (m^3/d)	Up to 50 51 to 500 501 to 5 000 Over 5 000	1 2 4 8	
		TOTAL	

* Special treatment: e.g. any membrane treatment, activated carbon, softening, ion exchange, fluoridation, etc.

The table above should be used as follows:

- For each parameter in column 1 select which option in column 2 best describes the plant.
- Allocate the number of points in column 4 corresponding to the selection made in column 2 and enter this point value in column 4.
- Once a point value has been allocated and entered in column 4 for each classification parameter, add all the values in column 4 to obtain a total point value.
- Use the obtained point value to assign a class of works (A, B, C or D) as per the above rating table.

Please refer to the example on the use of Schedules I to IV following Schedule IV.

SCHEDULE II

CLASSIFICATION OF A WATERWORKS USED FOR THE PURIFICATION, TREATMENT OR DISPOSAL OF **SEWAGE OR EFFLUENT**

Rating:

Class of works…………………………… Range of Points…………………………..	D 4 – 7	C 8 – 12	B 13 – 21	A Above 21

Points to be awarded at the discretion of the Director-General in accordance with the following criteria:

Classification Parameter	Parameter Selection	Point Allocation	Plant Total
Design capacity (m^3/d)	Up to 50 51 to 500 501 to 5 000 Over 5 000	1 2 4 8	
Concentration of raw effluent or sewage, as COD	Less than 600 mg/L 600 mg/L or more	2 4	
Process	Primary sedimentation and anaerobic process e.g. pond, septic tank Biofilters (Biof) or biodiscs Activated sludge (AS) - any form Tertiary treatment (e.g., sandfilters) **Extras:** Mechanical or physical/chemical sludge treatment including stabilisation and/or dewatering, add Nutrient removal (extra to AS or Biof), add Complicating factors (gas engines, etc), add	1 2 4 8 +6 +4 +8	
Sensitivity of water into which purified or treated effluent is discharged	Low - e.g. evaporation pond Medium - e.g. where the General Standard prescribed under the Act is applicable High - e.g. where a sensitive catchment area is applicable such as a shared river basin or upstream of a potable water supply source	1 4 8	
		TOTAL	

The table above should be used as follows:

- For each parameter in column 1 select which option in column 2 best describes the plant.
- Allocate the number of points in column 3 corresponding to the selection made in column 2 and enter this point value in column 4.
- Once a point value has been allocated and entered in column 4 for each classification parameter, add all the values in column 4 to obtain a total point value.
- Use the obtained point value to assign a class of works (A, B, C or D) as per the above rating table.

Please refer to the example on the use of Schedules I to IV following Schedule IV.

SCHEDULE III

CLASSIFICATION OF PERSONS (EXCLUDING UNSKILLED LABOURERS) ACCORDING TO EDUCATIONAL QUALIFICATIONS AND EXPERIENCE TO BE EMPLOYED FOR THE OPERATION OF WATER CARE WORKS

Minimum Requirements:

Educational	Years appropriate experience					
	CLASS					
	Trainee	I	II	III	IV	V
GRADE 8	0	-	-	-	-	-
GRADE 8 plus water treatment related course	0	6	-	-	-	-
GRADE 10 plus relevant Trade Certificate	0	4	4	-	-	-
GRADE 12 plus relevant Trade Certificate	0	2	3	-	-	-
GRADE 12 plus water related, NQA accredited course	0	1	2	3	-	-
3 YEAR B.Sc (in appropriate field)					1	5
Professional Engineer-in-Training (completion of a recognized Engineering Degree is a pre-requisite)					1	5
Professional Engineer in appropriate field						3

Please refer to the example on the use of Schedules I to IV following Schedule IV.

SCHEDULE IV

MINMUM NUMBER OF PERSONS TO BE EMPLOYED FOR THE OPERATION OF A WATERWORKS

Work Class	Class and number of persons as operators	Class of Person as supervisor	Class of Person for inspection quarterly [2]
D	1 x Trainee	I	II
C	1 x Trainee 1 x I	II	III
B	1 x Trainee 2 x I 1 x II	III	IV
A	1 X Trainee 2 x I 1 x II 1 x III 1 x IV	IV	V

Note:

1) These are the minimum requirements for the operation of the various classes of Waterworks and do not include maintenance or laboratory personnel.

2) If the owner of a water care work has no person of this class employed on his Waterworks, a consultant with the required qualifications shall be appointed as prescribed in Schedule III in respect of that particular class of person, to visit the work weekly.

3) Please note, for safety reasons there must be a minimum of two people on site at any one time.

Please refer to the example on the use of Schedules I to IV following Schedule IV.

EXAMPLE ON THE USE OF SCHEDULES I TO IV

The following should serve as an example indicating the correct use of Schedules I to IV.

Example: A small settlement with 250 people makes use of a borehole with borehole pump and chlorination that supplies 25 m^3/d of drinking water to the community.

1) Use Schedule I to classify the works for treatment of water for human consumption:
    a. The population supplied for is 250 and thus falls into the “up to 1 000” group. Therefore allocate 1 point.
    b. The water quality from a borehole is fair, with little or no variation. Therefore allocate 1 point.
    c. The process only involves pumping and chlorination. Therefore allocate 1 point.
    d. The design capacity is 25 m^3/d and thus falls into the “up to 50” group. Therefore allocate 1 point.
    e. Add the allocated plant points: 1 + 1 + 1 + 1 = 4
    f. Rate the plant according to the range of points. For 4-6 points plant is classified as Class D.
2) Use Schedule IV to determine the required minimum number and type of persons employed for the operation of the waterworks:
    a. For a Class D plant 1 x trainee operator, 1 x Class 1 supervisor and 1 x Class 2 inspector is required.
3) Use Schedule III to determine the qualification required for the plant operator, supervisor and inspector:
    a. Operator (Trainee): Any person with an educational background up to “Grade 12 plus Water and Wastewater Treatment Certificate” with no experience is classified as a trainee and may operate the plant.
    b. Supervisor (Class 1): Any person with an educational background up to “Grade 12 plus Water and Wastewater Treatment Certificate”, excluding someone with only Grade 8, with the relevant number of years experience as shown in the column under heading Class I is classified as Class 1 and may supervise the plant operator.
    c. Inspector (Class 2): Any person with an educational background up to “Grade 12 plus Water and Wastewater Treatment Certificate”, excluding someone with less than Grade 10, with the relevant number of years experience as shown in the column under heading Class II is classified as Class 2 and may inspect the plant on a quarterly basis.

APPENDIX D: APPLICATION FOR DEREGISTERING A WATERWORKS

DEPARTMENT OF WATER AFFAIRS & FORESTRY

FAX: (061) 208 7160		PRIVATE BAG 13184
TEL: (061) 208 7111		WINDHOEK
REFERENCE NO: ………………………..		NAMIBIA

DEREGISTRATION OF A WATERWORKS IN TERMS OF PART XI OF THE WATER RESOURCES MANAGEMENT ACT, 2013 (Act No. 11 of 2013 - as published in the Government Gazette of the Republic of Namibia, No. 5367 of 19 december 2013, Government Notice No. 332)

1. Applications must be submitted in duplicate to:

    The Permanent Secretary
    Attn.: Law Administration
    Ministry of Agriculture, Water and Forestry
    Private Bag 13184
    WINDHOEK

2. Application Fee (to accompany this document): N$_____________

3. A separate application needs to be filled in for each different plant/works.

NAME OF WATERWORKS (to be deregisterd)**:** ________________________________

PLACE: ________________________ **GPS Coordinates:** ________________
(e.g. town, settlement)

A. GENERAL INFORMATION

1. Name of applicant: ____________________

2. Address
   - Contact Person: ____________________
   - Postal: ____________________
   - Physical: ____________________
   - Tel No.: ____________________
   - Fax No.: ____________________
   - E-mail: ____________________

3. Region in which plant is situated: ____________________

4. Constituency in which plant falls: ____________________

5. Type of establishment: (e.g. school, town, industry) ____________________

6. Source of water supply: (e.g. borehole, river, sea) ____________________

7. Total water consumption:

   (*ADWF = Average Dry Weather Flow)
   - Consumption based on the average usage over a 12-month period.
   - List different sources separately

   ____________________ m^3/day ADWF*

   ____________________ m^3/day ADWF*

   ____________________ m^3/day ADWF*

   ____________________ m^3/day ADWF*

8. Application:
   - Process Controller: Name : ____________ Position: ____________
     Signature: ____________ Date: ____________
   - Owner/Responsible Executive: Name : ____________ Position: ____________
     Signature: ____________ Date: ____________

B. DEFINITIONS

5. A “**Waterworks**” is any water treatment plant, which includes any works or plant that is or will be provided for treating potable and/or wastewater;
6. An “**Operator**” is any natural person employed at a Waterworks, who has achieved the relevant competencies required to effectively undertake the duties assigned to that person to ensure that the Waterworks as a whole operate properly at all times;
7. A “**Process Controller**” is any natural person employed at a Waterworks, who has achieved the relevant competencies required to effectively operate all unit processes installed at the Waterworks, or a person authorised to design, construct, install, operate and maintain all unit process installed at the Waterworks to ensure that the Waterworks as a whole operate in accordance with the design at all times;
8. The “**Act**” means the Water Resources Management Act, 2011 or any subsequent amendments to this act.

C. DECOMMISSIONING PLAN AND ENVIRONMENTAL IMPACT ASSESSMENT

In order to authorise a waterworks to be decommissioned, it is required that:

- An appropriate environmental impact assessment (EIA) is done to show that the proposed decommissioning of an existing waterworks will not result in wastewater not being treated or a potential health and environmental risk being created;
- A proper procedure for decommissioning (the Decommissioning Plan) has to be drawn up and must be attached to this application;
- A commitment must be given that all remaining structures will be left in such a condition, that it will not cause a danger or risk to any humans or animals that visit the site of the decommissioned waterworks afterwards.

1. It is confirmed that an environmental impact assessment has been done for the project and is submitted. Yes/No

2. It is confirmed that a proper method statement for decommissioning has been drawn up and is hereby attached. Yes/No

3. It is confirmed that the remaining structures will not cause a danger to or create a risk for humans or animals visiting the site after decommissioning. Yes/No

M. FOR OFFICIAL USE

1. Department of Agriculture

Comments and recommendations by the Department of Agriculture. (In respect of the decommissioning method.)

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2. Department of Water Affairs and Forestry

Comments and recommendations by the Department of Water Affairs and Forestry in respect of the decommissioning method:

2.1 Hydrology Division (In respect of possible surface water source contamination)

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2.2 Geohydrology Division (In respect of possible groundwater contamination)

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2.3 Water Environment Division (In respect of the environment)

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2.4 Planning Division (In respect of economic and water use)

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2.5 Advisory Water Board/Water Committee

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3. Recommendation

The application is supported/not supported.

UNDER SECRETARY FOR WATER AFFAIRS
DATE:

The application is approved/rejected.

PERMANENT SECRETARY
DATE:
/mm/msw/form wa 002 application for a licence

APPENDIX E: FORMAT FOR IDENTITY CARD

Authorization number (*Card sequence number*), issued in terms of section XX of the Water Resources management Act, 2013 (Act 11 of 2013)

The bearer is authorized by me, the Minister responsible for Water Affairs, to enter upon any land, accompanied by such staff, with such vehicles, appliances and instruments and do all such acts thereon for the purpose of making such enquiries, investigations, as are described in the above-mentioned Act and in the relevant Regulations.

Card expiry date: yyyy/mm/dd

Government of Namibia
Department of Water Affairs
Identity Card

Photo

Initials and Surname
Rank within the Department
Identity number