Procurement of Transaction Advisory Services for Project Preparation of Olifantsfontein Wastewater Treatment Works Water Reuse Project

Issued under the Water Reuse Programme and Water Partnership Office

ANNEX C: TERMS OF REFERENCE FOR THE TECHNICAL DESIGN OF THE REFURBISHMENT, MODERNISATION, UPGRADE AND EXTENSION OF MUNICIPAL WASTEWATER TREATMENT WORKS.

This set of documents includes the following:

Terms of Reference for Transaction Advisors
Annex A: Technical Requirements and Scope of Project
Annex B: Table of Contents of the Feasibility Study
Annex C: Terms of Reference Technical Options
Annex D: Terms of Reference ESIA
Annex E: Terms of Reference for Socio-Economic Analysis
Annex F: Gender Action Plan

This document, Annex C - Terms of Reference Technical Options, is a template for use by the Project Office and the WPO when preparing the Request for Proposals documentation for:

1. Wastewater and sludge treatment plants and new water reuse plants
2. Improvements to and/or rehabilitation of, existing wastewater and/or sludge treatment plants, and either of these combined with,
3. Reuse of treated wastewater for Direct Potable Reuse (DPR) or Water Reuse Treatment Plant (RTP) configurations for industrial supply.

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1. Introduction

This Terms of Reference (ToR) document provides a comprehensive framework for Transaction Advisors involved in the technical design of refurbishing, modernizing, upgrading, and extending municipal wastewater and new water reuse treatment works. The ToR outlines the scope of services required, objectives to be achieved, and general considerations for the project. By adhering to these guidelines, Transaction Advisors can ensure that projects meet the defined technical objectives, sustainability goals, affordability targets, and strategic objectives, ultimately delivering effective and efficient wastewater treatment solutions.

Additional information, as well as an initial conceptual design for 3 wastewater plant sizes (20, 50 and 100 Ml/day) can be found in the Report "*Project Preparation Program for municipal wastewater treatment works: Terms of Reference and Conceptual design for the refurbishment, modernisation, upgrade and extension of municipal wastewater treatment works and new water reuse plants*", provided under **Relevant Materials**.

2. Scope of Services

The scope of services applies to **new extensions and green field** wastewater treatment plants and water reuse plants falling under the DBSA/Green Climate Fund (GCF)project preparation program. For **upgrading existing plants**, the scope will be limited to the extent that the existing infrastructure allows for the required modifications.

3. Design Responsibility

Although this ToR recommends specific unit processes and technologies to be considered, the functionality and performance of the wastewater treatment plant and new water reuse plants remains the sole responsibility of the appointed design Engineer.

4. Objectives

The objectives of the project preparation program and the evaluation criteria for each project are outlined below.

4.1 Primary Technical Objectives

Ensure that the final effluent produced from the wastewater treatment works (and for influent to the water reuse plant meets the licensed standards of the plant in 98% of all samples, with a minimum sampling rate of 1 sample every 12 hours.

Produce anaerobic digested residual biosolids/sludge of at least A1b quality, suitable for use as agricultural fertiliser/compost.

4.2 Secondary Technical Objectives

Optimize energy efficiency and strive for an electrical consumption of <0.3 kWatt.hr/kl throughput. An Electrical Rating shall be applied as follows, consumption within:

- 5% of the target design consumption will be rated as A^+ electrical efficiency.
- 10% of the target design consumption will be rated as A electrical efficiency.

The program should strive to achieve an overall A^+ electrical efficiency on a volumetric weighted basis.

Maximize biogas generation, aiming for production as close to the target of 0.15 m^3 biogas/kl throughput as possible, with an aggregate biogas production rate of no less than 0.12 m^3 biogas/kl throughput.

Combust at least 99% of the methane content in the biogas to produce electricity. Maintain a conversion efficiency of >38% and strive for an aggregate real price of R3.50 per kWatt.hr (2021 basis) for peak demand production.

Enhance space efficiency.

4.3 Sustainability Objectives

Ensure sufficient provision for long-term maintenance, with a minimum annual maintenance spend of **R0.80 per kl** throughput (2021 basis) and strive for an aggregate real (2021 basis) maintenance spend of **R1.00 per kl** throughput.

Ensure sufficient provision for operating capacity and resources, with a minimum annual management and labour spend of R0.80 (2021 basis) per kl throughput and strive for an aggregate real (2021 basis) management and labour spend of **R1.00 per kl** throughput.

4.4 Affordability Objectives

Ensure that the project remains affordable to the relevant municipality/WSA. Consider the sanitation tariff charged by municipalities, covering bulk sewage treatment capacity, outfall sewers and collector's capacity, and billing and cost recovery. Aim for a sanitation fee that aligns with the municipality's affordability limit for any water reuse plant funded under this program. Note that the global tariff charged to consumers should cover the following three main cost items:

- Bulk sewage treatment capacity (40%)
- Outfall sewers and collector's capacity (40%)
- Billing and cost recovery (20%)

In each case the portion of the tariff (typically) attributed to the specific cost is indicated in brackets.

For example: if a municipality charges a global sanitation fee of R10/kl then the allocation towards its bulk sewage treatment capacity would be R4.00/kl. This would then represent its affordability limit for any water reuse plant funded under this program.

4.5 Financing Objectives

Ensure that each water reuse project prepared is fully bankable and can be financed through limited recourse project finance (and if required – a capital grant application can be submitted to the Budget Facility for Infrastructure to reduce the cost of capital). Aim for 70% of the project's value to be financed through limited recourse project finance (note capital grant application). Establish a suitable legal structure to ring-fence the project, ensure a contracted level of revenue for adequate coverage ratios, and establish fully funded debt service reserve and capital contingency reserve accounts.

4.6 Strategic Objectives

Maximize the use and benefit of water reuse resources for the municipality and any other customers.

In addition:

- Explore opportunities for co-digestion by adding other organic waste streams to the anaerobic digestion process, increasing biogas and electricity production.
- Identify opportunities for waste integration by integrating municipal wastewater treatment and solid waste management through co-digestion, co-combustion, and co-generation, extending the life of existing solid waste disposal sites and deferring capital expenditure.
- Maximize the use of intermittent renewable energy resources by providing on-demand renewable energy to supplement those resources, creating effective base load renewable energy.
- Enhance community benefits by making digested biosolids and other by-products available for urban agriculture initiatives to improve soil conditions and production yields, addressing poverty and unemployment in township communities.

5. Project Preparation Matrix

A project preparation matrix has been developed to assist in identifying technical options that need to be considered to make the project suitable for funding. Transaction Advisors will be responsible for utilizing this matrix to guide their analysis and decision-making processes.

DBSA - Project Preparation Plan decision matrix

QUESTION		VIABLE FOR FUNDING		ANTICIPATED OUTCOME
Does the WWTW have a suitable and functioning Activated Sludge Process?	NO	Upgrade of ASP using efficient technology	Evaluate cost benefit & lifespan to upgrade or retrofit new technology vs. new plant - must include: (1) Efficient aeration technologies & DO Control (2) Improved technology retrofit (e.g. Granular AS)	- compliance to discharge standards - efficient works process (lower opex)
YES				
Is the ASP Process efficient and optimised electrically? (Fine bubble aeration & Aeration control)	NO	Implement energy optimisation	(1) Fine bubble aeration system implementation (2) Improved technology retrofit (e.g. Granular AS or MBBR) (3) Aeration control system (DO control optimisation)	- compliance to discharge standards - Saving on electricity costs - saving on operational costs
YES				
Does the WWTW have AD's sufficient to treat all sludge?	NO	Upgrade & optimise AD's and their operation	(1) Incr. digester capacity (2) Pre-digestion sludge thickening (3) Sludge hydrolysis (4) Efficient heating & mixing	- Saving on operational costs - Saving on disposal costs
YES			**Heat Recovery**	
Does the WWTW have Gas production optimisation and CHP ?	NO	Implement CHP & Biogas optimisation	(1) Install Gas scrubbing & CHP plant (2) Maximise peak operation time of CHP for fastest returns Optimisation considerations: (a) Co-digestion	- Saving on electricity costs - Saving on heating costs
YES				
Does the WWTW have Biosolids beneficiation ?	NO	Implement Biosolids beneficiation process	(1) N & P recovery (Struvite removal) (2) Biosolids granulation & sale (3) Fertiliser	- Saving on sludge disposal - Income from Nutrient sale - Saving on ops & maintenance

Figure 1: Project Preparation Plan Decision Matrix

6. General Considerations

Transaction Advisors should consider the following general considerations throughout the project: Consider water reuse project sizes that typically fall between **20 Ml/d and 100 Ml/d.**

Give special attention to those works that have an efficient and cost-effective aeration system, focusing on high oxygen transfer (fine-bubble) aeration diffusers, diffuser depth, head/energy losses, blower efficiency, and control systems.

Prioritize anaerobic processes for energy net positive operations, diverting feed COD towards anaerobic processes to minimize energy consumption in aerobic treatment.

Conduct financial modelling over a minimum lifespan of 20 years to determine the lowest net present value and comparative pay-back periods for technology systems. The following modelling variables should be used unless otherwise specified by the WPO in Table 1.

Table 1: WPO Modelling Variables

Discount rate	8.5% per annum
Inflation rate (general)	4% per annum
Electrical energy inflation rate	8% per annum
Civil maintenance cost	0.25% per annum*
Mechanical maintenance cost	2% per annum*
Electrical maintenance cost	3% per annum *****

Notes: * based on % of total *replacement* cost

Emphasize energy efficiency by selecting equipment with the highest available energy efficiency in the market at the time of project preparation.

7. Unit Processes and Systems for Main Liquid Stream

Design and optimize unit processes and systems for the main liquid stream into the water reuse plant, considering screening, de-gritting, primary settling, balancing, biological nutrient removal activated sludge (BNRAS), clarification, disinfection and reuse technologies to improve commercial viability of reuse water.

Consider the General Limit and Special Limit as per the General Authorisation as initial guideline for required treated effluent quality.

Engage with the Department of Water and Sanitation to establish the effluent standard and conditions that will apply to the proposed water reuse plant. The design should ensure that the proposed water reuse plant complies with the agreed and final license effluent quality and conditions and reuse water quality for off-take customers.

Optimize spatial efficiency in the design of reactors, process tanks, and general arrangements.

Optimize pumping systems by considering pipe diameter, dynamic head loss, and energy consumption over the system life cycle, considering a projected energy escalation rate. The WPO should indicate the best energy cost escalation rate at the start of the project. The energy cost forecast must cover the first 20 operating years of the pumping system. The use of valves or similar means to generate head loss and control flow must be avoided.

Upgrade aeration systems to fine bubble diffused aeration (FBDA) systems wherever possible.

Existing aeration systems due for upgrade should consider all options and analysed based on the lowest net present value (NPV). Technology selection should be based on the NPV outcome of a financial model analysis. New extensions and green field plants should install FBDA systems of reputable brand. Aeration control should be based on **ammonia** control.

In the context of activated sludge, there exists an opportunity to **denitrify**, which is a mandatory condition when applying to the Green Climate Fund. The prescribed denitrification process entails the following crucial aspects:

- **Energy Conservation:** Denitrification is a process that facilitates energy saving. It allows for the recovery of oxygen used in the nitrification process by facultative bacteria, using it for the metabolism of organic carbon, instead of elemental oxygen. The process has the potential to recover up to 30% of oxygen, thereby substantially reducing the required oxygenation.
- **Alkalinity Restoration:** Denitrification reinstates alkalinity, which is used up in the nitrification process, given its acidic nature. This is especially pertinent for sewage with low alkalinity, where a lack of sufficient alkalinity could disrupt the nitrification process.
- **Nitrate Removal:** The activated sludge process in a wastewater treatment plant is likely the final opportunity to eliminate nitrate from return flows. It is widely accepted that nitrate concentrations over 10 mg/L are toxic, particularly for infants. If not removed during the wastewater treatment, it can cause the resultant return flows, even when mixed with other water sources, to be unsuitable for purification to potable water standards without the addition of processes such as reverse osmosis or ion exchange.

The Transaction Advisor is expected to provide comprehensive assistance and guidance on all technical, financial, and regulatory aspects related to the implementation of the denitrification process in compliance with the GCF standards.

8. Sampling

The design should be based on a reputable mathematical model. Prior to designing the plant, Transaction Advisors should undertake a sampling campaign by conducting a minimum of seven consecutive-day flow-related sampling, including grab samples and composite samples of the influent, fractionation analysis of daily composite samples, and analysis of composite samples of the final effluent. The requirements for sampling are as follows:

1. Sample for a continuous 7-day period and take 2 hourly grab samples (84 in total) of the influent, which is then analysed for:
    - Total COD
    - TKN

- TP
- Suspended solids
- Alkalinity

Note: Design Reports on the Olifantsfontein WWTW are available

2. To do the fractionation of the various parameters, the designer must also analyse the daily composite samples for the 7-day sampling run (7 in total), for:
    - Total COD
    - Filtered COD
    - FF COD (refer attached procedure)
    - TKN
    - Ammonia
    - Total phosphate
    - Ortho-P
    - VSS
    - TSS
    - Total BOD
    - Filtered BOD
    - Calcium
    - Magnesium

Note: Design Reports on the Olifantsfontein WWTW are available.

3. In addition, a composite sample of the final effluent (one in total), must be is analysed for:
    - Total COD
    - FFCOD
    - TKN
    - Ammonia
    - Nitrate & Nitrite

Note: Design Reports on the Olifantsfontein WWTW are available

9. Equipment Selection

Transaction Advisors should carefully consider equipment selection for the project, including pumps, motors, aeration blowers, other relevant components and water reuse technologies. Specifically:

- **Pumps:** Solid's handling pumps tend to be less efficient than clean water pumps. Pumps with the best suited solids handling capability for each specific application, together with best efficiency at the intended duty point should be selected for new and replacement pumps. Pump selection of a reputable brand should be based on the best efficiency at the system duty point, with the lowest life cycle cost.

- **Motors:** Use only energy efficient motors (IE3 Top Premium Efficiency). All pump motors equal to larger than 11 kW or that will contribute significantly to power consumption must be fitted with VSD to facilitate load matching. All motors that will collectively be responsible for 80% of the projected plant power consumption, should be equipped with VSD.
- **Aeration blowers:** Turbo or high-efficiency hybrid blowers should be considered with variable vanes. Aeration control with variable speed adjustment is imperative and the anticipated turndowns required for aeration control should remain within the blowers 'sweet-spot' of efficiency.

10. Unit Processes and Systems

The solids processing stream should include the following unit process steps:

- Combining of primary and WAS streams,
- Thickening,
- Cell lysis,
- Anaerobic digestion,
- Dewatering,
- Solar drying and beneficial application of biosolids with a target classification of class A1a solids according to the "Sludge Guidelines". If a target pollutant class "a" cannot be achieved due to industrial pollution in the catchment, industrial pollutant discharges should be managed by imposing appropriate penalties on the relevant industries.
- Applicable water reuse technology

Specifically:

- **Sludge thickening (pre-digestion):** Sludge can be thickened by means of gravity thickeners, DAF, dehydrators, gravity belt thickeners, etc. Gravity belt thickeners are the preferred option to thicken sludge to between 6% and 8% before being fed to the AD's. Other technologies which are capable of achieving similar solids concentrations and energy efficiency may be considered. Gravity belt thickeners should preferably have a belt with in the order of 2.5 meters and polymer consumption should be less than 4 kg/ton dry solids.
- **Cell Lysis:** Cell lysis or hydrolysis improves digestibility of the sludge and therefore the biogas production during earlier stages of digestion and will therefore result in improved biogas production at shorter retention times (i.e. cases with limited anaerobic digester (AD) capacity). Cell lysis would therefore be advantageous in cases where AD's are overloaded. Cell lysis can be achieved by various means such as thermal hydrolysis, ultrasonic cell destruction, chemically, mechanically, etc. and should preferably be applied after thickening to reduce capital as well as O&M costs. Technology selection should be based on a life cycle cost analysis based on guaranteed performance with associated advantages. Cell lysis is

more effective on secondary sludge and single train lysis could be considered in order to reduce capital and operational costs.

- **Sludge stabilisation approach:** Due to the high energy costs associated with aerobic digestion, it is recommended that aerobic digestion systems should be replaced with anaerobic sludge digestion. The selected technology should be based on the NPV outcome of a financial model analysis. Both primary and secondary sludge should be anaerobically treated to achieve a Class 1 with regard to sludge stability. Sludge should be thickened to a target range of between 6% and 8% before being fed into anaerobic digesters. This will minimise required AD process volume (or increase SRT) as well as heating energy to maintain mesophilic operating temperature.
- **Anaerobic digestion:** All extensions, green field sites and existing sites should be equipped with AD's equipped for mesophilic operation, i.e. mixed and heated (35°C to 38°C). The heating system should be designed to maintain the target heat to within ± 1°C. AD's should be sized to digest both primary and secondary sludge with a target sludge retention time of 15 to 20 days and a volatile solids (VS) loading rate of between 1.6 and 3.2 kgVS/m^3.d. The target VS destruction should be more than 38% in order to produce a sludge that complies with the "sludge Guidelines" stability requirement, i.e. a "class a" sludge.
- **Digester monitoring:** It is recommended that each anaerobic digester (AD) is equipped with at least a biogas flowmeter, pH meter and thermometer to facilitate monitoring the health of each AD.
- **Digester feed sludge:** The primary and secondary sludge collection and thickening system should facilitate an AD feed regime that is as close as possible to continuous. Feed sludge solids concentration monitoring will be advantageous, as well as feed sump mixing system to maintain a homogeneous solids feed concentration.
- **Digester mixing:** AD mixing approach must be based on energy conservation principles and should be able to maintain a minimum mixing intensity of 10 W/m3. AD mixing equipment must be equipped with VSD control to facilitate optimised mixing. Ease of accessibility to- or removal of mixing equipment should be considered for maintenance purposes.
- **Digester heating:** It is important for anaerobic process stability to limit the operating temperature change during a day to maximum of ±1°C. A typical wastewater treatment plant Combined-Heat-and Power (CHP) system should be able to produce more than the required heat energy to maintain mesophilic conditions in the AD's by the recovery of heat energy from the envisaged CHP system. A potential challenge may be to make the required heat energy available at the required time of the day because of the fact that the CHP units may only be operated during power tariff peak periods. This may result in an imbalance between the timing of heat energy supply and heat energy demand. It is not recommended that boilers are used for heat energy augmentation.

The following technologies are recommended as alternative heat sources during periods the CHP units are not running: (a) Extracting heat from the treated effluent via electrically driven turbine and heat exchanger during periods the CHP is not operational, i.e. electrical energy off peak periods; (b) The pre-digestion thickened sludge in the AD feed sump can be heated to elevated temperatures (>38°C) via the CHP during the periods the CHP is operational and the AD content is already at the required temperature (c) Slow release heat mechanisms (e.g. oil as a heat-retaining medium) can be considered to evenly transfer heat to the AD's during periods when the CHP is not operational.

- **Biogas flaring:** Provision should be made for the flaring of biogas more than system capacity or CHP requirements to mitigate negative greenhouse gas impact on the environment. Capacity of the flaring system should not be less than the average projected biogas production at full plant capacity.
- **Biogas storage:** Biogas storage should have adequate capacity to store all biogas produced between the worst-case peak power cost intervals, i.e. it should have adequate capacity to store all biogas produced during the periods the CHP units are not operational during a worst-case 24-hour weekday cycle. This cycle will differ from site to site. Power supply to the plant should be evaluated for each specific site in terms of daily peak tariff periods as adjusted seasonally as applicable. Biogas storage capacity to accommodate storage during weekend deviation from weekday peak cost period is not required, unless such storage can be motivated to be financially beneficial.
- Applicable water reuse technology

11. Solids Dewatering and Drying

Transaction Advisors should incorporate methods to reduce the mass of solids and improve stability. The following options should be considered as a minimum:

- **Belt filter press:** Dewatering by belt filter press is the popular option in South Africa. Typical solids content of dewatered digested sludge cake is >18%.
- **Solar drying:** Solar drying is achieved by spreading dewatered cake on an uncovered concrete paved area to a maximum depth of approximately 400 mm. The application rate varies between 0.14 to 0.31 m3/m2 (25 to 71 kgDS/m^2) to achieve a drying time of between 19 and 34 days (Highveld climate). Daily turning of sludge cake is required, preferably by mechanical sludge turner, to prevent crusting and achieve the stated drying cycle times. Dewatered sludge cake should be solar dried to a solids content of 45% to 55% in order to ensure the required porosity of the sludge is maintained during the composting process.
- **Composting:** The Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volume 5, state that one of the options for the stability class 1 and vector attraction reduction as being "Option 5: Use aerobic processes at a temperature greater than 40°C (average temperatures 45°C) for 14 days or longer (e.g. during sludge composting)". Once the sludge is solar dried to 45% to 55% dry solids, the composting process can proceed as follows:

- At a solids content of 45% to 55% the sludge can be heaped into rows of approximately 3 m high without slumping, thus allowing natural air flow through the heap to maintain an aerobic process. Dry solids content improves to more than 60% resulting in rapid uncontrolled heating to more than 60°C, rapid drying and inhibition of the composting process. If the sludge reaches temperatures of 60°C the windrows should be restacked to prevent excessive temperatures. It is essential that the dry solids content during the composting period is maintained between 45% (start) and 65% dry solids (end). Once the required temperatures are maintained for the required fourteen-day period, the composting process is complete and biosolids can be removed for curing.

- **Organic fertiliser:** The Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volume 5 Part B, make provision for the production of an organic fertiliser by disinfection and addition of nutrients at required proportions as per agricultural requirement. A minimum sludge quality of class A1b is required. Class A1a has no application limits for agricultural applications while Class A1b may require additional soil analyses.

12. Combined Heat and Power (CHP)

Transaction Advisors should evaluate the implementation of CHP at wastewater treatment works with functional anaerobic digestion, ensuring financial viability. Consideration should be given to:

- **Biogas conditioning:** Biogas should be treated for the removal of particulates, moisture, hydrogen sulphide and siloxanes before feeding to the CHP.
- **CHP facility:** The CHP plant should have the capability to operate continuously (365 days a year and 24hrs a day – although it may only be operated during peak tariff periods) from an availability and reliability perspective, supported by a >95% availability and a reliable automated operational philosophy. Engine electrical efficiency should be >38% and thermal efficiency >50%, thereby achieving a 'combined heat and power' efficiency of >88%. Technical ability, local references and local support should be high on the contractor evaluation criteria. Engine capacity should be determined to produce maximum power output (i.e utilise all stored biogas) over a 2-hour period. Engine start-up and shut-down time periods should be specified to achieve maximum pricing of electricity supplied into the grid.
- **Generated power:** The site arrangement should be thoroughly evaluated to determine the optimum position for feed-back into the system to facilitate export of energy into the grid during peak periods and/or use of generated power on the site.
- **CHP control:** Gas quality (H2S, Methane, O2, CO2, etc.) should be monitored through the use of gas analysers. Scada with remote monitoring systems are recommended, with appropriate metering and reporting. The measuring and control system should facilitate effective performance monitoring.
- **Battery limits:** Battery limits of the CHP facility are an important consideration and should take into consideration the facilitation of maximum CHP benefit, either during peak tariff

periods or otherwise, while not negatively impacting the mainstream or solids treatment processes.

13. Phosphorus Management

Proper management of phosphorus should be incorporated into the project design, considering options such as ferric chloride precipitation and struvite recovery. These measures will help control phosphorus release and ensure the efficient and sustainable treatment of wastewater.

14. Water Reuse Technologies

Proper understanding of the types of water reuse technologies should be incorporated into the project design, considering technology options such as dissolved air flotation, sand filtration, activated carbon, ultrafiltration and reverse osmosis. These measures will help produce the desired water quality for customers that require high quality industrial water.

Below is a description of core components of the Ozone-BAF water reuse process (for example).

Ozone Disinfection

How it works: Ozone gas (O_3) is generated on-site and injected into the water, where it rapidly oxidizes and inactivates pathogens.

Benefits: Ozone is a potent disinfectant, effective against a wide range of microorganisms, including bacteria, viruses, and cysts like Giardia and Cryptosporidium. Ozone's disinfection process is faster than chlorine. Ozone decomposes back into oxygen, leaving no harmful chemical residues in the treated water. Ozone can also oxidize other contaminants, such as iron, manganese, and organic matter, improving water quality. Ozone can help reduce or eliminate unpleasant tastes and odours in water.

Limitations: Ozone treatment can lead to the formation of oxidation byproducts, some of which may be harmful, especially in bromide-containing waters. Ozone generation can be energy-intensive. Ozone does not mineralize organic compounds.

Applications: Ozone is used for disinfection and oxidation in drinking water treatment. Ozone can be used to disinfect wastewater and remove organic matter. Ozone is used in various industrial applications, including food and beverage, and pharmaceutical industries.

BAF (Biological Aerated Filter)

Description: BAFs are a type of wastewater treatment system that uses a submerged, packed bed of granular media. This media provides a surface for the growth of microorganisms that consume organic matter in the wastewater. Air is introduced into the system to ensure the microorganisms have enough oxygen for their metabolic processes. BAFs are known for their ability to remove both soluble and suspended organic matter.

BAF can also be used for nitrification (converting ammonia to nitrate) and denitrification (converting nitrate to nitrogen gas). BAFs are compact and efficient solution for wastewater treatment, especially in areas with limited space or high pollutant loads.

How BAF works: Wastewater flows downward (or sometimes upward) through the bed of media. As the wastewater flows, microorganisms attached to the media consume the organic matter. Air is introduced into the system to maintain the aerobic conditions necessary for the microorganisms to thrive. The treated water then flows out of the BAF.

Advantages of BAFs: Compact design, suitable for areas with limited space. High pollutant and/or hydraulic loading capacity. Can be used for plant upgrades, expansions, water reuse, and various industrial processes. Elimination of the need for secondary clarification. Potential for lower capital and operating costs compared to conventional treatment alternatives.

Disadvantages of BAFs: Aeration consumes a significant amount of energy. Requires careful design and operation to ensure optimal performance.

15. Disclaimer

Although specific unit processes and technologies are described herein for reference purposes, it remains the sole responsibility of the design engineer to ensure the efficacy and viability of these options within the framework of the intended purpose of the project.

END