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TNO report

Preliminary Business Case for RWZI Bubali Aeration

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Contents

1 Introduction

The department of Dienst Openbare Werken (DOW) of the Ministry of Infrastructure and the Environment is responsible for the treatment of residential-, commercial- and industrial wastewater before discharging the effluent in the environment and/or using it for irrigation. DOW manages the three wastewater treatment plants (RWZI Bubali, RWZI Parkietenbos, and RWZI Zeewijk) in Aruba. TNO Caribbean has been requested by DOW to assess the three wastewater treatment plants for technology and/or system enhancements as part of their Wastewater Management Roadmap towards 2030.

The RWZI Bubali is their first priority due to the fact that this is the largest treatment plant and treats most of the wastewater. This report describes the system of the Bubali RWZI and the problems encountered during the quick scan of the system whilst focusing on the existing aeration system.

In the current situation RWZI Bubali treats sewage water from the areas of Oranjestad, Bushiri and the low & high-rise hotel. Due to the rapid growth of the population and the tourism sector, an increase in the quantity of sewage water for this area has been seen and consequently the RWZI Bubali has exceeded its maximum processing capacity (influent). The aeration capacity (oxidation ditch; using surface aerators “Rotor”) at the moment seems not be sufficient to process the amount of influent introduced in the plant. The major bottleneck is the inability to supply enough oxygen (oxygenation) for full oxidation of the pollutants present in the wastewater. As a result the plant is not operating in optimal conditions and as such the maximum treatment efficiency of 75 to 80% (target efficiency) is not being reached.

The currently aeration system at RWZI Bubali consist of 12 surface aerators which are at the end of their technical lifespan and therefor consume a relatively high amount of energy. This results into high maintenance and operational cost. It is therefore imperative that the aeration will be replaced as to achieve more efficiency with the treatment. DOW has requested TNO Caribbean to evaluate the aeration system (including energy consumption of the same) for the Bubali plant, as to present evaluate a more effective system and efficient aeration at Bubali RWZI. TNO Caribbean will execute a scan of the system (with respect to efficiency in both aeration and electricity consumption and will make a proposal for a solution complete technical proposal, including a CAPEX guestimate. After introduction of this new system is implemented, the whole RWZI operation is to be revised for further enhancement.

In this report a comparison of available aeration technologies for the situation at RWZI Bubali is given. This includes cost figures guesstimates (investment- & operational costs) for these alternative aeration technologies. Based on the results of the assessment, a recommendation will be given for the most suitable technology.

2 RWZI Bubali

2.1 General Information

The wastewater treatment plant Bubali (RWZI Bubali) has been operating since 1972. The type of system is oxidation ditch with surface aeration. In the current situation the RWZI Bubali is processing sewage water from the furthest area Cas Paloma/Simeon Antonio through Oranjestad, Bushiri and the Low- and High Rise hotels (including the Palm Beach area). Part of the sewer collector network is shown in Figure 4. The rapid growth of the population and tourism over the past few years has led to substantial increase of wastewater (influent) production. Consequently, the RWZI Bubali has exceeded its maximum hydraulic capacity and biological load for which it is designed. The process diagram of RWZI Bubali is shown in Figure 1.

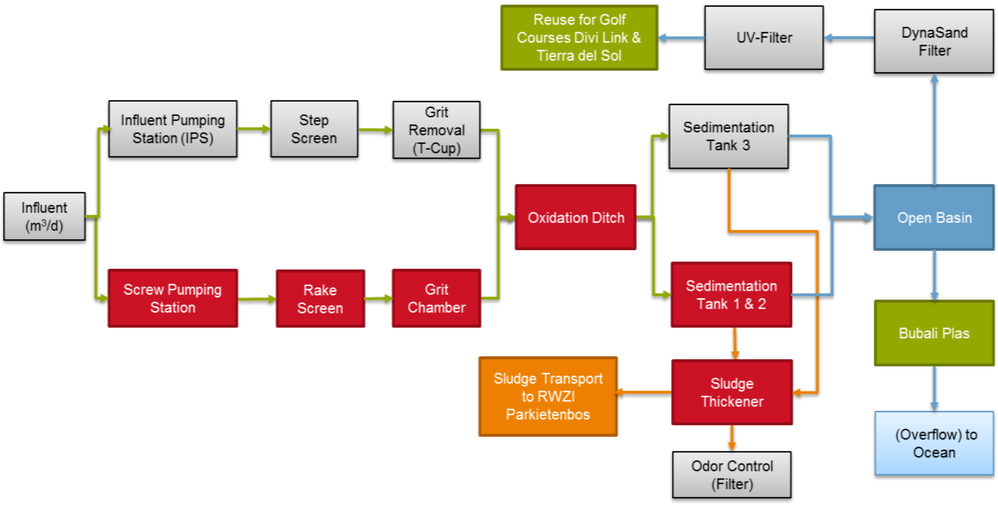

Figure 1: Process Diagram RWZI Bubali current situation.

Figure 1 shows two processing steps a red- (bottom) and grey line (above). The red line is the original (design) process sequence of RWZI Bubali for the processing of the influent. Due to influent increase a second line (grey) was added to this system in 2003. The influent is primarily treated as per the grey line. When the maximum hydraulic capacity (710 m^3/h) of the IPS is reached, the system shown by the red line will be activated for the additional treatment capacity. This operational sequence will prevent overflow of the sewers lines near the Low Rise Hotels.

2.1.1 Description of present process sequences and associated technologies

This section describes the two processing sequences and their associated technologies. Table 1 describes the red line processing sequence and associated technologies of RWZI Bubali as shown in figure 1 and table 2 shows the currently process sequence and associated technologies of RWZI Bubali as shown in figure 1 by the grey line for the treatment of wastewater.

Table 1: *RWZI Bubali original process steps and description of technologies.*

RWZI Bubali (Original, Red Line)	
Process Steps	**Description of technologies**
Primary Treatment	
Screw Pumping Station	The existing screw pumping station has a number of 3 existing screw pumps with a capacity of 300 m^3/h each. Only 1 pumps are still in operation.
Rake Screen (1)	The rake screening has a capacity of 600 m^3/h and is in operation when the screw pump is activated.
Grit Removal (1) (horizontal-flow chamber)	The sand removal has a capacity of 600 m^3/h and is in operation when the screw pump is activated.
Secondary Treatment	
Oxidation Ditch “Pasveer”	Sewage water is treated in large (oval) ditches with one or more horizontal aerators, typically called brush aerators which drive the sewage water around the ditch and provides aeration. A volume capacity of 7500 m^3.
Sedimentation Tank 1 & 2	Sedimentation is a physical treatment process using gravity to remove suspended solids (sludge) from water. A volume capacity of m^3.
Sludge Thickener	The sludge thickener is a procedure used to increase the solids content of sludge by removing portion of the liquid fraction. (Back then, the sludge was dried in dry beds, because of the nuisance odours this is stopped).
Tertiary Treatment	
DynaSand Filter	The DynaSand is an up-flow, moving bed filter technology that is constructed with various media depths for different applications and configurations. This filtration steps is to remove floating sludge from the effluent or sludge that did not settle in the sedimentation tanks.
UV Filter	UV filter is being used to disinfectant for the effluent, it does not alter the water quality (expect for inactivating microorganisms).

Table 2: *RWZI Bubali additional process steps and description of technologies*

RWZI Bubali (Grey Line)	
Process Steps	**Description of technologies**
Primary Treatment	
Influent Pumping Station	The new IPS has a number of 2 pumps in operation with a capacity of 710 m^3/h each. Both pumps are in used and only 1 pump is currently operating, due water pipe capacity.
Stepping Screen (1)	The new Stepping Screen has a capacity of 710 m^3/h and is daily in operation
Grit Removal (1) T-Cup	The sand removal has a capacity of 710 m^3/h and is daily in operation.
Secondary Treatment	
Oxidation Ditch “Pasveer”	The original ditch is still being used nowadays, the only changes on the ditch is they put two extra brush aerators from the original design. A volume capacity of 7500 m^3.
Sedimentation Tank 3	A new Sedimentation tank is built to support the other two sedimentation tanks. The new Sedimentation tank is used in current operation and this tank has a volume capacity of 3354 m^3.
Sludge Thickener	Nowadays the sludge is collected in the sludge thickener and then transported to RWZI Parkietenbos where the sludge is further dried in a belt press. Since the sludge is being treated at RWZI Parkietenbos there are no odours nuisance anymore in the hotel area.
Tertiary Treatment	
DynaSand Filter	The DynaSand is an up-flow, moving bed filter technology that is constructed with various media depths for different applications and configurations. This filtration steps is to remove floating sludge from the effluent or sludge that did not settle in the sedimentation tanks.
UV Filter	UV filter is being used to disinfectant for the effluent, it does not alter the water quality (not on chemical components, expect for inactivating microorganisms).

2.1.2 Sources of wastewater

The main sources of wastewater being processed at RWZI Bubali is Domestic Wastewater from household, commercial establishments (restaurants, hotels, schools, apartments and public restrooms) and institutions, hospitals, etc. It should also be noted that Non-Sewage water derived from floods (storm water), urban runoff water (water from carwash garages, swimming pools and rainwater), etc. are also collected by the collection system and sent the RWZI Bubali for treatment.

The wastewater is being treated before discharge into the environment. The effluent from RWZI Bubali overflow into water bodies, such as Bubali Plas (a Bird Sanctuary and Salina's in the nearby area of the hotels) after the second stage treatment. Partly of the effluent is treated by the third stage treatment (sand filter and UV) and is being used for irrigation purposes, mainly for the two golf courses of Aruba (Divi Links & Tierra del Sol). At no conditions, untreated water will be discharged into the Bubali Plas or the sea, as this will pose a serious threat for the aquatic life. Figure 2, shows the location of Bubali Plas.

Figure 2: The location of Bubali Plas Aruba, Bubali Plas is a Bird Sanctuary.

As shown in figure 1 above, the overflow of RWZI Bubali is connected to Bubali Plas and a minimum of 3000 m^3 effluent needs to be discharged daily into Bubali Plas and as such keeping the ecosystem a life and from drying out. This ecosystem is one of the biggest tourist attraction on the island, where different kind of birds and other exotic animals can be watched in the wild. It is therefore imperative to prevent to discharge of untreated wastewater into the Bubali Plas and as such preventing eutrophication of Bubali Plas, i.e. chain destruction of the ecosystem and as such affecting the entire life cycle in the Bubali Plas.

Figure 3: An aerial photo of the Bubali Plas.

2.1.3 Overview of wastewater infrastructure in area

The RWZI Bubali has a wastewater collection network consisting of 17 lift stations with an approximately total length of 53 km and covers the west side of the island. Figure 4 shows part of the wastewater collector network connected to RWZI Bubali which covers the areas of Cas Paloma/Simeon Antonio, Oranjestad, Madiki, Santa Helena, Dakota/Tarabana and the Low Rise hotels.

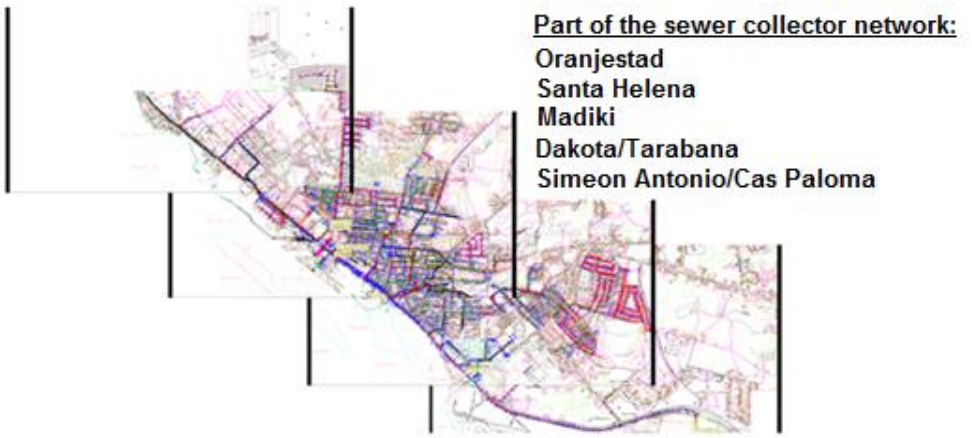

Figure 4: Shows part of the wastewater collection network on the west side of the island.

Future expansion of the wastewater collection network of RWZI Bubali will be in the area Noord (Bubali). Marriot Hotel is planning to develop a Residence in the neighborhood of Bubali (See Figure 5). Most of these Residence will be connected to the wastewater collection network of RWZI Bubali. This means all the houses and commercial establishment in that area which are not yet connected, will be connected to the wastewater line in the future. As such there will be an increase in the influent and load of the Bubali treatment plant. This report does not include the feasibility study which is to be performed for the above mentioned capacity and load increase conditions.

Figure 5: Indication of the location where Marriot Residence will be built.

2.2 The current situation of aeration system

The existing aeration system of RWZI Bubali dates back to the early start of the treatment facility. The aeration system is an oxidation ditch type (Pasveer) with surface aeration (Brush Aerators). Figure 6 shows a schematic of the RWZI Bubali oxidation ditch with the surface aerators. Table 3 gives the technical specification of the oxidation ditch and the twelve Mammoth Rotors.

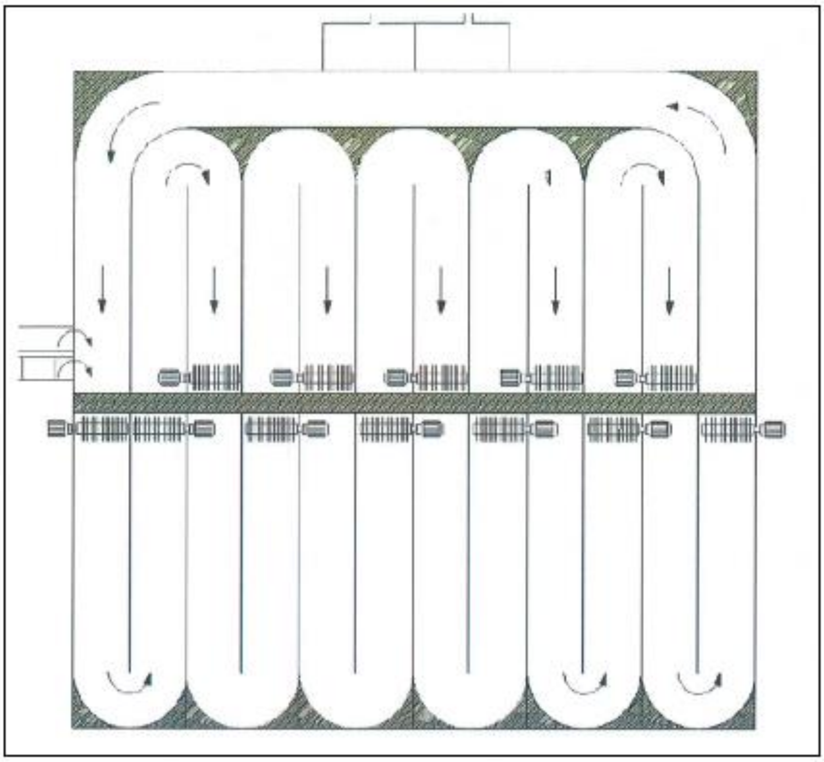

Figure 6: Schematic drawing of the aeration system of RWZI Bubali.

The total oxygenation input capacity (kg O_2/h) which can be achieved with the present Mammoth Rotors is shown in table 3. The dissolved oxygen has been measured during a site visited at RWZI Bubali and the results are 0,0 mg/l (HQd Portable Meter, HACH Lange). Figure 7 shows a picture of the aeration system of RWZI Bubali. The lack of oxygen brings various problems such as foaming, etc. (see figure 7 for the foaming problem). There are a main group of filamentous bacteria which can cause this problem. The most commonly bacteria causing this problem is *Microthrix Parvicella*. The *Microthrix Parvicella* can grow over a wide range of oxygen concentration. This especially when the dissolved oxygen is 0,4 mg/l or lower. Another factor could be the present of gas bubbles (e.g. CO_2, CH_4, N_2) and detergents.

Table 3: *Specification of oxidation ditch.*

Parameter	Unit	Value
Number of Aerators (Mammoth Rotors)	#	12
Oxygen Input per Aerator (Mammoth Rotors)	kg O_2/h	22
Total Capacity (Oxygen Input)	kg O_2/h	264
Oxidation Ditch (volume)	m^3	7.500
Oxidation Ditch (depth)	m	1,5
Oxidation Ditch (wide per section)	m	6,5
Oxidation Ditch (length per section)	m	65

Figure 7: Aeration system of RWZI Bubali.

2.3 Design capacity of the RWZI Bubali

2.3.1 Current design capacity & actual situation

The current design capacity of RWZI Bubali is shown in table 4 with the actual average biological load. The actual average daily hydraulic load (influent) in 2017 (8.607 m^3/d) is two times higher than the current design hydraulic capacity of the existing RWZI Bubali (4.500 m^3/d). The actual maximum inflow rate in 2017 (1.010 m^3/h) is a factor one and half higher than of the current influent design capacity of 600 m^3/h. The average daily hydraulic load has grown 2,0 to 3,0 % yearly since 2002. The actual biological load of RWZI Bubali has increase with 50% with respect to its current design capacity. This results into a much higher BOD load for the RWZI Bubali system.

The current design BOD load for the RWZI Bubali system is 0,05 kg BOD/kg.ds.d at the current design capacity of the influent. The actual BOD load at the RWZI Bubali is approximately 0,15 to 0,2 kg BOD/kg.ds.d. This is an increase of a factor 3 to 4 of the design load.

The required oxygenation capacity for effective treatment cannot be achieved with the present twelve brush aerators. The twelve brush aerators has each an oxygen transfer capacity of 22 kg O_2/h, in total an oxygen transfer of 264 kg O_2/h, whilst the requirements are much higher. The oxygen demand for the actual situation at RWZI Bubali is given in the following section.

Table 4: *Current Design Capacity Specification and Biological load.*

Parameter	Unit	Design Capacity RWZI Bubali	DOW Avg. load in 2002	Actual data Avg. load in 2017
Total TOD (based on 136 g BOD/pe)	-	33.000	35.864[5)]	50.275[4)]
Total PE (based on 54 g BOD/pe)	-	30.000	29.167[5)]	73.296[4)]
Maximum inflow rate	m^3/h	600	>600[5)]	1.010[2)]
Average daily flow	m^3/d	4.500	6.300[5)]	8.607[2)]
Hours of dry weather flow	h/d	16[1)]	16[1)]	22[3)]
Design temperature	^oC	28	28	28
COD load	kg/d	3.250	3.150[5)]	4.415[2)]
BOD load	kg/d	1.620	1.575[5)]	3.958[2)]
N-total load	kg/d	270	378[5)]	567[2)]
P load	kg/d	-	-	72
TSS load	kg/d	-	-	-
BOD/N ratio influent	-	6,0	4,2[5)]	7,0[2)]
Effluent disinfection	m^3/h	200	200[5)]	-

[1)] Assumption on the current design capacity and previous measurement DOW

[2)] Calculation of the actual hydraulic capacity based on the data measured by DOW and biological load from DOW laboratorial data.

[3)] Data collected from Meteo Aruba.

[4)] Calculated based on the data measured by DOW. Limited data has been provided by DOW.

[5)] Data measured and provided by DOW

2.4 Design Principles

A wastewater treatment plant will be designed, in general, to the hydraulic capacity (m^3/h) requirements and the degree of pollution (BOD) of the influent. Due to the fact that RWZI Bubali does not have a holding tank, the processing of the influent will be continuous. Hence, the hydraulic capacity depends on the capacity of the aeration tank and the aeration capacity.

2.4.1 Hydraulic Capacity

The hydraulic design of the wastewater treatment plant is determined by the maximum influent flow rates (m^3/d), taking into consideration the dry- and rainy season. Table 5 shows the design hydraulic capacity of the RWZI Bubali, current situation and the prediction up to 2030. This influent is affected by the amount of wastewater produced and the amount of rain water expected in the collection system. Hence, the collection system of the RWZI Bubali is connected to the rain collection system.

For the calculation of the amount of wastewater produced, the term Population Equivalent (PE) is the is the number expressing the ratio of the sum of the pollution load produced during 24 hours by industrial facilities and services to the individual pollution load in household sewage produced by one person in the same time. For practical calculations, it is assumed that one unit equals to 54 grams of BOD per 24 hours. DOW do not have the actual data of the amount of houses, commercial establishment or industries connected to the sewer network to RWZI Bubali. This method is used to calculate the actual PE for RWZI Bubali based on the actual hydraulic- and biological load data measured by DOW.

Furthermore, the effect of the rain (Qdwa-max) will have a great impact on the maximum influent capacity design of the RWZI Bubali in the future. The rainwater influence the maximum hydraulic capacity of a wastewater treatment plant. In Aruba the rain- and the wastewater is mixed together before reaching RWZI Bubali. Despite the constant weather in Aruba during the year. When it rains an average of 100 to 400 m^3 of rainwater falls for each square kilometer. The factor used for the minimum cope is 3 to 5 times the Qdwa-max. A wastewater treatment plant must be able to withstand a large hydraulic fluctuations, when the sewer collector network is used for both waste- and rainwater transported table 5 shows the current (2017) maximum hydraulic capacity for dry weather of 641 m^3/h.

Table 5: *Hydraulic Capacity of RWZI Bubali.*

Hydraulic Capacity (design principles)						
Parameter	**Unit**	**1972**	**2002**	**2017**	**2030**
Population Equivalent	i.e.	30.000 1)	29.167 1)	73.299 2)	103.330 2)
	v.e.	32.970 1)	35.864 1)	50.275 2)	70.138 2)
dry weather flow (Qdwa/d)	m^3/d	4.200 1)	4.083 1)	10.262 3)	14.466 3)
Qdwa-max. [Qdwa/d / 16 hours piek]	m^3/h	263 4)	263 4)	641 4)	1.209 4)
Qrwa-max. [Qdwa/d x 3 factor]	m^3/h	788	788	1.924	3.627
Qrwa-max. [Qdwa/d x 5 factor]	m^3/h	1.313	1.313	3.207	6.045
Qdwa-avg. [Qdwa/d / 24 hours]	m^3/h	175	170	428	806
1) The current hydraulic capacity of design (RWZI Bubali)					
2) The actual hydraulic capacity (Qdwa/d) is calculated based on the measured data of DOW. [PE i.e. = BOD load/0,054] & [TOD v.e. = COD + 4,57*N-kj*Qdwa/0.136]					
3) PE i.e. = 140 liter per person per day. Calculated based on this term. DOW measured for 2017 a Qswa/d of 8607 for RWZI Bubali.					
4) Qdwa-max is based on a 16 hours piek. Calculation of the hydraulic capacity to compare with the measuring data received of DOW.					

2.4.2 Biological load

The wastewater contamination (hence the environmental contamination if discharged to the nature) is determined by the organic material's supply load (BOD or COD) and the nutrients (nitrogen and phosphate). The contamination load is expressed in population equivalents (i.e.) or the pollution equivalent. In general the definition of i.e. is used for domestic wastewater and the pollution equivalent is used for industrial or company wastewater. Table 6 shows the contamination load in population- and pollution equivalents. In general, domestic wastewater contains a lot of organic material and few toxic substances. The BOD: COD ratio in fresh (domestic) wastewater corresponds to 1: 2 to 2.5 (if the wastewater ratio is higher, it is better biodegradable). According to the actual data, there is a clear increase in the BOD- (factor of 2,5), COD- (factor of 1,5) and N-total load (factor of 1,5) since 2002.

The daily load is mostly used as a starting point for the dimensioning and in some situations variations during the day as well as seasonal fluctuations must be taken into account. Therefore, the hydraulic- and biological load calculated for the future depends also on the expansion of the sewage collecting network. The infrastructure planning (Urban Wastewater Drainage Network) for the collecting of wastewater is very important for the future expansion of the aeration system.

Table 6: Biological load of RWZI Bubali.

Biological Load (design principles)					
Parameter	**Unit**	**1972[1)]**	**2002[2)]**	**2017[3)]**	**2030[4)]**
Population Equivalent	i.e.	30.000	29.167	73.299	103.330
	v.e.	32.970	35.864	50.275	70.138
Average daily flow	m^3/d	4.500	6.300	8.607	11.779
COD load	kg/d	3.250	3.150	4.415	6.223
BOD load	kg/d	1.620	1.575	3.958	5.580
N-total load	kg/d	270	378	567	868
P load	kg/d	-	-	72	-
TSS load	kg/d	-	-	-	-
BOD:COD	-	2,0	2,0	1,1	1,1
BOD/N ratio influent	-	6,0	4,2	7,0	6,4

[1)] The current design data for the biological load received from DOW.
[2)] The data of 2002 is also measured by DOW.
[3)] The data of 2017 is partly measured by DOW and calculated based on the measuring data received.
[4)] The data of 2030 is a forecast calculated with the limited data received from DOW.

2.4.3 *Sludge load*

The sludge load for the aeration tank of RWZI Bubali is shown in table 7. The sludge load of the aeration tank is determine according to the data received by DOW. The sludge load gives an impression of the ratio between the daily load and the total biomass (bacterial mass). The sludge load can varieties between a very low sludge load (0,05 kg BOD/(kg.ds.d)) to a high sludge load (>1,0 kg BOD/(kg.ds.d)). The sludge load affects a number of important factors and processes during treatment, such as:

- Purification efficiency
- Sludge growth and Sludge age (& stabilization degree of sludge)
- Nitrification & Denitrification
- Oxygen Demand of Sludge

The actual avg. sludge load in 2017 (0,16 – 0,18 kg BOD/(kg.ds.d) is three times higher than the current design sludge capacity of the RWZI Bubali (0,064 – 0,072 kg BOD/(kg.ds.d). The sludge load can increase in the coming years depends on the Qdwa and BOD load increase due to the future expansion of the sewer collection system.

The current design of sludge load (1972) has a sludge age of more than 25 days and the actual sludge load (2017) measured and calculated data shows that the sludge age is only 6 to 9 days.

Table 7: *Sludge load of RWZI Bubali.*

Sludge Load (design principles)					
Parameter	**Unit**	**1972[1)]**	**2002[2)]**	**2017[3)]**	**2030[4)]**
Population Equivalent	i.e.	30.000	29.167	73.299	103.330
	v.e.	32.970	35.864	50.275	70.138
Qdwa-day	m^3/d	4.500	6.300	8.607	11.779
Aeration Tank (*V*)	m^3	7.500	7.500	7.500	7.500
Aeration Tank (*V*)[3)]	m^3	8.488	8.488	8.488	8.488
Sludge load AT (*X*)[3)] [usually b/w 3,0 - 5,0]	kg/m^3	3,0	3,0	3,0	3,0
BOD load (S_0)	kg/m^3	0,360	0,250	0,460	0,474
Sludge load (*V* = 7500) [(Qdwa-d x S_0)/(V x X)]	kg BOD /(kg.ds.d)	0,072	0,070	0,18	0,25
Sludge load (*V* = 8488) [(Qdwa-d x S_0)/(V x X)]	kg BOD /(kg.ds.d)	0,064	0,062	0,16	0,22
Sludge age (*V* = 7500)	d	> 25	> 25	6 – 9	2 – 4
Sludge age (*V* = 8488)	d	> 25	> 25	6 – 9	2 – 4
1) The current design of the sludge is calculated based on the measurement data received from DOW.					
2) The data of 2002 of the sludge is calculated based on the measurement data received from DOW.					
3) The data of 2017 of the sludge is calculated based on the measurement data received from DOW.					
4) The data of 2030 is a forecast calculated with the limited data received from DOW.					

2.5 Oxygenation capacity (OC) and Oxygen demand (OD)

To design a new aeration system, the oxygen demand is to be calculated. Where after the technologies may be evaluated.

2.5.1 Oxygen demand (OD)

The total oxygen demand of an activated sludge system is made up of various factors. There are a number of methods being used to calculated the oxygen demand. The two methods most used are as follow:

- BOD, Nkj-Balance and Endogenous respiration (method 1)
- COD balance and Nkj balance (method 2)

Method 1 is considered as the traditional method (Hochschulansatz, HSA model) mainly used for the calculation of the total oxygen demand in wastewater using the BOD, Nkj-balance and Endogenous respiration and is being used for the calculation of the total oxygen demand (see table 8).

Method 2 is be called the COD method. This method does not use the Endogenous respiration. A good estimation for the sludge waste (given in COD) is required for the use this method. Due to lack of measuring data received from DOW, this method is not applied.

<u>Calculation:</u>
Oxygen Demand (OD) = $O_e + O_s + O_n + O_o + O_z$

OD = Total Oxygen Demand (kg/d)
O_e = Endogenous Respiration oxygen consumption (kg/d)
O_s = BOD oxygen consumption (kg/d)
O_n = Nitrification oxygen consumption (kg/d)
O_o = Oxygen consumption for the conversion of (rapidly) oxidizable components (kg/d)
O_z = Discharge of dissolved oxygen in effluent (kg/d)
* (under normal circumstances O_o and Oz are negligible)

<u>Endogenous Respiration Oxygen Consumption:</u>
$O_e = b \times V \times G_a$

b = Specific Endogenous Respiration factor (kg O_2/(kg.ds.d)
V = Volume aeration tank (m^3)
G_a = Sludge load aeration tank (kg ds/m^3)
* (In an aeration tank the sludge load is usually regulated between 3,0 to 5,0 kg ds/m^3)

The specific Endogenous Respiration factor (b) depends on the sludge load and temperature (for design principles: b = 0,06 kg O_2/(kg.ds.d) at 0,05 kg BOD/(kg.ds.d) and b = 0,10 kg O_2/(kg.ds.d) at higher sludge load > 1,0 kg BOD/(kg.ds.d). Table 8 shows the calculation of the Endogenous Respiration (O_e).

Calculation RWZI Bubali Oxygen Demand, as follow:
RWZI Bubali (aeration tank *V*, according to excel file): 8488 m^3
The sludge load aeration tank (G_a): 2,995 kg ds/m^3
Specific Endogenous Respiration (b): 0,10 kg O_2/(kg.ds.d)

O_e = 8488 x 2,995 x 0,10 → OD = 2.542 (Oe) + 1.880 (Os) + 2.073 (On)
OD = 6.495 kg O_2/d → 271 kg O_2/h

The current requirements are: 271 kg O_2/h

Table 8: *Oxygen Demand for RWZI Bubali.*

Oxygen Demand (OD)					
Parameter	**Unit**	**1972[1)]**	**2002[2)]**	**2017[3)]**	**2030[4)]**
Population Equivalent	i.e.	30.000	29.167	73.299	103.330
	v.e.	32.970	35.864	50.275	70.138
Average daily flow	m^3/d	4.500	6.300	8.607	11.779
Oe (η 80%)[5)] b = 0,06 kg O_2/(kg.ds.d) design sludge load [b x *V* x Ga]	kg/d	1.800	1.800	1.800	1.800
Oe (η 80%)[5)] b = 0,10 kg O_2/(kg.ds.d) high sludge load [b x *V* x Ga]	kg/d	3.000	3.000	3.000	3.000
Os (η 95%) [0,5 kg O_2 per kg]	kg/d	770	748	1.880	2.650
On (η 80%) [4,57 kg O_2 per kg]	kg/d	988	1.382	2.073	3.174
OD total/d b = 0,06 kg O_2/(kg.ds.d) design sludge load [Oe + Os + On]	kg/d	3.558	3.930	5.753	7.624
OD total/d b = 0,10 kg O_2/(kg.ds.d) high sludge load [Oe + Os + On]	kg/d	4.758	5.130	6.953	8.824
Oxygen Demand (OD) b = 0,06 kg O_2/(kg.ds.d) design sludge load [Oe + Os + On]	kg/h	149	164	240	318
Oxygen Demand (OD) b = 0,10 kg O_2/(kg.ds.d) high sludge load [Oe + Os + On]	kg/h	199	214	290	368
OD RWZI Bubali[6)]	kg/h	137	152	228	306
OD (RWZI Bubali)[7)]	kg/h	221	237	313	391
[1)] The oxygen demand of current design is calculated based on the measurement data received from DOW.					
[2)] The oxygen demand of data (2002) is calculated based on the measurement data received from DOW.					
[3)] The oxygen demand of data (2017) is calculated based on the measurement data received from DOW.					
[4)] The data of 2030 is a forecast calculated with the limited data received from DOW.					
[5)] Oe = volume 7500 m^3 & Ga 4,0 kg ds/m^3					
[6)] Data OD = volume 8488 m^3 & Ga 2,995 kg ds/m^3					
[7)] Data OD = volume 8488 m^3, b 0,14 & Ga 2,995 kg ds/m^3					

2.5.2 *Oxygenation Capacity*

Once the Oxygen Demand (OD) is determined, the Oxygenation Capacity (OC) can be calculated. The oxygenation capacity of an aeration system is defined as the amount of oxygen that the system can bring per hour in clean, oxygen-free water at an temperature of 10 ºC and at a pressure of 101,3 kPa. The OC is expressed in kg O_2 per hour and depending on the specification (or characteristics) of specific aeration system or device. The OC and OD are related as follow:

Oxygenation Capacity (OC) = OD * β / α

α = Alpha-factor (varies between 0,6 & 0,8 → assumption is 0,6)[4]
β = Beta-factor or deficit factor (7,47 g/l at T = 29 & 30ºC → 1,251)[4]

Table 9: *Oxygenation Capacity of RWZI Bubali.*

Oxygen Capacity (design principles)					
Parameter	**Unit**	**1972¹⁾**	**2002²⁾**	**2017³⁾**	**2030⁴⁾**
Population Equivalent	i.e.	30.000	29.167	73.299	138.170
	v.e.	32.970	35.864	50.275	92.976
Qdwa-day	m^3/d	4.500	6.300	8.607	15.359
OD (design load)	kg/d	3.557	3.930	5.753	9.895
OD (high load)	kg/d	4.757	5.130	6.953	11.095
OD (RWZI Bubali)3)	kg/d	3.282	3.655	5.478	9.621
OD (RWZI Bubali)4)	kg/d	5.316	5.689	7.512	11.654
OC (design load)	kg/d	7.416	8.194	11.994	20.632
OC (high load)	kg/d	9.918	10.696	14.496	23.134
OC (RWZI Bubali)3)	kg/d	6.843	7.621	11.422	20.059
OC (RWZI Bubali)4)	kg/d	11.083	11.862	15.662	24.299
OC (design load)	kg/h	309	341	500	860
OC (high load)	kg/h	413	446	604	964
OC (RWZI Bubali)3)	kg/h	285	318	476	836
OC (RWZI Bubali)4)	kg/h	462	494	653	1012
1) The oxygen capacity of current design is calculated based on the measurement data received from DOW.					
2) The oxygen capacity of data (2002) is calculated based on the measurement data received from DOW.					
3) The oxygen capacity of data (2017) is calculated based on the measurement data received from DOW.					
4) The data of 2030 is a forecast calculated with the limited data received from DOW.					
5) Data OD = volume 8488 m^3 & Ga 2,995 kg ds/m^3					
6) Data OD = volume 8488 m^3, b 0,14 & 2,995 kg ds/m^3					

The alpha-factors differs per aeration system. For the calculation of the Oxygenation Capacity in an active sludge system, the following alpha factors are mostly used worldwide:

- Bubble Aeration: 0,6 – 0,7
- Surface Aeration: 0,8 – 0,9
- Rotors Aeration: 0,9
- (Fast) Surface Aeration: 0,9

These numbers are the alfa-factor without the decreases over time due to pollution or aging of the aeration system.

3 Aeration Technology

3.1 General
Biological treatment system require oxygen to function properly. The actual oxygen requirement is used to identify the oxygen demand for a system (e.g. RWZI Bubali). Each wastewater treatment plant is specific and unique. Important parameters include temperature, dissolved oxygen level, plant elevation and the design of aeration equipment.

Either for domestic sewage or industrial wastewater, the purification is carried out by biological aerobic activated sludge process. In aerobic processes the pollutant present in the wastewater stream are removed or broken down by living micro-organisms. While the presence of nitrogen is essential for the growth of the micro-organisms that treat the waste stream, the presence of high nitrogen compounds in the effluent (not achieving the efficiency) can exert an oxygen demand and lower the dissolved oxygen content of the water. This can promote different detrimental in the aeration system, such as algae, light sludge, foaming, etc. In order to accomplish this efficiency, the aeration technology and system elected must not only be capable of transferring oxygen, but also maintain sufficient mixing of the micro-organism (sludge) with the oxygenated processes water without harming the activated sludge flocs. Therefore, the aeration equipment is the most important part of an activated sludge process.

3.1 Aeration Systems

In wastewater treatment processes, aeration introduces air into influent, providing an aerobic environment for microbial degradation of organic matter. The purpose of aeration of influent is two-fold:

1). To supply the required oxygen to the metabolizing micro-organisms and mixer for mixing the sludge in the aeration tank.
2). To provide mixing so that the micro-organisms come into intimate contact with the dissolved and suspended organic matter.

The two most common aeration system are bubble- (subsurface) and surface (mechanical) aerators. Figure 8 shows the aeration system most used worldwide. In a bubble aeration system air, usually from air compressor, is introduced by diffusers or other devices submerged in the aeration tank. Surface aeration system is a mechanical system that agitates the influent by various means (e.g. propellers, turbine or brushes) to introduce are from the atmosphere.

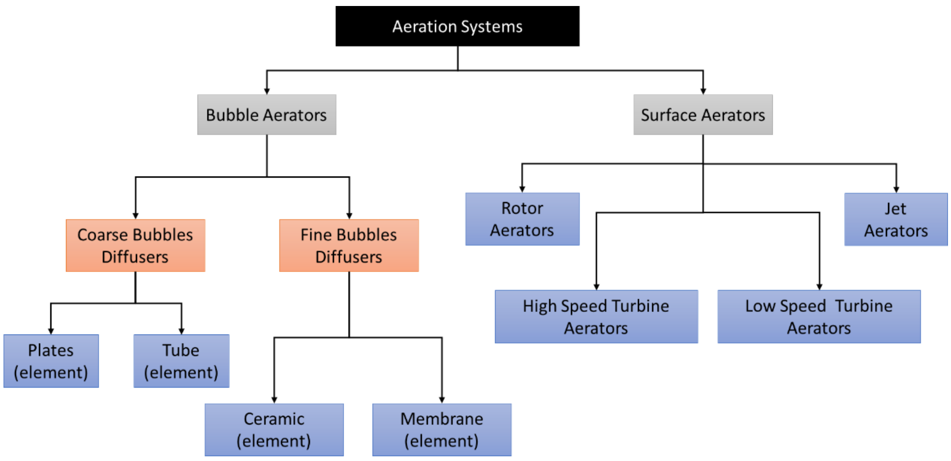

Figure 8: The most common aeration system available worldwide.

3.2 Bubble Aerators

Bubble aeration system are split in two section: coarse bubbles diffusers and fine bubble diffusers. Figure 9 shows the different between fine bubble diffusers and coarse bubble diffusers, both diffuser holds benefits over each other's.

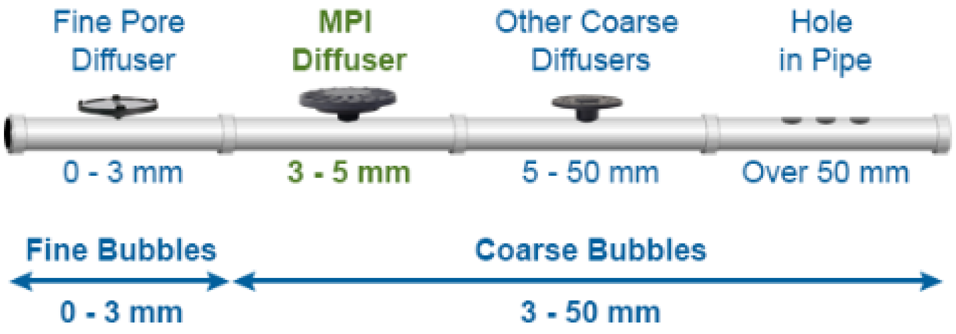

Figure 9: Different between fine- and coarse bubbles.

The biggest challenges with bubbles diffusers are their relatively short life span, due to clogging, blow off or cracking. Any bubble diffusers that eliminates these problems would deliver a huge costs-savings, not only in product replacement costs, but in system downtime needed for their cleaning or exchange.

Fine bubbles diffusion introduces very small bubbles into aeration system of the wastewater treatment plant. The main principle behind using fine bubbles is that the smaller bubbles result in more bubble surface area per unit volume and resulting into a greater oxygen transfer. The bubble sizes range from 0 to 3 mm.

Coarse bubbles diffusers introduces a larger bubbles than fine bubbles diffusers. Coarse diffusers offer affordable and a more durable system. These systems are ideal for situations that combine airflow mixing and oxygen transfers, mostly used in wastewater with high-solids content. Coarse bubble sizes range from 3 to 50 mm.

Although many materials (discs, tubes, domes, and plates, usually made either from ceramics, plastics or flexible perforated membranes) can be used to make fine or coarse pore diffusers. These diffusers systems can be controlled to achieve a desired amount of oxygen transfer by means of flow control from the compressor supplying the air.

This efficiency is dependent on the input power, air injection flow rate, the aerator submergence operation condition and tank or basin volume and geometry. The performance of bubble aerators are varied according to the type of material (ceramics or membrane) for diffusors, and the type of compressor. The standard aeration efficiency for bubble aerators is between 2,2 and 4,8 kg O_2 per kWh.

3.2.1 Maintenance of Bubble Aeration Systems:

An explanation of the minimum annual maintenance of bubble aeration system is as follow:

- Inspection and cleaning of the diffusers (routine),
- Inspection of the compressors (depending on the amount),
- Replace oil and (maintenance) air filters of compressors,
- Maintenance of the air distribution network, flow meter and valves.

3.2.2 Advantages and Disadvantages of Fine- & Coarse Bubble Diffusers:

Fine Bubble Advantages:

- High aeration efficiency,
- High oxygen transfer efficiency,
- Require less energy to run (compared to other aeration devices),
- Easily adapt to existing basins (for replacements or upgrades),
- Lower volatile organic compound emissions (compared to other aeration devices),
- Some advanced membrane materials offer outstanding resistance to chemical and fouling,
- Satisfy high oxygen demands.

Fine Bubbles Disadvantages:

- Diffusers are susceptible to chemical or biological fouling, which may impair transfer efficiency and generate high head loss,
- More expensive (require more routine cleaning and replacement, plus additional costs of maintenance and downtime),
- Energy costs challenges (when the pores of diffusers become clogged),
- Air flow distribution is critical and conflicting air flow requirements (mixing versus oxygen transfer),
- Aeration basin design must incorporate a means to easily dewater the tank for cleaning In small systems where no redundancy of aeration tanks exists, an in-situ, non-process-interruptive method of cleaning must be considered.

Coarse Bubbles Advantages:

- Less prone to plugging due to air mass coming from the larger hole openings,
- Optimal mixing capacity in tanks with thicker mass and sediments,
- Ideal solution for secondary treatment phase.

Coarse Bubbles Disadvantages:

- Consume more energy to operate (energy for air flow),
- Less efficient oxygen transfer,
- Less contact time (larger bubbles will ascend more quickly through the wastewater than smaller bubbles).
- Aeration basin design must incorporate a means to easily dewater the tank for cleaning In small systems where no redundancy of aeration tanks exists, an in-situ, non-process-interruptive method of cleaning must be considered.

3.3 Surface Aerators

Bubble aeration system are split in four type of aerators: Rotors-, Jet-, High- and Low Speed Turbine Aerators (See Figure 8 and 10). These four types of aerators are the most common for surface aerators worldwide. The impellers of the surface aerators have been improved to achieve better aeration since introduction of the surface aeration. Some system has been equipped with auxiliary propeller to enhance the gas bubbles dispersion inside the aeration tank of the wastewater treatment process.

It is important to mention that surface aeration efficiency is highly affected by the ambient temperature, since the major part of the aeration is achieved at water surface. However, due to the fact that the local the temperature is constant and with a small varieties during the day and night a couple of degrees, this will not affect the efficiency if implemented. The comparison of the standard aeration efficiencies for different aeration systems (SEA is defined as the transferred oxygen mass rate to the liquid per the power consumed at standard condition).

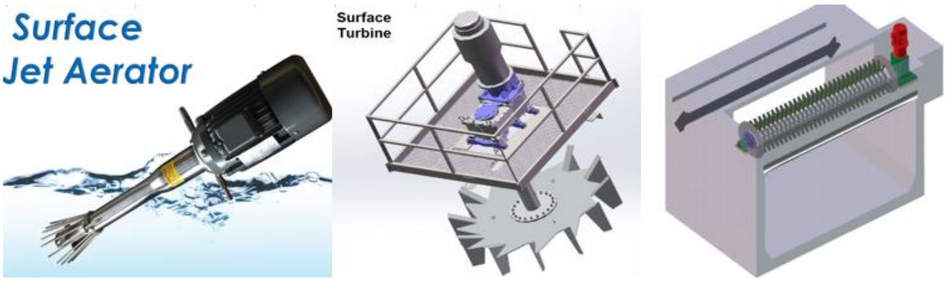

Figure 10: Surface Aerators.

As stated before, the efficiency dependent on the input power, air injection flow rate, the aerator submergence operation condition and tank or basin volume and geometry.

Surface Aerators								Supplier	Actuele Conditions
Surface Aerators	**Supplier**	**Model**	**Length**	**Diameter**	**Power**	**OC**	**Efficiency**	**Efficiency**	**Efficiency**
Type	[-]	[-]	[m]	[m]	[kW]	[kg O_2/h]	[kg O_2/kWh]	[kg O_2/kWh]	[kg O_2/kWh]
Brush	Landustrie	LANDY-1000	[-]	[0,7 - 9,0]	[30 - 47]	[54 - 85]	[1,8 - 2,0]	1,8	1,3
Brush	KAMPS	Brush	[-]	[1,0 - 9,0]	[3,0 - 37]	[5,0 - 65]	[1,5 - 1,8]	1,5	1,3
HS Turbine	Landustrie	LANDY-7	[-]	[1 - 3]	[1 - 250]	[25 - 400]	[1,8 - 3,3]	1,8	0,9
HS Turbine	SUEZ	Turbine	[-]	[8 - 15]	[2 - 50]	[10 - 90]	[1,8 - 2,2]	1,8	0,9
LS Turbine	KAMPS	AIRMAX	[-]	[1,15 - 3,5]	[5,5 - 200]	[15 - 400]	[1,8 - 3,3]	1,8	1,1
LS Turbine	EUROPELEC	SOFIE	[-]	[1,9 - 2,5]	[4 - 37]	[48 - 74]	[1,3 - 2,0]	1,3	1,1
Jet	Flygt Jet		[-]	[1,5 - 3,7]	[2,2 - 45]	[2,4 - 95]	[0,7 - 1,5]	1,5	0,9
Jet	Sulzer	ABS Venturi Jet	[-]	[-]	[1,6 - 20]	[5,0 -20]	[1,3 - 1,8]	1,3	0,9

Figure 11: The comparison of the standard aeration efficiencies (SEA) for different aeration system for standard conditions and practical conditions.

The most applied surface aerators the Rotors- and Turbine Aerators. Even though that their efficiency has increase drastically in the past decades, the surface aerators has a big disadvantage. Their energy consumption is higher compared to the bubble aerators.

3.3.1 Maintenance of Surface Aeration Systems:

An explanation of the minimum annual maintenance of surface aeration system is as follow:

- Inspection of the surface aerators,
- Replace oil of the surface aerators.

3.3.2 Advantages and Disadvantages of Surface Aerators:

Surface Aerators Advantages:

- Investment costs,
- Low maintenance costs,
- Universal applications (can be installed in a fixed or floating configuration in virtually any tank,
- Simple and robust construction,
- Higher life span (> 20 years) and excellent reliability,
- High mixing and easy to adjustment of the oxygen input capacity,
- No additional energy consumption for stirring the wastewater,
- Portable and thereby easy to install by simple floating.

Surface Aerators Disadvantages:

- Lower oxygen transfer efficiency, than bubble aerators,
- Use more energy (required more power 60% more), than bubble aerators,
- Dead zones in the aeration tank (ineffective in deep water) – have limited ability to mix lower than 6 feet below and sludge accumulation inevitably occurs on the bottom,
- Trouble in cold weather,
- The lack of control of the oxygenation rate or flow,
- The ability to destroy the sludge formation (sludge flocs).

4 Recommendation advice

4.1 General information

The technical description of the alternative aeration technologies are briefly explained in this section. The cost estimates are based on the following:

- The results of assessment of the current situation at RWZI Bubali for the aeration system. Replacement of all 12 brush aerators for a new aeration technology suitable for RWZI Bubali and the Oxygenation Capacity (between 500 – 600 kg O_2/h).
- Specifications of the alternative aeration technologies (replacement of the current aeration system, to handle the current influent and future influent load for RWZI Bubali).
- The current oxidation ditch is more than 45 years old and it surpass its technical life-span (the oxidation ditch has to be replace or renovate). Recommendation is to build new aeration tank and system for RWZI Bubali.

The aeration tank has to include a compact aeration system, which is equipped with the latest proven aeration technology or system. It is recommended to construct a new aeration tank complete with a new aeration system as to ensure a better quality of the effluent. This new aeration tank can be provided with a state-of-the-art processing, in which the focused will be on an optimal purification, low energy consumption and low maintenance costs.

4.2 Infrastructure of RWZI Bubali

The infrastructure at RWZI Bubali is shown in Figure 12. There is enough area where adaptation can be apply for enhancement of the wastewater treatment plant.

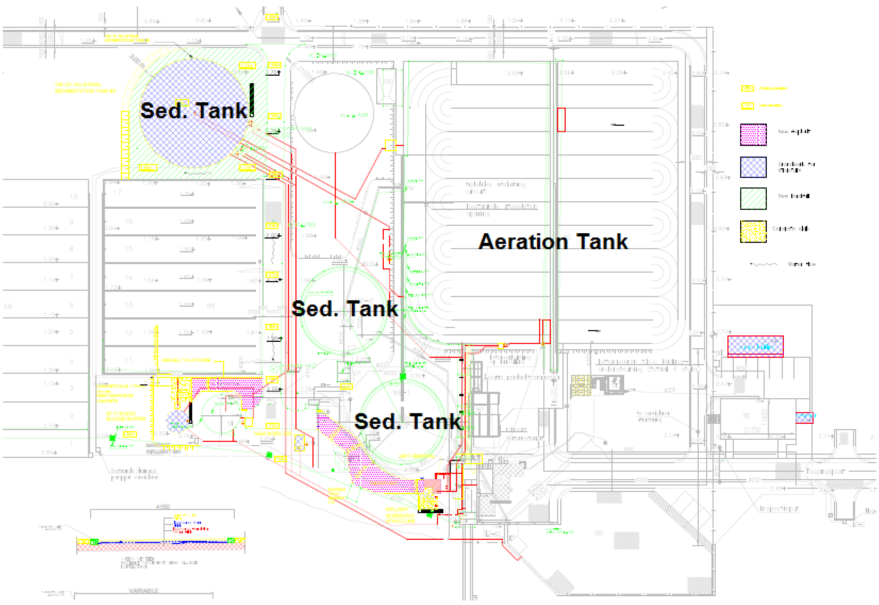

Figure 12: Drawing of the current situation of RWZI Bubali.

Figure 13 shows the proposed adaptation of RWZI Bubali. Build 2 new aeration tank and converted the 2 sedimentation tank into presettling tanks for the aeration. Restore the old aeration tank as an effluent storage tank before overflowing to Bubali Plas. Further, studies has to be done on the integration/adaptation of the RWZI Bubali. The process cannot be stop for performance enhancement.

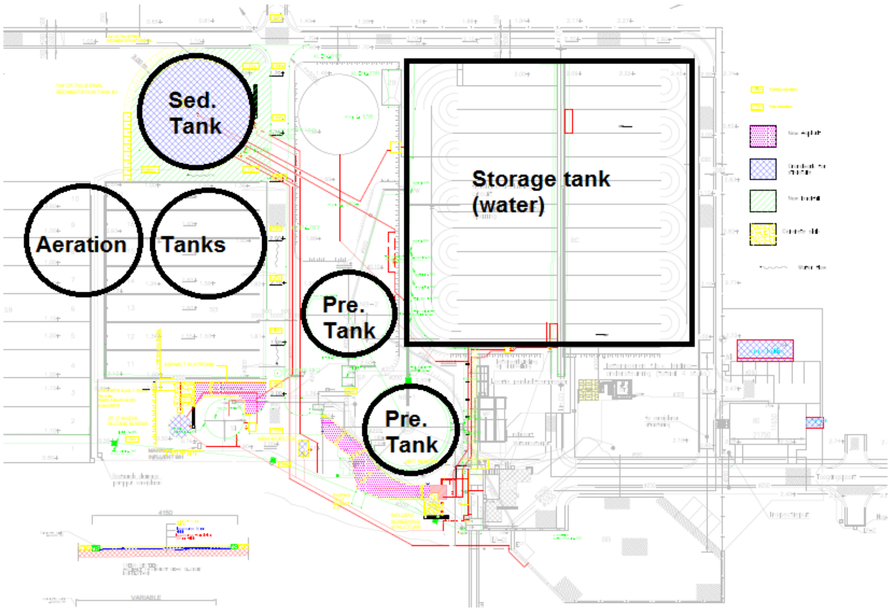

Figure 13: Proposed adaptation of RWZI Bubali.

4.3 Energy Consumption

The energy consumption of the alternatives aeration technologies are based on the known supplier and practical conditions. The standard aeration system efficiency in kg O_2/kWh in actual conditions for the following aeration technologies:

- Fine Bubbles; 2,4 kg O_2/kWh
- Coarse Bubbles; 2,2 kg O_2/kWh
- Surface Aerators High Speed Turbine; 0,9 kg O_2/kWh
- Surface Aerators Low Speed Turbine; 1,1 kg O_2/kWh

The energy consumption is being calculating using these efficiency. The standard aeration efficiency given by supplier are usually higher than practical conditions. The supplier measure it in standard condition efficiency (SAE) and wastewater treatment plant uses actual aeration efficiency (AAE). SAE is usually 50% higher than AAE.

Table 10 shows the energy consumption for the current situation (the oxygen capacity is not enough to achieve a good quality effluent quality) and the alternative aeration system (to achieve the oxygen demand and optimum effluent quality) for the influent load of RWZI Bubali. For the current situation, the Brush rotors are not coping with the minimum oxygen demand and enhance the current process will not reduce the energy cost and/or enhance the effluent quality.

The propose new aeration system for RWZI Bubali is fine- or coarse bubble aerators, due to their lower energy consumption compare to surface aerators.

Table 10: *Energy consumption aeration system versus current situation*.

Energy Consumption						
Parameter	**Unit**	**Current[1)]**	**SA, HS Turbine[2)]**	**SA, LS Turbine[3)]**	**Fine Bubbles[4)]**	**Coarse Bubbles[2)]**
Aeration required	kg O_2/h	264	500	500	500	500
Efficiency aeration unit	kg O_2/ kWh	-	0.9	1.1	2.4	2.2
Energy usage per day	kWh/d	4.044	13.344	10.920	5000	5472
Energy usage per year	AWG/ year	753.028	2.482.487	2.031.125	930.933	1.015.563
[1)] Current situation at RWZI Bubali 12 Brush Rotors						
[2)] Surface Aerators, SUEZ High Speed Turbine						
[3)] Surface Aerators, KAMPS Low Speed Turbine						
[4)] Fine Bubble Aerators						
[5)] Coarse Bubbles Aerators						

4.4 Financial analysis

A rough financial analysis has been carried out, in which the following components have been evaluated:

- Capital Expenditure (CAPEX)
- Operating Expenditure (OPEX)

* (the accuracy of the estimate can be assumed at +/- 15%)

4.4.1 CAPEX

Table 11 summarizes the investment costs for the new alternative aeration system. The investment costs includes the following:

- 2 new aeration tanks, Aqua store Tanks (Civil Engineering)
- Aeration system, Mixer or Propeller and Decanter Device (Mechanical Engineering)
- Electrical & Process Automation (based on 10% of Civil & Mechanical Costs)
- Indirect- or additional costs

<u>* Aeration System;</u>

- Surface Aerators Investment Costs includes:

  - ➢ surface aerators,
  - ➢ steel bridge construction,
  - ➢ aerators house (cover),
  - ➢ draft tube and adjustable spillway.

- Bubbles Aerators Investment Costs includes:

  - ➢ compressor,
  - ➢ aeration element,
  - ➢ piping & fittings,
  - ➢ energy building and lift stations.

These costs are based on information from the desk study and some previous practical research. The contractor’s cost varies between 30 – 40%. This is depending of the type of construction use.

Table 11: *Capital Expenditure (CAPEX) for an oxygen capacity 500 kg O_2/h.*

Capital Expenditure (CAPEX)				
	SA, HS Turbine[1)]	**SA, LS Turbine[2)]**	**Fine Bubbles[3)]**	**Coarse Bubbles[4)]**
Construction Cost				
Civil Eng. 2 AquaStore tank (V = 6000 m^3)	3.489.545	3.489.545	3.489.545	3.489.545
Mechanical Eng. (aeration system)	2.087.227	954.046	2.975.098	2.975.098
Electrical & Process Automation (10%)	557.677	444.359	646.464	646.464
Total Equipment Cost (AWG)	6.134.450	4.887.951	7.111.108	7.111.108
Contractor Cost				
Contractor (35%)	2.147.057	1.710.783	2.488.888	2.488.888
Indirect Cost (10%)				
Civil Eng.	348.955	348.955	348.955	348.955
Mechanical Eng.	208.723	143.107	297.510	297.510
E & PA	55.768	44.436	64.646	64.646
Total Indirect Cost (AWG)	613.445	536.497	711.111	711.111
Total Investment Cost (15%, uncertainty, insurance and additional costs)	10.229.195	8.205.516	11.857.773	11.857.773
[1)] Surface Aerators, SUEZ High Speed Turbine				
[2)] Surface Aerators, KAMPS Low Speed Turbine				
[3)] Fine Bubble Aerators				
[4)] Coarse Bubbles Aerators				

4.4.2 OPEX

Table 12 shows a summary of the operating expenditure costs, which only contains the operating expenses directly related to the investment. Other costs such as sludge removal, personnel, transport, etc. are not included as that these are cost already being incurred. The current total OPEX of RWZI Bubali is 1.391.000 AWG per year. The current total OPEX for the 12 Brush Aerators is 788.028 AWG per year.

The new calculate OPEX costs depends on the new aeration system chosen for RWZI Bubali. The current Maintenance Costs of the 12 Brush Aerators is 35.000 AWG per year and the Energy Costs is 753.028 AWG per year. The description of the current maintenance costs for the aerators is not specific on what kind of maintenance it is: Civil Eng., Mechanical Eng. or Electrical & Process Automation.

Table 12: *Operating Expenditure (OPEX) for an oxygen capacity 500 kg O_2/h.*

Operating Expenditure (OPEX)				
	SA, HS Turbine[1)]	**SA, LS Turbine[2)]**	**Fine Bubbles[3)]**	**Coarse Bubbles[4)]**
Maintenance Costs				
Civil Eng. (2,0%)	69.791	69.791	69.791	69.791
Mechanical Eng. (aeration system)	17.694	3981	21.563	21.563
Electrical & Process Automation (5,0%)	27.884	20.068	32.323	32.323
Total Maintenance Costs (AWG)	**115.369**	**95.990**	**123.677**	**123.677**
Energy Costs				
Aeration Technology	2.482.487	2.031.125	930.933	1.015.563
Total Energy Costs (AWG)	**2.482.487**	**2.031.125**	**930.933**	**1.015.563**
Total Maintenance Costs (15%, uncertainty and additional costs)	**2.987.534**	**2.446.183**	**1.212.802**	**1.310.126**
[1)] Surface Aerators, SUEZ High Speed Turbine				
[2)] Surface Aerators, KAMPS Low Speed Turbine				
[3)] Fine Bubble Aerators				
[4)] Coarse Bubbles Aerators				

4.4.3 Payback Period

According to the forecast calculated for RWZI Bubali shows that action must be taken soon (within 2 years) in order to be able to process the current- and future influent. It is known that the current aerators have to be replaced for a new aeration system to reach the minimum oxygenation capacity required.

The payback period of the new investment (aeration system) will be determined based on the savings of the energy costs per year. Table 13 shows the payback period of the investment. Assumption depreciation years is 20 and interest rate is 4,5%, the payback time of the investment is 5,84 years. The payback time can be shorter and the total savings costs per year can be higher depending on the new design, the operating costs and amount of effluent being bought by hotels or private parties.

Table 13: *Payback Period.*

Payback Period			
	Unit	**Current Costs**	**New Aeration System**
Investment	AWG		9.599.996
Annuity[1)]	AWG/year		792.678
Effluent (Costs) of 3500 m^3/d Profit [1,5 AWG per m^3]	AWG/year		1.642.500
Payback Period	year		5,84

[1)] The annuity (a) = 0,077 (depreciation years 20 year and 4,5% interest rate)

[2)] The 3500 m^3 is the amount of effluent that is being distributed to Divi Links and Tierra del Sol. The actual price is 1,0 AWG, due to a higher quality effluent the price is 1,5 AWG per m^3.

5 Summary and Conclusion

In this preliminary business case of RWZI Bubali, TNO executed a Quick Scan on the aeration system of RWZI Bubali and on the alternative aeration technologies available at present. This project is divided into sub-activities, the results of the sub-activities are as follow:

The current aeration tank has concrete degradation (major bacterial corrosion, physical damage or chemical damage), which is very dangerous for the operation of RWZI Bubali. If the concrete wall of the aeration tank collapse, all the wastewater cannot be processed and all the drainage collection network will overflow in Oranjestad and Hotels areas. This can have a major effect on our major income which is tourism.

Based on the calculation in chapter 2, the current aeration system (Mammoth Rotors) cannot achieve the oxygen demand required for the biological load present in the influent. Because of this issue, the effluent quality is not being achieve, which the target is set to 80% efficiency. The current efficiency is lower than 50% and has a negative impact on the wetland Bubali Plas. This Bubali Plas has an overflows to the sea, which may cause irrecoverable damages to the marine life. The high nutrients disposal has an negative effect on our coral reefs and beach erosion (coastal management). This may also affect our tourism in the coming year in the demand of wastewater increases yearly, where diving areas are being affected by this issue and our beaches are washed out by erosion. The replacement of the current aeration system is imperative and urgent as to prevent further damages to the eco-system and also to prevent calamities (overflow at the Hotels).

Another, current affect is the post-treatment process is overloaded and need more frequent maintenance, as influence of higher maintenance cost yearly for the DynaSand and the UV-filter (more downtime).

It is recommended to replace the current system with an SBR system using fine bubble aeration technology is the most suitable technology available now on the market for the performance enhancement of RWZI Bubali. Especially, the low cost of energy consumption.

The investment costs for an SBR system with fine bubble aeration technology can have a return payback of 6 years, depending on the amount of effluent being sell to the hotels for irrigation or farmers.

Furthermore, it is recommended to execute a complete assessment of the wastewater treatment plant of RWZI Bubali for future improvement of the treatment plant. This should include monitoring of the Bubali RWZI for approximate 6 months minimum as collect data on the operation-, maintenance-, and energy costs for the current equipment’s and water samples (influent & effluent). Further, DOW needs to develop a Wastewater Treatment Management Plan for its 3 wastewater treatment plants and a Sewerage Management Plan.

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Appendix List of description

	Discription
Activated Sludge	Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogloeal bacteria) in aeration tanks in the presence of dissolved oxygen. The term “activated” comes from the fact that the particles are teeming with fungi, bacteria, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.
Aeration	The process of adding air to water. In wastewater treatment, air is added to freshen wastewater and to keep solids in suspension.
Aeration tank	The tank where raw or settled wastewater is mixed with return sludge and aerated. This is the same as an aeration bay, aerator, or reactor.
Aerobe	An organisms that requires free oxygen for growth.
Aerobic	(i) Having molecular oxygen as a part of the environment. (ii) Growing only in the presence of molecular oxygen, as in aerobic organisms. (iii) Occurring only in the presence of molecular oxygen, as in certain chemical or biochemical processes such as aerobic respiration.
Algae	Phototrophic eukaryotic microorganisms. Algae could be unicellular or multicellular. Blue-green algae are not true algae; they belong to a group of bacteria called cyanobacteria.
Anaerobe	An organism that lives and reproduces in the absence of dissolved oxygen, instead deriving oxygen from the breakdown of complex substances.
Anaerobic	(i) Absence of molecular oxygen. (ii) Growing in the absence of molecular oxygen, such as anaerobic bacteria. (iii) Occurring in the absence of molecular oxygen, as a biochemical process.
Anaerobic respiration	Metabolic process whereby electrons are transferred from an organic, or in some cases, inorganic compounds to an inorganic acceptor molecule other than oxygen. The most common acceptors are nitrate, sulfate, and carbonate.
Bacteria	Living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.
BOD	Biochemical Oxygen Demand – the rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from this oxidation. (amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter).
Chlorination	The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.
Denitrification	An anaerobic biological reduction of nitrate nitrogen to nitrogen gas, the removal of total nitrogen from a system, and/or an anaerobic

	process that occurs when nitrite ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubbles attach to the biological floc in the activated sludge process and float the floc to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers or gravity thickeners (See Nitrification).
CAPEX	Capital expenditure or Capital expense is the money or funds used to acquire or upgrade a company's fixed assets, such as expenditures towards property, plant, or equipment (PP&E).
COD	Chemical Oxygen Demand – the amount of oxygen in mg/l required to oxidize both organic and oxidizable inorganic compounds.
Denitrification	An anaerobic biological reduction of nitrate nitrogen to nitrogen gas, the removal of total nitrogen from a system, and/or an anaerobic process that occurs when nitrite ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubble attach to the biological floc in the activated sludge process and float the floc to surface of the secondary clarifiers or gravity thickeners (See Nitrification).
Disinfection	The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine or UV filter being the most frequently used in water and wastewater treatment plants.
Dissolved solids	Chemical substances either organic or inorganic that are dissolved in a waste stream and constitute the residue when a sample is evaporated to dryness.
Effluent	Effluent is an outflowing of water to natural body of water, or from a manmade structure. (liquid waste flowing out of a factory, farm, commercial establishment, or a household into a water body such as river, lake, lagoon or a sewer system or reservoir) The term "effluent" is treated water before being discharge into the environment or water body.
Endogenous respiration	A reduced level of respiration (breathing) in which organisms break down compounds within their own cells to produce the oxygen they need.
Filamentous organisms	Organisms that grow in a thread or filamentous form. This is a common cause of sludge bulking in the activated sludge process. *Microthrix Parvicella* is another filament former, which causes foaming and interferes with flocculation in a waste treatment plant.
Flow rate	Measure of the amount of fluid passing through the filter. This is always a variable of filter area, porosity, contamination and differential pressure.
HSA model	The HSA-method is based on an exchange of experiences from German universities (Hochschulansatz), wastewater treatment plants and water quality managers. In the STOWA manual of Nitrogen Removal" it has been proposed to use this German method in the Dutch situation for the design of a wastewater treatment plant with biological nitrogen removal (STOWA-1993). The HAS model is currently the most widely used method in the Netherlands for the design of an activated sludge system.
Hydraulic load	Hydraulic load refers to the flows (m^3/day) to a treatment plant or treatment process.

Influent	The liquid-raw (untreated) or partially treated – flowing into a reservoir, basin, treatment process or treatment plant.
Nitrification	An aerobic process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrifaction stage" (first-stage BOD is called the "carbonaceous stage")
Nitrifying bacteria	Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).
Primary treatment	A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.
OPEX	Operational expenditure or operating expense is an ongoing cost for running a process, business or system. In short, this is the money the business spends in order to turn inventory into throughput.
Qdwa	The amount of wastewater that is processed in a wastewater treatment plant depends on the (type of) system. (dry weather flow)
Qrwa	The amount of rainwater that is entering the drainage system and the wastewater treatment plant. (rainwater flow)
Runoff	Water running down slopes rather than sinking in Ex. erosion due to deforestation (Storm).
Secondary treatment	A wastewater treatment process used to convert dissolved or suspended materials into a form
Sedimentation	The process of subsidence and deposition of suspended matter from a wastewater by gravity.
Sewage	The used water and water-carried solids from homes that flow in sewers to a wastewater treatment plant. The preferred term is wastewater.
Sludge	The settleable solids separated from liquids during; the deposits of foreign materials on the bottoms of streams or others bodies of water.
Sludge age	A measure of the length of time a particle of suspended solids has been retained in the activated sludge process.
TSS	Total suspended solids – it is a water quality parameter used for example to assess the quality of wastewater after treatment in a wastewater treatment plant (the dry-weight measure of particulates present in the water).
Wastewater	The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater".