Manual

Design and Economy
of Aeration Systems

Preface

AQUA AERO has been accurately built and tested. Nethertheless – like in every software product - we cannot give a guaranty that this software is completely error free. So the responsibility for the result of the design remains at the consultant or engineer.

document:	manual
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1 Introduction

The aeration system is the most important equipment of a wastewater plant. 75% of the energy used for the wastewater treatment is covered by the aeration system. The correct design of the aeration system and the investing costs usually decide over the operation of the aeration system. A real comparison of two systems must cover the operation costs of the whole life cycle.

With AQUA AERO you are able to design the aeration system with the mixers and the pipelines for different chamber geometries. You have the choice of membrane aerators (as tubular-, disc- or plate aerators) and surface aerators (in the next version of AQUA AERO). Out of a database you can choose fitting aggregates for the single calculation steps.

As important efficiency parameter the oxygen efficiency is provided. With the calculation of investment, reinvestment and operating costs the economical calculation of AQUA AERO covers the whole life cycle of the aeration.

We added an important feature to AQUA AERO for all who want to optimize their construction: You can calculate more than just one project and compare them objectively by one value.

And you get a detailed documentation of the calculations and true scaled drawings of the equipment.

Shortly combined:

AQUA AERO is a powerfull tool for an economical and procedual planning of the aeration system for a sludge treatment plant.

2 User Hints

In the following we show some important details for the usage of the guide.

Important Text

Important text is marked with these symbols.Their meanings are:

info	Here you will find technical information regarding the way of calculation, for aeration technologies or the economical calculations.
⚠	Important advice for the use of AQUA AERO or for the technical or economical construction
Example	Calculation example to show mathematical or engineering correlations.

Conventions

In this documentation we use the following conventions:

- Controls like control panel, menu title, inputs and so on are printed **bold**
- Menu title and inside menu points are printed **bold** and are connected with “ > ”.

  Example: **File > Close**
- Numbers- and currency formatings are taken from Windows presettings.

Copyright

Like the software this documentation underlies a widespread, national and international law saved copyright.

3 Installation

Precondition

AQUA AERO requires a PC with about 50 MB of hard disk space, that is compatible with Windows 7,Windows 8 or Windows 10.
For reports requires a Microsoft Word from version 14 (MS Word 2010).

AQUA AERO is a software working with a graphic user interface using windows features. This is why Windows must be installed on your computer prior to running AQUA DESIGNER.

Installation

Downlaod AQUA AERO from our website bitcontrol.info . After start with **setup.exe** you have the demo version of AQUA AERO.

4 Handling

In this chapter the handling of AQUA AERO is described, beginning by the start of the software over the menu and symbol bar up to the flow sheme and the calculation forms.

4.1 Start and exit AQUA AERO

After a succeeded installation start AQUA AREO with the icon on your desktop.

Chose **File** > **Exit** in the menu bar. AQUA AERO and all open projects will be closed.

4.2 Control Elements

Menu Bar

The menu bar contains the functions **File**, **Side View**, **Reports**, **Options**, **Window** and with „**?**“ the help.

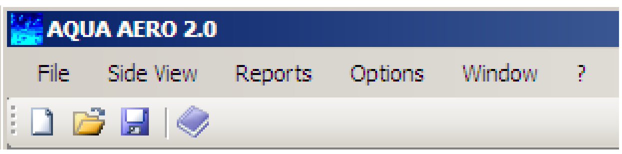
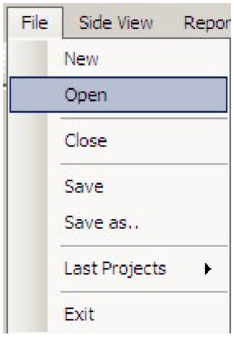
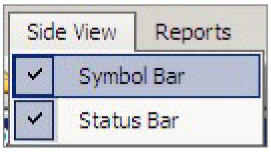
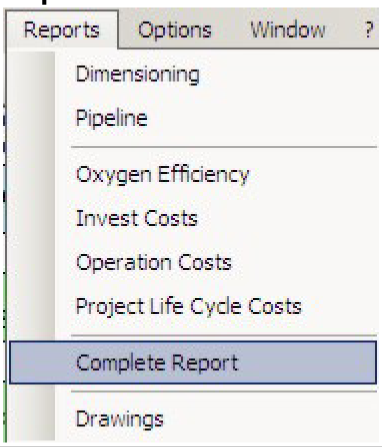
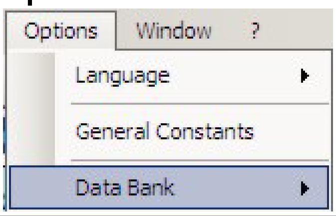
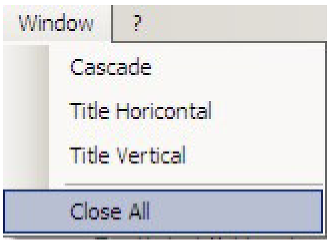


Fig. 1: Menu bar

Summary of the menu commands:

Menu	**Command / Description**
File 	**New:** Opens a new project **Open:** Opens an existing project (*.aero) **Close:** Closes the actual opened project **Save / Save as:** Saves a project with an individual name (*.aero) **Last Projects:** Shows a list of max. 4 projects **Exit:** Exit AQUA AERO
Side View 	**Symbol Bar** Show/hit symbol bar **Status Bar** Show/hit status bar at the bottom of the screen
Reports 	**Detailberichte:** Generates detailed reports in MS Word **Complete Report:** Generates the complete report from dimensioning up to the project life cycle costs **Drawings:** Shows a CAD-Drawing of the aeration
Options 	**Language:** Change language german / english **General Constants:** Access to some parameters, for example water temperature or pressure losses **Data Bank:** Change, add and delete aggregates
Window 	With AQUA AERO you can display and calculate more than just one project. **Cascade** **Title Horizontal** **Title Vertical** **Close All:** Closes all projects
Help ?	**Help:** Opens AQUA AERO's help

	Info: Infodialog of AQUA AERO

Icon Bar

You reach the following functions by the Icon Bar:

Opens a new AQUA AERO Project

Opens a saved AQUA AERO project

Saves an AQUA AERO project

Opens the online help

Flow Diagram

After opening a new project you will see a **flow diagram** at the left side of the screen. It shows the status of your calculation and the next possible calculation step. The **flow diagram** (block) shows the calculation steps and is always visible while calculating.

Meanings:

Color	Description
green	Calculation step was completed
yellow	Next possible calculation step
grey	Calculation step isn't possible at the moment
bold	Activated calculation form

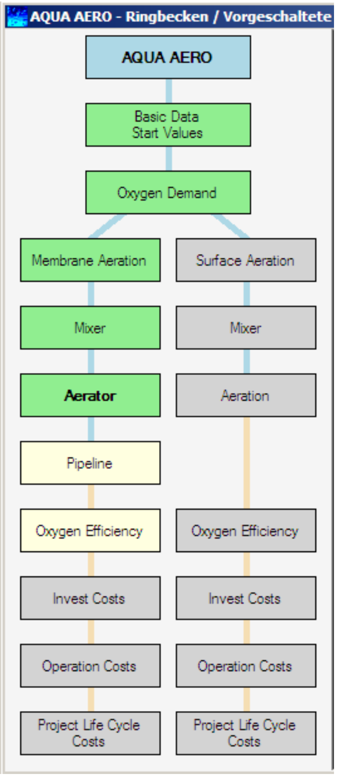


Fig. 2: Flow diagram

With a click onto a green or yellow block the inside calculation form will open.

Calculation Form

With a click to the block in the flow diagram you open the according form. After calculating you finish the form with the button **Apply** and go to the next calculation form via the flow diagram (yellow).

Color	**Meaning**
White	Input field
Grey	Not editable field

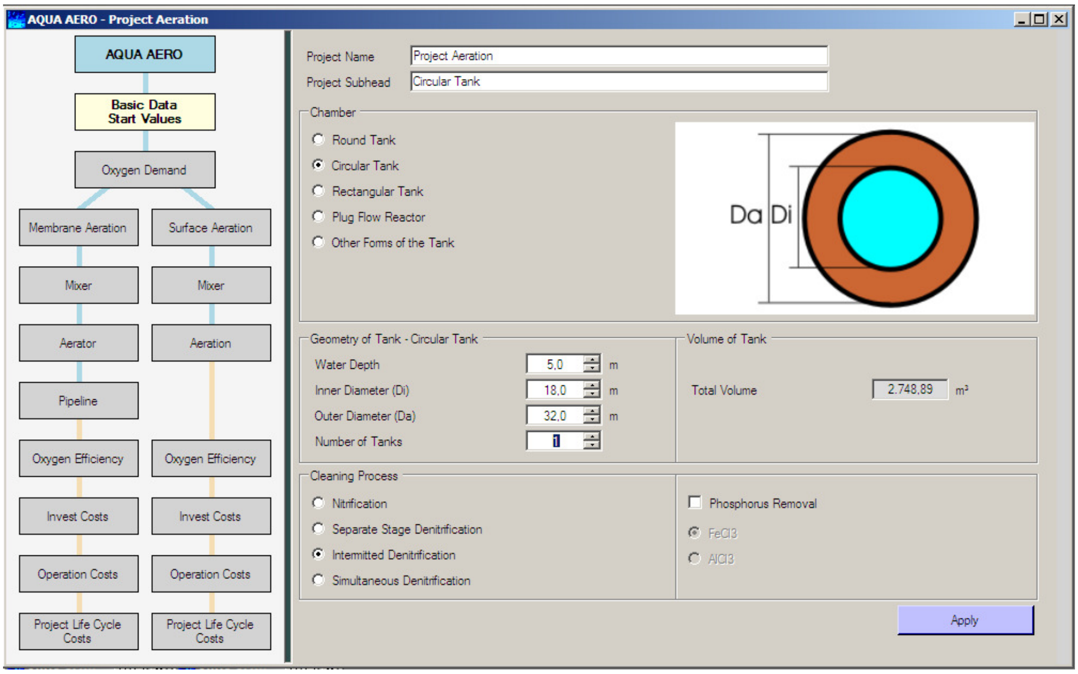


Fig. 3: Calculaion Form: Basic Data / Start Values

4.3 Context sensitive Help

The online help supports you in working with AQUA AERO.

You can activate the online help with the "**?**". Once you've pushed the question mark the help will open in a tree structure, where you can find themes quickly.

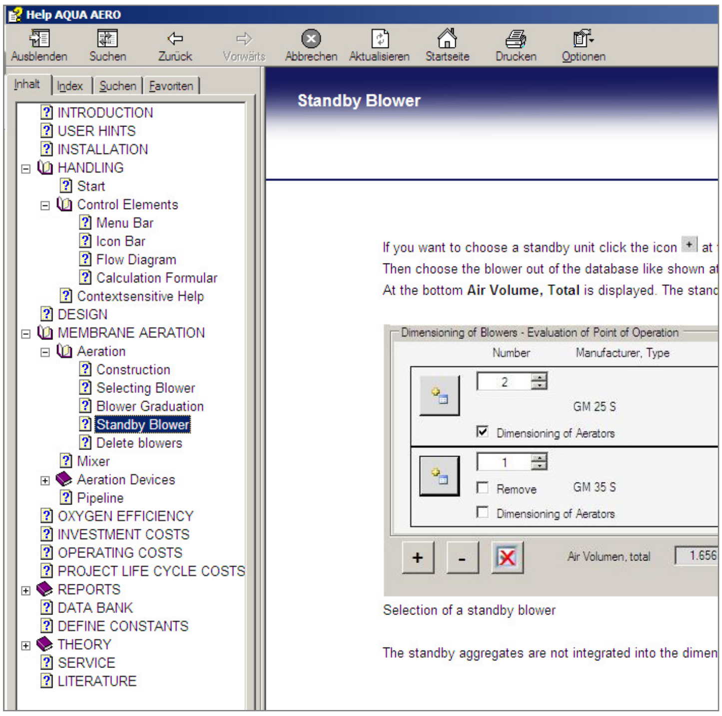


Fig. 4: Context sensitive help

In the registry **Index** important words are sorted alphabetically.

In the **Icon bar** of the help function there are some standard functions, which are described below:

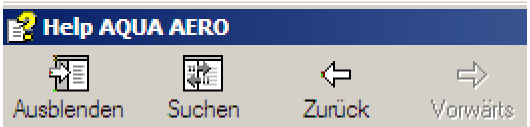


Fig. 5: Icon bar of the help function

With **Ausblenden** (hide), you remove the block scheme of the help function.

With **Zurück** (back) and **Vorwärts** (next) you skim through the pages of the help, that you already used (history). Here the functions were taken over, that you know from the internet.

With **F1** you come from AQUA AERO directly to the corresponding information at the help function.

5 Project Handling

New Project

In the icon bar click the Icon . The flow diagram and the calculation form will open.

Open Project

To open an existing project, go to **File > Open** and follow the standard diaolog of windows. Under **File > Last Projects** you'll find a list of the last four projects.

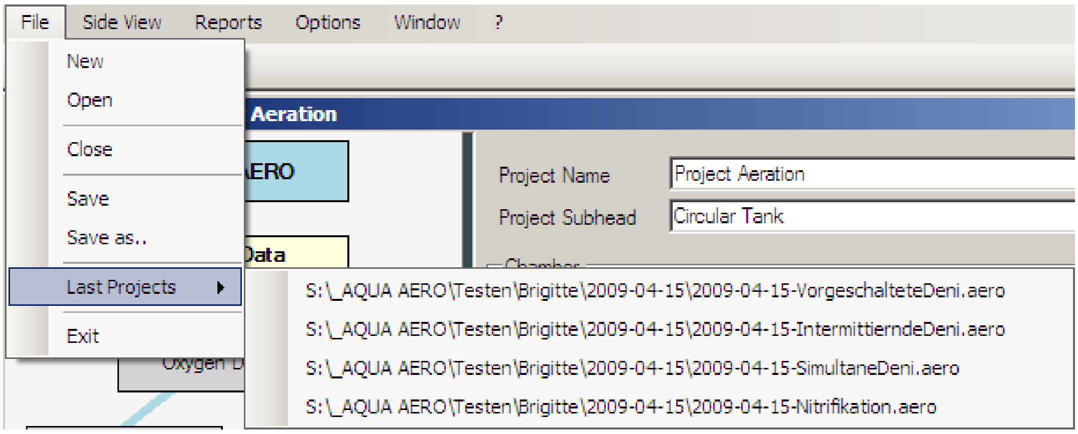


Fig. 6: Last Projects

Save Project

If you want to save a project, choose **File > Save** and follow the standard dialog of windows. With **File > Save as** it is possible to save a project additionaly at another position.

Change Project

If you make modifications in a project, all following steps has to be edited again, also all data bank contents has to be collected once again.

There are two exceptions:

If you choose an aerator with the same loading, the blower selection will remain.

The selected aerators will remain even if you make modifications.

All inputs in the white fields and partly the state of the chex boxes (active/inactive) will remain.

⚠ At modifications in a project, the inputs will remain. Please check, whether the data and check box contents are still matching or not.

6 Basic Data

Click on **Basic Data** / **Start Values** in the flow sheme and the first calculation form will be opened.

At first insert a project name and the subhead. Both positions are the title in the reports.

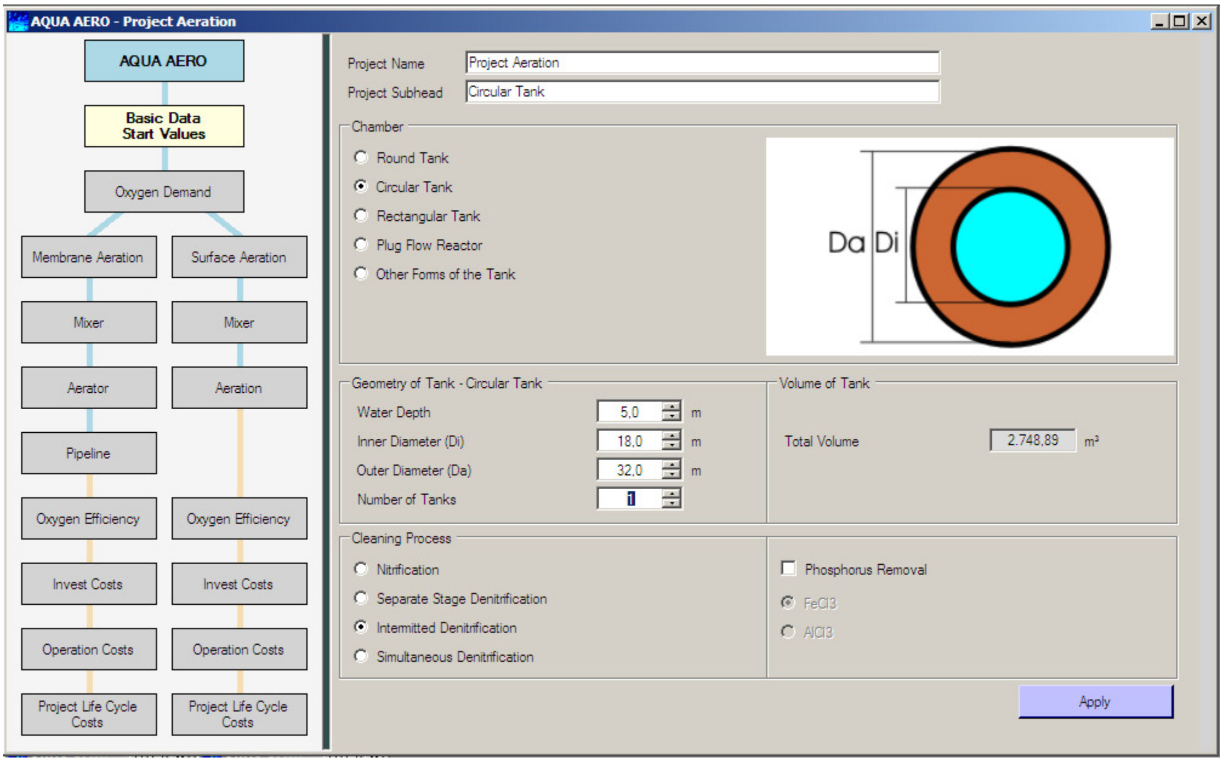


Fig. 7: Basic Data / Start Values

6.1 Geometry of the Tanks

The theoretical basis will be found under **Geometry**, page **47**.

Select the kind of chamber by the option buttons.

There are circular chambers, ring chambers, rectangular chambers, oxidation ditches and miscellaneous chamber types available.

The input fields will adapt to the chosen chamber geometry.

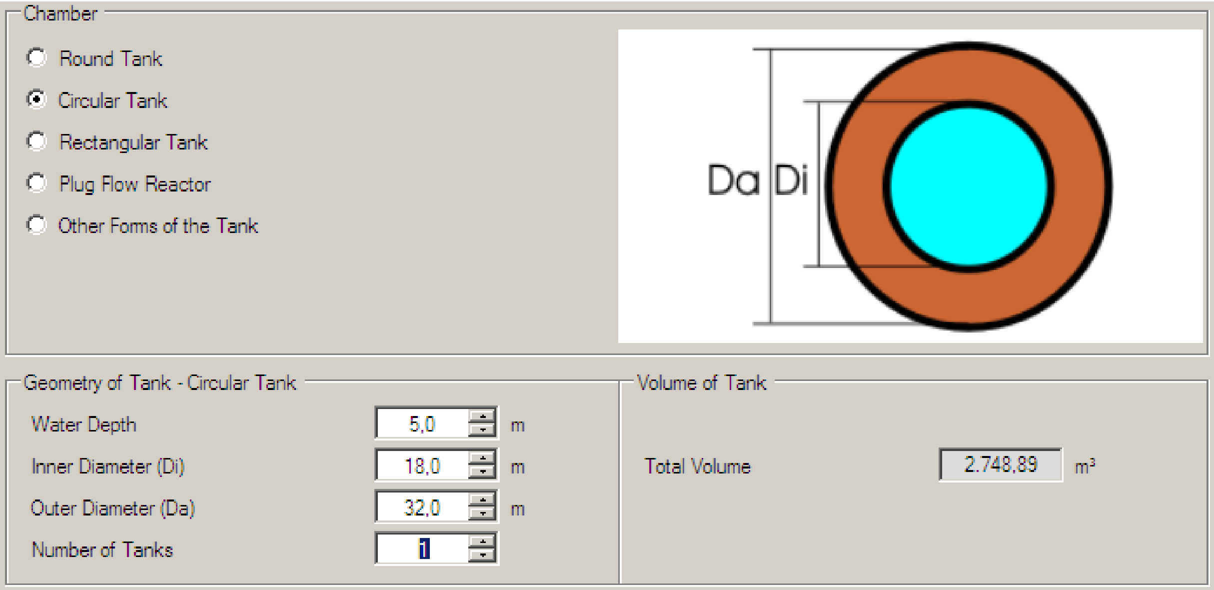


Fig. 8: Geometry of a Circular Tank

You can choose a number of lines of chambers. All calculation steps – except the mixers and aerators – reference on the total volume. In the reports you will find both the data for one line and for the total project.

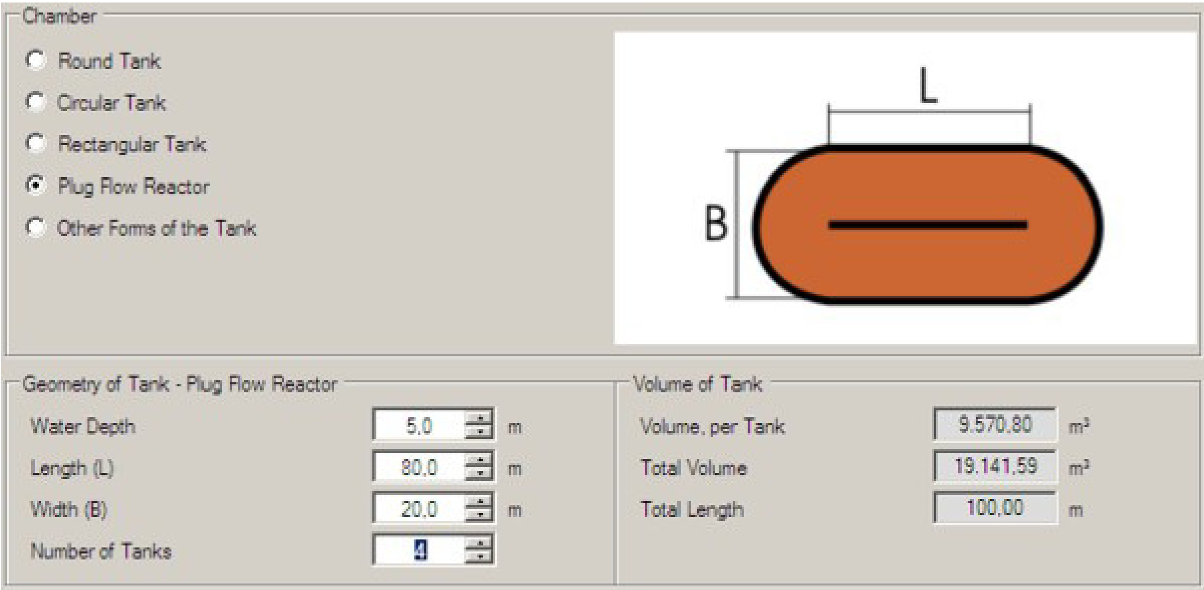


Fig. 9: Volume of four plug flow reactors

6.2 N- and P- Elimination Processes

Nutrient Elimination

The theoretical basis will be found under **Nutrient Elimination**, page **47**.

The aeration time is depending on the kind and the parameters of the chosen nutrient elimination process.

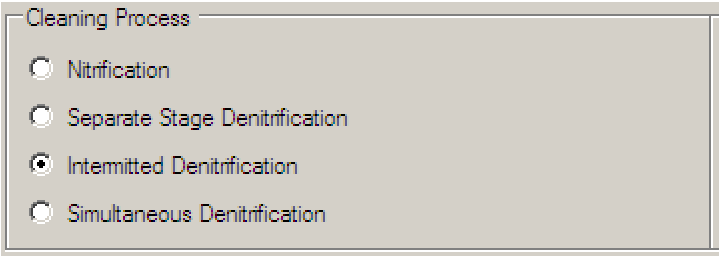


Fig. 10: Processes of Nutrient-Elimination

The following options are available:

- Nitrification (without denitrification; tL=24 h * tR/tZ)
- Separate Stage Denitrification (tL=24 h * tR/tZ)
- Intermittent Denitrification (tL is calculated)
- Simultaneous Denitrification (tL=24 h * tR/tZ)

Phosphate Elimination

The theoretical basis will be found under **Biological Phosphate Elimination**, page **50**.

The excess sludge production will increase by chemical precipitation, the sludge age will decrease.

By the check box you select, whether a phosphate precipitation should be included.

With the options button you select the precipitant.

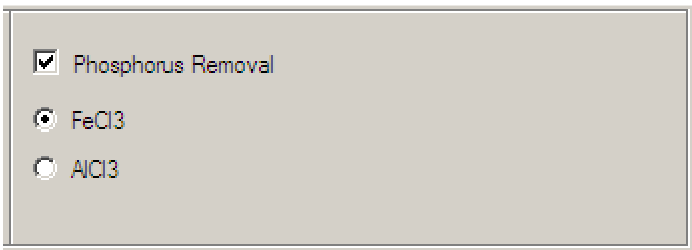


Fig. 11: Chemical Phosphate Precipitation

Click on **Apply** and then go to **Oxygen Demand** in the flow sheme.

7 Oxygen Demand

The theoretical basis will be found under **Determination of the Oxygen consumption** , page **51**.

In the form **Oxygen Demand** based on your pre selection for

- Chamber geometry
- Elimination processes
- Water amount and
- Concentrations or loads

The oxygen demand OUh and the oxygen supply SOTR for membrane aeration and surface aeration will be calculated and displayed.

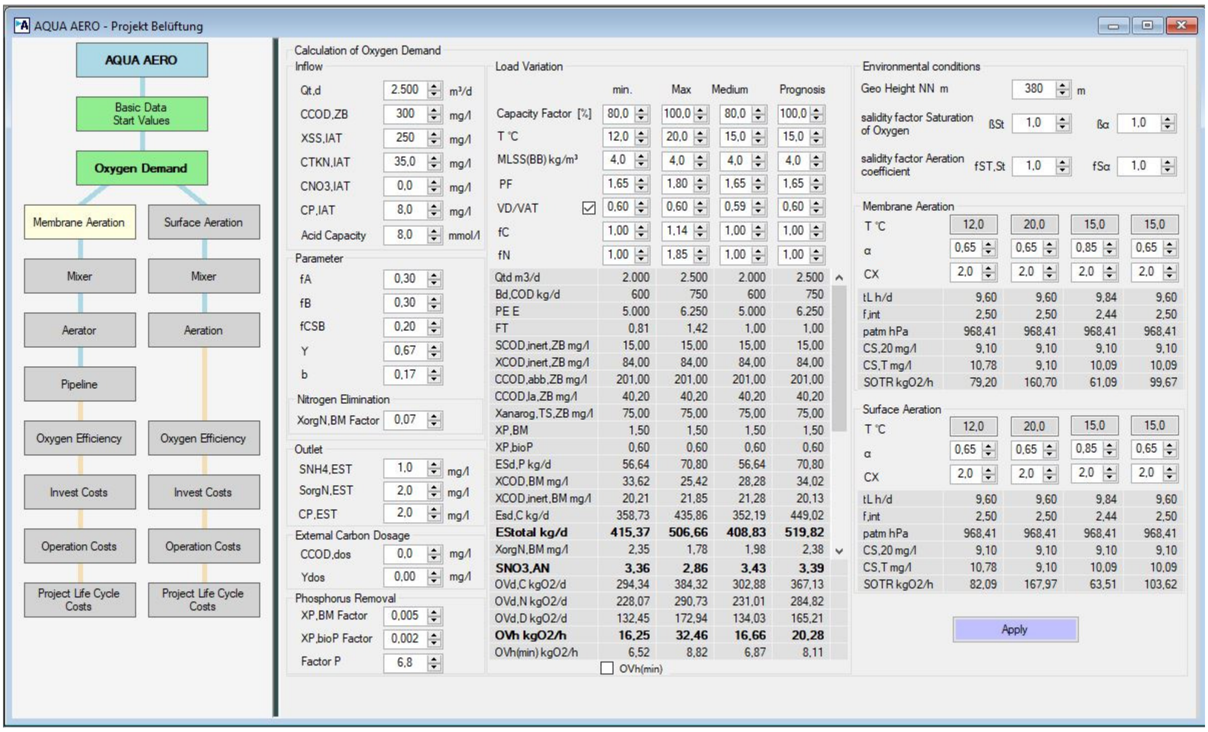


Fig. 12: Calculation of oxygen demand and oxygen supply

7.1 Inflow, Biology, Outflow

As the first step you have to input all data of the waste water inflow and the outflow require-ments.

In the form biology you define:

- how much nutrient will be incorporated in the biomass (XorgN,BM),
- the amount of biological eliminated phosphorus (XP,BM + XP,bioP)
- the security factor for the nitrification respectively the aerobic sludge age.

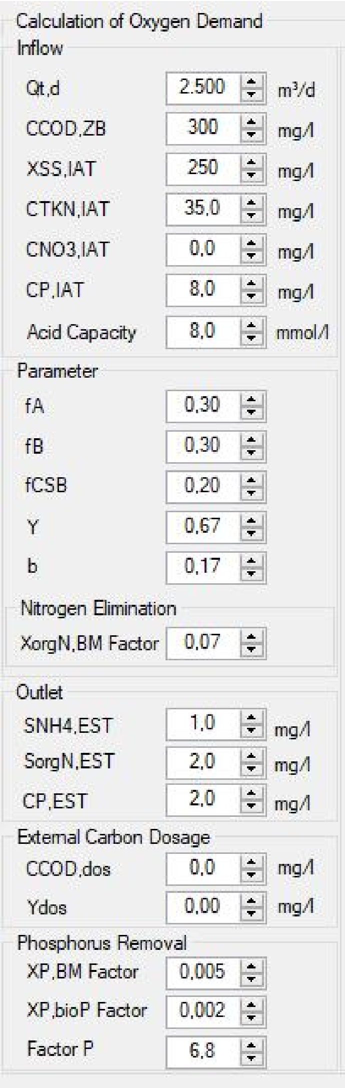
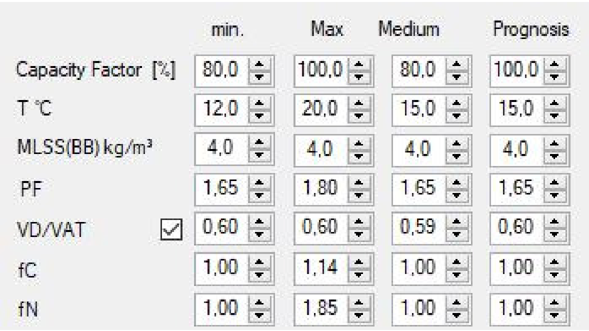


Fig. 13: Input of water amount and concentrations

The oscilation factor for nitrification takes the oscilations in the growth of nitrificians and the inflow concentrations in consideration. As standard the check box for the security factor is activated and the value will be interpolated based on the DWA-Values.

If you decide to continue with another factor, deactivate the check box and enter the preferred value.



	min.	Max	Medium	Prognosis
Capacity Factor [%]	80,0	100,0	80,0	100,0
T °C	12,0	20,0	15,0	15,0
MLSS(BB) kg/m³	4,0	4,0	4,0	4,0
PF	1,65	1,80	1,65	1,65
VD/VAT ☑	0,60	0,60	0,59	0,60
fC	1,00	1,14	1,00	1,00
fN	1,00	1,85	1,00	1,00

Fig. 14: Manually selection of the security factor

7.2 Loads

To illustrate the different load cases, four load case calculations are provided, as required in M 229-1.

• Load case1, minimum air requirement

• Load case 2, maximum air requirement, dimensioning of air requirement

• Load case 3, medium air requirement

• Load case 4, prognosis

Load Variation

	min.	Max	Medium	Prognosis
Capacity Factor [%]	80,0	100,0	80,0	100,0
T °C	12,0	20,0	15,0	15,0
MLSS(BB) kg/m³	4,0	4,0	4,0	4,0
PF	1,65	1,80	1,65	1,65
VD/VAT ☑	0,60	0,60	0,59	0,60
fC	1,00	1,14	1,00	1,00
fN	1,00	1,85	1,00	1,00

Qtd m3/d	2.000	2.500	2.000	2.500
Bd,COD kg/d	600	750	600	750
PE E	5.000	6.250	5.000	6.250
FT	0,81	1,42	1,00	1,00
SCOD,inert,ZB mg/l	15,00	15,00	15,00	15,00
XCOD,inert,ZB mg/l	84,00	84,00	84,00	84,00
CCOD,abb,ZB mg/l	201,00	201,00	201,00	201,00
CCOD,la,ZB mg/l	40,20	40,20	40,20	40,20
Xanarog,TS,ZB mg/l	75,00	75,00	75,00	75,00
XP,BM	1,50	1,50	1,50	1,50
XP,bioP	0,60	0,60	0,60	0,60
ESd,P kg/d	56,64	70,80	56,64	70,80
XCOD,BM mg/l	33,62	25,42	28,28	34,02
XCOD,inert,BM mg/l	20,21	21,85	21,28	20,13
Esd,C kg/d	358,73	435,86	352,19	449,02
EStotal kg/d	**415,37**	**506,66**	**408,83**	**519,82**
XorgN,BM mg/l	2,35	1,78	1,98	2,38
SNO3,AN	**3,36**	**2,86**	**3,43**	**3,39**
OVd,C kgO2/d	294,34	384,32	302,88	367,13
OVd,N kgO2/d	228,07	290,73	231,01	284,82
OVd,D kgO2/d	132,45	172,94	134,03	165,21
OVh kgO2/h	**16,25**	**32,46**	**16,66**	**20,28**
OVh(min) kgO2/h	6,52	8,82	6,87	8,11

☐ OVh(min)

Fig. 15: Load cases

As next select the MLSS in the activated chamber.

In the following field the maximum denitrification ratio is displayed. If the check box is inactivated, the calculation continous with this automatically calculated value. If you decide to lower the denitrification ratio, activate the check box and enter your suitable value. For the following calculations this value will be taken into account.

Load Variation			
T °C	10,0	12,0	20,0
MLSS(BB) kg/m³	5,0	5,0	5,0
VD/VAT ☑	0,25	0,40	0,45

Fig. 16: Denitrification ratio, chosen for T = 20°C

7.3 Peak Oxygen Uptake

The results in the following table will be automatically adapted to your inputs, so you easily can test the effect of variations in denitrification ratio, temperature etc.

In AQUA AERO not only the results – for example the oxygen peak - will be displayed. By showing all intermediate results, beginning with the sludge age, via the nutrient balance to the peak factors, the calculations are very transparent.

Load Variation			
T °C	10,0	12,0	20,0
MLSS(BB) kg/m³	5,0	5,0	5,0
VD/VAT ☑	0,25	0,40	0,45
BSS kg/kg/d	0,055	0,055	0,055
tSSaerob d	9,99	8,21	3,75
tSStotal d	13,37	13,59	14,38
OUC,BOD	1,10	1,14	1,24
VD/VATmax	0,25	0,40	0,50
SNO3,D	26,52	30,71	35,64
SNO3,D Req	33,20	33,20	33,20
SNO3,EST	**6,68**	**2,49**	**-2,44**
OUd,C kgO2/d	3.156,58	3.247,49	3.559,42
OUd,N kgO2/d	1.855,88	1.855,88	1.855,88
OUd,D kgO2/d	999,75	1.157,59	1.251,64
fC	1,17	1,16	1,16
fN	1,97	1,95	1,88
OUh,D (maxN)	242,01	237,76	241,57
OUh,D (maxC)	182,14	178,70	188,51
OUh,N (maxN)	283,67		
OUh,N (maxC)	230,73		

Fig. 17: Peak oxygen uptake OUh

7.4 Required Oxygen Supply

With the peak oxygen uptake the required oxygen supply SOTR for both aeration methods is the next step.

The required oxygen supply SOTR for the two different types of aeration is determined and compared by the peak oxygen consumption.

You can still influence the required oxygen concentration by entering your experience value for the oxygen supply factor α. The worksheet M 229-1 includes some tips for that.

Experienced values for the oxygen supply factor α you will also find in the theoretical part, see **Oxygen Supply Factor**, page **58**.

Membrane Aeration

T °C	12,0	20,0	15,0	15,0
α	0,65	0,65	0,85	0,65
CX	2,0	2,0	2,0	2,0
tL h/d	9,60	9,60	9,84	9,60
f,int	2,50	2,50	2,44	2,50
patm hPa	968,41	968,41	968,41	968,41
CS,20 mg/l	9,10	9,10	9,10	9,10
CS,T mg/l	10,78	9,10	10,09	10,09
SOTR kgO2/h	79,20	160,70	61,09	99,67

Surface Aeration

T °C	12,0	20,0	15,0	15,0
α	0,65	0,65	0,85	0,65
CX	2,0	2,0	2,0	2,0
tL h/d	9,60	9,60	9,84	9,60
f,int	2,50	2,50	2,44	2,50
patm hPa	968,41	968,41	968,41	968,41
CS,20 mg/l	9,10	9,10	9,10	9,10
CS,T mg/l	10,78	9,10	10,09	10,09
SOTR kgO2/h	82,09	167,97	63,51	103,62

Fig. 18: Required oxygen supply SOTR

After this you decide with what kind of aeration method you continue.

8 Design Membrane Aeration

8.1 Membrane Aeration

8.1.1 Aerator Design

Before starting the design and selection of the blowers, the kind of aerators is required. There are tube aerators, disc aerators and plate aerators available.

Click on the symbol for the data bank and select the suitable aerator. With **OK** you leave the aerator data bank.

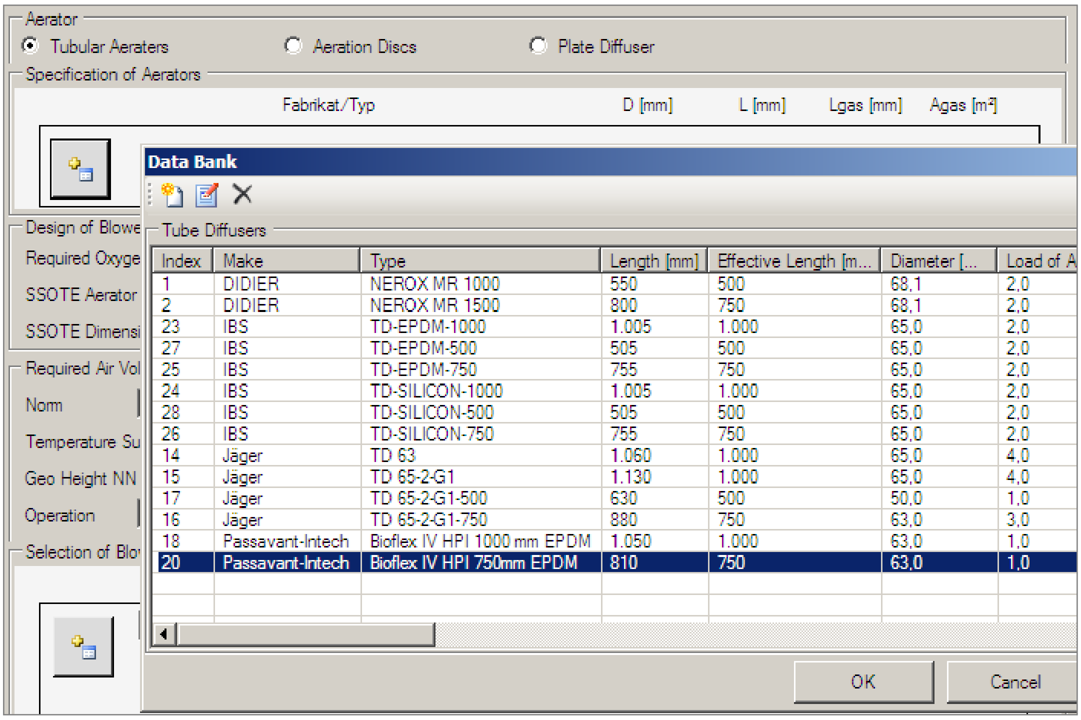


Fig. 19: Selection of aerator

The selected aerator will be displayed with the relevant properties. Deciding for the determination of the blowers is the specific oxygen yield and the pressure loss of the aerators. Both values are provided in the data bank.

8.1.2 Blower Design

The theoretical basis will be found under **Blower**, page **60**.

The blowers are designed by the required air volume in operation and the counter pressure of the aeration system. The dimensioning is for all chambers.

The required air volume in operation depends on the suction temperature, the geodetical height and the specific oxygen yield.

The counter pressure is the sum of water level, pipeline losses and the pressure loss of the aerator. The pressure loss of the pipelines can be edited in **Options > Generel Constants**. The standard value is 100 mbar.

⚠ If there are modifications in the **Generel Constants**, you have to start the project from the beginning.

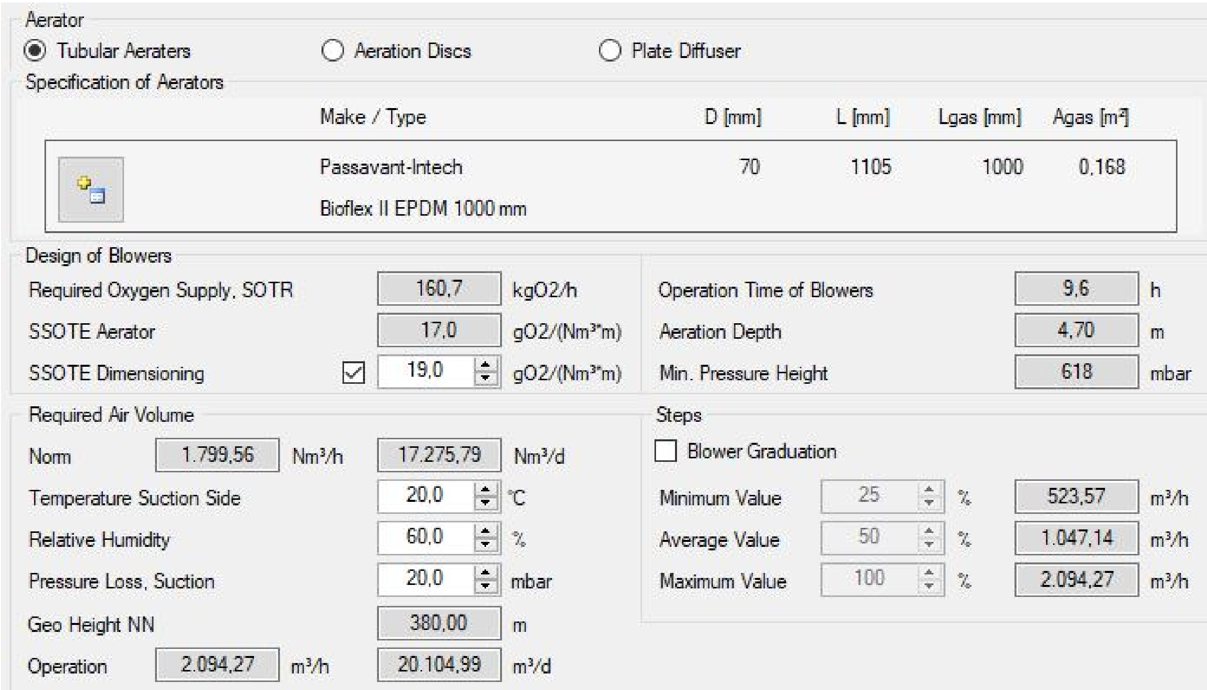
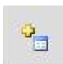


Fig. 20: Parameter for the design of blowers

8.1.3 Blower Selection

First choose the number of blowers. Then click the icon  to choose the aggregate.

The data bank will open and show the first blower in blue that fullfills the requirements. The blowers are sorted by the counter pressure in the data base.

It is possible to sort by any other column, if you click on the header.

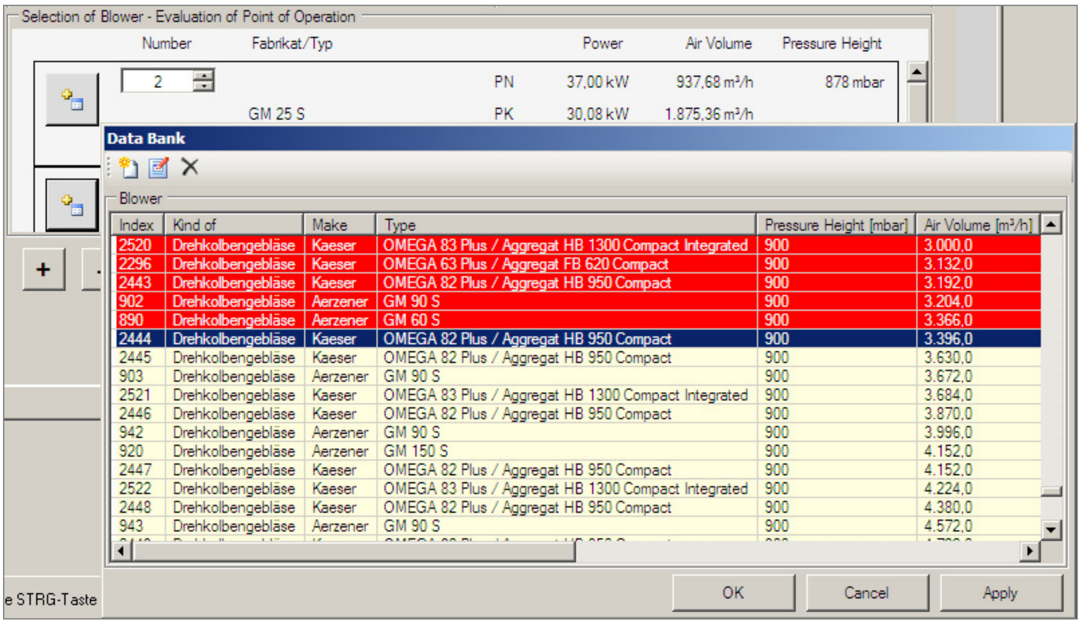


Fig. 21: Selection of blowers

The colors mean:

Color	Meaning
red	Construction terms are not fullfilled – The blower counter pressure or the air transfer are too small.
blue	Mark
yellow	Construction terms are fullfilled

Mark the blower and hit **OK.** The data bank closes and you get back to the calculation form.

The following data will be displayed in the blower frame:

- Manufacturer, Type
- Motor power and coupling power of the blower
- Air volume of each blower and the total air volume of the type
- The relation of blower air supply and the required air volume
- The counter pressure for the selected blower

The coupling power and the air volume will be interpolated for the operation point.

info	**Evaluation of the operation point** In the data bank for every blower type the motor power is present for the required counter pressure. This means, every blower is listed in the data bank for several times for different pairs of counter pressure and motor power. All operation points between will be interpolated.

If you like to select more blowers, click on the button + at the lower border of the form. A further frame for the blower selection will occure. The check box **Blower Design** is activated.

info

Blower selection / stepping

For a good design its recommend to proofe how the loading will be during the life time of the equipment. If there will be a phase of low capacity loading, for example at the beginning of operation of the plant or during the seasons (touristic, wine) its convenient to have blowers of different capacities, so that you have matching blowers for all loading conditions.

At normal loading conditions it depends on the denitrification process, the activated sludge process and the size of the plant, how much the air demand is varying.

Separate stage denitrification

If there is a contineous aeration, the aeration will commenly be controlled via the reference value. The air demand is then oscilating like the inflow load. For this case its recommended to step the blowers.

Intermittent denitrification

Here the oxygen demand is compressed to the aeration time. The oscilation of the demand is not as significant as in the separate stage denitrification. Especially for small and middle size plants two blowers of the same size are suitable for most of the times.

8.1.4 Blower Graduation

Blower graduation is usefull to adapt the aeration capacity to different load conditions, for example when you have low loads at the beginning of the operation of the plant or for the low loads in the night.

Click the check box **Blower Graduation** and input the wanted steps – in our example 25, 50 and 100%.

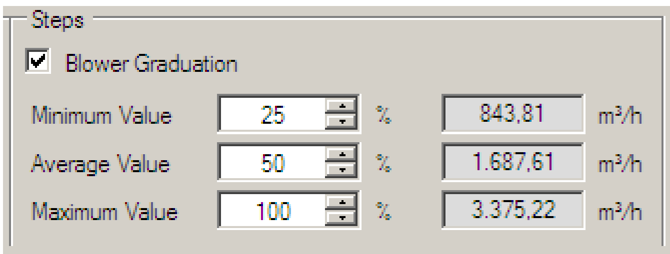


Fig. 22: Blower graduation

At the frame of the blower selection click the icon . In the data base there is an automatic filter for the chosen steps.

For example click 50% so all blowers will be marked light blue, that apply to these criteria. Mark a blower and click **OK**. The data base closes.

If you now for example want to add two blowers with 25% click onto the icon + and input the number of blowers. Take care that the check box of the aeration control is activated. Open the data base and click 25% and choose a suitable beige marked blower.

To check witch part is covered by the blower, click **Apply**. In the calculation form the value is displayed in %. Click **OK**, to exit the data bank.

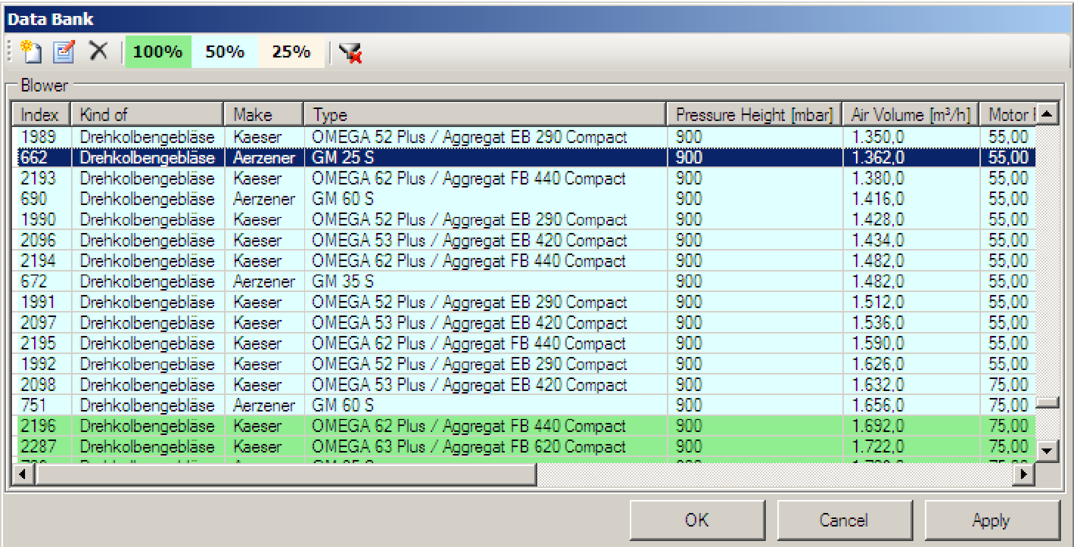


Fig. 23: Filter for blower graduation (here: 50%)

8.1.5 Standby Blower

If you want to choose a standby unit click the icon + at the bottom frame of the calculation form. A further frame appears to choose a blower.
Deactivate the check box **Blower Design**.

Then choose the blower out of the data base like shown at the top.

At the bottom **Air Volume,total** is displayed. The standby blower will not be included in this value.

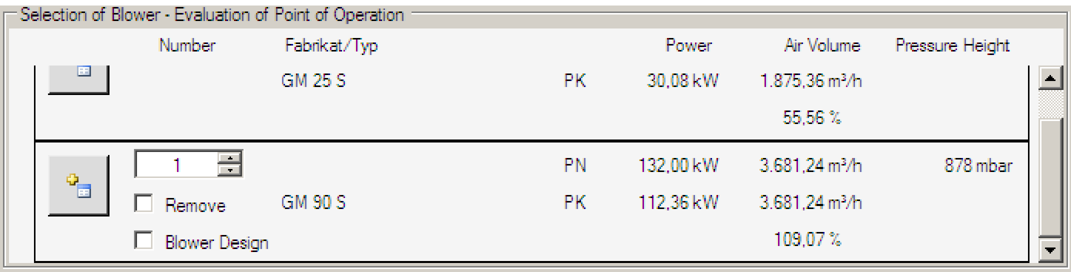


Fig. 24: Selection of a standby blower

The standby aggregates are not integrated into the dimensioning of the blowers and pipelines. They won't be part of the operating costs, but they will be contained in the investment costs.

8.1.6 Remove Blower

If you notice that you don't need a blower click the check box **Remove** and push the icon . If you only want to delete the last blower click - .

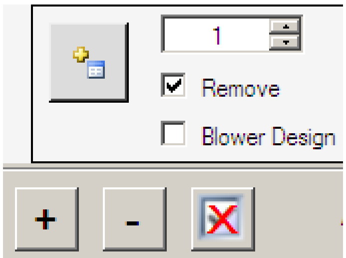


Fig. 25: Remove blower

8.2 Mixer

Design Mixer

Choose **Mixer** in the flow diagram. A calculation form opens to design and select the mixer.

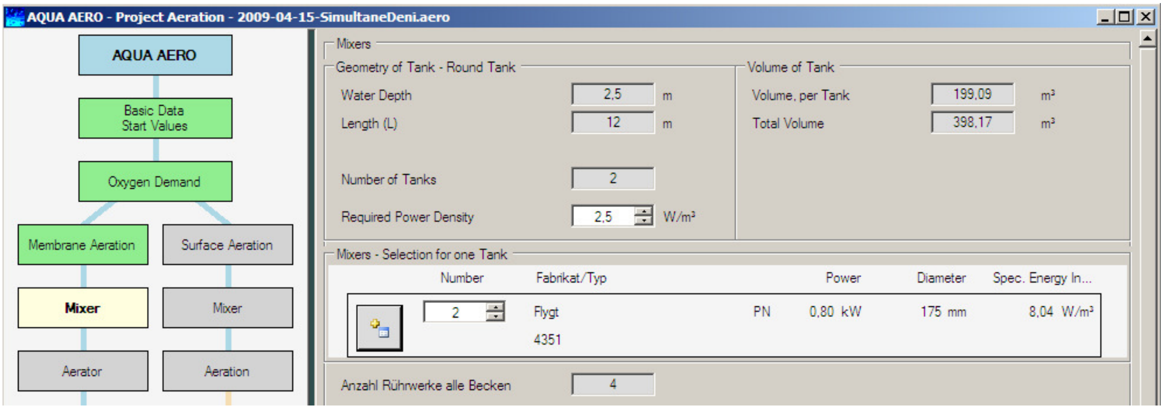


Fig. 26: Design and selection of a mixer

Basic parameter for the construction of the mixer is the required power densitiy, which is pre-set with 2,5 W/m³.

Selection Mixer

The selection of mixers applies for <u>one</u> chamber.

After inputting the power density (standard value), you input the number of mixers and choose them from the data base. The mixers that match the nominal value are marked yellow. Mark a fitting mixer and click **OK**.

The following informations will be showed:

- Make / Type
- Motor power of the mixer
- Diameter and
- Power densitiy
- Number of mixer for all tanks.

No Mixer

Off course you don’t have to choose a mixer, if the mixing for example with aeration shots is approached. This has the advantage that the investing costs and the operating costs could be less at specific conditions. Input the number **0** and go on over the flow diagram.

8.3 Aerator

8.3.1 Kind of Aerator

The kind of aerator you already have chosen in the form **Membrane Aeration**, because we need the data of the aerator for dimensioning of the blowers.

info

Tube aerators:

With tube aerators the data base shows the length of the aerators.

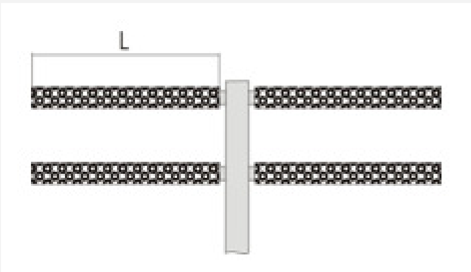
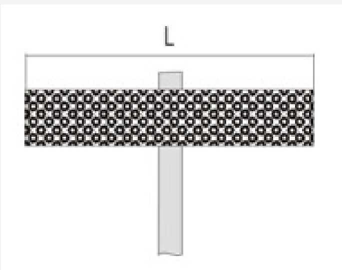


Plate and disc aerators:

For the plate and disc aerators the figure for the true scaled drawing its supposed that the disc are central placed on the distribution pipes.



8.3.2 Construction

> ⚠ The construction of the aeration equipment is for <u>one</u> chamber.

The theoretical basis will be found under **Aerator**, page **60**.

Depending on the chamber geometry and the kind of aerator you are able to arrange the aeration equipment by several parameters and options.

You can vary:

- The load of the aerator (it should be not higher than the max. value, given in the data bank)
- Number of grits
- Number of distributors
- Arrangement of the aerators
- Distances wall, aerator, grid, mixer

For the option **Other Forms** of the tank there is no possibility of constructing the equipment. By the aerator load you are only able to change the number of aerators.

All changes will be actualized directly, so you can simply and fast adapt the construction to the given situation.

The construction will be displayed in a true scaled drawing in a CAD-tool. You are able to zoom and move the drawing and export it in standard formats like dxf.

Some examples:

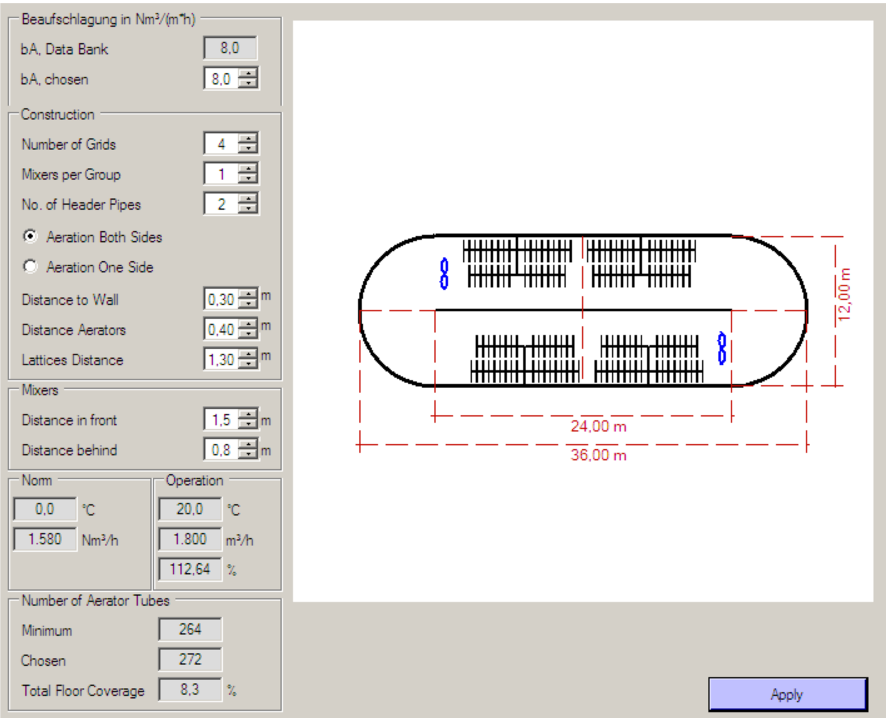


Fig. 27: Tube aerators in plug flow reactor

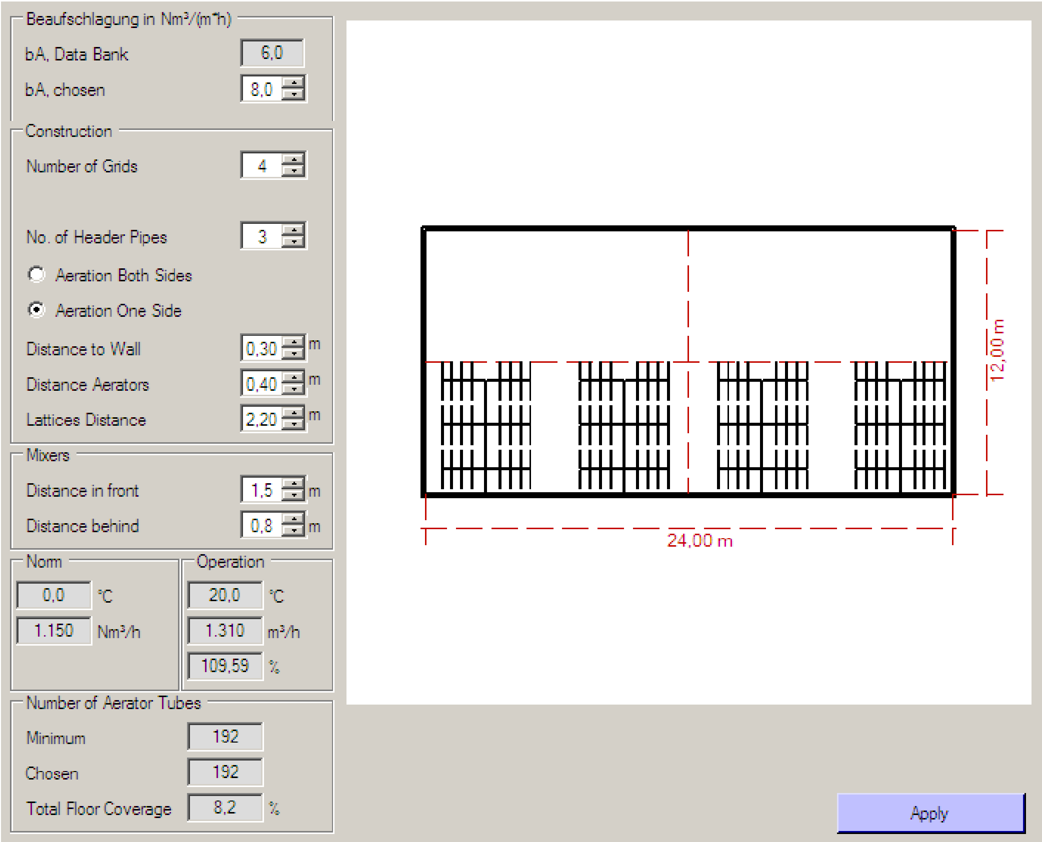


Fig. 28: Tube aerator in rectangular tank, aeration on one side

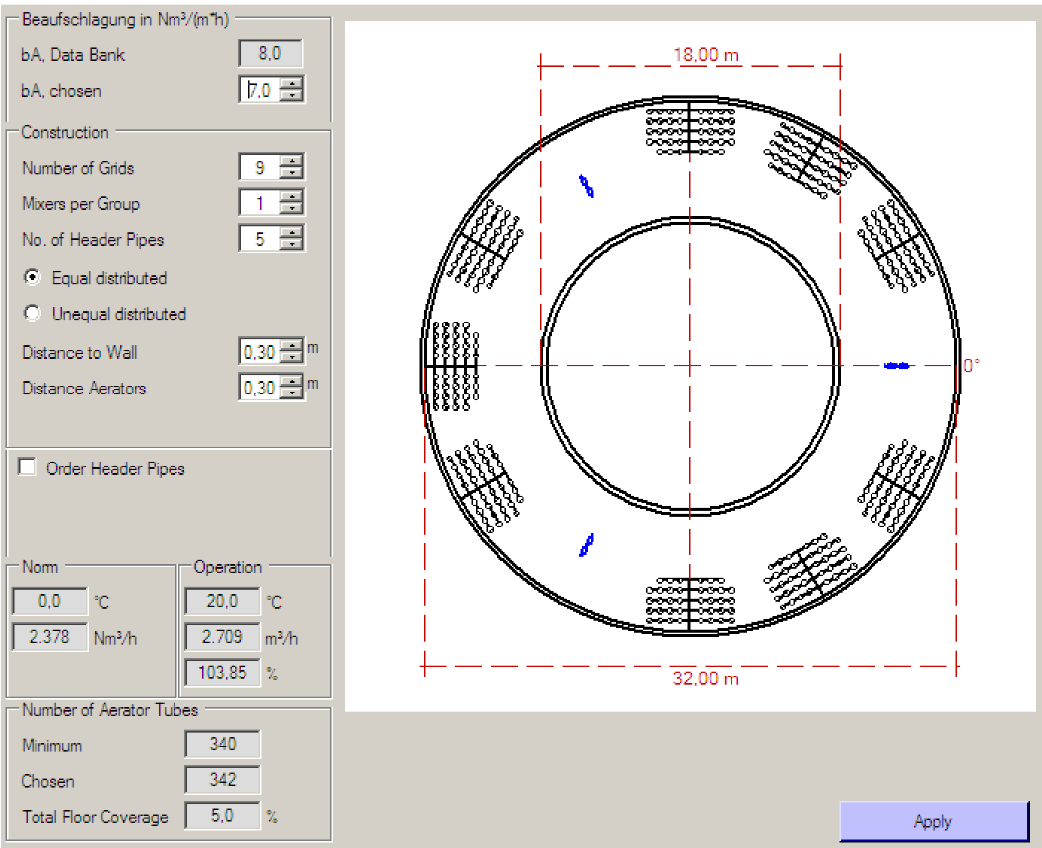


Fig. 29: Disc aerators in circular tank

8.4 Pipelines

The theoretical basis will be found under , page **61**.

Click **Pipelines** in the flow diagram so the calculation form for the construction of the pipelines will open.

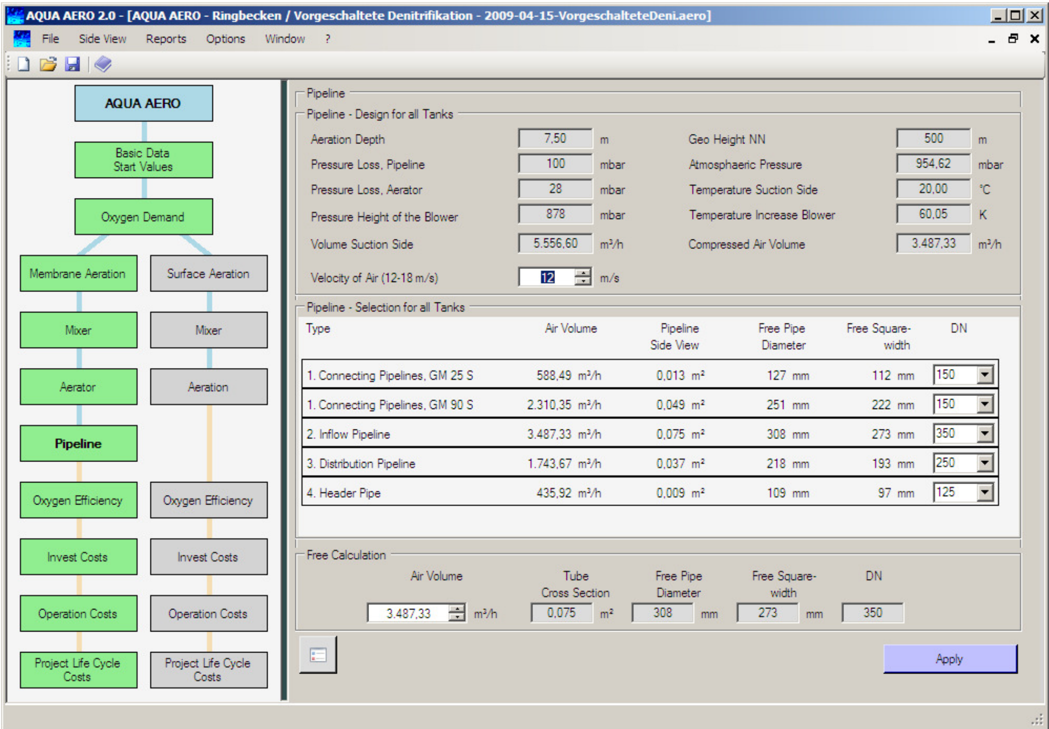


Fig. 30: Dimensioning of pipelines

In the top frame the pre selections are displayed. Under the assumption of adiabatic compression the compressed air volume is calculated out of the suction volume.

Now, finally select the velocity in m/s.

info	A velocity of air between 12 – 18 m/s is recommended.

In the frame **Pipeline – Selection** for all Tanks you get a listing of all pipes for the chosen chambers and blowers.

Pipeline - Selection for all Tanks

Type	Air Volume	Pipeline Side View	Free Pipe Diameter	Free Square-width	DN
1. Connecting Pipelines, GM 25 S	588,49 m³/h	0,013 m²	127 mm	112 mm	150
1. Connecting Pipelines, GM 90 S	2.310,35 m³/h	0,049 m²	251 mm	222 mm	150
2. Inflow Pipeline	3.487,33 m³/h	0,075 m²	308 mm	273 mm	350
3. Distribution Pipeline	1.743,67 m³/h	0,037 m²	218 mm	193 mm	250
4. Header Pipe	435,92 m³/h	0,009 m²	109 mm	97 mm	125

Fig. 31: Pipelines

For information about the various diameters click [button]. A drawing with the name of the pipeline will be displayed.

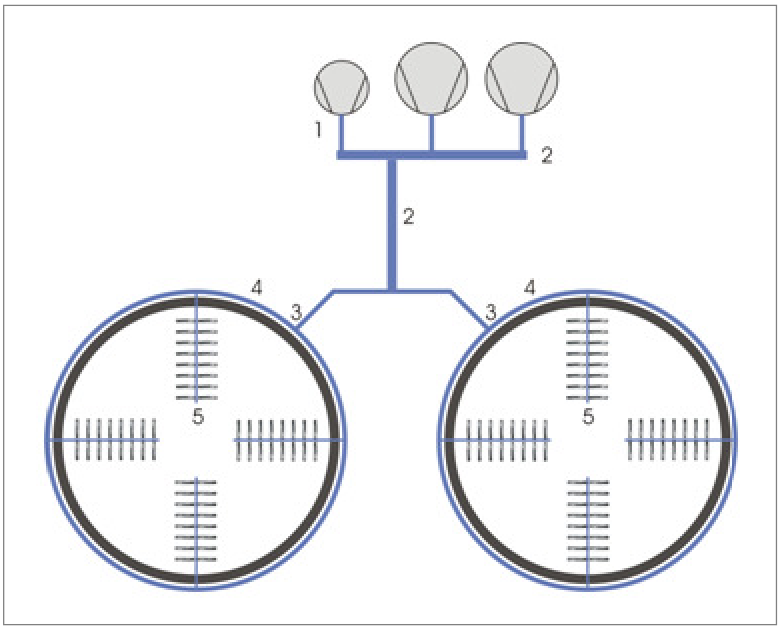


Fig. 32: Labeling of pipelines

It is valid for all pipes:

The connecting pipelines are designed for the compressed air volume of the appropriate blower.

All other pipes are dimensioned for the total volume of all blowers, considered for the aerator dimensioning. The total volume is divided by the number of pipes.

Example	**Chosen:**	**Displayed:**
	Two blower GM 35S	Connecting pipe (1) for blower GM 35S For the invest costs two connecting pipes for the two blowers will be taken into account.
	One standby GM 80L	Connecting pipe (1) for GM 80L
	Two oxidation ditches	Inflow pipe (3) to the two chambers; the compressed air volume will be divided to the two chambers. For the invest costs, the two inflow pipes will be taken into account.

Finally select the pipeline diameter DN for the different pipes and confirm with **Apply**.

In the frame **Free Calculation** you have the possibility, to convert the air volume to the diameter quickly for any desired volume. It is only a little tool. The calculation doesn't affect the other measurements.

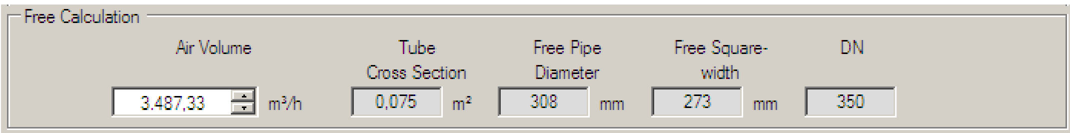


Fig. 33: Free calculation

With the construction of the pipelines the design of the aeration system is finished. In the flow diagram you can notice this by the blue connections of the blocks.

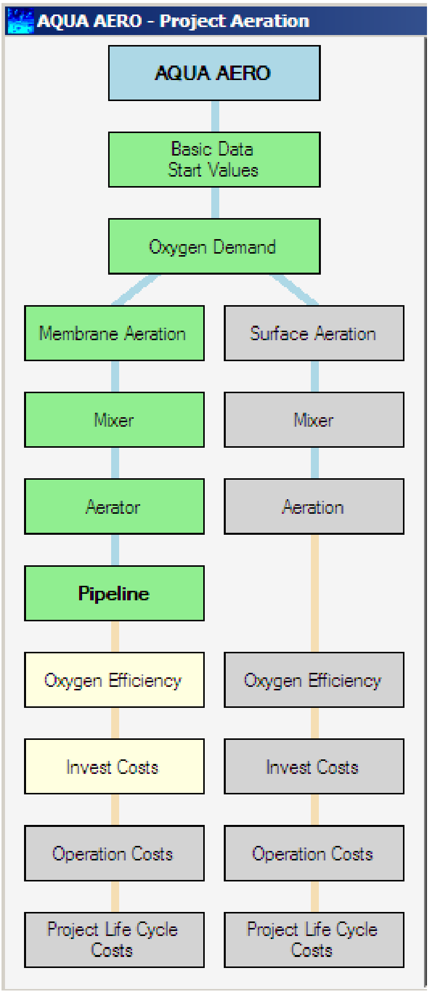


Fig. 34: Finished design of membrane aeration

Further and following tools are the oxygen efficiency, invest- and operational costs and the life cycle costs.

9 Oxygen Efficiency

The theoretical basics will be found under **Oxygen Efficiency**, page **65.**

The oxygen efficiency is the key figure for the economy of an aeration system. It shows how much energy is needed to charge the required oxygen.

For the calculation of the oxygen efficiency the power consumption of blowers and mixers is required.

First enter the mechanical losses and the losses of the frequency converter, if given. With these losses, the efficiency of the motor and the coupling power of each blower, the total power consumption is calculated.

The real power consumption of the mixers depends on several factors. Its recommended to request this from a supplier. The motor power is preselected by AQUA AERO.

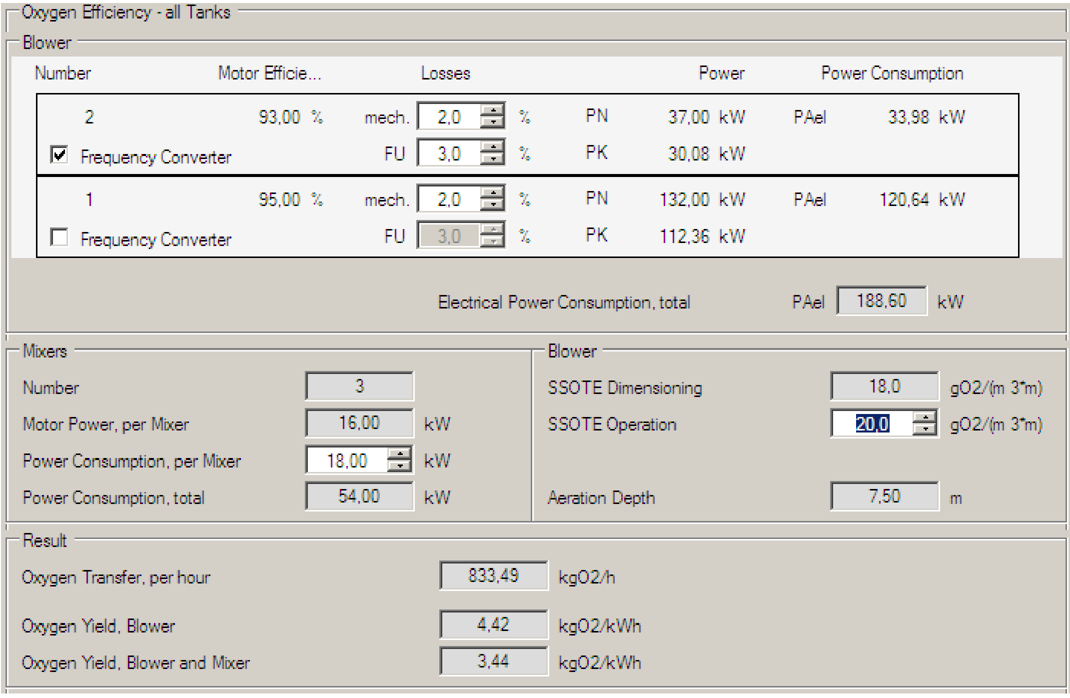


Fig. 35: Calculation of the oxygen efficiency

Yor are able to input a **specific oxygen yield** for operation, independent from the design value. This value will be taken into account for the calculation of the oxygen efficiency.

For the specific standard oxygen transfer efficiency SSOTE applies:

Design:	For the peak demand
Operation:	For the average demand (usually a better value)

As result you get the hourly oxygen input SOTR and the oxygen efficiency for the blowers and for the sum of blowers and mixers.

10 Investment Costs

The theory for the calculation of invest costs will be found under **Investment Costs**, page **67**.

In the calculation of the investment costs the following positions are included:

- Planning costs
- Costs for construction of blower room (Construction I)
- Costs for excavation (Construction II)
- Mechanical equipment and pipelines
- Electrical equipment
- Measuring equipment

Additional to the parameters for the invest, also the life time of each component is requested here. So all informations for each component can be entered at one place. The life time has no effect to the invest costs, but for the calculation of the reinvest.

10.1 Consulting and Construction

Consulting costs are considered as lump-sum.

For the blower room length, width and height are calculated with the number and size of the chosen blowers. Nevertheless you enter your own size values. With the orientation price, the construction costs are calculated.

Also excavation can be edited.

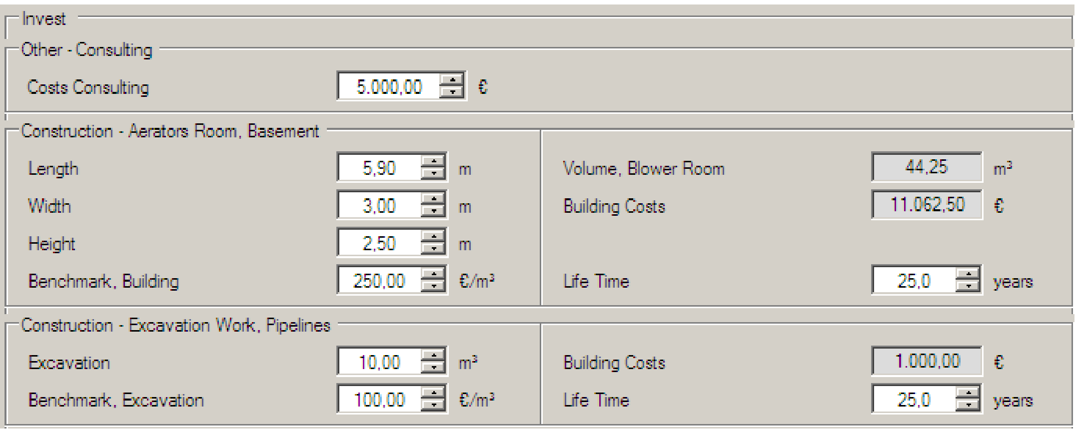


Fig. 36: Costs for consulting and constructing

10.2 Mechanical Equipment

In the frame **Mechanical Equipment** all aggregates resulting from the way of design will be displayed. Furthermore the required pipelines are contained.

The following inputs are necessary:

- Material and length of the different pipes (length of distribution pipe and falling pipe are preselected)
- Number and kind of valves

- Sound box yes/no
- Selection of a data set of the aeration grid
- Number of lift devices for the aerator equipment (preselected is the number of chambers)
- Unit price for all positions (prices are partly provided by the data banks)
- Life time for all positions (an experienced life time is presetted)

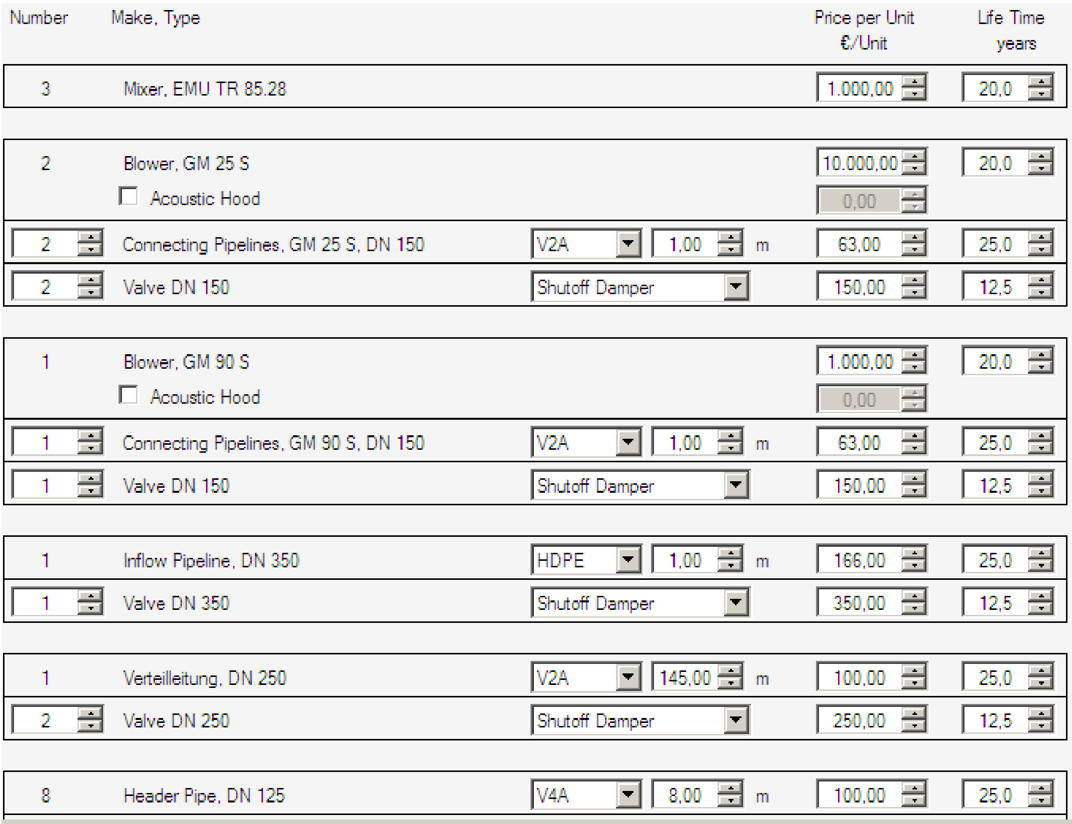


Fig. 37: Costs for mechanical equipment and pipelines

info The life time is used for the calculation of the reinvest costs. Its not considered by the invest costs.

10.3 Electrical and Measuring Equipment

For electrical and measuring equipment you enter lump sums and life time.

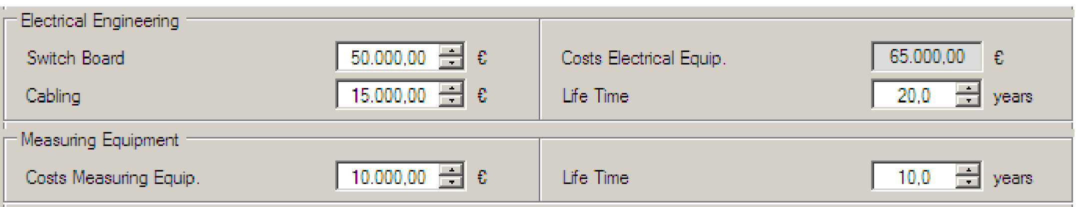


Fig. 38: Costs for electrical and measering equipment

10.4 Result

The complete invest costs for the aeration system with consulting, construction, mechanical, electrical and measuring equipment will be displayed at the bottom of the form. Therefore move the scroll bar to the bottom.

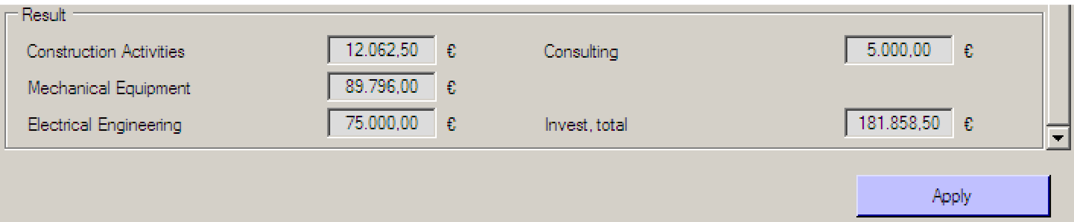


Fig. 39: Result of invest costs

Click on **Apply** and select the next Step in the flow sheme.

11 Operating Costs

The theory for the calculation of the operational costs will be found under **Operating Costs**, page **68**

Click the block **Operation Costs**. A calculation form opens, where the operating costs are detected:

- Energy costs blower
- Energy costs mixer
- Costs for ressources
- Maintenance

Energy Costs

Enter the energy price of the provider in the frame **Basic Data**.

The factor average O2-demand means the difference between the design oxygen demand and the average demand in operation. The preselected value is matching to the common conditions.

If only a part of all mixers are designated to be in operation in the aeration phase, you can enter this in **Number, in aerated phase**.

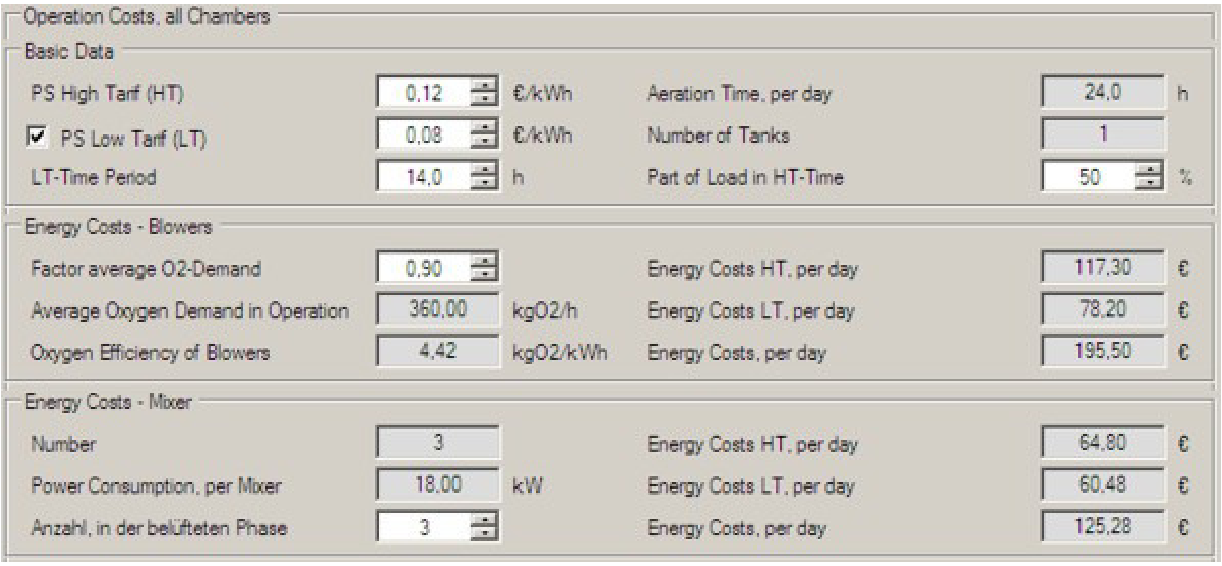


Fig. 40: Energy costs

Other Operating Costs

Activate the check box **Miscellanous** for further components of the operation costs.

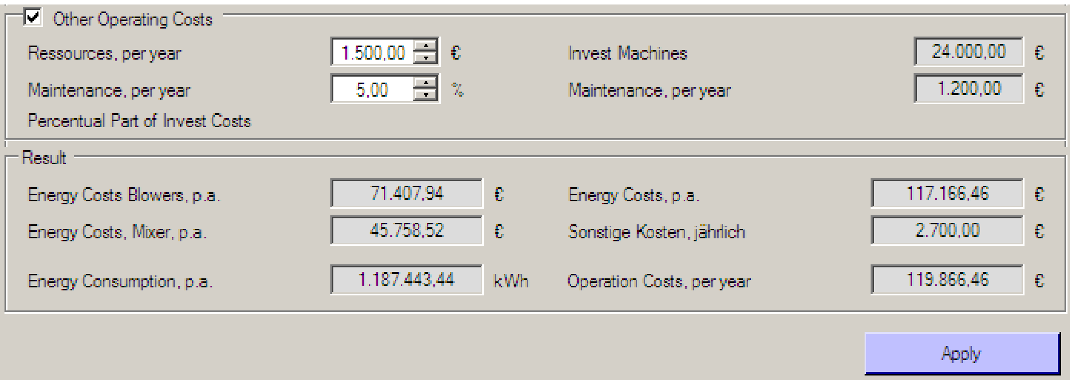


Fig. 41: Other operating costs and result

Result

Finally click **Apply** and the operating costs will be displayed in the bottom part of the form.

12 Project Life Cycle Costs

The theory will be found under **Project Life Cycle Costs** , page **71**.

With the **Project Life Cycle Costs** two aeration systems with different investment and operating costs can be compared. For this the coming costs will be calculated to the point of starting the operation (year = 0).

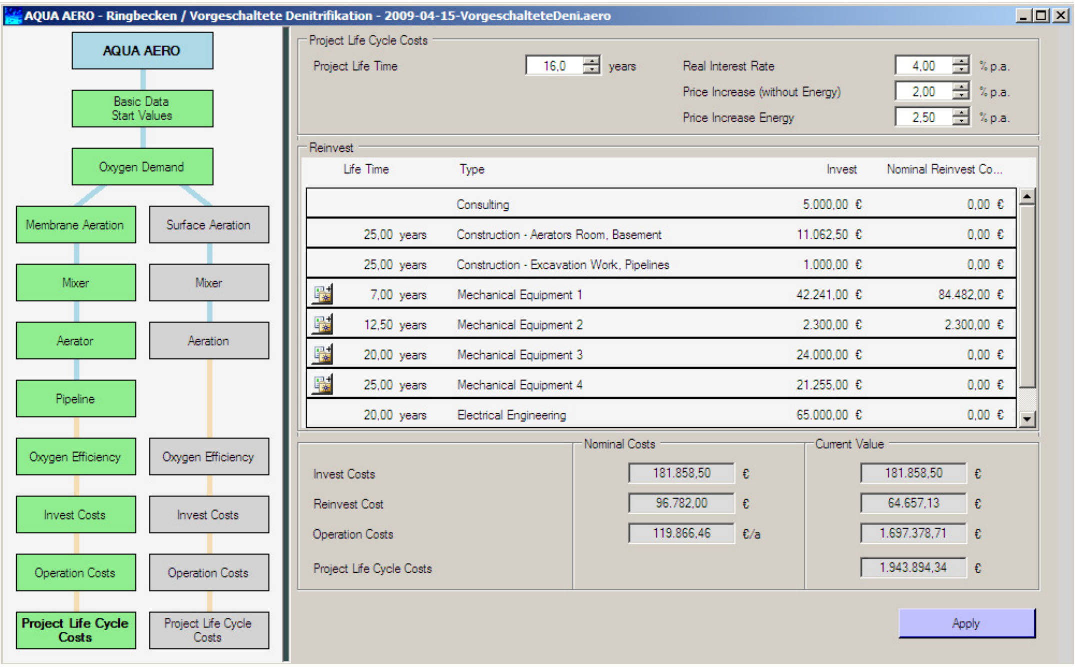


Fig. 42: Project life cycle costs

The first value is the life time of the project. Commonly this is 25 years for aeration mechanical equipment. In the literature for the evaluation of the oeconomic of replacing an existing system a life time of 10 years is recommended.

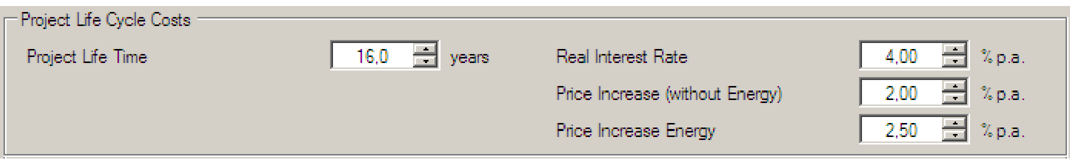


Fig. 43: Project life time, interest and increase rate

In the frame the invests are displayed. Here all invest components are sorted and sampled by the life time into packages Mechanical Equipment 1…, Reinvest

Life Time	Type	Invest	Nominal Reinvest Co...
	Consulting	5.000,00 €	0,00 €
25,00 years	Construction - Aerators Room, Basement	11.062,50 €	0,00 €
25,00 years	Construction - Excavation Work, Pipelines	1.000,00 €	0,00 €
7,00 years	Mechanical Equipment 1	42.241,00 €	84.482,00 €
12,50 years	Mechanical Equipment 2	2.300,00 €	2.300,00 €
20,00 years	Mechanical Equipment 3	24.000,00 €	0,00 €
25,00 years	Mechanical Equipment 4	21.255,00 €	0,00 €
20,00 years	Electrical Engineering	65.000,00 €	0,00 €

Fig. 44: Invest and nominal reinvest

If you click on the button left to the packages, the groups will be extended and you see the contained components.

Reinvest

Life Time	Type	Invest	Nominal Reinvest Co...
25,00 years	Construction - Excavation Work, Pipelines	1.000,00 €	0,00 €
7,00 years	Mechanical Equipment 1	42.241,00 €	84.482,00 €
	Grid	36.000,00 €	72.000,00 €
	Aerator Passavant-Intech Roeflex EPDM, HL	6.240,00 €	12.480,00 €
	Removal Device	1,00 €	2,00 €
12,50 years	Mechanical Equipment 2	2.300,00 €	2.300,00 €
	Valve DN150	300,00 €	300,00 €
	Valve DN150	150,00 €	150,00 €

Fig. 45: Reinvest "opened"

In the bottom part of the form you get the result of the cost calculation:

- Nominal costs for invest, reinvest and operation
- Current value for invest, reinvest, operation are discounted to the zero point, incl. the interest rate for operating cost
- **Project Life Cycle Cost** as sum of the current value

	Nominal Costs	Current Value
Invest Costs	181.858,50 €	181.858,50 €
Reinvest Cost	96.782,00 €	64.657,13 €
Operation Costs	119.866,46 €/a	1.697.378,71 €
Project Life Cycle Costs		1.943.894,34 €

Apply

Fig. 46: Result: nominal and current values

You now have the complete calculation from the construction of the aeration system to the detection of the oxygen efficiency, investment and operating costs to the project life cycle costs.

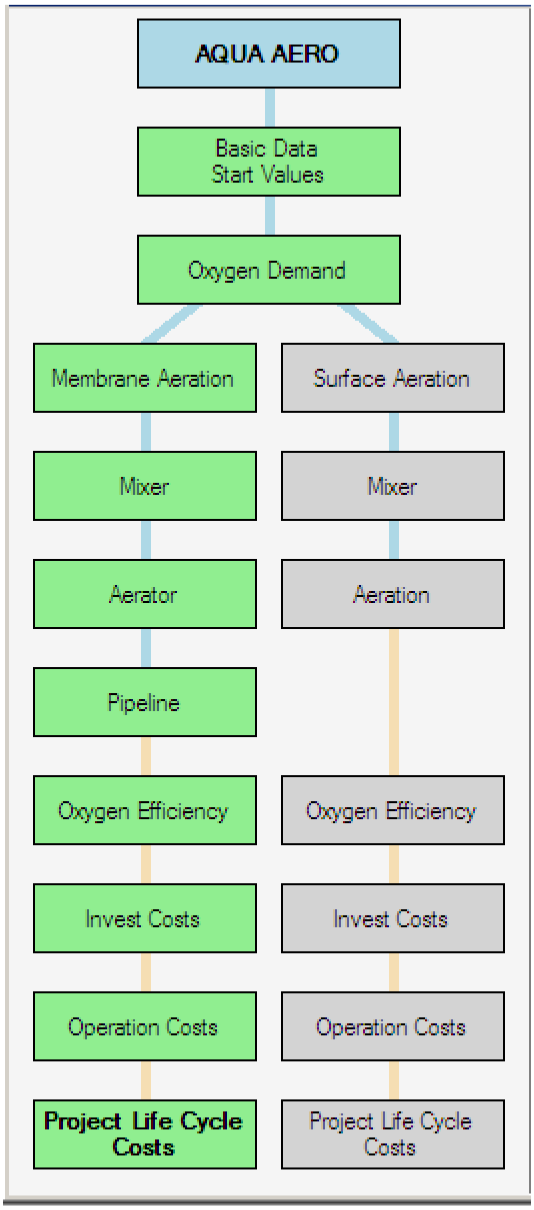


Fig. 47: Completed project

13 Reports

For every step of calculation a detailed report is generated, with all intermediate results, formulas and the ways of calculation.

Its possible to generate the following reports in MS Word:

- Dimensioning
- Pipeline
- Oxygen efficiency

- Invest costs
- Operation costs
- Project life cycle costs
- Complete report

To generate the reports, it is first necessary to complete the according calculation. The data will be confirmed by clicking **Apply**. Then the section in the flow sheet is marked green.

Only for the report **Design** its possible to generate intermediate reports. The report will be generated up to the steps which are completely finished. For example, if you only need to calculate the oxygen demand, it is not necessary to go through the following steps **Membrane Aeration** and **Mixer.**

If you have finished a complete project from **Basic Data** to the **Project Life Cycle Costs**, there is a **Complete Report** containing all results and sections.

To generate a report goto **Menu > Reports** and select a detailed report or the **Complete Report**.

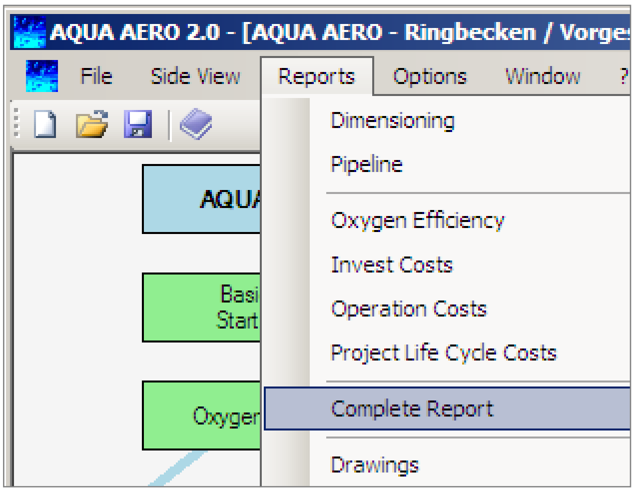
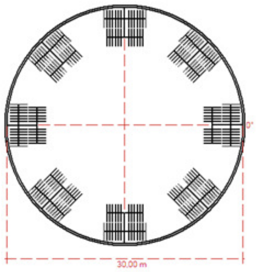


Fig. 48: Reports

MS Word will open and a detailed Report will be generated. On the first page you will find the project data. Now the report is completely available in Word for further handling.



Calculation of one Tank

Number of Tanks	nAT =	2	
Air Volume Blower, total	QL,total =	5.081,64	m³/h
Aerator Unit, min		776	
Minimum Aerator Length		776,00	m
Number of Aerator Segments		16	
Aerator Tube, per Grid		52	
Effective Aeration Length of each Aerator		1	m
Effective Number of Aerators		832	
Effektive total Length		832,00	m

Pipelines

			Suction Side	Pressure Side
Pressure	p	mbar	1.013,25	1.536,25
Temperature	T	K	298,15	335,80
Air Volume Blower	QL,Blower	m³/h	5.081,64	3.774,85

Permitted Velocity in the Pipes vL = 12,00 m/s

No	Description	Volume Flow m/h³	Cross Section m²	Free Pipe Diameter mm	Free Square-width mm	DN
2	GM 60 S	1.887,43	0,044	236	209	250
1	FB 620 C	2.535,32	0,059	273	242	250
1	Collecting Pipeline	3.774,85	0,087	334	296	350
2	Inflow Pipeline	1.887,43	0,044	236	209	250
2	Distribution Pipeline	943,71	0,022	167	148	200
16	Header Pipe	235,93	0,005	83	74	100

The compressed air volume will be calculated under the simplified prediction of adiabatic compression.

Oxygen Efficiency

Blower

Pos	No	Blower	Type	η %	Mech. Losses %	FU Losses %	PK kW	PAel kW	PAel Total kW
1	2	Roots Blower	GM 60 S	94,00	2,0	-	44,5	48,2	96,5
Total	2	-	-	-	-	-	-	-	96,5

Power Consumption, all Blowers PABlower = 96,5 kW

The power consumption of a blower is calculated with the following formula:

$$PA = \frac{PK * (1 + Vmech\%) * (1 + VFU\%)}{\eta} \quad [kW]$$

Mixers

Keine Rührwerke gewählt.

Oxygen Yield

Aeration Depth	hD =	3,7	m
Air Volume, all Blowers	QL,total =	5.081,64	m³/h
Spec. O2-Transfer Capacity, operation	SSOTE =	20,0	gO2/(Nm³*m)
Oxygen Transfer, Operating Cond.	SOTR =	376,04	kgO2/h
Oxygen Yield, Blower	SAE,Blower =	3,90	kgO2/kWh

Oxygen demand and oxygen efficiency are calculated by the following formula:

$$SOTR = \frac{Q_L * SSOTE * h_D}{1000} \quad \left[\frac{kgO_2}{h}\right]$$

$$SAE = \frac{SOTR}{PA} \quad \left[\frac{kgO_2}{kWh}\right]$$

Fig. 49: Report with detailed data and true scaled drawing

14 Drawing

You can generate a CAD-Drawing of the aeration construction. Click on the drawing and the CAD-tool will start. Now further functions are available.

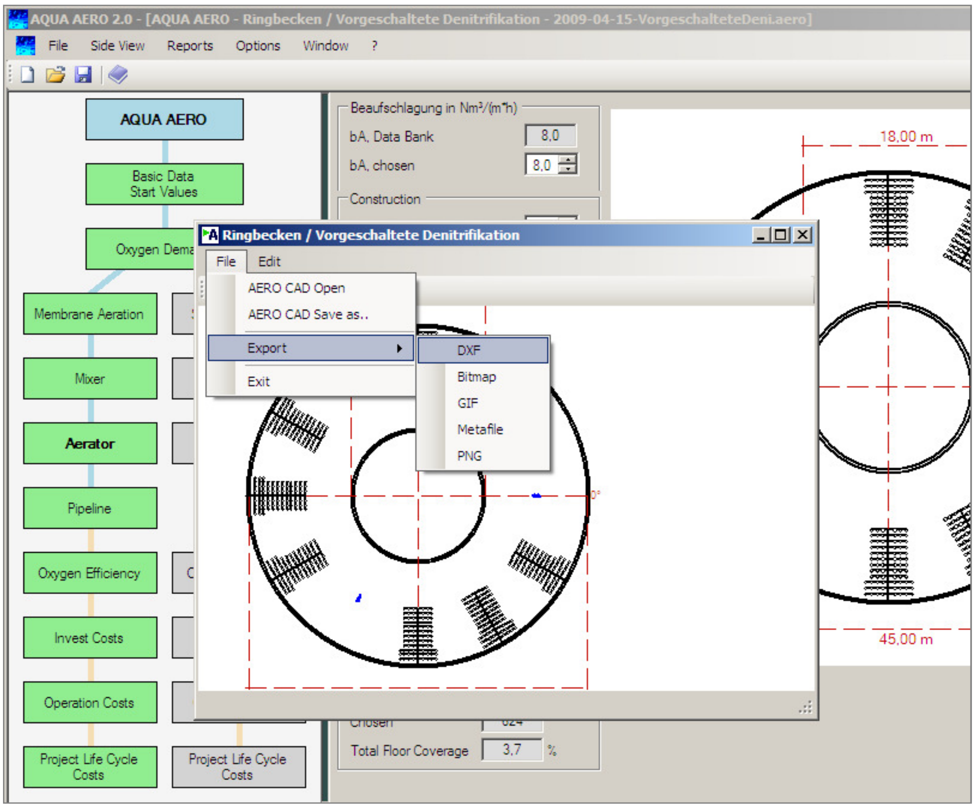


Fig. 50: CAD-drawing

You can save the file for later editing or handling. Chose **File > AERO CAD Save As**. With the menu **Documentation > Drawings** you can open the Drawing modul and the chosen field.

If you want to save the drawing in another format choose **File > Export** and the required format.

Formats available:

- DXF
- Bitmap
- GIF
- Metafile
- PNG

You leave the CAD-Modus with **File > Exit**.

15 Define Constants

Several constants as basis for the calculations are available and editable under **Options > General Constants.**

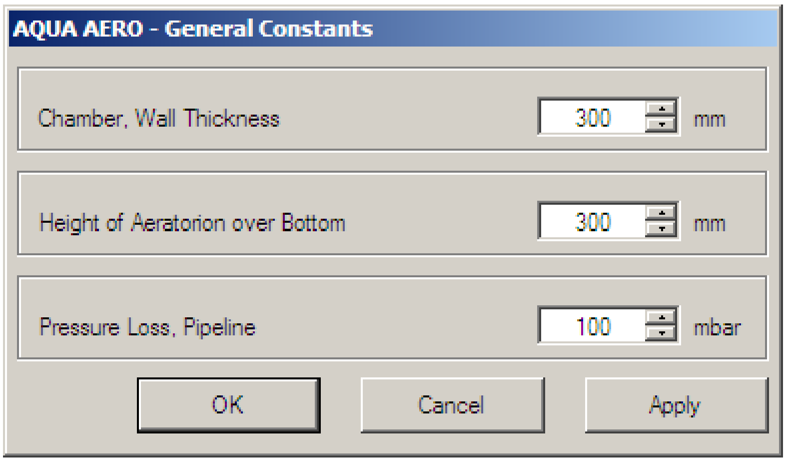


Fig. 51: General constants

The following constants could be defined:

- Wall thickness of the chambers
- Height of Aeration over the bottom
- Pressure loss of the pipelines.

The thickness of walls is necessary for the true scaled drawings.

The construction height of the aerators is needed to calculate the counter pressure by the water level.

The pressure loss of the pipelines is also needed for the counter pressure of the blowers.

> ⚠ If a general constant will be changed this affects on the total way of calculation. Therefore for all running projects AQUA AERO goes back to the form **Basic Data** if you change a general constant. Input values and selected data sets will mostly remain.

Adapt the values to your demand and press **OK**.

Because the design basis will be changed by editing a general constant, all projects will be reseted to the basic parameters.

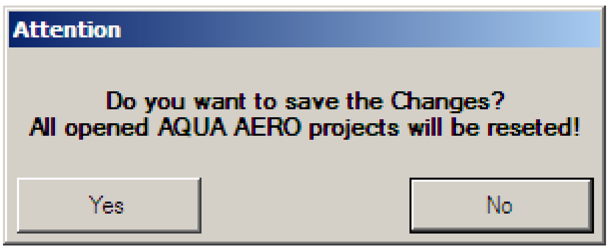


Fig. 52: Attention request

Affirm with **Yes** and store the input with **OK.** Restart the design with the **Basic Data.**

16 Data Bank

In AQUA AERO all equipment with their descriptions and parameters are saved in **one** data base.

The data bank contains common brands. The user can add own data or edit the present data. At a later update the earlier files of course will be optained.

For each component an own table is created which you can reach over **Options > Data Bank.**

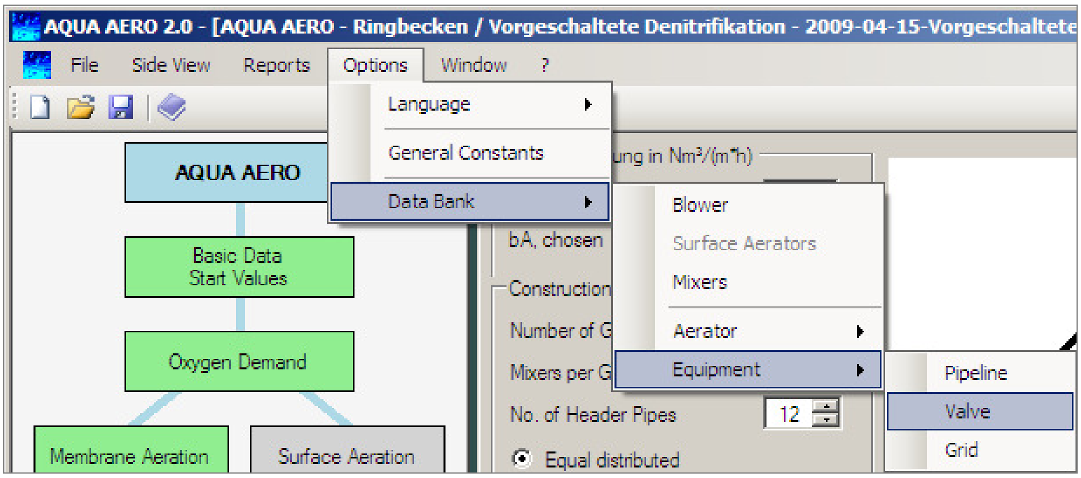
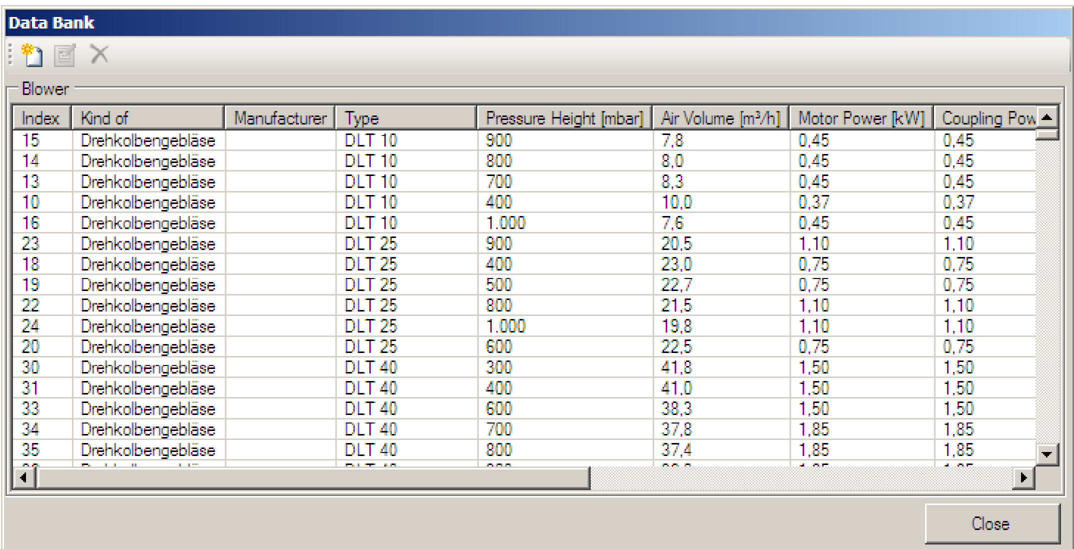


Fig. 53: Options > Data Bank

The chosen table out of the data bank opens.

With the icons on top of the form you can add, edit and delete aggregates.



Index	Kind of	Manufacturer	Type	Pressure Height [mbar]	Air Volume [m³/h]	Motor Power [kW]	Coupling Pow
15	Drehkolbengebläse		DLT 10	900	7,8	0,45	0,45
14	Drehkolbengebläse		DLT 10	800	8,0	0,45	0,45
13	Drehkolbengebläse		DLT 10	700	8,3	0,45	0,45
10	Drehkolbengebläse		DLT 10	400	10,0	0,37	0,37
16	Drehkolbengebläse		DLT 10	1.000	7,6	0,45	0,45
23	Drehkolbengebläse		DLT 25	900	20,5	1,10	1,10
18	Drehkolbengebläse		DLT 25	400	23,0	0,75	0,75
19	Drehkolbengebläse		DLT 25	500	22,7	0,75	0,75
22	Drehkolbengebläse		DLT 25	800	21,5	1,10	1,10
24	Drehkolbengebläse		DLT 25	1.000	19,8	1,10	1,10
20	Drehkolbengebläse		DLT 25	600	22,5	0,75	0,75
30	Drehkolbengebläse		DLT 40	300	41,8	1,50	1,50
31	Drehkolbengebläse		DLT 40	400	41,0	1,50	1,50
33	Drehkolbengebläse		DLT 40	600	38,3	1,50	1,50
34	Drehkolbengebläse		DLT 40	700	37,8	1,85	1,85
35	Drehkolbengebläse		DLT 40	800	37,4	1,85	1,85

Fig. 54: Table blower

To **add** new data click this icon , at the right of the icon bar. A dialog opens where you can for example input parameters of a new blower. With **OK** the new data will be saved and you will get back to the table.

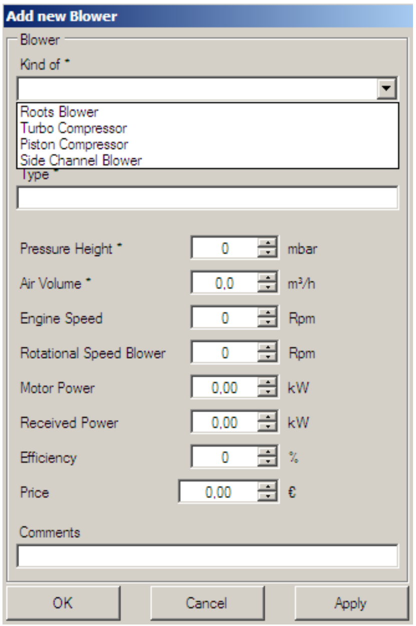


Fig. 55: Add blower

To **edit** a data set mark it and click the icon in the middle of the icon bar. A dialog opens where you can edit files.

To **delete** a data set mark it and click the icon . A safety question appears that you should answer with **yes**.

Finally click **Close** in the table to leave the data bank.

17 Theory

17.1 Introduction

In the following chapters the theoretical basics for AQUA AERO are described.

Part of this is the design of the aeration system with evaluation of the oxygen demand and the oxygen supply, the transfer from clean water conditions to waste water conditions and the adaption to local conditions.

As an important value for the efficiency of an aeration system the way of calculation for the oxygen efficiency is described.

The third parts includes oeconomical calculations as invest-, operation- and reinvest costs and as a conclusion the project life cycle costs.

17.2 Basic Data

The main parameters for the design of the aeration system are the load, the chamber geometry and the chosen elimination processes.

17.2.1 Geometry

There are four standard types of chambers available.
The volume of the chamber results from the geometry.

Round tank

$$V_{AT} = n_{AT} * h_W * \frac{\pi}{4} * D_{AT}{}^2 \qquad [m^3]$$

Circular tank

$$V_{AT} = n_{AT} * h_W * \frac{\pi}{4} * (D_{AT}{}^2 - D_{AT,i}{}^2) \qquad [m^3]$$

Rectangular tank

$$V_{AT} = n_{AT} * h_W * L_{AT,1} * L_{AT,2} \qquad [m^3]$$

Plug flow reactor

$$V_{AT} = n_{AT} * h_W * \left(L_{AT} * D_{AT} + \frac{\pi}{4} * D_{AT}{}^2 \right) \qquad [m^3]$$

Other chamber types

$$V_{AT} \quad edit$$

International:		German:		
D_{AT}	Outer free diameter of the activated chamber	D_{BB}	Äußerer lichter Durchmesser des Belebungsbeckens	m
$D_{AT,i}$	Inner Diameter of a ring chamber	$D_{BB,i}$	Innendurchmesser beim Ringbecken	m
h_W	Water level	h_w	Höhe des Wasserspiegels	m
L_{AT}	Length of the aeration tank	L_{BB}	Länge Belebungsbecken	m
n_{AT}	Number of tanks	n_{BB}	Beckenanzahl	-
V_{AT}	Volume of the aeration tank	V_{BB}	Volumen des Belebungsbeckens	m³

17.2.2 Elimination Processes

General

Four variants for the nutrient elimination and three processes for phosphate elimination are available.

Nutrient Elimination

Only Nitrification

After the conversion of organical bounded nutrient into ammonia, the ammonia will be oxidated into nitrate by the two steps of nitrification. Therefore oxygen is required by nitrosomonas and nitrobacter.

$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$

$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$

This process can only take part, if the retention time is sufficient for the nitrificants. This means the aerobic sludge age has to be high enough, see **Sludge Age**, page **51**.

If the option **nitrification** is selected, denitrification will not take part.

The aeration time for the design:

$$tL = 24h$$

Nitrification / Denitrification

At the denitrification process the solved nitrate (and nitrite) will be reduced to elementar nutrient N_2 at absence of oxygen. By this process oxygen is reused by the bacteria. Nutrient disappears as gas into the atmosphere.

Equation for Denitrification:

$$2\ NO_3^- + 2\ H^+ \rightarrow N_2 + H_2O + 2{,}5\ O_2$$

If you choose a denitrification process, this means:

- As first step you need the nitrification, so the aerobic sludge age has to be verified.
- For intermittent denitrification the aeration time will be calculated, for all other process the aeration time is 24 h/d.

Depending on the denitrification process the denitrification ratio is:

$$\frac{V_D}{V_{AT}} \max = 1 - \frac{t_{SS,aerob}}{t_{SS}}$$

International:		German:		
tSS	Sludge age, cell residence time	tTS	Schlammalter	d
tSS,aerob	Aerobic sludge age	tTS,aerob	Aerobes Schlammalter	d
V_{AT}	Volume of the aeration tank	V_{BB}	Volumen des Belebungsbeckens	m³
V_D	Volume of the biological reactor used for denitrification	V_D	Für Denitrifikation genutztes Volumen des Belebungsbeckens	m³

Separate Stage Denitrification

At separate stage denitrification the two steps nitrification and denitrification take part in different tanks. The denitrification part will only be mixed and the nitrification part will be aerated 24 h/d.

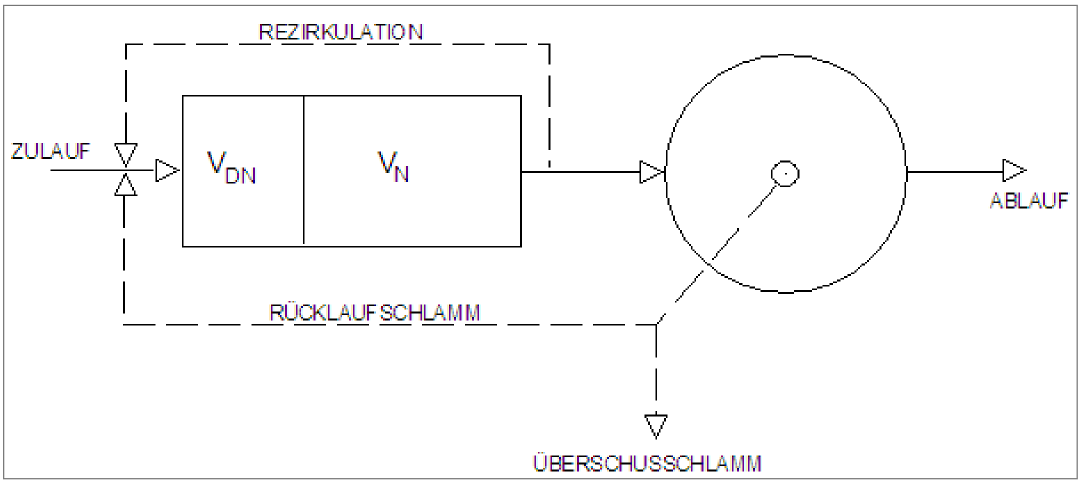


Fig. 56: Flow diagram of separate stage denitrification

The aeration time is:

$$tL = 24h$$

Simultaneous Denitrification

At simultaneous denitrification the wastewater passes aerated and anoxic zones in one chamber, for example an oxidation ditch.

The aeration time will be:

$$tL = 24h$$

It is difficult to control this process and to define the recirculation ratio exactly. Oxidation ditch and ring chamber are matching to this process.

Intermittent Denitrification

At the intermittent denitrification the oxidation of ammonia to nitrate and the reduction of nitrate to N_2 will be reached by a change of aerated and unaerated times in a chamber.

The aeration time is similar to the denitrification ratio:

$$tL = \left(1 - \frac{V_D}{V_{AT}}\right) * 24h \qquad [h]$$

Because the aeration of the oxygen input does not proceed for 24 hours, but only during the aeration time, the aeration system has to be larger than for the other processes.

The advantage of the intermittent denitrification is the good control ability and the high theoretical recirculation rate and so the high denitrication rate.

Biological Phosphate Elimination

Bacterias use the phosphate for the energy catabolîsm and anabolism. Furthermore there are bacteria which use phosphate for energy storage. This is named as biological precipitation.

The total amount of biological phosphate elimination will be requested by AQUA AERO. It will be divided into the part for metabolism (XP,BM) and for extended biological elimination (XP,bioP).

$$\mathrm{bioP,tot} = P,BM + P,bioP \quad with \quad \max P,BM = 0{,}0015 \left[\frac{kgP}{kgBSB}\right]$$

$$\mathrm{X}_{P,BM} = P,BM * C_{BOD,IAT} \qquad \left[\frac{mg}{l}\right]$$

$$\mathrm{X}_{P,\mathrm{bioP}} = P,bioP * C_{BOD,IAT} \qquad \left[\frac{mg}{l}\right]$$

Chemical Phosphate Elimination

Additional to the biological elimination the chemical precipitation can be chosen. Aluminium and iron precipitants are available. The chemical precipitation rate depends on the further biological elimination.

The part of chemical phosphate precipitation result on a phosphate balance:

$$\mathrm{X}_{\mathrm{P,Prec}} = \mathrm{C}_{\mathrm{P,IAT}} - \mathrm{C}_{\mathrm{P,EST}} - \mathrm{X}_{\mathrm{P,BM}} - \mathrm{X}_{\mathrm{P,BioP}} \qquad \left[\frac{mg}{l}\right]$$

International:		German:		
$C_{BOD,IAT}$	Concentration of BOD_5 in the homogenised sample, Influent activated tank	$C_{BSB,ZB}$	BSB_5-Konzentration im Zulauf zum Belebungsbecken	mg/l
$C_{P,EST}$	Concentration of phosphorus, effluent sedimentation tank	$C_{P,NB,Z}$	Phosphor Konzentration im Ablauf Nachklärung	mg/l
$C_{P,IAT}$	Concentration of phosphorus, inflow aeration tank	$C_{P,BB,Z}$	Phosphor Konzentration im Zulauf Belebungsbecken	mg/l
Pbio,P	Total bio phosphate, referred to BOD_5	Pbio,P	Gesamtes Bio-Phosphat, bezogen auf den BSB_5	kg P/kg BSB_5
$X_{P,BioP}$	Concentration of phosphorus removed with biological excess phosphorus removal process	$X_{P,Prec}$	Bei der biologischen P-Elimination biologisch gebundener Phosphor	mg/l
$X_{P,BM}$	Concentration of phosphorus embedded in the biomass	$X_{P,BM}$	In die Biomasse eingebauter Phosphor (Zellaufbau)	mg/l
$X_{P,Prec}$	Concentration of phosphorus removed by simultaneous precipitation	$X_{P,Fäll}$	Durch Fällung eliminierter Phosphor	mg/l
P,BM	Phosphate for celle design, referred to BOD_5	P,BM	Phosphat für Zellaufbau, bezogen auf den BSB_5	kg P/kg

BSB_5

Both the biological and the chemical phosphate elimination increase the excess sludge production and affect the retention time of the activated sludge in the activated chamber respectively the sludge age.

17.3 Determination of the Oxygen consumption

17.3.1 General

The calculation methods for the design of the aeration equipment are mainly based on the ATV-A 131 /2/.

In AQUA AERO the following steps are calculated:

- Determination of the sludge age
- Daily oxygen demand for C- and N-Elimination
- Hourly peak-oxygen uptake under consideration of peak factors.

Therefore, the temperature and pressure dependence of biological and physical processes are taken into consideration in the aeration tank.

17.3.2 Sludge Age

The oxygen uptake for the C-Elimination depends on the total sludge age (t_{SS}). The slude age is a parameter for the retention time of the sludge in the activated system.

For stable nitrification processes the aerobic sludge age has to be ensured.

If the total sludge age is lower than the required aerobic sludge age, the retention time is not sufficient to establish the nitrificants in the system. Then in AQUA AERO the oxygen demand is zero for nitrification.

Aerobic Sludge Age

For nitrification the minimum aerobic sludge age is required.

$$t_{SS,aerob,\dim} = SF * 3{,}4 * 1{,}103^{(15-T)} \qquad [d]$$

The security factor depends on the variation factors f_C, f_N and the cleaning requirements.

Municipal WWTP:

$$B_{d,BOD} \leq 1200 kg/d: \quad SF = 1{,}8$$

$$B_{d,BOD} \geq 6000 kg/d: \quad SF = 1{,}45$$

It is linearly interpolated between these values.

International: German:

$B_{d,BOD}$	Daily BOD_5-load	$B_{d,BSB5}$	Tägliche BSB_5-Fracht	kg/d
SF	Safety factor for nitrification	SF	Sicherheitsfaktor für Nitrifikation	-
T	Temperature	T	Abwassertemperatur	°C
$t_{SS,aerob}$	Aerobic sludge age	$t_{TS,aerob}$	Aerobes Schlammalter	d

The security factor considers variations in the growth rate of the nitrificants and in the concentrations in the feed and in the effluent. /2/.

Total Sludge Age

The total sludge age is iterated for three temperature conditions.

The following formulas are used:

$$SP_{d1} = V_{AT} * SS_{AT} / t_{SS} \qquad \left[\frac{kg}{d}\right]$$

$$SP_{d2} = B_{d,BOD} * \left(0{,}75 + 0{,}6 * \frac{X_{SS,IAT}}{C_{BOD,IAT}} - \frac{0{,}102 * t_{SS} * F_T}{1 + 0{,}17 * t_{SS} * F_T)}\right) + SP_{d,P} \qquad \left[\frac{kg}{d}\right]$$

with:

$$F_T = 1{,}072^{(T-15)}$$

Condition:

$$SP_{d1} = SP_{d2}$$

International:		German:		
$B_{d,BOD}$	Daily BOD_5-load	$B_{d,BSB5}$	Tägliche BSB_5-Fracht	kg/d
$C_{BOD,IAT}$	Concentration of BOD_5 in the homogenised sample; Influent activated tank	$C_{BSB,ZB}$	BSB_5-Konzentration im Zulauf zum Belebungsbecken	mg/l
F_T	Temperature factor for endogenous respiration	F_T	Temperaturfaktor für endogene Veratmung	-
SP_d	Daily waste activated sludge production (solids)	$ÜS_d$	Tägliche Schlammproduktion	kg/d
$SP_{d,P}$	Daily sludge production from phosphorus removal	$ÜS_{d,P}$	Tägliche Schlammproduktion aus der Phosphorelimination	kg/d
SS_{AT}	Mixed liqour suspended solids in the activated tank (MLSS)	TS_{BB}	Trockensubstanzgehalt im Belebungsbecken	kg/m^3
t_{SS}	Sludge age, cell residence time	t_{TS}	Schlammalter	d
$X_{P,BM}$	Concentration of phosphorus embedded in the biomass	$X_{P,BM}$	In die Biomasse eingebauter Phosphor	mg/l
$X_{P,Prec}$	Concentration of phosphorus removed by simultaneous precipitation	$X_{P,Fäll}$	Durch Fällung eliminierter Phosphor	mg/l
X_{SS}	Concentration of suspended solids of wastewater; Influent activated	$X_{TS,ZB}$	Trockensubstanzkonzentration im Zulauf zum Belebungsbecken	mg/l

tank

The excess sludge production for biological and chemical phosphate elimination $SP_{,d,P}$ will be taken in consideration.

$$SP_{d,P} = Q_{d,DW} * (3 * X_{P,BioP} + 6{,}8 * X_{P,Prec,Fe} + 5{,}3 * X_{P,Prec,Al})/1000 \quad \left[\frac{kg}{d}\right]$$

with:

$$X_{P,BioP} = P_{Bio,t} * C_{BOD,IAT} - X_{P,BM} \quad \left[\frac{mg}{l}\right]$$

$$X_{P,Prec} = C_{P.IAT} - C_{P,EST} - X_{P,BM} - X_{P,BioP} \quad \left[\frac{mg}{l}\right]$$

At precipitation with $FeCl_3$, $XP_{,Prec,Al} = 0$, at precipiation with $AlCl_3$, $XP_{,Prec,Fe}=0$

International:		German:		
$C_{BOD,IAT}$	Concentration of BOD_5 in the homogenised sample, Influent activated tank	$C_{BSB,ZB}$	BSB_5-Konzentration im Zulauf zum Belebungsbecken	mg/l
$C_{P,EST}$	Concentration of phosphorus, effluent sedimentation tank	$C_{P,NB,Z}$	Phosphor Konzentration im Ablauf Nachklärung	mg/l
$C_{P,IAT}$	Concentration of phosphorus, inflow aeration tank	$C_{P,BB,Z}$	Phosphor Konzentration im Zulauf Belebungsbecken	mg/l
$P_{bio,t}$	Total bio phosphate, referred to BOD_5	$P_{bio,t}$	Gesamtes Bio-Phosphat, bezogen auf den BSB_5	kg P/kg BSB5
$Q_{d,DW}$	Inflow at dry weather per day	$Q_{t,d}$	täglicher Trockenwetterzufluß	m³/d
$SP_{d,P}$	Daily sludge production from phosphorus removal	$ÜS_{d,P}$	Tägliche Schlammproduktion aus der Phosphorelimination	kg/d
$X_{P,BioP}$	Concentration of phosphorus removed with biological excess phosphorus removal process	$X_{P,Prec}$	Bei der biologischen P-Elimination biologisch gebundener Phosphor	mg/l
$X_{P,BM}$	Concentration of phosphorus embedded in the biomass	$X_{P,BM}$	In die Biomasse eingebauter Phos-phor (Zellaufbau)	mg/l
$X_{P,Prec}$	Concentration of phosphorus removed by simultaneous precipi-tation	$X_{P,Fäll}$	Durch Fällung eliminierter Phosphor	mg/l

17.3.3 Oxygen Uptake

The oxygen uptake in the activated chamber results from the demand for C-degradation, nitrification and the reuse of oxygen because of the denitrification.

$$OU_{d,C} = B_{d,BOD} * \left(0{,}56 + \frac{0{,}15 * t_{SS} * F_T}{1 + 0{,}17 * t_{SS} * F_T}\right) \quad \left[\frac{kgO_2}{d}\right]$$

$$OU_{d,N} = Q_d * 4{,}3/1000 * (S_{NO3,D} - S_{NO3,IAT} + S_{NO3,EST}) \quad \left[\frac{kgO_2}{d}\right]$$

$$OU_{d,D} = Q_d * 2{,}9/1000 * S_{NO3,D} \quad \left[\frac{kgO_2}{d}\right]$$

If nitrification is chosen (without denitrification) $OU_{d,D}$ ($OV_{d,D}$) = 0.

If the total sludge age is smaller than the aerobic sludge age then $OU_{d,N}$ ($OV_{d,N}$) = 0.

The oxygen uptake for the C-elimination OUd,C depends on the temperature. This will be considered both for the sludge age and the temperature factors.

The oxygen uptake of the N-elimination results from the nutrient balance.

$$S_{NO3,tobedenitrified} = C_{N,IAT} - S_{orgN,EST} - S_{NH4,EST} - S_{NO3,EST} - X_{orgN,BM} \quad \left[\frac{mg}{l}\right]$$

$$S_{NO3,denitrificable} = \frac{0{,}75 * OU_{d,C} * V_D / V_{AT}}{2{,}9 * Q_d} * 1000 \quad \left[\frac{mg}{l}\right]$$

$$\frac{V_D}{V_{AT}} \max = 1 - \frac{t_{SS,aerob}}{t_{SS}}$$

The following points have to be considered:

- For the balance the nitrate outflow concentration is set to 0 mg/l.
- SNO3,D is the minimum from the denitrificable and the nitrate to be denitrificated.

International:		German:		
$B_{d,BOD}$	Daily BOD5-load	$B_{d,BSB5}$	Tägliche BSB5-Fracht	kg/d
F_T	Temperature factor for endogenous respiration	F_T	Temperaturfaktor für endogene Veratmung	-
$OU_{d,C}$	Daily oxygen uptake for carbon removal	$OV_{d,C}$	Täglicher Sauerstoffverbrauch für die C-Elimination	kg/d
$OU_{d,D}$	Daily oxygen uptake for carbon removal, which is covered by denitrification	$OV_{d,D}$	Täglicher Sauerstoffverbrauch für die C-Elimination, der durch die Denitrifikation gedeckt wird	kg/d
$OU_{d,N}$	Daily oxygen uptake for nitrifikation	$OV_{d,N}$	Täglicher Sauerstoffverbrauch für Nitrifikation	kg/d
$Q_{d,DW}$	Daily wastewater inflow with dry weather	Q_d	Täglicher Abwasserzufluss bei Trockenwetter	m³/d
$S_{NH4,EST}$	Concentration of ammonium nitrogen, effluent of sec. settling tank	$S_{NH4,AN}$	Ammonium Stickstoff, Ablauf Nachklärbecken	mg/l
$S_{NO3,D}$	Concentration of nitrate nitrogen to be denitrified	$S_{NO3,D}$	Zu denitrifierender Nitratstickstoff	mg/l
$S_{NO3,denitrificable}$	Concentration of denitrificable nitrate nitrogen	$S_{NO3,denitrifizierbar}$	Konzentration des denitrifizierbaren Nitratstickstoffs	mg/l
$S_{NO3,EST}$	Concentration of nitrate nitrogen, effluent of sec. settling tank	$S_{NO3,D,AN}$	Nitratstickstoff, Ablauf Nachklärbecken	mg/l
$S_{NO3,IAT}$	Concentration of nitrate nitrogen, influent of activated tank	$S_{NO3,ZB}$	Nitratstickstoff, Zulauf Belebungsbecken	mg/l
$S_{orgN,EST}$	Concentration of nitrate nitrogen, effluent of sec. settling tank	$S_{orgN,AN}$	Nitratstickstoff, Ablauf Nachklärbecken	mg/l

t_{SS}	Sludge age, cell residence time	t_{TS}	Schlammalter	d
V_{AT}	Volume of the aeration tank	V_{BB}	Volumen des Belebungsbeckens	m³
V_D	Volume of the biological reactor used for denitrification	V_D	Für Denitrifikation genutztes Volumen des Belebungsbeckens	m³
$X_{orgN,BM}$	Concentration of organic nitrogen embedded in the biomass	$X_{orgN,AN}$	In die Biomasse eingebauter organischer Stickstoff	mg/l

The real nitrate outflow value is the difference between the nitrate denitrificable and the nitrate to be denitrificated. If the first one is higher then $S_{NO3,EST}$ = 0 mg/l

17.3.4 Peak Oxygen Uptake

For the dimensioning of the aeration, the peak oxygen uptake per hour is decisive. This will be taken into consideration at the conversion from daily to hourly O_2-uptake with the peak factors.

$$OU_h = \frac{f_C * (OU_{d,C} - OU_{d,D}) + f_N * OU_{d,N}}{24} \qquad \left[\frac{kgO_2}{h}\right]$$

International:		German:		
f_C	Peak factor for carbon respiration	f_C	Stoßfaktor für die Kohlenstoffatmung	-
f_N	Peak factor for ammonium respiration	f_N	Stoßfaktor für die Ammoniumoxidation	-
$OU_{d,C}$	Daily oxygen uptake for carbon removal	$OV_{d,C}$	Täglicher Sauerstoffverbrauch für die C-Elimination	kg/d
$OU_{d,D}$	Daily oxygen uptake for carbon removal, which is covered by denitrification	$OV_{d,D}$	Täglicher Sauerstoffverbrauch für die C-Elimination, der durch die Denitrifikation gedeckt wird	kg/d
$OU_{d,N}$	Daily oxygen uptake for nitrifikation	$OV_{d,N}$	Täglicher Sauerstoffverbrauch für Nitrifikation	kg/d
OU_h	Oxygen uptake rate (hourly)	OV_h	Stündlicher Sauerstoffverbrauch	kg/h

The peak factors f_N and f_C are linear interpolated (in two directions) with the following table.

tSS [d]	4	6	8	10	15	25
fC	1,3	1,25	1,2	1,2	1,15	1,1
fN (BdBOD<=1200)			2,5(*)	2,5	2	1,5
fN (BdBOD>6000			2	1,8	1,5	1,5

Table 1: from table 8, DWA-A131/2/

(*) the value has been set for the interpolation between 8 and 10 days and B_{dBOD} between 1200 and 6000

Different load cases for N and C-peaks are calculated because both peaks usually don't occure at the same time. For the middle load f_N and f_C are set to 1.

At separate stage, intermittent and simultaneous denitrification 8 load cases have to be veri-

fied. 6 load cases for denitrification and 2 for nitrification for low temperature conditions.
If only nitrification is required, only 6 load cases for nitrification have to be verified.

	Nitrification	Nitrification / Denitrification	
Load case winter	fC and fN = 1 fC = 1 and fN	fC and fN = 1 fC = 1 and fN	In middle europe commonly the winter temperature is assumed to 10°C.
Load case design temperature	fC and fN = 1 fC = 1 and fN	fC and fN = 1 fC = 1 and fN	Recommended: 12°C.
Load case highest temperature	fC and fN = 1 fC = 1 and fN	fC and fN = 1 fC = 1 and fN	usually 20°C. Because of the lower solubility of oxygen in water at high temperature this usually is the most unfavourable case for the aeration.

Table 2: Load cases for intermittent denitrification

After the evaluation of the peak oxygen uptake the further way of calculation is different for pressure and surface aeration.

For pressure aeration you can continue here. The theory for surface aeration is described under **Surface Aeration**, page **63**.

17.4 Membrane Aeration

17.4.1 Required Oxygen Uptake

With the peak oxygen uptake OU_h the required oxygen transfer αOC is calculated. Basis is a algorithm of Wagner /1/.

Intermittent denitrification:

$$req\alpha OC = \alpha SOTR = OU_h * \frac{f_d * C_{S,20}}{(f_d * C_{S,T} - C_X) * \Theta^{(T-20)}} * \frac{1}{1 - V_D / V_{AT}} \qquad \left[\frac{kgO_2}{h}\right]$$

All other denitrification processes:

$$req\alpha OC = \alpha SOTR = OU_h * \frac{f_d * C_{S,20}}{(f_d * C_{S,T} - C_X) * \Theta^{(T-20)}} \qquad \left[\frac{kgO_2}{h}\right]$$

Oxygen solubility with Lutz Härtel /12/:

$$C_{S,T} = \frac{2234{,}34}{(T+45{,}93)^{1{,}31403}} \qquad \left[\frac{mg}{l}\right]$$

The water pressure is considered for the pressure aeration with f_D:

$$f_d = 1 + 0{,}5 * h_D / 10{,}35$$

The standard value for the construction hight is 0,3 m. This value can be adapted in **Options > Menu** to the given situation or product.

$$h_D = h_W - 0{,}3$$

International:		German:		
req.αOC	Oxygen transfer of an aeration facility in activated sludge with C_x, T, p	erf.αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x, T, p	kg/h
f_d	Factor for the effect of pressure on oxygen saturation concentration	f_d	Faktor für Einfluss des Wasserüberdruckes auf die O_2-Sättigungskonzentration	-
C_S	Dissolved oxygen saturation concentration dependent on the temperature and partial pressure	C_S	Sauerstoff-Sättigungskonzentration, ab-hängig von der Temperatur und dem Partialdruck	mg/l
$C_{S,T}$	Dissolved oxygen saturation concentration dependent on temperature and standard pressure	$C_{S,T}$	Sauerstoff-Sättigungskonzentration, ab-hängig von der Temperatur und dem Standard-Druck	mg/l
C_X	Dissolved oxygen concentration in aeration tanks (DO)	C_X	Sauerstoffkonzentration im Belebungsbe-cken	mg/l
Θ=1,024	Temperature correction	Θ=1,024	Temperaturkorrektur Belüftungskoeffizient	-
T	Temperature	T	Temperatur	°C
OU_h	Oxygen uptake rate (hourly)	OV_h	Stündlicher Sauerstoffverbrauch	kg/h
V_{AT}	Volume of the aeration tank	V_{BB}	Volumen des Belebungsbeckens	m³
V_D	Volume of the biological reactor used for denitrification	V_D	Für Denitrifikation genutztes Volumen des Belebungsbeckens	m³
h_D	Immersion depth of air	h_D	Einblastiefe	m
h_W	Water level	h_W	Höhe des Wasserspiegels	m

For the further design of the aeration system the maximum oxygen supply reqαOC resulting from the load cases is valid. reqαOC is the oxygen supply of an aeration system in activated sludge under operation conditions.

The aeration system usually will be tendered for the verification of the oxygen supply OC under pure water conditions. The relation between activated sludge and pure water conditions is the α-factor.

$$SOTR = OC = \frac{req.\alpha OC}{\alpha} \qquad \left[\frac{kgO_2}{h}\right]$$

International: German:

OC	Oxygen transfer of an aeration facility in clean water with C_x=0, T=20°C, p=1013hPa	OC	O_2-Zufuhr einer Belüftungseinrichtung in Reinwasser bei C_x=0, T=20°C, p=1013hPa	kg/h
αOC	Oxygen transfer of an aeration facility in activated sludge with C_x=0, T=20°C, p=1013hPa	αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x=0, T=20°C, p=1013hPa	kg/h
req.αOC	Oxygen transfer of an aeration facility in activated sludge with C_x, T, p	erf.αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x, T, p (Betriebsbedingungen)	kg/h
α	Quotient of oxygen transfer in activated sludge and in clean water	α	Verhältnis von Sauerstoffzufuhr in belebtem Schlamm und in Reinwasser	-

The α -factor is < 1 and that means OC > αOC.
The higher value has to be verified by the suppliers of the aeration equipment.

Oxygen Supply Factor

Below you will find some experienced factors for different flow and mixing conditions, geometry and sludge conditions.

Mixing Conditions	Sludge Age d	Air Volume m³/(m³*h)	α -Factor
Plug Flow	30	0,67	0,84
Plug Flow	25	0,37	0,80-0,87
mixed	8-15	0,16 – 1,43	0,36-0,66

Table 3: α –values in activated chambers with divided mixing and aeration (Table 1□□3/□

Sludge Age d	α -Factor
3	0,3
10	0,37
25	0,82
30	0,83

Table 4: α –values depending on the sludge age (/3/: picture 13)

	Belt Aeration System	Extensive Arrangment	Plate Diffusers	Divided Mixing / Aeration
Number of values		4	4	2
Average value	0,64	0,62	0,69	0,85

Table 5: α –value for membrane aeration systems (/3/: table 4.1)

Required Air Volume

Standard Conditions

The required hourly air volume $Q_{L,D}$ will be calculated as follows:

$$erf.Q_{L,d,0} = \frac{1000 * SOTR}{SSOTE * h_D} = \frac{1000 * SOTR}{3 * SSOTE\% * h_D} \qquad \left[\frac{Nm^3}{h}\right]$$

Required $_{QL,D}$ is the required hourly air volume under standard conditions:

$$T_0 = 273{,}15\,K$$

$$p_0 = 1013{,}25\,mbar$$

Operating Conditions

The required hourly air volume $reqQ_L$ under operation conditions results with the international formula for the geodetic height and the ideal gas equation as follows:

Adaption to the operation pressure

International geodetic height formula (T = 288,15 K, pN = 1013,25 mbar, Temperature Gradient 0,65 K/100m, valid up to 11 km height)

$$p = p_0 * \left(1 - \frac{0{,}0065 * h}{288{,}15}\right)^{5{,}255} \qquad [mbar]$$

Adaption to the suction temperature: ideal gas equation

$$Q_L = \frac{Q_{L,0} * p_0 * T}{p * T_0} \qquad \left[\frac{m^3}{h}\right]$$

International:		German:		
h	Geo height NN	h	Höhe über NN	m
h_D	Immersion depth of air	h_D	Einblastiefe	m
p	Operating pressure	p	Betriebsdruck	mbar
p_0	Standard pressure (=1013,25 mbar)	p_0	Normdruck (=1013,25 mbar)	mbar
Q_L	Air volume flow per hour	Q_L	Stündliche Luftmenge	m³/h
$Q_{L,0}$	Air volume flow per hour, standard conditions	$Q_{L,0}$	Stündliche Luftmenge unter Normbedingungen	m³/h
SOTR=OC	Standard oxygen transfer rate	SOTR=OC	Erforderliche Sauerstoffzufuhr unter Standardbedingungen	kgO2/h
SSOTE	Specific standard oxygen transfer efficiency	SSOTE	Spezifische Sauerstoffzufuhr unter Standard-Bedingungen	gO2/(m³*m)
SSOTE%	Specific oxygen transfer capacity	SSOTE%	Spezifische Sauerstoffausnutzung	%/m
T	Operating tempertur	T	Betriebstempertur, hier: An-	K

	(suction side)		saugtemperatur	
T_0	Standard temperature (=273,15 K)	T_0	Standard Temperatur (=273,15 K)	K
Φ	Relative humidity	φ	Relative Feuchte	%

For the pressure air technology commonly a suction temperature of T = 293,15 K is used. This temperature is the basis for the parameters in catalogues of suppliers.

Daily Air Volume

The required daily air volume results from the mulitiplication with the aeration time.

17.4.2 Blower

The blower will be selected by the required air volume Q_L and the required counter pressure.

The required air volume will be adapted to the operation conditions (T,P). With the international height formula also the geodetic height is taken into account. The air demand increases with the geodetic height.

If a number of blowers are chosen, the capacities will be added to the total air supply Q_L.

The counter pressure is the sum of pipeline losses, aerator losses and the immersion height. The pipeline losses are available under **Options > Generel Constants**. The aerator losses will be provided in the **data banks**.

Evaluation of the operation point

In the data bank for every blower type the motor power is listed depending on the required counter pressure.

This means, one blower is listed several times with different pairs of counter pressure and motor power.

All points between will be interpolated.

17.4.3 Aerator

<u>Number</u>

The aerator elements will be dimensioned for the standard conditions. That means, the total air volume of the blowers has to be converted again to standard conditions.

$$Q_{L,0} = \frac{QL * p * T_0}{p_0 * T} \qquad [m^3]$$

The number of aerator elements respectively the aerator length results as follows:

$$n = \frac{Q_{L,0}}{b_A} \qquad [piece, m]$$

International:		German:		
b_A	Load of the aerators	b_A	Belüfterbeaufschlagung	Nm³/(m*h) oder Nm³/(Stück*h)
n	Number of aerotors	n	Anzahl Belüftersegmente	-
Q_L	Air volume flow per hour	Q_L	stündliche Luftmenge	m³/h
$Q_{L,}$	Capacity of a blower	$Q_{L,}$	Tatsächliche Förderkapazität der gewählten Gebläse	m³/h
$Q_{L,0}$	Capacity of a aerator (standard conditions)	$Q_{L,0}$	Förderkapazität der Belüfterelemente (Normbedingungen)	m³/h

Floor coverage

One important value for the oxygen input is the distribution of the aerators on the bottom of the chamber.

The gasing area usually is listed in the data bank. If there is no value in the data set, the gasing area will be calculated with a formula of Wagner /WAR 100, 1.38/. It is assumed that tube aerators gas out along the hole surface.

On the side of the tubes there are unperforated strips. These strips has to close the tubes when the aeration is off. The width of the strips is about 30 mm.

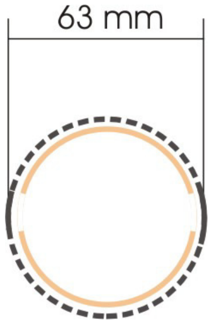


Fig. 57: Perforated area of a tube aerator

Typical perforated area: 0,16 m² per m length of aerator

17.5 Pipelines

17.5.1 Cross Section

The aeration system usually contains a ramified pipeline system. This pipeline system consists of various diameters.

The air will be suctioned at environmental pressure and the temperature of the blower room. By the blowers the air will be compressed to the operation pressure in the pipeline system. Hereby the temperature will increase because of the compression.

For the dimension of the pipe diameters the compression and the temperature increase are considered.

It is assumed, that the heat of compression will totally affect the temperature increase of the gas (adiabatic compression).

Then the formular of Poisson /13/, page 130 f is valid for the pressure relation.

$$\frac{p_C}{p_S} = \left(\frac{T_C}{T_S}\right)^{\chi/(\chi-1)} = \left(\frac{Q_{L,S}}{Q_{L,C}}\right)^{\chi}$$

International:		German:		
Index C	Pressure site (compression)	Index D	Druckpage	
p_S	Pressure, suction site	p_A	Druck, Ansaugpage	mbar
$Q_{L,S}$	Capacity of a blower, suction site = $Q_{L,Blower}$	$Q_{L,,A}$	Luftmenge der gewählten Gebläse, Ansaugpage = $Q_{L,Gebläse}$	m³/h
T_S	Temperature, suction site	T_A	Temperatur, Ansaugpage	T
κ = 1.4	Coeffizient for adiabatic compression	κ =1,4	Adiabatenkoeffizient für 2-atomige Gase	-

With the equation above the temperature after compression T_C and the compressed air volume $Q_{L,C}$ can be evaluated.

The required pipe diameter results from the air volume and the velocity.

$$A_{pipe} = \frac{Q_{L,C}}{v_L * 3600} \qquad [m^2]$$

International:		German:		
A_{pipe}	Cross section of a pipe	A_{Rohr}	Rohrquerschnitt	m²
$Q_{L,C}$	Capacity of a blower, pressure site	$Q_{L,D}$	Luftmenge, Druckpage	m³/h
V_L	Velocity of air	v_L	Luftgeschwindigkeit im Rohr	m/s

The flow velocity is preset with 12 m/s. The velocity should be less than 16 m/s. With the velocity the pressure will increase. Also at high velocities a noticeable whistling can occure.

17.5.2 Pressure Losses

The pressure loss of the pipes is preselected with 100 mbar under **Opions > General Constants**.

The pressure loss depends on a number of factors, for example:

- Length of the pipeline system
- Number of bows
- Material of the pipe
- Velocity in the pipes

With short pipelines and low velocities the value for the pressure loss can be decreased. If there are no experienced values, the losses should be calculated.

17.6 Surface Aeration

Please notice:

The surface aeration is not yet part of AQUA AERO. The theoretical basis is already included in the documentation to show the differences between the aeration systems.

17.6.1 Oxygen Supply

With the peak oxygen uptake OUh the required oxygen supply αOC of the aeration system will be evaluated. As for the pressure aeration also here the algorythm of Wagner /1/ is used.

Intermittent Denitrification:

$$req\alpha OC = \alpha SOTR = OU_h * \frac{f_d * C_{S,10}}{(f_d * C_{S,T} - C_X) * \Theta^{(T-10)}} * \frac{1}{1 - V_D / V_{AT}} \quad \left[\frac{kgO_2}{h}\right]$$

All elimination processes:

$$req\alpha OC = \alpha SOTR = OU_h * \frac{f_d * C_{S,10}}{(f_d * C_{S,T} - C_X) * \Theta^{(T-10)}} \quad \left[\frac{kgO_2}{h}\right]$$

The first part of the equation contains a model for the respiration of the bacteria (OUh), the second part handles the diffusion of oxygen from the gas bubble to the liquid phase.

With Lutz Härtel /12/ the oxygen saturation concentration cs at temperature T will be evaluated as follows:

$$C_{S,T} = \frac{2234,34}{(T + 45,93)^{1,31403}} \quad \left[\frac{mg}{l}\right]$$

fd takes the influence of the water pressure in consideration. For surface aeration is valid:

$$f_d = 1 + 0,07 h_W / 10,35$$

International:		German:		
C_S	Dissolved oxygen saturation concentration dependent on the temperature and partial	C_S	Sauerstoff-Sättigungskonzentration, abhängig von der Temperatur und dem	mg/l

	pressure		Partialdruck	
$C_{S,T}$	Dissolved oxygen saturation concentration dependent on temperature and standard pressure	$C_{S,T}$	Sauerstoff-Sättigungskonzentration, abhängig von der Temperatur und dem Standard-Druck	mg/l
C_X	Dissolved oxygen concentration in aeration tanks (DO)	C_X	Sauerstoffkonzentration im Belebungs-becken	mg/l
f_d	Factor for the effect of pressure on oxygen saturation concentration	f_d	Faktor für Einfluss des Wasserüberdru-ckes auf die O_2-Sättigungskonzentration	-
h_W	Water level	h_w	Höhe des Wasserspiegels	m
OU_h	Oxygen uptake rate (hourly)	OV_h	Stündlicher Sauerstoffverbrauch	kg/h
req.αOC	Oxygen transfer of an aeration facility in activated sludge with C_x, T, p	erf.αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x, T, p	kg/h
T	Temperature	T	Temperatur	°C
V_{AT}	Volume of the aeration tank	V_{BB}	Volumen des Belebungsbeckens	m³
V_D	Volume of the biological reactor used for denitrification	V_D	Für Denitrifikation genutztes Volumen des Belebungsbeckens	m³
Θ=1,024	Temperature correction	Θ=1,024	Temperaturkorrektur Belüftungskoeffi-zient	-

17.6.2 Power of the Aeration

The total power N for the oxygen transfer is as follows:

$$N = \frac{SOTR}{SAE} \qquad [kW]$$

The specific oxygen transfer is calculated:

$$SSOTR = k_B * h_d * D_m^{\ 2} * v_u^{\ (2,5bis3)}$$

Exponent 2,5, valid for horizontal axes surface aerator
3,0, valid for vertical axes surface aerator

Typical values of oxygen transfer rates for different types of surface aerators:

	Transfer rate kgO2/kW/h			
Aerator Type	Standard/ pure water 20°C, 0 mg/l		Operation/ waste water 15°C, 2 mg/l	
Slow rotation vertical axis	1,2	- 3,0	0,7	- 1,5
Fast rotation vertical axis	1,2	- 2,2	0,7	- 1,2
Horizontal axis	0,9	- 2,2	0,5	- 1,1

Table 6: From /8/, page 572

Typical chamber dimensions for surface aerators:

Power	Depth	Width
kW	m	m

7,0	3,0 - 3,7	9,1 - 12,2
15,0	3,7 - 4,3	10,7 - 15,2
22,0	4,0 - 4,6	12,2 - 1,3
30,0	3,7 - 5,2	13,7 - 19,8
37,0	4,6 - 5,5	13,7 - 22,9
56,0	4,6 - 6,1	15,2 - 25,9
75,0	4,6 - 6,1	18,3 - 27,4

Table 7: From /8/, page 574

Mixing

The required power input depends on the chamber volume and the shape.

Rectangular, Circular Chambers:

Volume	500 m³	1000 m³	2000 m³
Specific energy input W/m³	20	15	10

Table 8: Source /9/, 10 - 23

Oxidation Ditch, Ring Chamber

For oxidation ditch and ring chamber a specific energy input of 10 W/m³ is recommended.

Separate Mixing

For mixing by separate mixers a value of 1- 5 W/m³ is recommended /4/.

17.7 Oxygen Efficiency

The oxygen efficiency SAE is the parameter for the economic of the aeration system. It will be evaluated, how much energy is required to supply the oxygen into the water.

As first step the power consumption of the blowers and mixers will be evaluated. Then the real oxygen input into the activated chamber is calculated.

Blower

The power consumption of the blowers at the operation point has been evaluated with the values of the data bank. Here the losses because of motor efficiency, mechanical and frequency converter efficiency must be considered.

$$PA_{Gebläse} = \frac{PK * (1 + Vmech\%) * (1 + VFU\%)}{\eta} \qquad [kW]$$

Mixer

The real power consumption of the mixers cannot be calculated in AQUA AERO. Herefore you need informations of the suppliers. Therefore this value should be requested from the mixer suppliers.

Power Consumption

The total power consumption is the sum of the values from blower and mixer:

$$PA = PA_{Gebläse} + PA_{Rührwerk} \qquad [kW]$$

Standard Oxygen Transfer Rate

The chosen blowers are larger than the blowers required from the design. The standard oxygen transfer rate SOTR, resulting out of the real air volume flow has to be re evaluated.

$$SOTR = \frac{Q_L * SSOTE * h_D}{1000} \qquad \left[\frac{kgO_2}{h}\right]$$

Oxygen Efficiency

For the calculation of the oxygen efficiency SAE the oxygen input will be set in relation to the power consumption of the machines.

Oxygen efficiency related to the blowers:

$$SAE_{Gebläse} = \frac{SOTR}{PA_{Gebläse}} \qquad \left[\frac{kgO_2}{kWh}\right]$$

Oxygen efficiency related to blowers and mixers:

$$SAE = \frac{SOTR}{PA} \qquad \left[\frac{kgO_2}{kWh}\right]$$

International:		German:		
h_D	Immersion depth of air	h_D	Einblastiefe	m
PA	Power input	PA	Leistungsaufnahme	kW
PK	Coupling power	PK	Kupplungsleistung	kW
Q_L	Air volume flow per hour	Q_L	Stündliche Luftmenge	m^3/h
SAE	Oxygen efficiency	SAE=OP	Sauerstoffertragswert	kgO_2/kWh
SOTR=OC	Standard oxygen transfer rate	SOTR=OC	Erforderliche Sauerstoffzufuhr	kgO2/h
SSOTE	Specific standard oxygen transfer efficiency	SSOTE	Spezifische Sauerstoffzufuhr unter Standard-Bedingungen	gO2/(m^3*m)

The following table shows guide values for the oxygen efficiency for different membrane aeration systems.

Capacity table of aeration systems				
	Favorable		Average	
	SSOTE % %/m	SAE kg/kWh	SSOTE% %/m	*SAE kg/kWh*
Pure water conditions				
Extensively arranged aerators	8,0	4,5	6,0	3,4
Extensively arranged plates	10,6	5,5	8,0	4,1
Mixing and aeration	6,7	4,2	5,0	3,2
Operation conditions				
Extensively arranged aerators	4,8	2,7	3,6	2,0
Extensively arranged plates	6,4	3,2	4,8	2,5
Mixing and aeration	4,1	2,5	3,1	2,0

Table 9: Table 2 /1/ Modified table of reference values for membrane aeration systems

17.8 Economical Calculations

17.8.1 Basic Data

Two compare different aeration systems all costs over the life time of the system have to be considered. These are Invest-, Reinvest- and Operating Costs.

Costs, before the reference date have to be added up on interest. Costs which incure later have to be discounted. Costs at the reference date are the current worth, the sum is the **project life cycle cost**.

Value	**Description**
Life Time	Time of use of machines, buildings ... If the life time is shorter than the project life time, a reinvest is required.
Project Life Time	Estimated time of use for the whole system. For the aeration system a life time of 25 years is ok..
Reference Date	Beginning of the first year of operation.
Interest Rate	Long term interest rate for water and wastewater supply works, recommended 3,00 % p.a. /5/
Project Life Cycle Costs	Sum of the current worths of a project at the reference date.

Basis for the economical calculations is the KVR-Guideline/5/. The model 4.4.4 „Conversion of progressiv increasing cost lines“ is used.

17.8.2 Investment Costs

The invest costs are assumed as a single payment at the reference date. This is permissibly for a limited project like the aeration systems and because this invest is usually done a short time before starting the operation.

17.8.3 Reinvest Costs

There are some parts of the equipment, which has to be replaced during the life time. These components will be reinvested and have to be considered in the total costs. They will each be discounted to the reference date.

Discount factor DFAKE for single payments:

$$DFAKE(i;n) = \frac{1}{(1+i)^n}$$

The cash value IK(0) results out of the multiplication of the nominal reinvest costs with the discount factor.

$$\mathrm{IK}(0) = \mathrm{IK}(n) * \mathrm{DFAKE}$$

International:		German:		
DFAKE	Discount factor for a single payment	DFAKE	Diskontierungsfaktor für einmalige Zahlungen	-
i	Interest rate (absolute), for example 3% = 0,03	i	Zinssatz (absolut), z.B. 3% = 0,03	-
IK(0)	Current worth of investment at the reference date „0“	IK(0)	Barwert der Investitionskosten zum Zeitpunkt „0“	€
IK(n)	Investment costs at the date n	IK(n)	Investitionskosten zum Zeitpunkt n	€
n	Project life time in years	n	Beobachtungszeitraum in Jahren	-

Ecample

Evaluation time n = 25 Jahre, Interest rate i = 3%

Average life time of a pump = 10 years

During the evaluation time or project life time the pump has two be replaced for two times, in the year n1 = 10 and n2 = 20. The cost of the pump is IK(n) = 20.000,- €.

The reinvest costs (IK) of the pumpe will be calculated back to the zero point.

*IK (0) = IK (n) * (DFAKE (3%;10) + DFAKE (3%;20))*

*= 20.000 € * (0,74409 + 0,55368) = 25.944,40 €*

17.8.4 Operating Costs

General

The conversion of operating costs to the current worth is a little bit more complicated, because it is a cost row with a yearly increase rate.

The model for the discount factor of a numerical series with progressive increase is as follows:

$$\mathrm{DFAKRP}(\mathrm{r,i,n}) = (1+r)\frac{(1+i)^n - (1+r)^n}{(1+i)^n (i-r)}$$

$$\mathrm{BK}(0) = \mathrm{BK} * \mathrm{DFAKRP}$$

International:		German:		
BK	Operational costs	BK	Betriebskosten (bekannt)	€
BK(0)	Current worth of the operational costs, incl. cost increase	BK(0)	Barwert der Betriebskosten inkl. Preis-steigerung	€
DFAKRP	Discount factor for a numerical series with progressive increase	DFAKRP	Diskontierungsfaktor für eine Zahlungs-reihe mit Progressiver Steigerung	-
i	Interest rate (absolute), for example 3% = 0,03	i	Zinssatz (absolut), z.B. 3% = 0,03	-
n	Project life time in years	n	Beobachtungszeitraum in Jahren	a
r	Yearly rate of increase	r	Jährliche Preissteigerungsrate	-

⚠ *For i = r is DFAKRP = n.*

The operating costs are divided into energy costs and other operating costs. For both parts different increasing rates can be chosen.

Please note, that the substitution of equipment will be handled at the reinvest costs.

It is assumed that the stuff costs, repectively the time amount is comparable for the different aeration concepts. Therefore they are not concluded in the operating costs.

Energy Costs

At the membrane aeration the energy cost mainly consist of the energy consumption of blowers and mixers. Both energy amounts will be evaluated differently.

Blower

The operation of the blowers depends on the oxygen demand respectively the load of the WWTP. The blowers therefore will be operated very variable. An evaluation of the energy consumption by the operating time is not adequate.

Here the oxygen efficiency is used to adapt the energy consumption directly to the oxygen demand.

$$\mathrm{PA}_{\mathrm{m}} = \frac{SOTR * m}{SAE_{Blower}} \qquad [kWh/h]$$

$$\mathrm{BK}_{\mathrm{Blower}} = \mathrm{PA}_{\mathrm{Blower,\,middle}} * tL * \left(TarifHT * \frac{Load\%}{100} + TarifNT * \frac{100 - Load\%}{100} \right) \qquad [€/d]$$

International:		German:		
BK	Energy cost blower	BK	Energiekosten Gebläse	€
Load%	Load high tarif time	Fracht%	Fracht in der HT-Zeit	%
m	Factor	m	Faktor zur mittlere Sauerstoff-last	-
PA	Power input	PA	Leistungsaufnahme	kW
SAE	Oxygen efficiency	SAE=OP	Sauerstoffertragswert	kgO_2/kWh
SOTR	Standard oxygen transfer rate	SOTR	Mittlere Sauerstoffzufuhr	kgO2/h

Tarif	Energy price (high, low)	Tarif	Energiepreis HT- bzw NT-Zeit	€/kWh
t_L	Operation time of the blowers	t_L	Belüftungszeit	h/d

For the design of the aeration system peak loads are considered. For the operating costs we need the average oxygen demand. By evaluating the relation between peak and average load the average load is about 13 % lower than the peak load. For the calculation of the operating costs the average oxygen demand is presetted by 0,86.

The aeration time is – with the exception of intermittent denitrification – 24h.

Mixer

The energy demand of the mixers will be calculated by the operation time and the power consumption. For suitable chamber shapes it could be economical to stop the mixers during the aeration phase. The operation time for these aggregates will then only be considered for the unaerated time.

If suppliers data are available, they should be entered at the form oxygen efficiency. Then they will be automatically considered at the operating costs.

The energy demand W of the mixers is the sum of a part in the aerated and the anaerated period. Also operational costs are separately calculated for high and low tarif times.

$$W_{Mixer} = \mathrm{PA}_{\mathrm{bel.Phase}} * 24h/d + PA_{unbel.Phase} * (24h/d - tL) \qquad [kWh/d]$$

$$BK_{Mixer} = W_{Mixer} * \left(\frac{24 - tNT}{24} * TarifHT + \frac{tNT}{24} * TarifNT \right) \qquad [€/d]$$

International:		German:		
BK	Energy cost mixer	BK	Energiekosten Rührwerk	€
PA	Power input (aerated / non aerated)	PA	Leistungsaufnahme (belüftete / nur unbelüftete Phase)	kW
Tarif	Energy price (high, low)	Tarif	Energiepreis HT- bzw NT-Zeit	€/kWh
t_L	Operation time of the blowers	t_L	Belüftungszeit	h/d
tNT	Low tarif time	tNT	NT-Zeit	%
W_{Mixer}	Energy consumption of the mixer	$W_{Rührwerk}$	Energiebedarf der Mixer	kWh/d

If all mixers are operated continuously, the number of mixers in the aerated period is the same as the total number of mixers.

If there is only one current tarif, NT = 0.

Further Operating Costs

The further operating costs include:

- Consumables, which are necessary for maintenance of the equipment like fan belts or oil and
- Maintenance, as a part of the invest costs from blower (incl. acoustic hood and standby blower) and mixer.

17.8.5 Project Life Cycle Costs

The current worth of the project life cycle costs of an aeration system results from invest-, reinvest- and operating costs, converted to the reference date. The reference date is the start time of operation. Because here the reference date is the time of invest, the invest costs are current worths (year =0). Costs of reinvest and operating costs have to be discounted to the reference time.

$$\mathrm{PKBW}(0) = \mathrm{IK}(0) + \mathrm{RIK}(0) + \mathrm{BK}(0)$$

International:		German:		
BK(0)	Current worth of the operational costs	BK(0)	Barwert der Betriebskosten	€
IK(0)	Current worth of investment at the reference date „0“	IK(0)	Barwert der Investitionskosten zum Zeitpunkt „0“	€
PKBW(0)	Current worth at reference time „0“	PKBW(0)	Projektkostenbarwert zum Zeitpunkt „0“	€
RIK(0)	Current worth of the reinvest costs	RIK(0)	Barwert der Reinvestitionskosten	€

18 Symbols

German:		International:		
A_{Rohr}	Rohrquerschnitt	A_{pipe}	Cross section of a pipe	m²
b_A	Belüfterbeaufschlagung	b_A	Load of the aerators	Nm³/(m*h) Nm³/(St.*h)
$B_{d,BSB5}$	Tägliche BSB5-Fracht	$B_{d,BOD}$	Daily BOD5-load	kg/d
BK	Betriebskosten / Energiekosten	BK	Operational costs	€
BK(0)	Barwert der Betriebskosten inkl. Preissteigerung	BK(0)	Current worth of the operational costs, incl. cost increase	€
$C_{BSB,ZB}$	BSB_5-Konzentration im Zulauf zum Belebungsbecken	$C_{BOD,IAT}$	Concentration of BOD_5 in the homogenised sample, Influent activated tank	mg/l
$C_{P,NB,Z}$	Phosphor Konzentration im Ablauf Nachklärung	$C_{P,EST}$	Concentration of phosphorus, effluent sedimentation tank	mg/l
$C_{P,BB,Z}$	Phosphor Konzentration im Zulauf Belebungsbecken	$C_{P,IAT}$	Concentration of phosphorus, inflow aeration tank	mg/l
C_S	Sauerstoff-Sättigungskonzentration, abhängig von der Temperatur und dem Partialdruck	C_S	Dissolved oxygen saturation concentration dependent on the temperature and partial pressure	mg/l
$C_{S,T}$	Sauerstoff-Sättigungskonzentration, abhängig von der Temperatur und dem Standard-Druck	$C_{S,T}$	Dissolved oxygen saturation concentration dependent on temperature and standard pres-sure	mg/l
C_X	Sauerstoffkonzentration im Bele-bungsbecken	C_X	Dissolved oxygen concentration in aeration tanks (DO)	mg/l
D_{BB}	Äußerer lichter Durchmesser des Belebungsbeckens	D_{AT}	Outer free diameter of the activat-ed chamber	m
$D_{BB,i}$	Innendurchmesser beim Ringbe-cken	$D_{AT,i}$	Inner Diameter of a ring chamber	m
DFAKE	Diskontierungsfaktor für einmalige Zahlungen	DFAKE	Discount factor for a single pay-ment	-
DFAKRP	Diskontierungsfaktor für eine Zah-lungsreihe mit Progressiver Steige-rung	DFAKRP	Discount factor for a numerical series with progressive increase	-
f_C	Stoßfaktor für die Kohlenstoffat-mung	f_C	Peak factor for carbon respiration	-
f_d	Faktor für Einfluss des Wasser-überdruckes auf die O_2-Sättigungskonzentration	f_d	Factor for the effect of pressure on oxygen saturation concentra-tion	-
f_N	Stoßfaktor für die Ammoniumoxida-tion	f_N	Peak factor for ammonium respi-ration	-
F_T	Temperaturfaktor für endogene Veratmung	F_T	Temperature factor for endoge-nous respiration	-
h	Höhe über NN	h	Geo height NN	m
h_D	Einblastiefe	h_D	Immersion depth of air	m
h_w	Höhe des Wasserspiegels	h_W	Water level	m

German:		International:		
i	Zinssatz (absolut), z.B. 3% = 0,03	i	Interest rate (absolute), for example 3% = 0,03	-
IK(0)	Barwert der Investitionskosten zum Zeitpunkt „0"	IK(0)	Current worth of investment at the reference date „0"	€
IK(n)	Investitionskosten zum Zeitpunkt n	IK(n)	Investment costs at the date n	€
L_{BB}	Länge Belebungsbecken	L_{AT}	Length of the aeration tank	m
Fracht%	Fracht in der HT-Zeit	Load%	Load high tarif time	%
m	Faktor zur mittlere Sauerstofflast	m	Factor	-
n	Anzahl	n	Number	-
n_{BB}	Beckenanzahl	n_{AT}	Number of tanks	-
OC	O_2-Zufuhr einer Belüftungseinrichtung in Reinwasser bei C_x=0, T=20°C, p=1013hPa	OC	Oxygen transfer of an aeration facility in clean water with C_x=0, T=20°C, p=1013hPa	kg/h
$OV_{d,C}$	Täglicher Sauerstoffverbrauch für die C-Elimination	$OU_{d,C}$	Daily oxygen uptake for carbon removal	kg/d
$OV_{d,D}$	Täglicher Sauerstoffverbrauch für die C-Elimination, der durch die Denitrifikation gedeckt wird	$OU_{d,D}$	Daily oxygen uptake for carbon removal, which is covered by denitrification	kg/d
$OV_{d,N}$	Täglicher Sauerstoffverbrauch für Nitrifikation	$OU_{d,N}$	Daily oxygen uptake for nitrifikation	kg/d
OV_h	Stündlicher Sauerstoffverbrauch	OU_h	Oxygen uptake rate (hourly)	kg/h
p	Betriebsdruck	p	Operating pressure	mbar
P,BM	Phosphat für Zellaufbau, bezogen auf den BSB_5	P,BM	Phosphate for celle design, referred to BOD_5	kg P/kg BSB_5
p_0	Normdruck (=1013,25 mbar)	p_0	Standard pressure (=1013,25 mbar)	mbar
PA	Leistungsaufnahme	PA	Power input	kW
Pbio,P	Gesamtes Bio-Phosphat, bezogen auf den BSB_5	Pbio,P	Total bio phosphate, referred to BOD_5	kg P/kg BSB_5
PK	Kupplungsleistung	PK	Coupling power	kW
PKBW(0)	Projektkostenbarwert zum Zeitpunkt „0"	PKBW(0)	Current worth at reference time „0"	€
p_A	Druck, Ansaugpage	p_S	Pressure, suction site	mbar
Q_d	Täglicher Abwasserzufluss bei Trockenwetter	$Q_{d,DW}$	Daily wastewater inflow with dry weather	m³/d
$Q_{t,d}$	Täglicher Trockenwetterzufluß	$Q_{d,DW}$	Inflow at dry weather per day	m³/d
Q_L	Stündliche Luftmenge	Q_L	Air volume flow per hour	m³/h
$Q_{L,0}$	Stündliche Luftmenge unter Normbedingungen	$Q_{L,0}$	Air volume flow per hour, standard conditions	m³/h
$Q_{L,0}$	Förderkapazität der Belüfterelemente (Normbedingungen)	$Q_{L,0}$	Capacity of a aerator (standard conditions)	m³/h
$Q_{L,D}$	Luftmenge, Druckpage	$Q_{L,C}$	Capacity of a blower, pressure site	m³/h
$Q_{L,,A}$	Luftmenge der gewählten Gebläse, Ansaugpage = $Q_{L,Gebläse}$	$Q_{L,S}$	Capacity of a blower, suction site = QL,Blower	m³/h
r	Jährliche Preissteigerungsrate	r	Yearly rate of increase	-
erf.αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x,	req.αOC	Oxygen transfer of an aeration facility in activated sludge with C_x,	kg/h

German:		International:		
	T, p		T, p	
RIK(0)	Barwert der Reinvestitionskosten	RIK(0)	Current worth of the reinvest costs	€
SAE=OP	Sauerstoffertragswert	SAE	Oxygen efficiency	kgO_2/kWh
SF	Sicherheitsfaktor für Nitrifikation	SF	Safety factor for nitrification	-
$S_{NH4,AN}$	Ammonium Stickstoff, Ablauf Nachklärbecken	$S_{NH4,EST}$	Concentration of ammonium nitrogen, effluent of sec. settling tank	mg/l
$S_{NO3,D}$	Zu denitrifizierender Nitratstickstoff	$S_{NO3,D}$	Concentration of nitrate nitrogen to be denitrified	mg/l
$S_{NO3,denitrifizierbar}$	Konzentration des denitrifizierbaren Nitratstickstoffs	$S_{NO3,denitrificable}$	Concentration of denitrificable nitrate nitrogen	mg/l
$S_{NO3,D,AN}$	Nitratstickstoff, Ablauf Nachklärbe-cken	$S_{NO3,EST}$	Concentration of nitrate nitrogen, effluent of sec. settling tank	mg/l
$S_{NO3,ZB}$	Nitratstickstoff, Zulauf Belebungs-becken	$S_{NO3,IAT}$	Concentration of nitrate nitrogen, influent of activated tank	mg/l
$S_{orgN,AN}$	Nitratstickstoff, Ablauf Nachklärbe-cken	$S_{orgN,EST}$	Concentration of nitrate nitrogen, effluent of sec. settling tank	mg/l
SOTR=OC	Erforderliche Sauerstoffzufuhr	SOTR=OC	Standard oxygen transfer rate	kgO2/h
$ÜS_d$	Tägliche Schlammproduktion	SP_d	Daily waste activated sludge production (solids)	kg/d
$ÜS_{d,P}$	Tägliche Schlammproduktion aus der Phosphorelimination	$SP_{d,P}$	Daily sludge production from phosphorus removal	kg/d
TS_{BB}	Trockensubstanzgehalt im Bele-bungsbecken	SS_{AT}	Mixed liqour suspended solids in the activated tank (MLSS)	kg/m^3
SSOTE	Spezifische Sauerstoffzufuhr unter Standard-Bedingungen	SSOTE	Specific standard oxygen transfer efficiency	$gO2/(m^3*m)$
SSOTE%	Spezifische Sauerstoffausnutzung	SSOTE%	Specific oxygen transfer capacity	%/m
T	Temperatur	T	Temperature	°C
T_0	Standard Temperatur (=273,15 K)	T_0	Standard temperature (=273,15 K)	K
Tarif	Energiepreis HT- bzw NT-Zeit	Tarif	Energy price (high, low)	€/kWh
t_L	Belüftungszeit	t_L	Operation time of the blowers	h/d
tNT	NT-Zeit	tNT	Low tarif time	%
T_A	Temperatur, Ansaugpage	T_S	Temperature, suction site	T
tTS	Schlammalter	tSS	Sludge age, cell residence time	d
tTS,aerob	Aerobes Schlammalter	tSS,aerob	Aerobic sludge age	d
V_{BB}	Volumen des Belebungsbeckens	V_{AT}	Volume of the aeration tank	m^3
V_D	Für Denitrifikation genutztes Volu-men des Belebungsbeckens	V_D	Volume of the biological reactor used for denitrification	m^3
v_L	Luftgeschwindigkeit im Rohr	v_L	Velocity of air	m/s
$W_{Rührwerk}$	Energiebedarf der Mixer	W_{Mixer}	Energy consumption of the mixer	kWh/d
$X_{orgN,AN}$	In die Biomasse eingebauter orga-nischer Stickstoff	$X_{orgN,BM}$	Concentration of organic nitrogen embedded in the biomass	mg/l
$X_{P,Prec}$	Bei der biologischen P-Elimination biologisch gebundener Phosphor	$X_{P,BioP}$	Concentration of phosphorus removed with biological excess phosphorus removal process	mg/l
$X_{P,Fäll}$	Durch Fällung eliminierter Phos-	$X_{P,Prec}$	Concentration of phosphorus	mg/l

German:		**International:**		
	phor		removed by simultaneous precipitation	
$X_{TS, ZB}$	Trockensubstanzkonzentration im Zulauf zum Belebungsbecken	X_{SS}	Concentration of suspended solids of wastewater; Influent activated tank	mg/l
α	Verhältnis von Sauerstoffzufuhr in belebtem Schlamm und in Reinwasser	α	Quotient of oxygen transfer in activated sludge and in clean water	-
αOC	O_2-Zufuhr einer Belüftungseinrichtung in belebtem Schlamm bei C_x=0, T=20°C, p=1013hPa	αOC	Oxygen transfer of an aeration facility in activated sludge with C_x=0, T=20°C, p=1013hPa	kg/h
Θ=1,024	Temperaturkorrektur Belüftungskoeffizient	Θ=1,024	Temperature correction	-
κ =1,4	Adiabatenkoeffizient für 2-atomige Gase	κ = 1.4	Coefficient for adiabatic compression	-
φ	Relative Feuchte	φ	Relative humidity	%

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Supplier information mixer
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Supplier information blower
Aerzener, Kaeser

Supplier information aerator
OMS, OTT, Supraflex, Invent

Supplier information surface aerator
Passavant-Intech, Landustrie, Fuchs, Biogest

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21 Service

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