Static Mixers for Water- and Wastewater Treatment

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In the field of water treatment, mixing and contacting are important unit operations having a fundamental influence on the performance of individual process stages or even on the results of the complete process itself. The ever increasing demands on water quality call for continuous improvement of the cleansing processes. This has lead to a marked increase in the general use of in-line static mixers for mixing and contacting operations in this sector.

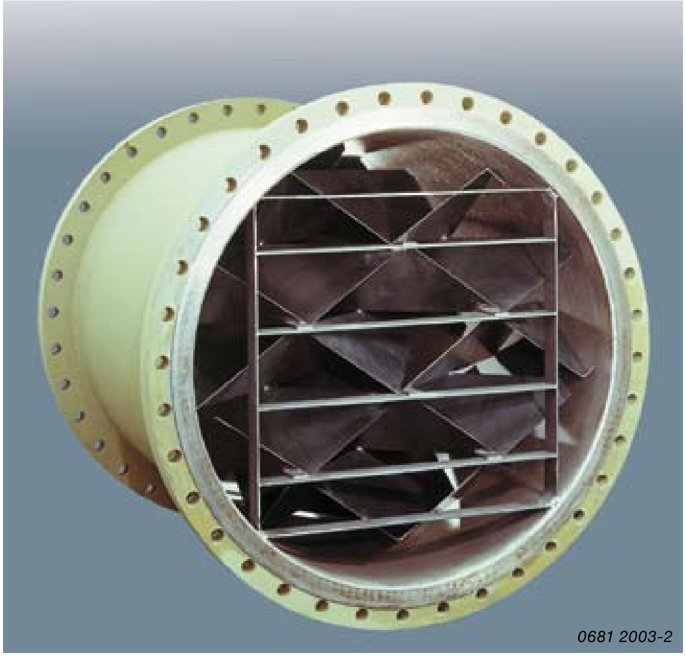

Figure 1: Sulzer mixer SMV™, NPS 1400 mm, for mixing raw water with partially softened water for pH control.

Design

Static mixers for mixing and contacting operations are installed in-line in a process stream. The associated pipe or conduit can be round, square or rectangular in shape. The mixers are available in different designs and in a variety of materials, enabling optimum adaptation to meet individual process requirements.
In the treatment of water, free of suspended solids, e. g. potable water, it is preferable to use the SMV mixer for both mixing and gas/liquid mass transfer procedures (figure 1). However, in mixing operations where the media involved contain solid particles, particularly fibres, plugging of the mixer can occur. In such circumstances, the use of the specially developed SMF mixer is recommended. The SMF mixing elements consist of inclined vanes which cross without touching each other and are fully open to the flow stream from all sides. This type of mixer is therefore not susceptible to plugging and is being used with success in the treatment of wastewater and sludge (figure 2).

Function

A static mixer consists basically of a sequence of stationary guide plates which result in the systematic, radial mixing of media flowing through the pipe. The flow path follows a geometrical pattern, precluding any random mixing. The mixing operation is therefore completed within a very short flow distance (figure 4).
The formation of fine gas bubbles in a water/gas mixture promotes intensive contact between the two phases (figure 3). The result is high mass transfer, for instance a high oxygen transfer rate or an excellent ozone utilization factor.
In contrast to stirred tanks or empty pipe systems, static mixers ensure that the complete fluid stream is subjected to compulsory or enforced mixing or contacting.
The energy required for mixing or for mass transfer is taken from the main stream itself, which is manifested by an insignificantly higher pressure drop than in an empty pipe system. This value depends on the design of the mixer and on the relative operating conditions. It is generally in the range 0.02 - 3 m w. g.
In comparison to dynamic agitator systems, the energy requirement of static mixers is smaller by at least an order of magnitude. In addition, the energy is evenly dissipated throughout the entire mixer volume.

Figure 1: Sulzer polypropylene mixer SMF-PP of open design for operation in wastewater treatment without the danger of clogging.

Features

- The face-to-face length of a mixer unit is short (1-5 pipe diameters) and consequently, the space requirement small. Retrofitting mostly presents no problem. The nominal diameter of the mixer is as a rule the same as that of the connected piping.

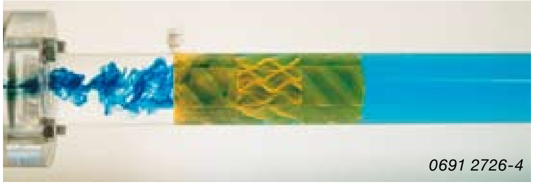

Figure 3: Blue colour concentrate is added to water in the pipe axis. A homogeneous mixture is achieved with a few SMV mixing elements.

- The mixing effect remains constant even at changing operating conditions. Additives, for instance flocculating agents, are distributed rapidly and uniformly. Excess dosing is no longer necessary and savings of up to 45% have been shown.
- The complete process stream is subjected to enforced mixing. Tanks can therefore be substantially reduced in volume or even be dispensed with altogether.
- The measured values are representative. This is a result of the continuous, balanced concentration across the entire cross-section of the flow.
- The plant can be started up quikkly. Continuous operation is a stable condition. The measurement data obtained are representative, thus enabling reliable control of the plant.
- The formation of fine bubbles results in a large interface between gas and liquid. The mass transfer rate is high.
- Pressure drop and energy consumption are low. The pressure drop in mixing operations is < 0.02-2 m w. g. and in mass transfer operations <2-3 m w. g.
- The static mixer has no moving parts. Therefore, there is practically no wear, and consequently very little maintenance is necessary.
- The SMF mixer is not susceptible to clogging. Operation with media containing solid matter, such as slurries or suspensions with fibres or flakes, presents no problems.
- Flexibility with regard to installation and material specification is high. Static mixers with round, square or rectangular cross-sections are available. Installation in an open channel is also possible. The mixers can be supplied in stainless steel, carbon steel, PP, PVDF or in fibreglass reinforced plastic.

Figure 4: Bubble bed with vertical and horizontal Sulzer mixer SMV-12 NPS 50 mm and phase separation in the horizontal empty pipe. System air/water. Flow velocity 0.5 m/s. m/s.

Examples of Practical Applications

… over 4,500 references

Figure 6: SMF-mixers for various mixing operations in wastewater and sludge treatment processes.

The application potential in water, wastewater and sludge treatment extends over a wide range. Below, some examples taken directly from actual practice are explained.
Diagram 1 shows a whole range of possible applications for static mixers in the chemical-physical treatment of water. Similar uses in treatment plants equipped with an additional biological stage are also possible.

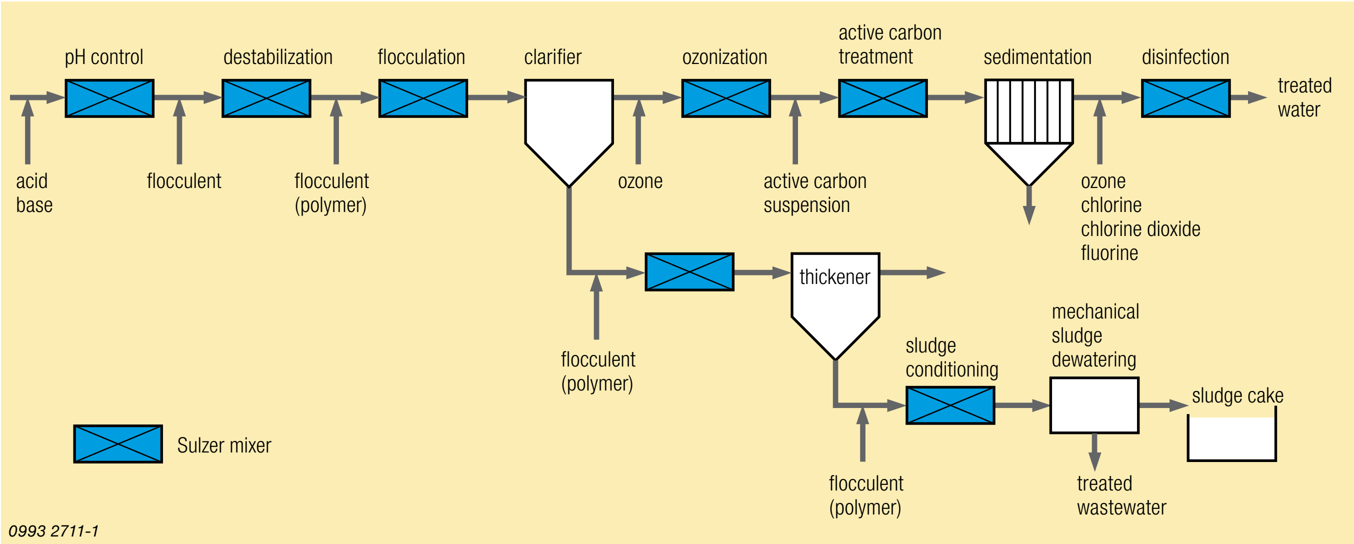

Diagram 1: Examples of applications of static mixers in a chemical-physical water treatment plant.

Flocculation (Diagram 2)

In order to achieve optimum flocculation, alum (PAC), $FeCl_3$, $FeSO_4$ or polyelectrolyte has to be distributed throughout the entire process stream as rapidly and as uniformly as possible. These objectives are ideally achieved by employing new Sulzer CompaX mixers (figure 5). The enforced-flow mixer ensures that the entire fluid stream is completely and uniformly mixed within fractions of seconds. Pockets of over-concentration are prevented, thereby economizing on flocculent. Savings of up to 45% have been achieved in practice.

CompaX or SMF mixers are normally recommended for flocculation processes. The CompaX mixers have a total length of 0,5-1 pipe diameter, the SMF mixers have a length of 2-5 pipe diameters (figures 2, 5 + 6). The mixer type is selected according to the specific process and customer requirements.

For details on the pH value, refer to the description relating to diagram 4.

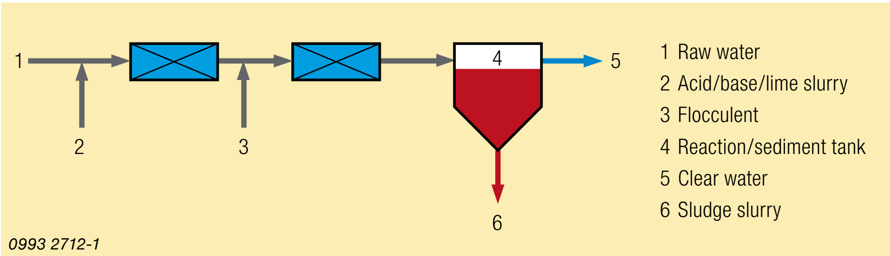

Diagram 2: Flocculation stage with pH control.


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In-line dilution of flocculents
(Diagram 3)

In order to achieve optimum activation of the flocculent, the prime solution has to be diluted with 10 to 100 times its volume of water prior to addition to the sludge. As the prime solution (polymer) is in most cases of high viscosity, dilution in water is not spontaneous. It is therefore necessary to ensure thorough mixing, since the more uniformly the polymer is distributed in the water, the greater its activity. Efficient mixing is secured by the use of a suitable static mixer. The result is a reduction in flocculent consumption and consequently a saving in costs.
SMV mixers made of PP or 316 Ti (= 1.4571) have proved successful in this application.


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Figure 5: CompaX™ NPS 1200 FRP for the admixing of flocculents in water treatment.

Admixing of flocculent to sludge before dewatering
(Diagram 3)

The blending of flocculent into sludge prior to dewatering is an important process step having significant influence on the economics of the process as a whole. A complete, and at the same time careful mixing operation using a static SMF mixer can reduce flocculent consumption and/or increase the dry solids content of the dewatered sludge (figure 6). Static mixers are being used successfully in conjunction with all classic dewatering methods.
Tasks relating to sludge dewatering are solely the domain of the SMF mixer. It normally is manufactured of stainless steel 316 Ti (= 1.4571).
The pressure drop amounts to <3-4 m w.g.

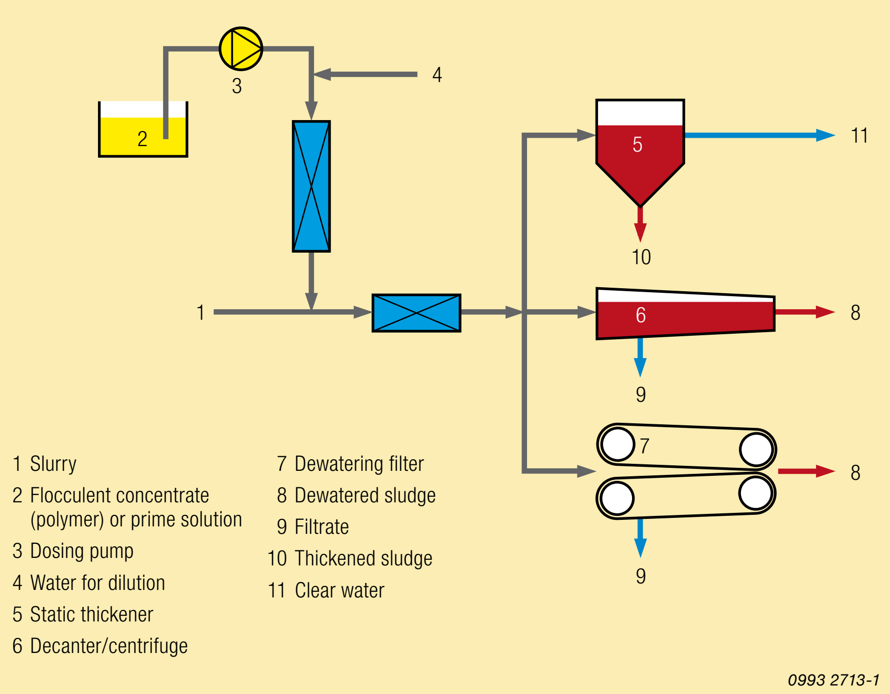


Diagram 3: In-line dilution of flocculent and its addition to sludge prior to dewatering.

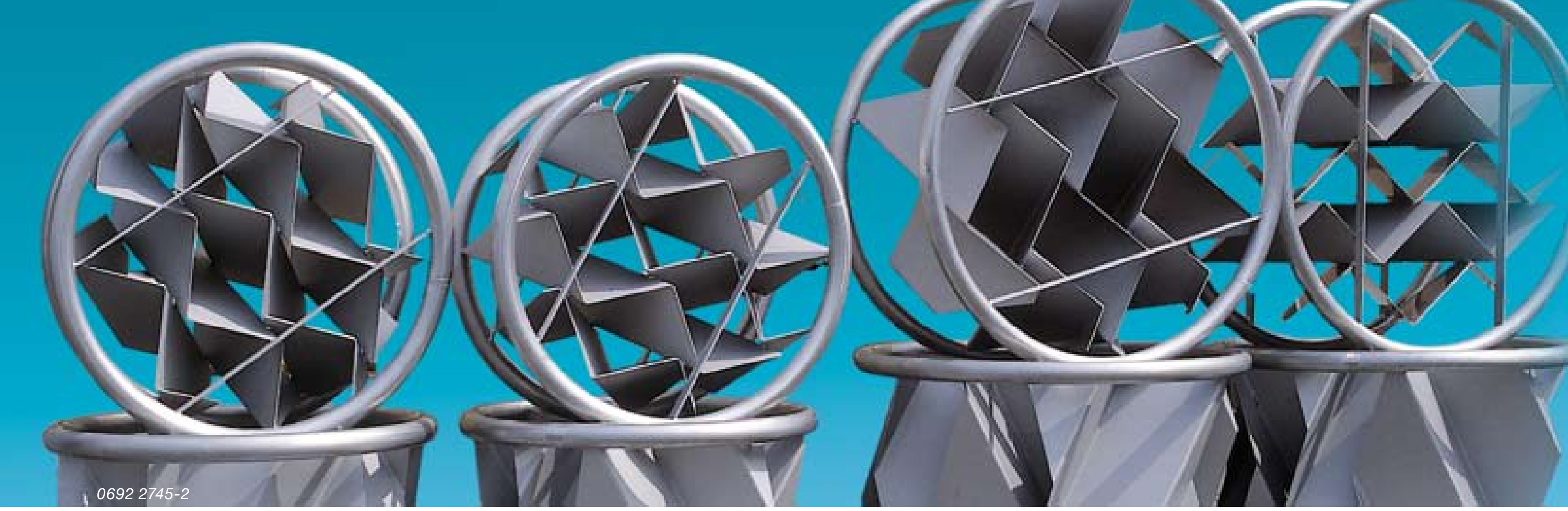
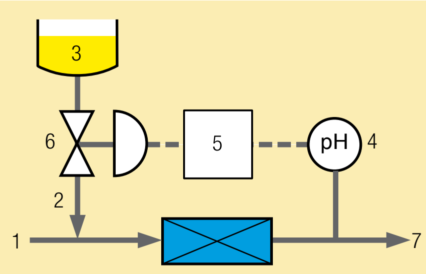


Figure 7: Mixing elements NPS 1000 mm and 1200 mm for admixing of flocculents and for adjustement of the pH value in a plant for treatment of drinking water. The mixing elements made of stainless steel will be installed in cement-walled pipes. The rings position the mixers to protect the pipe lining against damage.

ph control or neutralization
(Diagram 4)

Neutralization reactions generally take place within a short time, but under the condition that mixing of the reaction components in the process stream is effected quickly. This duty is well suited for the static mixer which enables the in-line neutralization reaction to be carried out directly in the pipe. Consequently, the volume of neutralization tanks can be greatly reduced or they can even be eliminated altogether. This space and energy saving solution is being used with increasing success in water treatment plants (figure 7). Not only is it possible to save on tanks but also a decrease in energy cost and the absence of maintenance work normally attached to dynamic agitators lead to an overall reduction in running costs.

Diagram 4: pH control or neutralization.



In order to promote the mixing of the neutralization media (acid, base, lime slurry), they are prediluted directly in-line in a supplementary small static mixer prior to being injected into the main stream (figure 8).

Downstream of static mixers, the measurement of representative data is secured, an important factor for the reliable functioning of a control system. The probes for controlling the neutralization agent dosing are as a rule placed 2-4 pipe diameters beyond the exit from the mixer. Neutralization is carried out using either SMV or SMF mixers of plastic or stainless steel. Their length is 2-5 pipe diameters and the pressure drop lies in the range of 0.02-2 m w. g.

Admixing of disinfectant
(Diagram 5)

Prior to entering the distribution network, the treated drinking water undergoes the addition of a small amount of disinfectant or fluorine. In order to obtain the desired effect, the disinfectants have to be blended uniformly throughout the entire water stream and, in the case of chlorines, in the shortest time possible. This operation is carried out with ease by SMV, SMI and/or CompaX mixers made of stainless steel. The pressure drop is about 0,02 – 1 m w. g.

One of the main features of the CompaX mixers is short installation length, the simple dosing nozzle and the low pressure drop at the same efficient mixing performance. The CompaX mixers are nearly independent of mixing ratio and also have excellent turn down ratios.

Diagram 5: Admixing of disinfectant.

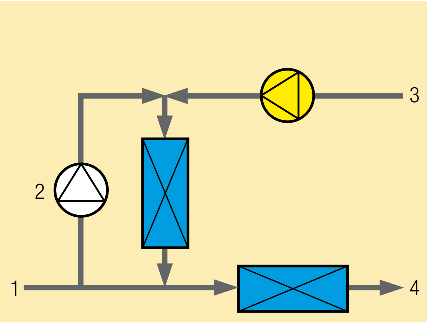


Figure 8: Sulzer mixer SMV in polypropylene (left) with feed pipe for additive injection (middle) and unit in PVDF for mixing of corrosive fluids (right).

Deacidification with caustic soda solution (Diagram 6)

If water is deacidified by the addition of caustic soda solution, there is generally danger of excessive precipitation of lime brought about by local overalkalinization. In time this can lead to blockages. Such an occurrence can be avoided if the concentrated lye (30 or 50%) is diluted to a 2% solution by the addition of softened water. This predilution takes place in a small SMI or CompaX mixer (made of stainless steel or PP) which can be directly integrated in the dosing system leading to the main mixer. The pressure drop of the mixer is about 0,05 – 2 m w.g. The empty pipe length in front of the main mixer dosing nozzle requires only 3 pipe diameters.

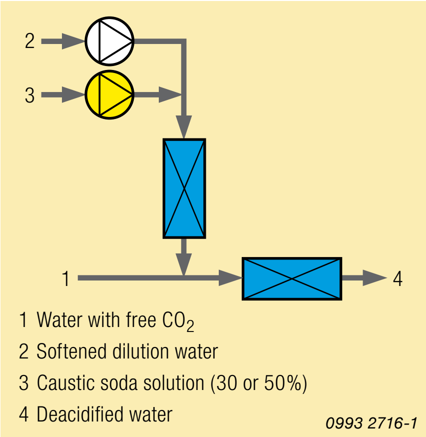


Diagram 6: Deacidification with caustic soda.

The SMI or CompaX main mixer is made of stainless steel. The pressure drop amounts to 0,02 – 2 m w. g. The mixer type is selected to match specific requirements and process data. Main criteria are the main water throughput, the turn down ratios, the mixing ratio and the space limitations.

Physical deacidification using air (single stage) (Diagram 7)

Aggressive water can be physically deacidified by contacting with air. A stream of water is brought into intensive contact with as much air as possible at the lowest overpressure possible. As a rule, the water is contacted with three to four times the amount of air. The static mixer splits up the air into fine bubbles of 1-2 mm in diameter. This results in a large interface of several thousands m^2/m^3. An almost total equilibrium between the phases is established. Using suitable static mixers, a reduction of the free carbon dioxide by a factor of 2.5 is reached in one single stage. The mixer is manufactured of stainless steel and the pressure drop amounts to 1 -3 m w. g.

Diagram 7: Physical deacidification using air (single stage).

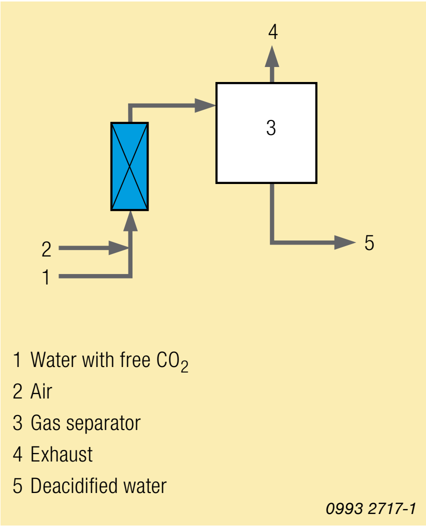


Figure 9: SMI mixer with flanged additive dosing nozzle, made of stainless steel.

Figure 9a: CompaX mixers – available in different materials and sizes.

Figure 10: SMV mixer NPS 1200 mm for the admixing and dissolving of CO_2 gas in drinking water produced in a sea-water desalination plant.

Oxygen enrichment of drinking water using by-pass aeration (Diagram 8)

Drinking water entering the distribution network must have an oxygen content of at least 5-6 mg 0_2/l. For this reason, treated water has often to be subsequently conditioned with pure oxygen. A small amount of oxygen has to be fully dissolved in the water. It is recommended that only a side-stream of water is highly enriched and then injected into the main stream. SMV mixers of stainless steel are used for this process. The mixer for the side-stream is slender and long, pressure drop < 10 m w. g.) and the mainstream mixer is thick and short, pressure drop 0.05-2 m w. g.).

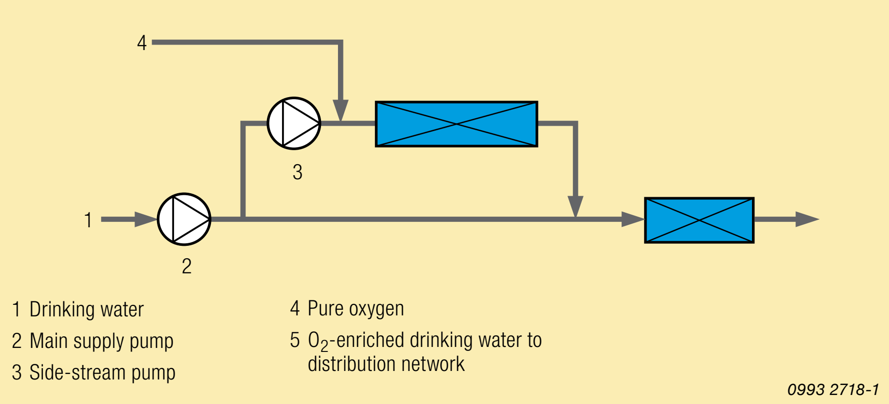


Diagram 8: Oxygen enrichment of drinking water by means of side-stream aeration.

Direct aeration in a ground-water well (Diagram 9)

For ground-water requiring no other treatment other than oxygen enrichment, the Sulzer enhanced aeration system has proved itself very successful. This system operates directly in the ground-water pumping shaft. Atmospheric air is brought into intensive contact with the water so that part of the oxygen content is dissolved in the ground-water. Such aerators have been operating efficiently in urban water treatment plants for many years. The equipment is distinctive for its low maintenance requirement, high degree of operational reliability and its efficiency. This aerator system can be installed both in new and in existing plants.

The aerators are based on the SMV mixer and are adapted individually to suit the well site conditions. The length of the unit is 5-10 pipe diameters, the pressure drop 0.5-2 m w. g. and manufacture is of stainless steel.

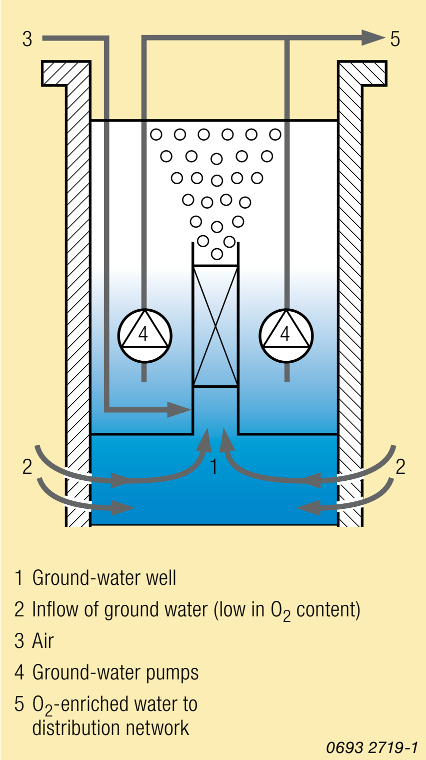
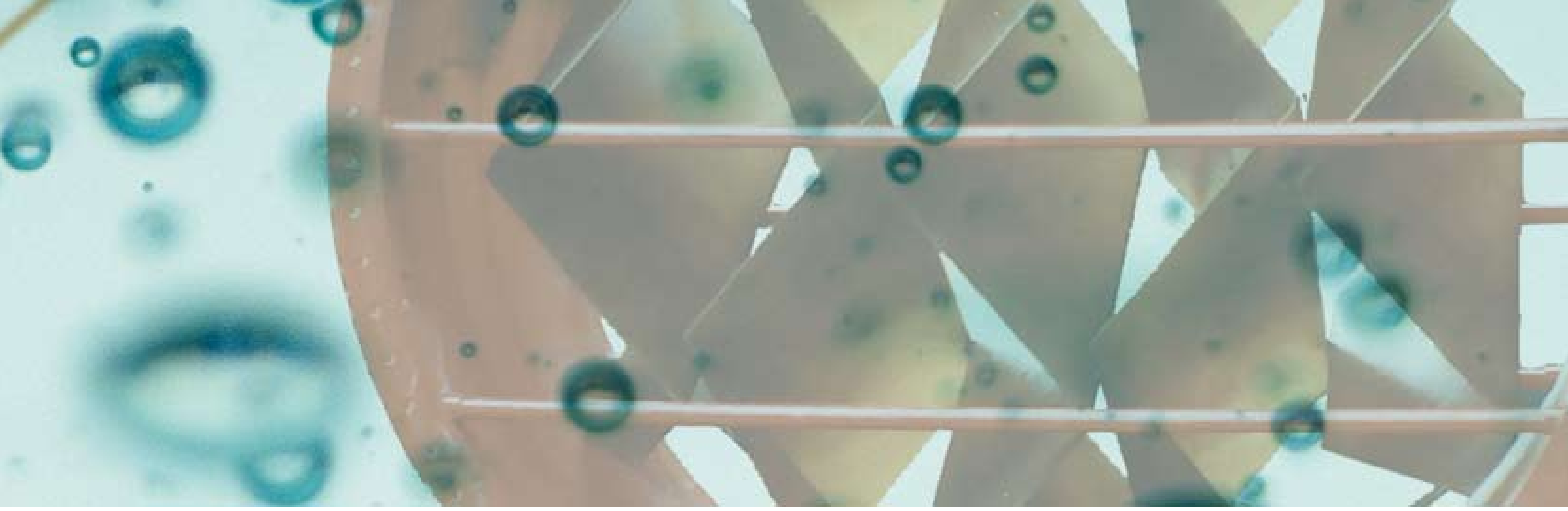


Diagram 9: Direct aeration in ground-water well.



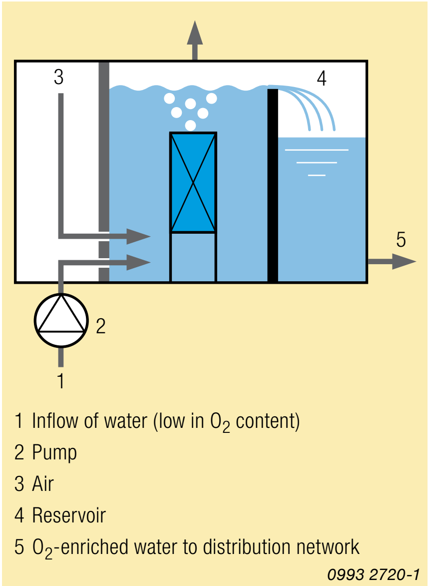


Diagram 10: Oxygen enrichment of drinking water in a reservoir.

Oxygen enrichment in drinking water reservoirs (Diagram 10)

Aeration of drinking water directly in a reservoir is carried out in the same manner as in groundwater well shafts (Diagram 9).

In-line, side-stream ozonization (Diagram 11)

As production of ozone is expensive, it is important to achieve the highest possible rate of its absorption. In practice, the SMV mixer has proved itself to be the most effective contacting device to meet this objective. It provides means of intensive contacting of water with ozone. When correctly dimensioned, a utilization degree of 90-99% of the physically possible value can be attained. The side-stream arrangement shown in the diagram has, above all, been successfully employed where the main stream is subject to considerable fluctuations in flow rate. The mixer in the side-stream is operated under hydraulically constant conditions so that even if the total flow rate is low, the ozone utilization rate still remains high. As in the case of oxygen enrichment of drinking water in a reservoir, the mixer in the main water stream can be relocated to the retention/reaction tank. By taking appropriate measures, it is also possible to increase the contact time between the ozone gas and the water in order to attain an even higher ozone utilisation. This is of particular advantage in cases where the water has a high ozone absorption rate.

As the entire water stream is subjected to enforced contact with ozone when flowing through the mixer, the subsequent residence tanks can be reduced in size. It is only necessary to dimension the tanks in relation to the actual reaction time without having to take the slow mixing into account.

In this type of ozone introduction system, the side-stream mixer has a very short length with a pressure drop of 2-3 m w. g. It can therefore be fed directly with gas from the ozone generator without the necessity of an additional compressor. The pressure drop in the main mixer is < 2 m w. g., its length 3-6 pipe diameters. These mixers are manufactured from stainless steel.

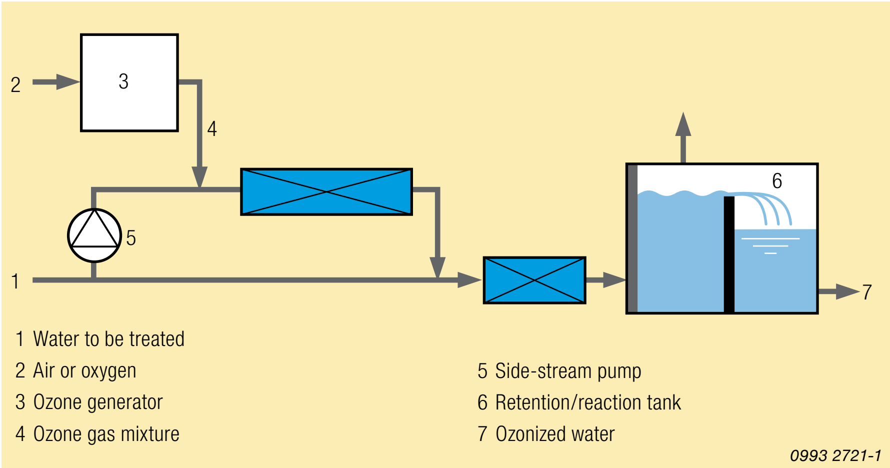


Diagram 11: In-line, side-stream ozonization

Figure 11: SMO_2 mixer in polypropylene for the aeration of water in the oxidation process for iron and manganese removal.

Iron and manganese removal stage (Diagram 12)

The successful SMV mixer has been used as a basis for the development of the static aerator SMO_2 (figure 11). This compact, field-proven aeration unit made of polypropylene is mainly used in the introduction of atmospheric oxygen into water during an iron and manganese removal process. With the help of this mixer, the oxygen necessary for oxidation is transferred efficiently into the water. Six different sizes of aerator from NPS 50-250 mm are available for treating water quantities ranging from 4-320 m^3/h. The overall length of the mixer is 4-8 pipe diameters and the pressure drop is maximum 3 m w. g.
When designing this stage, it is necessary to remember that the rate of oxidation depends largely on the pH value of the water. The optimum pH value is to be determined by the water engineer in charge. The value has no influence on the design of the aerator.

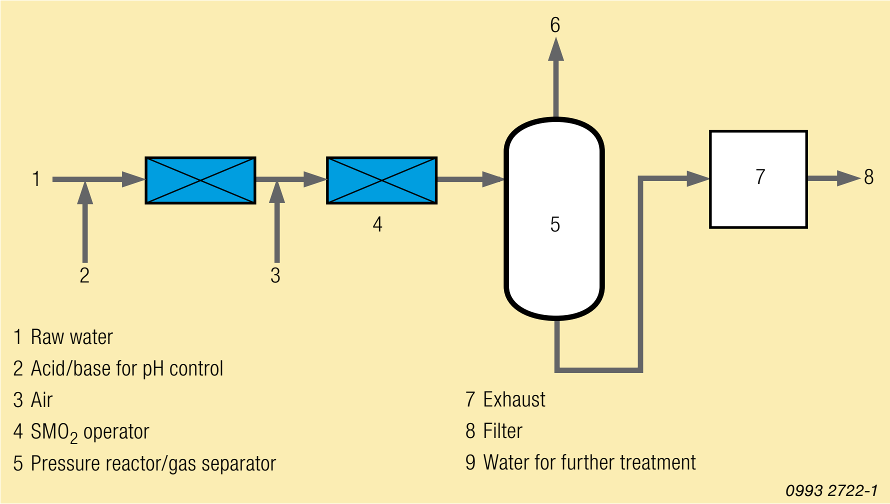
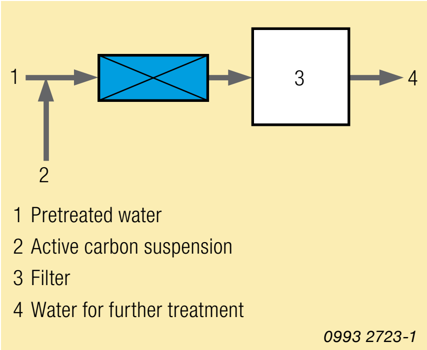


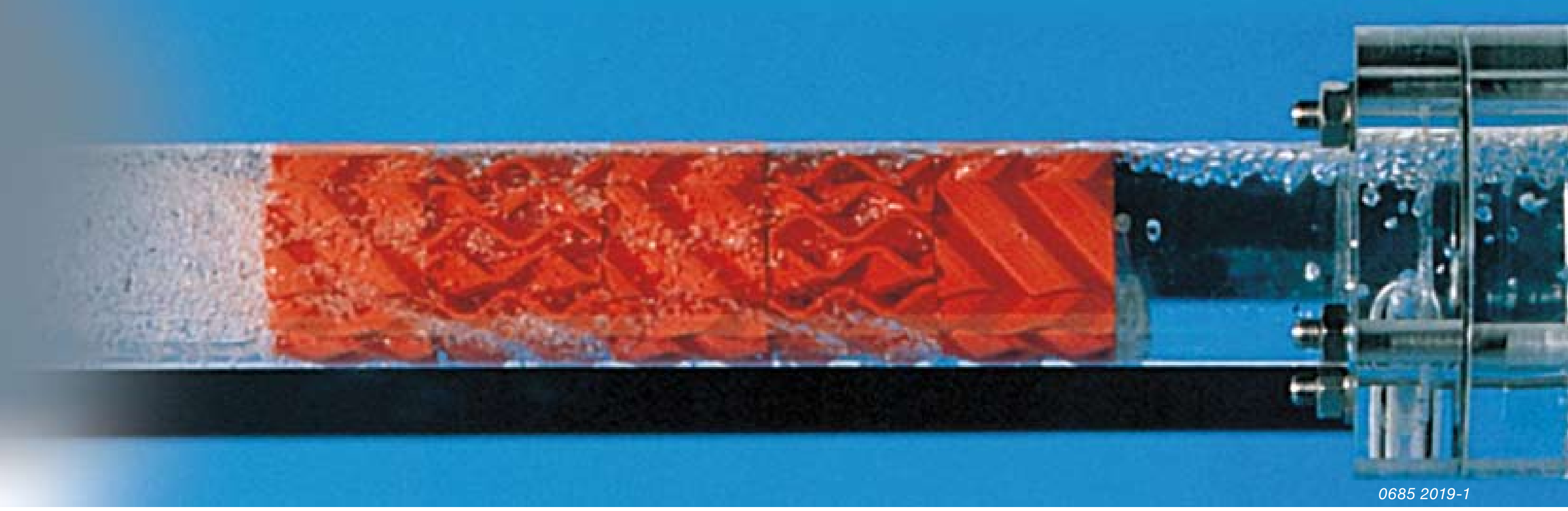
Diagram 12: Stage for removal of iron and manganes.

Active carbon treatment stage (Diagram 13)

In order that any substance present in the water can be fully adsorbed by the active carbon, it is of utmost importance for the efficacy of this treatment stage that the active carbon suspension is well and thoroughly mixed with the entire water stream. The suitable mixing principle of the static mixers ensures that this objective is fully achieved.
This task is solved efficiently by the SMF mixer made of stainless steel, with a length of 4-6 pipe diameters at a pressure drop of 0.05-1 m w. g.

Diagram 13: Active carbon treatment stage.





Operating range and installation position of static mixers

Static mixers from Sulzer Chemtech cover a wide range of operating conditions and requirements. For the mixing of liquids, the static mixer is generally designed for a flow velocity of 0.5-1.5 m/s. However, depending on the pipe diameter, the mixers can present perfect mixing results even at substantially lower flow rates. For most applications, the Sulzer mixer can be installed in any position whatsoever. If, however, there are large differences in the densities of the media to be mixed and if the minimum flow rate is extremely low, setup in a vertical position with upward flow is recommended.

In processes involving gas/liquid contacting, the optimum bubble diameter is in the range of 1-2 mm and the necessary flow velocity between 0.5 and 2 m/s. To ensure that bubbles are distributed across the entire cross-section of the flow stream, the flow velocity should not fall below a minimum of 0.3 m/s. Below 0.7 m/s, installation in a vertical position with upward flow is a standard. At higher rates, the choice of position and the flow direction is entirely optional.

Available reprints and technical information literature

Further details can be obtained from reprints or from technical information literature which deal closely with problems surrounding water and wastewater treatment. On request, we can supply articles of special interest. The following publications are presently available:

- Static Mixers Cut Chemical Costs
- Sulzer SMF-PP Polypropylene Static Mixers for Water and Wastewater Treatment
- Sulzer mixer SMI for turbulent flow
- Sulzer CompaX – the space saving solution for your mixing operations
- Effective Ozonation Using Sulzer Static Mixers

Our brochure «Mixing and Reaction Technology“ gives information on the various applications of Sulzer mixers in different sectors of industry with over 60‘000 references.

Scope of supply

Sulzer mixers are available in a variety of materials. The adjacent table gives an overview of the current standard material specifications.

Mixers manufactured from special materials such as hastelloy, titanium or monel are available on request.

The largest SMV mixers manufactured to date for application in water treatment have a cross-section of 4m x 6.4 m or a diameter of 1.4 m, respectively.

Material	SMV™		SMF		SMI	CompaX™
	Mixing elements	Housing	Mixing elements	Housing		
Stainless Steel	≥ 1/2”	≥ 1/2”	≥ 1”	≥ 1”	≥ 1”	1/2” - 20”
Carbon Steel	≥ 6”	≥ 6”	≥ 6”	≥ 6”	≥ 1”	
PP	1/2” - 14”	≥ 2”	2”-16”			1/2” - 20”
PVDF	1/2” - 10”	1/2”-1 1/2				
PTFE	2” - 10”					
ETFE	1/2” - 1 1/2”					
CS/Liner		2”- 10”			≥6”	
GKF	≥ 10”	≥ 10”				≥ 24”

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Sulzer Chemtech Ltd, a member of the Sulzer Corporation, with headquarters in Winterthur, Switzerland, is active in the field of process engineering and employs some 1500 persons worldwide.

Sulzer Chemtech is represented in all important industrial countries and sets standards in the field of mass transfer and static mixing with its advanced and economical solutions.

The activity program comprises:

- Process components such as trays, structured and random packings, internals for separation columns and reaction technology
- Engineering services for separation and reaction technology such as optimizing energy consumption, plant optimization studies, pre-engineering for governmental approval, basic engineering
- Separation and purification of organic chemicals by means of crystallization and membranes
- Mixing and reaction technology with static mixers
- Tower field services

Distributed by:

23.83.06.40-IV.06-50 - Printed in Switzerland