LEWATIT The Better Change

Bayer

Bayer Processes

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1. Introduction

Initially ion exchange units and subsequent regeneration used co-current technic which we can regard as ion exchange process of the first generation.

In Westeurope only older, smaller plants or softener units operate as co-current systems.

In Asia, Easteurope and in the USA the counter-current counter-pressure system is today widely established and are even used in power plants.

2. Cocurrent Process (Figure 1)

Until the late fifties, the cocurrent process was generally used for ion exchange and subsequent regeneration.

The drawbacks of this process are:

- high chemical consumption (250 - 400 % of th.)
- high water consumption
- resins have to be backwashed after each exhaustion cycle
- low efficiency of the vessel volume (100 % freeboard for backwashing
- longer regeneration cycles

The advantages of this process are that the resin can be backwashed in the unit and the flow rate can varied between 0 % and 100 % without risking the resin performance.

Since ion exchange proceeds until equilibrium is achieved, the introduction of counter-current technology represented the first step towards more economical process technology.
The only process to gain widespread acceptance was the counter-current counter-pressure technic in which the direction of flow in the exhaustion cycle and the basic dimensions of the unit were the same as for the co-current process, but the column was regenerated upwards (upflow regeneration).

3. Counter-Current Counter-Pressure Process (Figure 2)

As Fig. 2 shows, this process requires a collector system about half way up the unit. For technical reasons, this is covered by an approx. 200 mm deep inactive resin layer (active resin). Air or water is used to create a pressure drop in this resin layer which holds the active resin bed in place during upstream regeneration and elution. Rinsing with fully demineralised water (or decationised water in the case of cation resins) can be performed in the same direction as exhaustion (downflow) at high speed. Fully demineralised water is needed to rinse anion resins, but decationised water is sufficient for cation resins. It is important to make sure that the fine polishing layer in the resin bed is not exhausted or destroyed prior to operation in order to ensure that the counter-current process produces the high-quality water required of it.

Advantages (compared with the co-current process):

- better water quality
- lower regenerant requirement
- lower water consumption
- high availability because of short regeneration cycle

Chemically, the advantage of counter-current regeneration is that, unlike the co-current process, regenerant chemicals without counterions are always passed through the lower section of the resin bed which determines the quality of the water. The high concentration differential facilitates the diffusion of the exchange ions in the solution.

The process of achieving equilibrium is thus always accompanied by transportation of a substance. This is influenced by diffusion (film or gel diffusion). In co-current regeneration, diffusion is hindered by the fact that the regenerant comes directly into contact with the most exhausted section of the ion exchange resin.

Disadvantages:

- When the regenerant is being fed into the column from below, the volume of the resin beads contracts, causing reclassification of the fine-polishing layer.

- The collector system impedes uniform flow somewhat during exhaustion.

- After a few exhaustion cycles, the resin bed below the collector system becomes denser and this, too, impairs flow properties.
  The unit therefore has to be backwashed after a certain number of cycles. This causes total reclassification of the uniform polishing layer. Since this layer has an important function in counter-current operation, more regenerant is required after backwashing to obtain the same water quality.

- The regenerant, which has high specific gravity, has to be forced upwards through the unit; the result is a higher rinsewater requirement, and the water used is expensive treated water.

4. Fluidized Bed (WS-) Process (Figure 3)

Bayer patented the fluidized bed process in the early sixties. This new process resulted from progressive development of counter-current technology.

The fluidized bed system comprises upflow exhaustion, followed by downflow regeneration. The resin is placed between two nozzle plates. Between the active resin bed and the upper nozzle plate there is a layer of inert resin. The depth of this inert resin depends on the diameter of the column. Its function is to prevent resin fines and impurities clogging the upper nozzle plate and ensure optimum diffusion of the regenerant.
Additional freeboard is required to take account of the resin swelling.
The specific flow rate influences the depth of the fluidized bed and thus improves utilisation of the resin capacity and reduces pressure losses.

The main advantages of this process are:

- narrower and thus cheaper units
- maximum chemical capacity because of high filling level
- lower service water consumption (for rinsing and dilution)
- short regeneration means high operational availability
- no channelling
- lower pressure loss
- more efficient regeneration, thereby reducing regenerant requirement

The combination of WS-System and using monidisperse Bayer-resins (Lewatit MonoPlus) leads the reachable operating capacities and water quality to an absolutely maximum.

5. Compound Fluidized Bed (VWS-) Process (Figure 4)

The filters used in this process comprise two vertical chambers, one on top of the other, separated by a nozzle plate. This permits use of a combination of weakly and strongly dissociated resins in a single unit without any problems caused by the resins mixing.

Advantages of the VWS-System:

- as for the WS system
- regeneration is even more efficient
- more economical in comparison to the WS-System

The choice of a single or compound fluidized bed system (WS or VWS system) depends on the raw water analysis. If the HCO_3^- - Concentration (m-value) is higher than 40 % of the total salt concentration is it worthwhile to use a VWS-System on the cation side. On the anion side must be sure, that the strongly dissociated component is at least 1000 mm deep.
Bayer has also developed other systems (Liftbed, Rinsebed, Multistep) based on the principle of upflow exhaustion. We will now outline their mode of action.

6. Liftbed Process (Figure 5)

Each unit comprises at least 2 compartments separated by an additional nozzle plate. The upper compartment is completely filled and acts as a fixed bed during exhaustion and regeneration.
The compartments are connected by a liftpipe which is used to transfer the resin from one compartment to the other. The upper nozzle plate in each compartment is protected by a layer of inert resin. About one-third of the total resin quantity is installed in the lower compartment, leaving enough freeboard for backwashing.

Advantages of the Liftbed-System:

- same as for WS-System
- internal backwashing
- higher operating capacity
- suitable for intermittent operation
- very low regenerant consumption
- suitable for water with a particularly high salt content
- suitable for water without optimised raw water pre treatment

Liftbed units may also have a third compartment for weakly dissociated resin if the quality of the raw water (salt content, organic load) makes this necessary. Combined arrangements, e.g. Liftbed / Fluidized bed can also be used.

7. Rinsebed Process (Figure 6)

The Rinsebed system is suitable for small to medium-sized units with a diameter of up to 2000 mm.
The units have a collector system just above the mid-point. The treated water is removed through this system. Immediately above the collector system is a perforated plate. The holes in this plate should be large enough to allow the resin beads to pass through it. The column is filled until the resin covers the perforated plate which divides the unit into a lower, active chamber and a so-called top layer (200-350 mm).
After backwashing, the finest beads return to the top layer which adsorbs certain ions during rinsing or if the regenerant is diluted with raw water.

This resin layer is responsible for producing the high-quality water required for rinsing and dilution.

Advantages of the Rinsebed process:

- as for WS-System
- internal backwashing
- raw water can be used for regeneration or to rinse cation resins
- decationised water can be used for regeneration or to rinse anion resins
- suitable for small, single units

The resin layer above the perforated plate fixes the lower, active resin bed in place during exhaustion. During regeneration it is

converted into the active form, allowing it to adsorb foreign ions from raw water used for rinsing and thus prevent a noticeable reduction in the quality of the treated water.

8. Multistep Process (Figure 7)

Depending on the end-use, multistep units comprise two or more chambers arranged one above the other and separated by nozzle plates. Each chamber - apart from the top one - contains a regenerant distribution system, which also serves as a drainage system for the regenerant effluent of the superposed chamber.

The system uses downflow regeneration. The lower chambers are protected from contamination by blocking water. The regenerant excess is the same as for the fluidized bed system (115-130 % theor.) which is about 50 % below the regenerant requirement for conventional mixed bed units.

In the three-compartment system (which is a substitute for mixed bed units) the buffer cation resins only have to be regenerated at very large intervals (> 6 months). Since exhaustion can be restarted very soon after regeneration (NaOH residues from regeneration of the anion resins are neutralised in the buffer unit), this system considerably reduces rinse water requirements.

Advantages of the Multistep-System:

- as for the WS-System
- only one filter unit is required for all functions from softening
- through dealkalisation to full demineralization and adsorption space-saving
- low capital costs
- requires less regenerant and auxiliaries (air) than mixed bed units
- exhausted components can be regenerated separately

- not sensitive to fluctuations in specific flow rate and ionic content of feedwater
- simple to automate

Multistep units are very versatile. Recently, the system has increasingly been used as a fine-polishing unit after reverse osmosis.

9. Comparison of the various processes (Figure 8)

The differences in performance data for all described systems are shown in figure 8.

Cocurrent-System

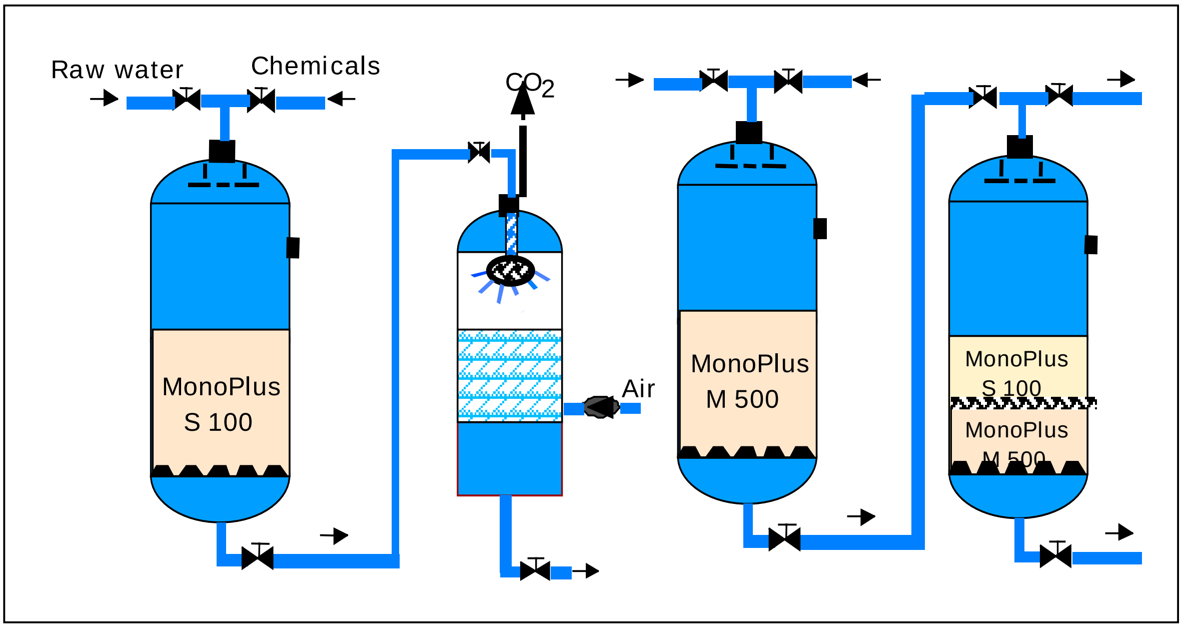

Figure 1

Advantages :

- Removing of impurities by internal backwashing
- Operating flow rates between 0 – 100 % possible

Drawbacks :

- Backwashing before regeneration is absolutely necessary to break up the pressed bed
- High chemical consumption for a good regenerated polisher layer
- Low efficiency of the vessel volume (100 % freeboard)
- High regeneration time and rinse water consumption

Counter-Current Counter-Pressure System

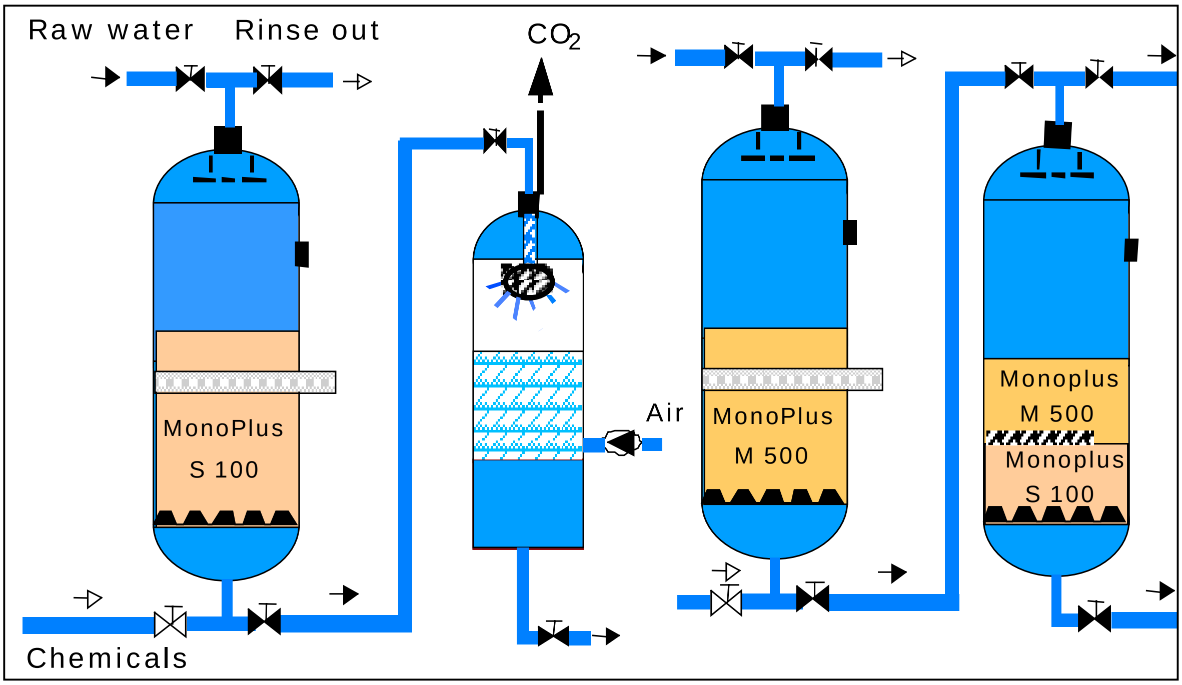

Figure 2

Advantages in comparison to co-current plants:

- High regenerated polishing layer
- Lower regenerant consumption

General drawbacks against WS/VWS-Systemen:

- All 10-15 cycles backwashing absolutely necessary
- High chemical consumption and therefore more waste water
- Low utilization of the vessel volume (100 % freeboard)
- Long regeneration time because of limited regeneration flow rate
- High consumption of rinse water

Schwebebett-Process (WS-System)

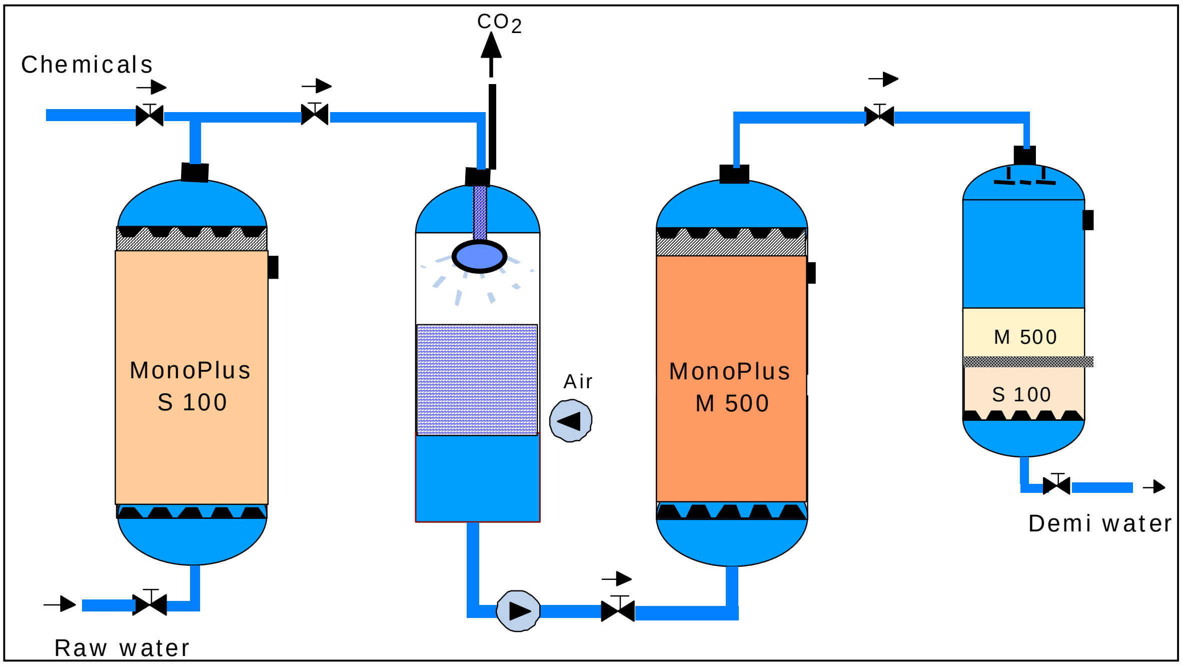

Figure 3

General advantages:

- Downflow regeneration on a fixed bed
- Lower chemical consumption
- High availability because of short regeneration time
- No channelling, low pressure drops
- Reduced waste water
- Improved water quality
- Reduced investment
- Reduced operating costs

Compound Fluidized Bed Process (VWS-System)

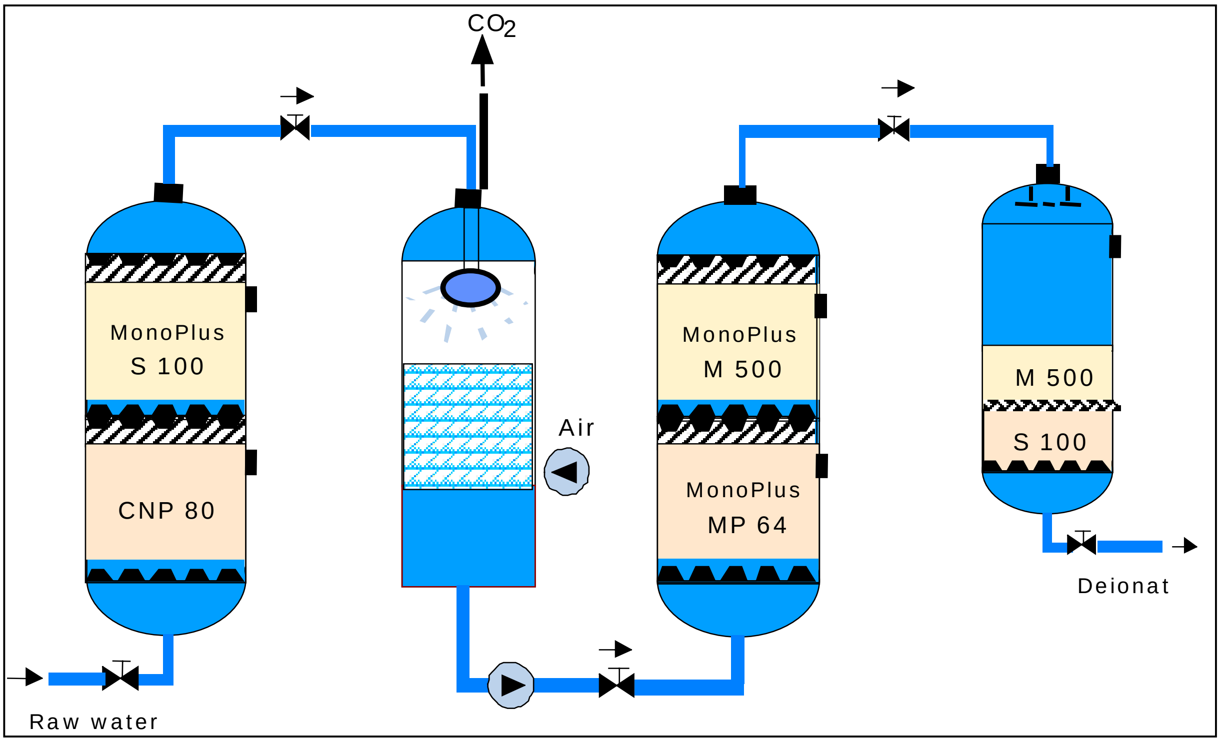

Figure 4

General advantages:

- Like Fluidized bed system
- Higher regeneration efficiency
- Using of weak and strong dissociated resins in one filter column

Liftbett-Process

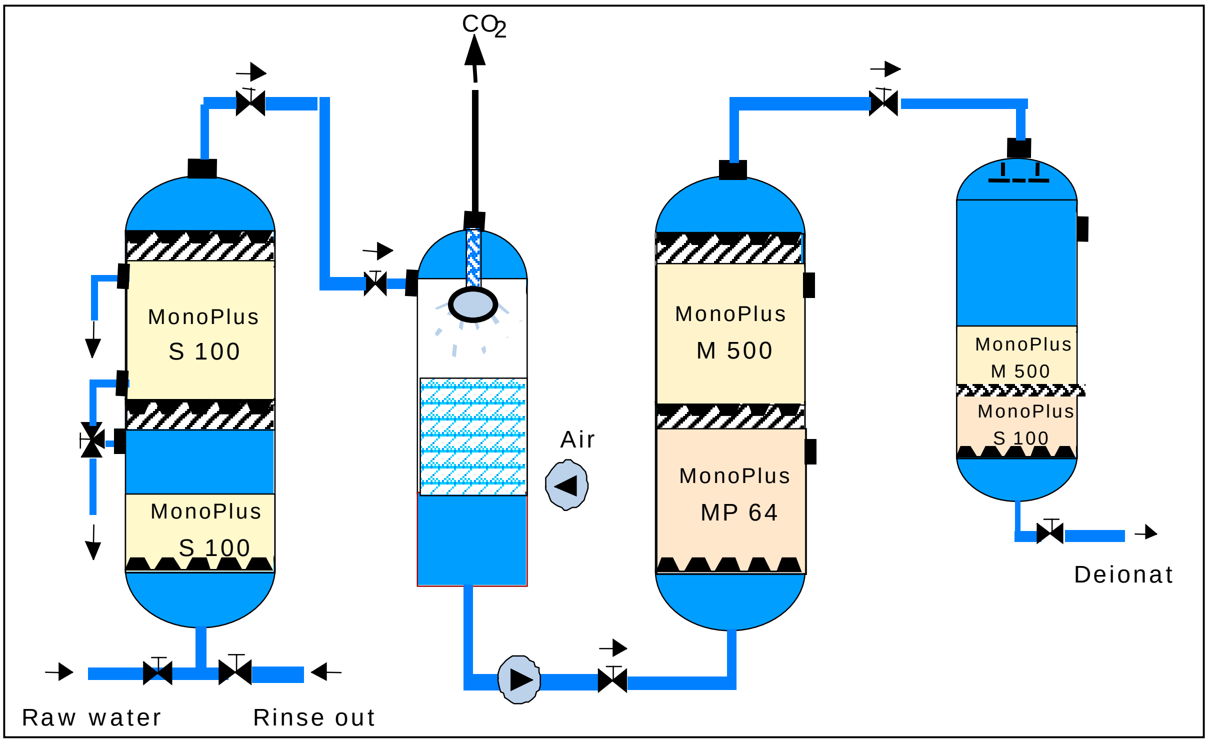

Figure 5

General advantages:

- Like Fluidized bed system
- Internal backwashing for both compatments possible
- Higher operating capacities due to higher bed depths
- Treatment of raw water with critical values of suspended matter

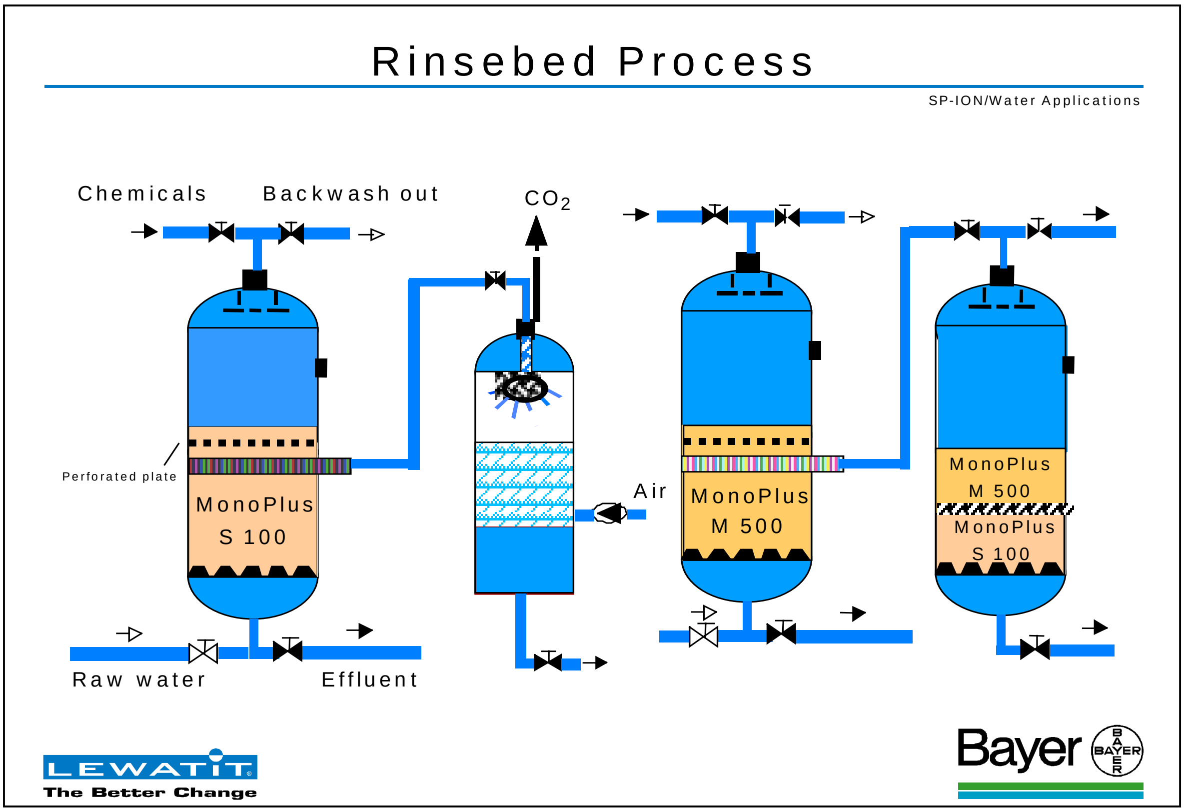

Figure 6

General advantages:

- Like Fluidized bed system
- Internal backwashing possible
- Raw water suitable for regeneration and rinsing (cation side) or softened water (anion side)
- Suitable for simple units operating as single stream

Multistep-Process

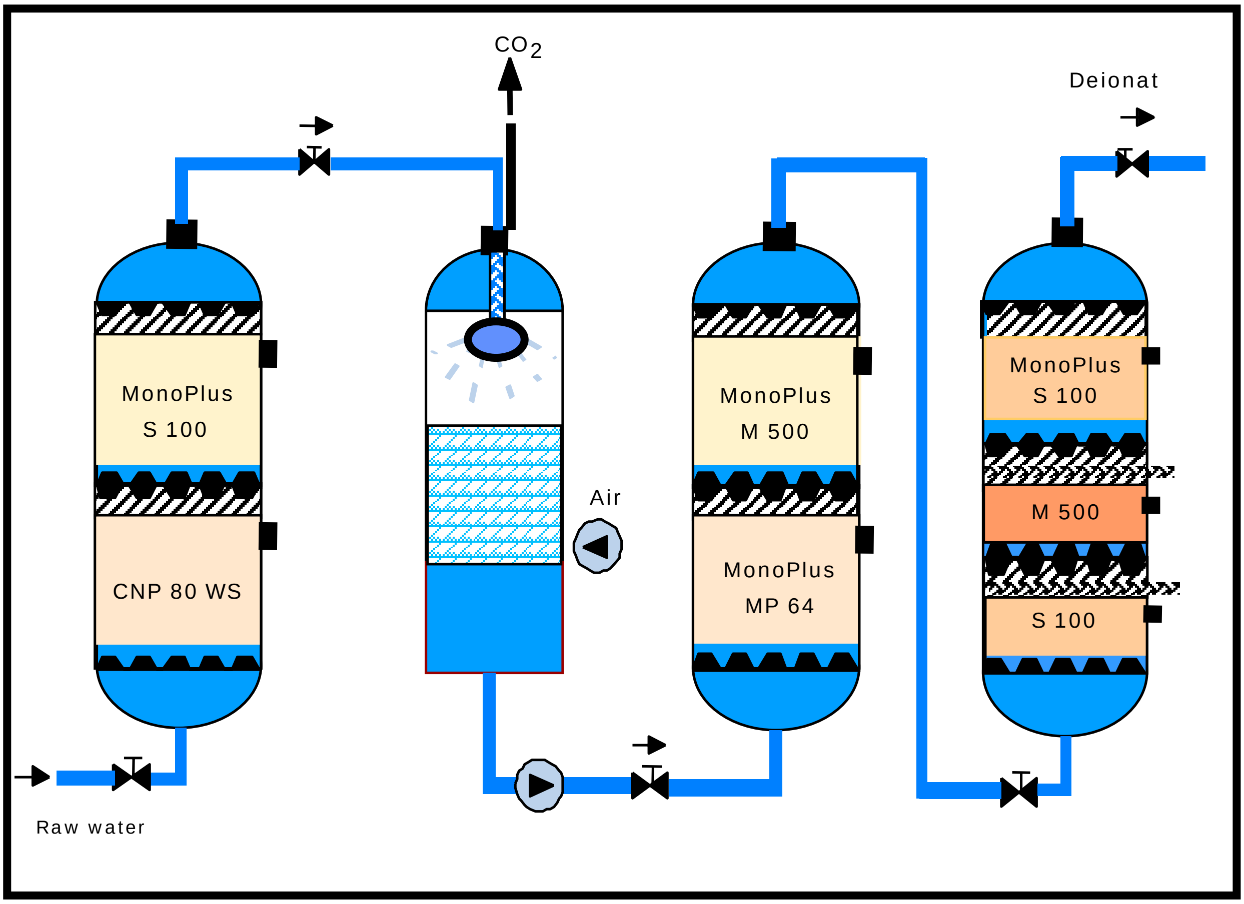

Figure 7

General advantages:

- All advantages like Fluidized bed system
- Only one unit for several ion exchange resin types
- Extremely low ion leakage (low conductivity)
- Suitable for all applications like softening, demineralization, polishing (downstream RO-Systems)

Comparison Co-current system against modern Bayer Technologies

	Co-current	Schwebebett (WS)	Liftbed	Rinsebed	Multistep
Operating data					
Regenerant excess (% of Th.)	250-400	115-125	110	130-140	115-125
Service water (BV)	6-10	2,5-3,5	2-2,5	2,5-3,5	2,5-3,5
Service flowrate (m/h)	0-40	5-50	5-50	5-35	5-120
Regeneration time (h)	3-5	1,5-2	1,5-2	2	2-3,5
Treated water quality					
Conductivity (µS/cm)	5-20*	< 2	< 2	< 5	< 0,08
SiO_2 Type I (ppb)	< 30*	< 20	< 15	< 20	< 10
SiO_2 Type II (ppb)	< 100	< 50	< 25	< 50	< 20
* = Depends on Na-content and excess of regenerant chemicals					

Figure 8