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Top quality drinking water treatment through low investment and operation costs

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ABSTRACT

Three drinking water treatment plants with different performance capacities have been constructed within the last few years. The treatment chains, developed and proven systematically over decades, were applied consistently in each of the treatment plants. Accordingly, the construction and operations costs were greatly reduced, in addition to a significant increase in the security of the treatment process. The future does not lie in extreme experimentation, but rather in the utilisation of the large investment in water resources protection through reliable drinking water treatment processes adjusted to each particular situation and able to adapt to short term disruptions in raw water quality.

Key words | drinking water treatment plants, operating costs, optimisation

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INTRODUCTION

In the last five years, three treatment works have been built using the same basic concept. The process to realise these three works took account of the varying raw water quality and with the benefit of decades of experience, led to the consistent application of a closed, under pressure and optimised treatment chain.

On 5 January 1994 the ground was broken for the Küsnacht/Erlenbach lakewater treatment plant (Figure 1) with a nominal throughput of 18,000 m^3/d. The raw water was drawn from Lake Zurich at a depth of 32 m. Drinking water production commenced on 15 March 1995 and the works were handed over to the clients on 17 June of the same year. The full load tests were conducted on 18 May 1995 and on 9 June 1998. The Limmat water treatment plant of the Zurich municipal water supply was initially required to supplement the groundwater acquifer, but was also developed to deliver treated water directly into the drinking water supply network of Zurich. The treatment plant, which is located next to the Limmat River shortly after the outflow from Lake Zurich, is also affected by the inflow of the River Sihl and the associated turbid water from storms and snow melt. The turbidity of the River Limmat can change within half an hour from 1.0 TE/F to 400 TE/F, though these high turbidity peaks are only of short duration (approx. one day). The Limmat water treatment plant has a nominal throughput of 100,000 m^3/d. After design, the civil work was started in October 1994 and drinking water was first delivered at the beginning of January 1997. The plant was turned over to the client on 27 March 1997 and the full load test was performed on 9 April 1997. Pilot plant trials were conducted before building the plant, from 1992 to the middle of 1994, to investigate the effect of the large variation in turbidity on sedimentation and dual media filtration. According to the considerations and descriptions presented in the ensuing report, the Limmat water treatment plant was considered to be like a lakewater plant with poor raw water quality. The large variations in turbidity are not dealt with in this paper. Process chain elements typical of lake water treatment works were incorporated for this plant such as: rake sieve to hold back coarse floating materials and sedimentation via flocculation to precipitate the large amount of sediment, which can be present in the River Sihl. Furthermore, the running time of the rapid filter can be set similarly to that of a lake water treatment plant (Figure 2).

Figure 1 | Küsnacht/Erlenbach lakewater treatment plant 18,000 m^3/d.

Figure 2 | Limmat water treatment plant 100,000 m^3/d.

Figure 3 | Frasnacht lakewater treatment plant 71,000 m^3/d.

For the Frasnacht lakewater treatment plant of the Regional Water Supply St Gallen AG on Lake Constance with a raw water intake depth of 60 m, the civil works began on 28 February 1997 and drinking water was first produced on 13 July 1998. The nominal throughput of the plant is 71,000 m^3/d. The hand-over to the clients followed on 9 September 1998 and the full load test was performed on 6 October 1998 (Figure 3).

Some new findings from these three plants are presented in this paper in an attempt, using the knowledge gained from the load tests, to provide insights for the future in full acknowledgement that various statements relate only to the day on which the tests were carried out. It is the task of the individual water supply authorities to perform research and long-term tests, particularly for the seasonal changes in raw surface water and particular optimisation tests. The purpose of this paper is to demonstrate that a new treatment model, based on a pressurised plant for compact construction via concrete, can be built and operated cost effectively.

PROCESS DESCRIPTION

The water treatment technology was optimised through a complementary sequence of treatment steps, taking into consideration the resulting costs for construction and operation. This process optimisation was possible due to the vast experience of engineering offices in the drinking water treatment field in cooperation with numerous other entities. In this manner, the decades of experience gained from lake and river water treatment in Switzerland was able to benefit the project. No one individual treatment step is responsible for the water quality improvement in the new treatment chains. Today, an interrelated approach is necessary at each step so that each step provides improvements in water quality and also establishes the pre-conditions for the subsequent treatment steps.

SEDIMENTATION

The first step of treatment occurs with sedimentation in the lake and the collection point correct according to flow technology. On the basis of today's knowledge, deep lake collectors of 40–60 m are ideal for the raw water withdrawal point.

PRE-OZONATION

Ozone is produced today from liquid oxygen. During pre-ozonation, the destabilisation of colloidal impurities should be assisted, in addition to the pre-oxidation. Pre-ozonation is applied for bacterial disinfection, virus inactivation, oxidation of iron and manganese, decomposition of organically bound manganese, decolourising, removal of odour and taste, elimination of algae, oxidation of organic substances, microflocculation of dissolved organic substances and as pre-treatment for downstream biological processes. For surface waters rich in algae, especially during seasonally induced conditions, ozone should be dosed at a concentration that prevents destruction of the algae cells and to preclude the organic macromolecular substances from reaching the water.

FLOCCULATION–FILTRATION

The addition of ozone causes a destabilisation of the impurities dissolved in the water and assists the microflocculation process. The destabilised water is dosed with the correct quantities of Fe^{+++} or Al^{+++}, so that the particles are bound together and filtered off, without terminating the previous aggregation. A separate flocculation chamber can be dispensed with, because with this process, in-line pipe flocculation enables destablisation and formation of microflocs occurs in the upper portion of the filter above the filter media (Figures 5–7).

Filtration over granular filter material is the oldest known process in water treatment technology. Of all the technologies used today, filtration has the highest practical significance. Filtration technology has been continuously developed and optimised. The development of the slow filter was the first step in filtration technology. The high capacity of slow filters is offset by the disadvantages of a gradual build-up of biological growth, very high space requirement and the costly regeneration of the media. The

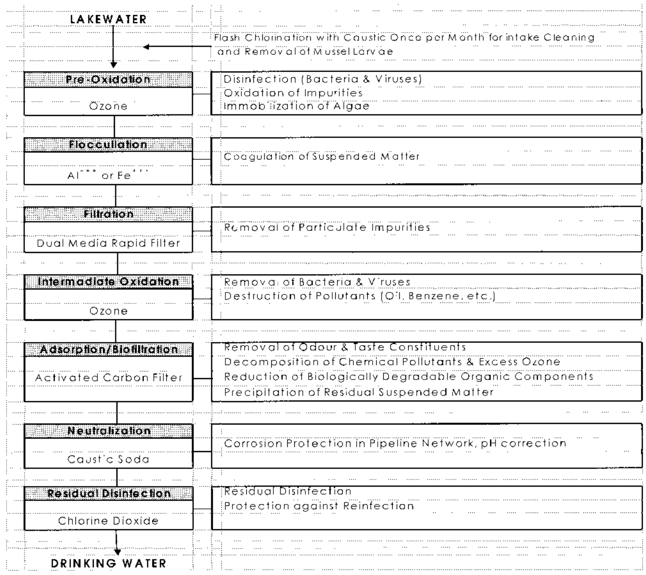

Figure 4 | Multistage treatment chain.

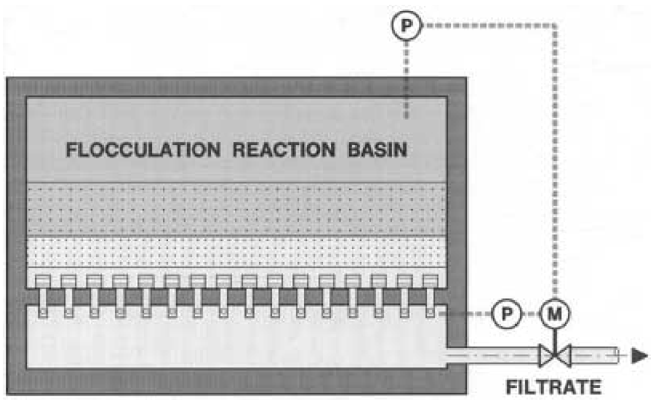

Figure 5 | Rapid filter with flocculation filtration basin.

continuously increasing water demand and the necessity to take qualitative and hygienic aspects into consideration, lead finally to the building of less costly, more modern multi-media filtration plants with back-washing systems. Today's multi-media filter which works both as full depth and surface layer filter, is used for separation of turbidity and can basically be charged with high quantities of solid matter (Figure 6). The advantage lies in a relatively slow running pressure rise as more impurities are retained in the media. Compared to the single bed filter, this leads to considerably longer filter running times. Only when the

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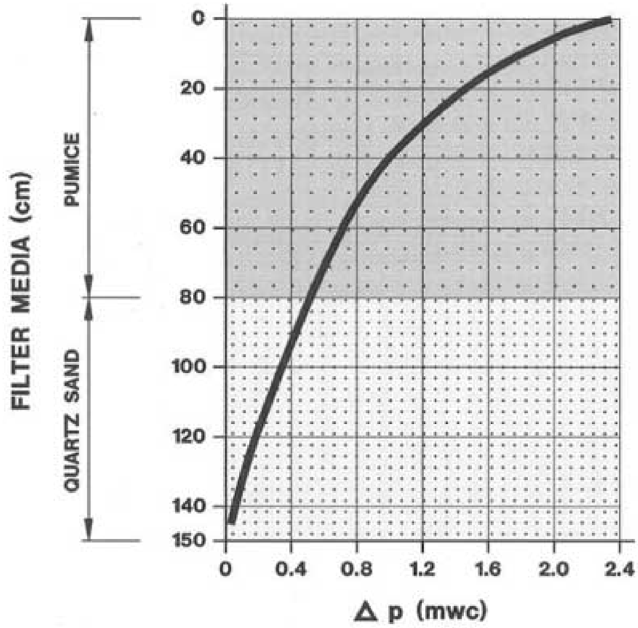

Figure 6 | Impurities—pressure profile in dual media filter.

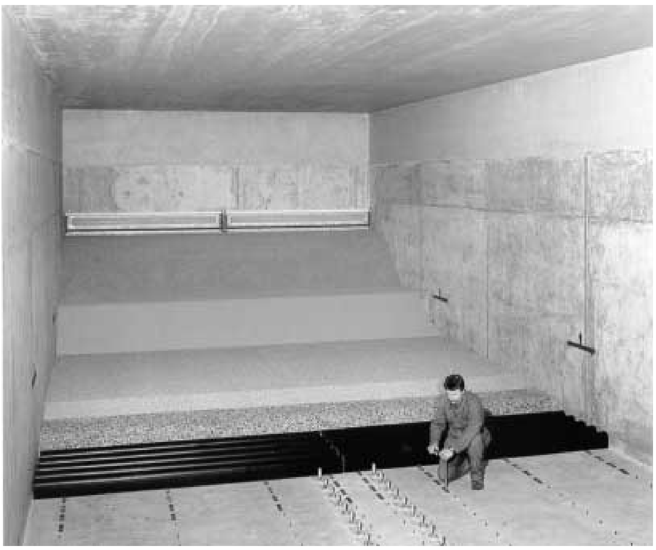

Figure 7 | Dual media drainage filter.

upper layer is fully laden with solids, does the lower fine bed come into operation and work as a flat filter. The solid impurities entrapped within the lower media bed improve the filtrate quality with increased running time. This effect is accelerated and optimised with flocculation filtration in combination with pre-ozonation. Through run-off regulation of the multi-media filter the volume above the filter mass is used as a reaction basin for flocculation (Figure 5).

By discharge regulation through throttle valves on the discharge from each filter, the total pressure drop in the filter is kept constant during the entire filter running time. That means that each filter has precisely the same amount of water, that it must process, regardless of the solid content. In this matter, the space above the media in each filter functions to compensate for the pressure drop according to solids build-up in the filter media. An advantage of this filter regulation is that the full height of the filter vessel can be used hydraulically. Beyond that, the space above the media serves for build-up of the microflocs for the flocculation filtration. In order to significantly reduce the costs and achieve optimum conditions for filtration, the actual filter hall for visual control purposes was dispensed with. Through skilful construction of the filter casing, the filter is built as a pressure filter. The full height of the filter can thus be used for the treatment process.

INTERMEDIATE OZONATION

Disinfection and conversion of organic matter are of primary consideration in the intermediate ozonation. The organic components are made amenable to adsorption via downstream activated carbon and biological decomposition is promoted. The most important objectives of intermediate ozonation are removal of bacteria and viruses, decomposition of pollutants, support of the biological activity on the activated carbon and relief of the activated carbon filter. The pre- and intermediate ozonation chambers are, like the filters, designed as cost effective concrete pressure vessels. Great care is devoted to the residual degassing of the ozone mixture for correct functioning of the treatment steps.

ACTIVATED CARBON FILTRATION

The residual ozone in the water is eliminated on the surface of the activated carbon. In the carbon bed an adsorptive and also, after the working-in and partial loading of the carbon, a biological reaction takes place. During normal operations, the filters are loaded to a throughput of at least 150 m^3 water/kg of carbon and then regenerated. At an average DOC loading of 40 g/kg activated carbon, the mean running duration is approximately 5 years. On the basis of the very good experience in other lakewater treatment plants and the full load tests in Küsnacht, it can be concluded after a certain running period, that mainly biological activities take place in the filter, particularly when part of the adsorbable organic materials is biologically decomposable. The results from these biological mechanisms include, on the one hand, carbonic acid, which lowers the pH value and, on the other hand, biomass. This is comparable to a self-regenerating process, which significantly extends the running period of the activated carbon. On grounds of minimising operating costs, water quality is monitored over plant operations, so that for the required purified water quality, the running period of the biologically active filter can amount to approx. 10 years. It has proved beneficial to put a layer of quartz sand underneath the activated carbon granules. In this way, as with the dual media rapid filter, it is no longer necessary to throw away the first filtrate after the backwashing of the filter, which again leads to significant cost savings.

NEUTRALISATION

Caustic soda solution is dosed in very small quantities to compensate for the disadvantageous acidification of the water through the flocculation additive and through CO_2 resulting from the biological processes in the activated carbon filter. This neutralises the somewhat aggressive surface water. Through this, internal corrosion of the water supply pipelines is avoided.

RESIDUAL DISINFECTION

Thanks to intensive oxidation by ozone the treated water is practically germ-free. Nevertheless, residual infection takes place in the activated carbon filters. The aerobic germ count in the activated carbon filter increases slightly. Chlorine dioxide is added to the water for residual disinfection directly prior to the purified water reservoir, so that the reaction can take place fully in the plant reservoir. This long-term germ inhibitor effectively protects the drinking water from reinfection.

THE COST-EFFECTIVE PLANT CONCEPT

The treatment plants consist of two similarly constructed plant halves. They can be operated individually or crosswise. This has the advantage that at least half of the plant is available for production of drinking water during small or major work outages for repairs or maintenance. According to state-of-the-art technology the entire plant is fully automated according to the needs of the purified water reservoir. By closure or opening of four shut-off valves, the half plant is ready for fully automatic operation and production. The individual plant halves can also be set-up for optimisation tests. Even mixed water considerations can be applied with this concept.

The closed filter and ozone chambers have the major advantage that the space requirement is significantly reduced, when compared with the building approach of an open filter. Additionally, contamination from the atmosphere or other sources is practically excluded. The filters are designed with a nozzle plate or a drainage filter system. From considerations of economics and filtration technology, the closed filters with nozzle plates are built with a maximum size of 120 m^2, for which 4 m has proved to be the optimum filter width. With the introduction of the drainage filter an economic alternative was created, for which the building of concrete pressure filters up to an area of 150 m^2 is allowable on grounds of process technology. The optimum filter width amounts to 6 m and the length to 25 m. The drainage filter has, instead of a nozzle plate, a network of pipes, which are subsequently erected on the floor inside the completed filter chamber. The separation of the delicate construction of the drainage pipes from the building work for the filter rooms, has therefore proved correct. Such filters can also be installed cost effectively in sewage treatment plants.

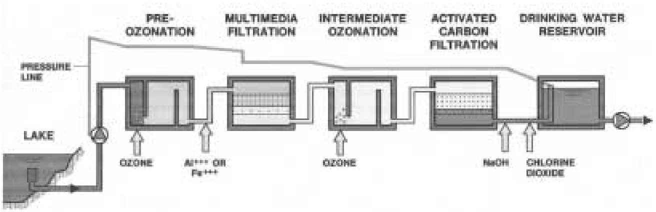

Figure 8 | Principle of a compact pressure treatment plant.

In addition to the economic advantages, this also permits faster progression through construction, which leads to a shorter overall plant completion time. A centric prestressing of the floors, walls and ceilings of the vessels is not always advantageous. Economic considerations and detailed studies of space requirements are critical to reach a decision concerning incorporation or elimination of prestressed elements. Modern concrete filter chambers have internal pressures from 7–14 mWC and the ozonation chambers somewhere between 8 and 11 mWC. Of prime consideration is the water tightness of the completed building structure, which is achieved through clear organisation of the concrete application stages in accordance with standards, with water tight joints as well as through a quality tested concrete technology. The economic advantages with this type of construction are achieved through the simple and massive building components, which are not further rendered, but satisfy demands for logical and high quality erection at the building site. In this way, optimisation of the concrete steps affords watertight construction of the complete building works. As a result of the open arrangement of the pipe cellars, the plant seems spacious and there is sufficient area available for all facilities. Furthermore, costs are lower through this arrangement.

We now consider the favourable investment costs and low operating costs of the plant. The raw water pumps transfer the water required for treatment to the highest point of the plant. Until the entry point into the purified water reservoir, there is no further pumping requirement (Figure 8).

In the ozone chambers, the main issue is that the dosing be optimal. For application to the raw water for the three works, counter current dosing proved to be the most effective approach. For venting of the residual ozone, it is

Figure 9 | Piping cellar Küsnacht/Erlenbach water lakewater treatment plant.

necessary to incorporate a proper discharge system which is reactive to the final residual quantity.

Precise investigations have established that the pipes for a relatively damp pipe cellar, should be manufactured from rust-free steel W1.4301 or W1.4435, according to use. Galvanised steel pipes, that need additional external protection with a two-component coating, are no more cost effective at today's price levels. This is even more so, because with the rust-proof steel variant, skilful arrangement permits substantial reduction in the number of flanges and the installation is simpler.

The elimination of open water surfaces has reduced the capacity requirements for the dehumidification plant. Investigations have shown that even in the ancillary plants (dehumidification, lighting etc.) significant investment and above all operating costs can be involved. State-of-the-art technology provides round-the-clock fully automatic operation of the plants with continuous monitoring of the principal quality parameters. Over- or understepping of quality parameters, drinking water shortfall, or unauthorised entry to the plant each trigger alarms, to alert the operating personnel, also outside normal working hours. All other disturbances can be checked and

Figure 10 | Filter piping cellar Limmat treatment plant.

Figure 11 | Piping cellar Frasnacht lakewater treatment plant.

rectified with today's straightforward concepts of automated operation, during normal working hours. In consideration, this factor results in a very large reduction in the relatively high man-hours for daily operation of the plants. Excluding planned maintenance, these new multi-stage treatment plants require control and adjustments by personnel only once a week.

THE QUALITY OF THE DRINKING WATER

After commissioning of the complete plants, a one-day full load test was performed on each plant, as mentioned at the start of this paper.

The objectives were to evaluate the:

- Water quality at nominal plant capacity,
- Water quality at overload (100% when possible),
- Influence of flocculation on the quality of the rapid filtrate,
- Influence of pre-ozonation on the quality of the rapid filtrate,
- DOC adsorption of the activated carbon filter,
- Ozone quantity in water,
- Hydraulic throughput, power intake, performance levels, as well as operating costs.

The following measurements and investigations were performed on drinking water quality:

- Turbidity value: raw water after the rapid filter (RF), after the activated carbon filter (ACF), purified water reservoir;
- Determination of absolute particle count: raw water after RF, after ACF, purified water reservoir;
- Oxygen content: raw water after pre-ozonation, after RF, after intermediate ozonation, after ACF, purified water reservoir;
- Ozone concentration: pre-ozonation inlet, pre-ozonation after the reaction chamber, intermediate ozonation inlet, intermediate ozonation after the reaction chamber;
- UV-extinction: raw water after pre-ozonation, after RF, after ACF, purified water reservoir;
- TOC decomposition: after pre-ozonation, after RF, after ACF, purified water reservoir;
- DOC decomposition: after pre-ozonation, after RF, after ACF, purified water reservoir;
- Removal of algae, divided between: total algae, algae >20 μm, algae 2–20 μm, algae <2 μm: raw water, after RF, after ACF, purified water reservoir;
- Removal of algae detritus: >20 μm, 2–20 μm, <2 μm: raw water, after RF, after ACF, purified water reservoir;
- Removal of flagellates: raw water, after RF, after ACF, purified water reservoir;

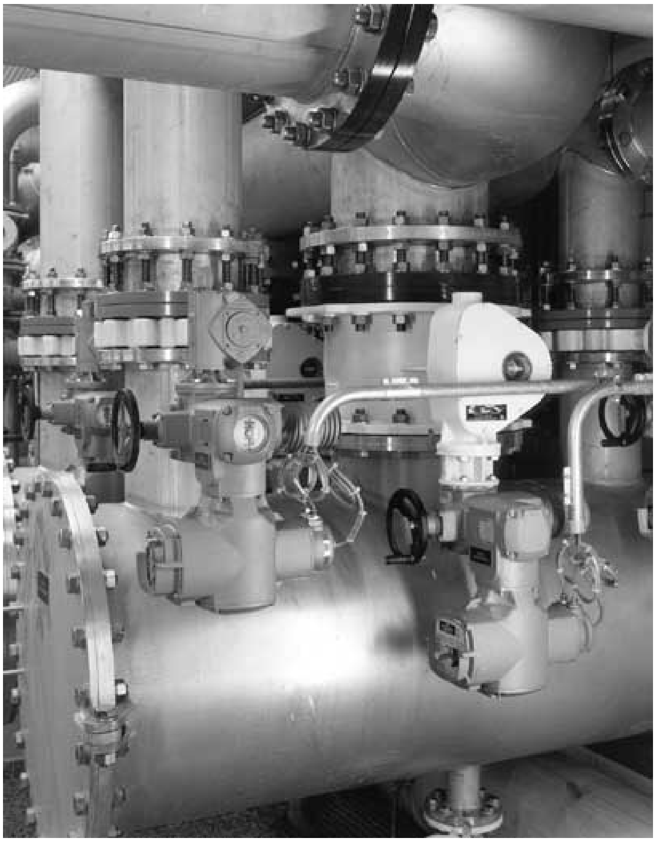

Figure 12 | Buffer room entry with filtrate washwater and cleaning air inlet.

Figure 13 | Ozone plant production 1.25 kg/h to 12.5 kg/h.

Figure 14 | Ozone plant production 0.3 kg/h to 2.7 kg/h.

- Bacterial investigations (20 °C/72 h and 30 °C/72 h): raw water, after pre-ozonation, after RF, after intermediate ozonation, after ACF, purified water reservoir.

All measured values satisfy the rules of the Swiss Foodstuffs Handbook and EU standards in their entirety. The treated drinking water is of very good quality. With the UV extinction, TOC/DOC analyses, as well as with the particle analyses, the positive influence of pre- and intermediate ozonation can be demonstrated for the elimination of organic contaminants in the water. The operation of RF can be significantly improved by correct introduction of pre-ozonation and flocculation additive. Through intermediate ozonation, some of the residual contaminants so extensively transformed that they are subsequently decomposed by the biological activity and adsorption in the activated carbon filter. The addition of ozone to the water results in efficiency levels of more than 99%.

An essential objective of the tests was to verify the dimensioning of the RF. In the first place, it was worth investigating the influence of increased filtration speed on the elimination of particular contaminants in the water. The residual turbidity in the respective filters is equal to or <0.1 TE/F through pre-treatment with ozone and flocculation additive (Figure 17). The residual turbidity in the

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Figure 15 | Automatic control center, Limmat water treatment plant.

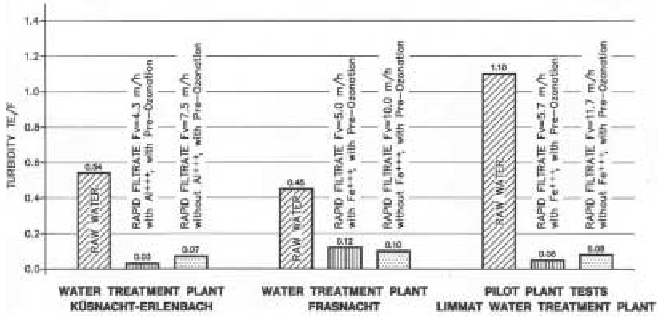

Figure 17 | Removal of raw water turbidity.

Figure 16 | Automatic control center, Seewasserwerk Frasnacht.

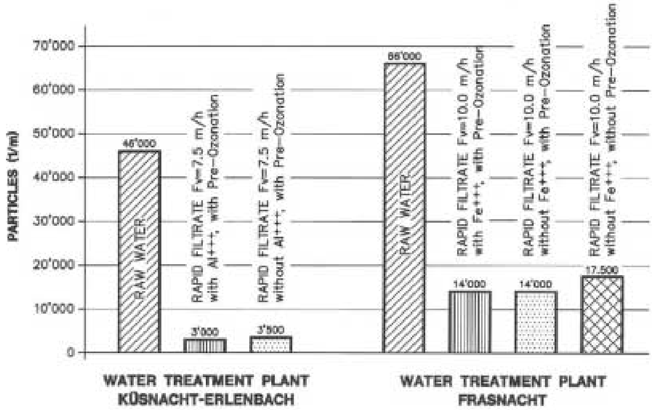

Figure 18 | Particle analysis in relation to pre-ozonation and flocculant dosing for dual media filter.

filtrate is slightly increased when the intake turbidity >1 TE/F and the filtration speed exceeds 10 m/h. During the tests with increased filtration speed, the addition of flocculant was shut off and also, on another occasion, the pre-ozonation. Dispensing with the flocculant in combination with pre-ozonation, exhibited a negative tendency on the residual turbidity, which could certainly be demonstrated by the particle analyses.

In comparing the effectiveness of iron and aluminium salts for reduction of particles in the order of 0.4–25 μm, these relative measurements showed that polyaluminium chloride (WAC) achieved better results. The influence of microflocculation and pre-ozonation is of particular interest (Figures 18 and 19).

After switching off pre-ozonation, a clear increase of algae biomass in the rapid filtrate was established. A dosing of ozone before the dual media rapid filter, which is only insignificantly higher than the spontaneous depletion, showed a very positive effect on the algae elimination.

The reduction of organic water impurities is shown in the individual treatment steps in Figure 20. The Küsnacht/Erlenbach lakewater treatment plant has been operating since March 1995. In Frasnacht, because of the short time since commissioning, no statement can be made about biological effectiveness. The DOC load in the activated carbon filter is about 30 g/kg of activated carbon. The 20% age reduction in the activated carbon filter should have been principally biological. The BDOC <0.2 mg/l. It is

Test No.	Pre-Ozonation	Fe-Dosage	Total Algae in Raw Water 1/ml	Total Algae in Rapid Filtrate 1/ml
1	X	X	703	161
2	X	0	639	53
3	0	0	928	779

Figure 19 | SWW Frasnacht, the influence of pre-ozonation and microflocculation.

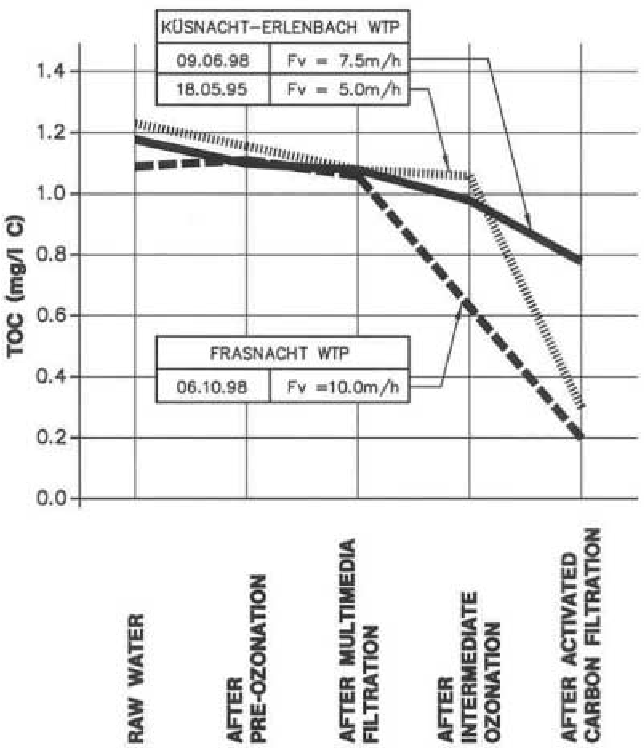

Figure 20 | TOC elimination at various activated carbon loadings.

to be expected that a permanent reduction of 15–20% is achieved in the TOC and in this way the limit value desired can be reached in the long-term.

CONCLUSIONS

All measured data were recorded in great detail, evaluated and collated in reports. The investigations should be continued within the framework of operations optimisation over the coming years. It is however, as stated in the first section, the task of the individual water supply authorities to undertake long-term investigations, particularly also for the seasonally dependent changes of the raw water. Results attained already today allow verification of the arrangement of the individual treatment steps.

- The pre-ozonation step with seasonally adjusted dosing between 0.4–0.8 g/m^3 O_3 is very effective for Lake Zurich as also for Lake Constance, which has to be integrated into the design for new waterworks. The dosage quantity is adjusted slightly higher than the current spontaneous depletion level. In this way the elimination of particular water impurities is clearly improved, especially the algae biomass.
- The improvement in lakewater quality, through effective watershed protection shows, from testing of the treatment stages, that with the multi stage processes, the hydraulic load of the rapid filters can be increased. Tests show that filtration speeds of 8 or even 10 m^3/m^2/h had no relevant impact on the quality of the rapid filtrate. A reduction in filter surface area enables significant savings both from the technical aspects of construction and also from the hydro-mechanical installations.
- The dosing of small quantities of metal salts, 0.2–0.5 g/m^3 Me, clearly improves the reduction of particulate matter. The turbidity values in the rapid filtrate are consistently below 0.1 TE/F. Quality of the initial filtrate are improved per distribution of the entrapped solids load in the filter medium. Results confirm that both iron chloride ($FeCl_3$) and polyaluminium chloride are suitable as flocculation additive. With both metal salts, the residual content in the rapid filtrate is measured as 20–30 μg/l Fe or Al, respectively. For elimination of solids, the aluminium salt tends to be more efficient. In any case the iron salt was not more efficient.
- The evaluated ozone plants produce O_3 from oxygen. The energy measurements taken, show that ozone gas with a concentration of 10% of weight is correct and permits a low specific energy consumption.

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- After adsorption, the activated carbon filter continues to work predominantly biologically. The reduction in dissolved organic carbohydrates remains stable at around 20%. In this way the target value of <1 mg/l DOC is reached also after years of operation time. The activated carbon is further capable of resisting an eventual microsoiling. The correct timing for the activated carbon regeneration should be determined individually for each treatment plant.
- In plants, larger than 100,000 m^3/d, it should in any case be investigated whether filters with a surface area of 150 m^2 can be built. This depends above all on how many filters are required to guarantee safe operation. Regeneration of filters and modification work apply as safety factors. From the financial point of view, large filter areas enable considerably lower costs, in these cost evaluations the large feed and delivery pipes as well as the regeneration installations must be included in the comparison. Operations demonstrate that the turbidity of the treated water also remains low also after filter washing. With multi-stage treatment processes, wasting the initial filtrate can be avoided, particularly when the last stage of filtration is, in the normal case, an activated carbon filter underlaid with quartz sand. The influence of possibly increased initial filtrate turbidity on the network water quality is directly determined by the number of filter cells. Also, plants which include only one or two filter cells, can face an eventual occurrence of quality reduction, i.e. a stepwise or slow re-starting of the filter or a short-term increase of the flocculant dosing.
- The efficiency of the rapid filter is, in addition to the already mentioned major influences like filtration speed, flocculant type and dosing amount and pre-ozonation, also dependent on the choice of filter medium and structure. More recent tests and operating experience show that with filtration speeds of from 5–10 m/h, a filter bed height of approximately 150 cm total, is best. In this way the height of the quartz sand layer (60–90 cm) and the grain size distribution (0.5–1.2 mm) can be matched with the corresponding raw water quality and requirements for the filtrate. In water treatment plants built in Switzerland, pumice granulate has been successful for the upper layer. The grain size distribution of 1.5–3 mm permitted the filter bed with 2–4 kg/m^3 to load particulate matter and the filter to operate up to a pressure drop of approx. 2.4 mWC, without making negative concessions on filtrate quality. Through the raised efficiency of the rapid filter the running time can be improved and the number of necessary back-washings clearly decreased (Figures 21 and 22). It is, however, absolutely necessary that the plants are operated with a constant base loading. The quality reductions which occur on starting a plant after 12 hours of idle time must be observed during operations.

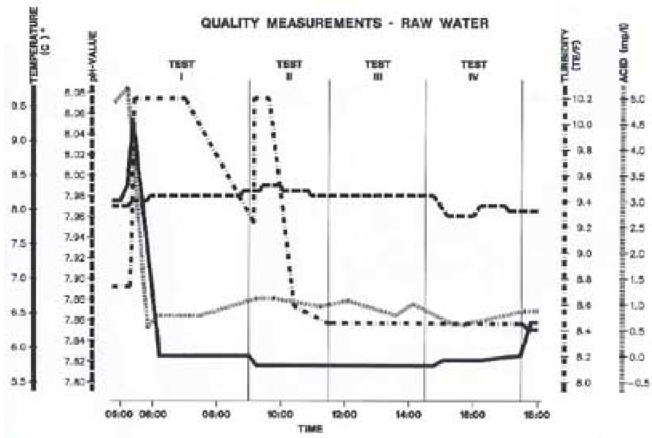

Figure 21 | Quality parameters of raw water at start of plant operation.

- The arrangement of the activated carbon filter treatment step is essentially determined by the organic constituents in the treatment stream. These should also be considered in the choice of the activated carbon. Today various qualitatively good activated carbons based on hard coal are available and other base materials, like olive kernels, are suitable alternatives. The back-washing of activated carbon can basically be performed with water alone, however, a periodic back-washing with air is imperative because of the biological activity.
- The back wash should be added back into the raw water stream at the head of the plant after integral treatment components for flocculation

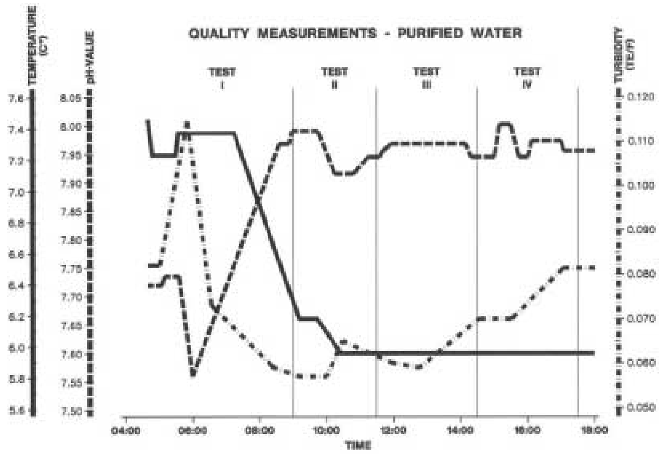

Figure 22 | Quality parameters of purified water at start of plant operation.

Plant Nominal Capacity m³/d	Specific Building Costs/m³	Operating Costs/m³
18'000	CHF 1'000	CHF 0,068
70'000	CHF 700	CHF 0,052
100'000	CHF 550	CHF 0,048

Figure 23 | Summary figures for building and operating costs.

sedimentation, and flocculation dual media filtration based on the findings of the SVGW Workshop on Cryptosporidium of 14 May 1997.

- Next to the savings attained from the treatment technology, investment and operating considerations are also decisive. In setting the performance capacity of such complex treatment plants, precise analysis must be made on whether the design should be based on the maximum possible daily demand value or on the mean maximum daily demand.
- The fully automatic operation of the plant according to the principle that the purified water reservoir is always full, independent of the supply from the treated water pumps, provides operational security, without significant impact on the operating costs.
- The consistent application of compact, pressurised treatment plants built of concrete as a total concept enables significant operations/security and investment cost reductions.
- When selecting the hydro-mechanical auxiliary units, their effectiveness, as well as their investment and operating costs should be taken into consideration.
- Lower investment and operating costs? On the basis of the detailed analysis of three plants executed in the time frame 1994–1998 with market related prices, common data can be compared (Figure 23). The price for the site is not included in the investment costs. The prices include a raw water pumping station with a lake pipeline of approx. 1,000 m long, and the complete treatment chain as described above, including relevant treated water pumping station for elevating the drinking water 100 mWC. The purified water pressure pipeline is taken into consideration up to one metre from the plant. For the calculation of operating costs, the cost of capital such as bank interest and depreciation are not included. However, the personnel costs, which in smaller plants are percentage-wise quite high, all chemicals and energy costs as well as sludge disposal charges (2.80 CHF/m^3) are included. The mean daily demand was taken as basis for the production quantity, i.e. 50% of the nominal throughput. Specific energy consumption at full load for the complete treatment plant, including elevation of the drinking water to a final reservoir, located 100 m higher than the treatment plant, is determined at approx. 0.4 kWH/m^3.
- Through multi-stage treatment processes a high level of production security is attained. In the sense of a long-term guaranteed supply with good drinking water quality, the number of stages is not reduced. In case of accidents in the catchment area of the raw water, the treatment plant must always be able to produce sound drinking water. In regard to overall costs for an entire drinking water supply system, the costs of a treatment plant (investment and operation) are not the determining factor.

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