To DIN or not to DIN: Ozonation of Pool Water in Public and Commercial Pools

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The German pool code, DIN 19643, is a comprehensive standard that regulates all aspects of pool design. It includes ozonation as part of the disinfection and treatment of the pool water. Compliance is mandatory in some, but not all, European countries. Health officials and pool designers in many countries around the world, where ozonation is not covered by existing codes, have accepted DIN 19643 as a guideline.

The paper presents some of the basic design concepts of DIN 19643, with emphasis on the ozonation parameters. These are contrasted with US designs, in process applications that employ pre-filter or post-filter injection and full flow or side stream ozonation. Results from several selected sites demonstrate the successful elimination of pool water problems. Recommendations include a list of suggested design dosages based on observations, and additional ozonation design criteria.

Introduction

The German pool standard, DIN 19643 (DIN: Deutsche Industrie Norm = German Industry Standard) is a federal standard for the "treatment and disinfection of swimming and bathing pool water" (DIN 19643 1984). All public municipal and commercial pools in Germany must be designed and built in compliance with the standard.

DIN 19643 is a process–oriented regulation that refers many of the details associated with pool water chemistry, special equipment, material selection, etc., to other applicable DIN standards. A revised version with numerous changes was distributed for comments in 1993, but has not been formally adopted.

DIN 19643 sets limits for the many different parameters that are used in describing the quality of pool water. It also lists the treatment sequences that may be used when designing a pool treatment system. Four process variations are described explicitly, but others are permitted, if it can be demonstrated that they meet all applicable quality and safety regulations.

One of the unusual features in the standard is a formula for the calculation of the circulation flow based on pool area, pool depth, and a process–specific efficacy called the specific load or b–value.

$$Q = (A \cdot n) / (a \cdot b)$$

where:
Q = Circulation flow [m^3/h]
A = Pool Surface Area [m^2]
a = Surface Area per Person [m^2]
b = Specific Load [$1/m^3$]
n = Specific Frequency [1/h]

Using the specified values for a (a function of the pool depth), b (process specific), n, and the actual pool surface A results in unique values for turnover and circulation flow that are based on the physical characteristics of the pool, and not the *fixed* turnover rates usually written into U.S. pool codes.

The turnovers calculated using the formula in DIN 19643 are usually much shorter, and the corresponding flow rates larger, than those based on most U.S. codes. A sample calculation for a typical 20' x 40' (hotel) pool demonstrates the different approaches.

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Pool Dimensions:	Length: 40 ft; Width: 20 ft; Depth: Linear slope from 3 ft to 5 ft
	Surface area: A_T = 40 ft x 20 ft = 800 ft^2 = 74.3 m^2
	Area of pool ≤ 1.35 m deep: A_1 = 571 ft^2 = 53 m^2
	Area of pool > 1.35 m deep: A_2 = 229 ft^2 = 21.3 m^2
U.S. Flow Calculation:	Pool Volume: 40 ft x 20 ft x (5 – 3)/2 ft = 3200 ft^3 = 23,936 gallon
	Turnover (typical): 6 h = 360 min
⇒	Flow = 23936/360 gpm = 66.5 gpm = *15.1 m^3/h*
DIN Calculation:	$Q_{tot} = \sum A_i /(a_i \cdot b) = 1/b \cdot \sum(A_i /a_i)$
	A_1 and A_2 see calculation above;
	From DIN: a_1 (for depth ≤ 1.35 m) = 2.7 m^2
	a_2 (for depth > 1.35 m) = 4.5 m^2
	b = 0.5 m^{-3} (standard process)
⇒	Flow Q = 1/0.5 · [53.0/2.7 + 21.3/4.5] = *48.7 m^3/h* = 215 gpm

Sample Calculation

In this hypothetical but typical pool the DIN code would require a treatment flow that is 48.7/15.1 = 3.23 times larger than the one determined by common U.S. practice. This increased flow through the purification equipment may be one of the many reasons for the superior water quality of German pools. Longer turnovers and smaller flows translate into smaller, less expensive equipment. The savings in capital cost may, however, be at the expense of the water quality. Some U.S. designers use turnover values similar to those calculated with the DIN formula, which are much faster than the minimum ones permitted by the applicable State code; the number of these progressive companies remains small.

In addition to describing the treatment processes and stating an efficacy value (b–value) to be used for the calculation of the turnover, DIN 19643 also lists the *requirements and acceptable limits* to be met by treated water, pool water and raw water.

They include microbiological requirements for heterotropic plate count (HPC), coliform, *E. coli* and *Pseudomonas aeruginosa*, and acceptable ranges for pH, turbidity, coloration, oxidation reduction potential (Redox or ORP), and free and combined chlorine. It is a federal German standard (all states within Germany must comply with the standard), but is also used in a number of other European countries, and worldwide, wherever ozonated pool systems are designed and installed. Regulating pool design, construction and operation with a federal code contrasts with the conditions in the U.S., where almost all states and some counties have their own pool/whirlpool standard, with widely varying requirements; some states (Kansas and Mississippi) have none at all.

Ozonation Parameters Specified in DIN 19643

One of the four treatment sequences listed in DIN 19643 includes the application of ozone. It states that the specific load (b–value) is "equal to 0.6 [1/m^3] for the combination of coagulation, filtration, ozonation, granular activated carbon filtration and chlorination." This b–value (at 0.6 [1/m^3]) is higher than the specific load of the other listed process combinations (at 0.5 [1/m^3]). It should be noted that both the addition of a coagulant and the dual filtration are highly unusual for U.S. installations, which almost universally use only single–stage filtration plus chlorination. While the National Spa and Pool Institute (NSPI) actually recommends not using coagulants or flocculants, observations from several sites demonstrate the improvement in pool water quality when injecting small quantities of polyaluminum chloride (referred to as PACl). Unpublished measurements by one of the authors showed a strong synergistic effect when using a combination of ozone and PACl.

Once a pool designer has decided to include ozonation as part of the treatment process, DIN 19643 lists the process parameters for the design. They are

DESIGN PARAMETERS	RANGE OR LIMIT	SPECIAL CONDITIONS / NOTES
Applied Ozone Dose	0.8 –1.0 mg/L	If Temperature 28°C (82°F)
	1.0 – 1.2 mg/L	If Temperature > 28°C (82°F)
Mass Concentration	> 18 g/m^3	Approx. 1.4% (by weight)
Contact Time	2 minutes	
Ozone in Pool Water	0.05 mg/L	Dissolved Ozone

Table 1: DIN 19643 Ozone Requirements

listed in Table 1.

Other items, such as hydraulics with requirements for gutter overflow and balancing tank, filter construction, the use and the backwashing of granular activated carbon (GAC), machines, components, accessories, corrosion protection and automatic control are covered in detail. The ozone generation plant construction (ozone generator requirements) is addressed in a separate standard DIN 19627.

Although DIN 19623 does not directly deal with the removal of the injected ozone and the carrier gas (air, oxygen enriched air or oxygen), other applicable German standards ensure that these gases are removed before the ozone–treated water is returned into the pool. Allowing offgassing in the pool area, which is permitted by some state codes in the US, is not allowed under German regulations. The objections to this "direct ozonation into the pool" are shared by a number of experienced international pool consultants.

DIN 19643 lists design values for the ozonation. This means that systems must be *designed in compliance* with the stated values. It certainly does not mean that pool ozone systems *actually operate* with such applied doses and concentrations. Most units will inject only approximately 30 – 50% of the (maximum) design ozone concentration. The lower actual ozone output and injection rate is especially easy to observe in ORP–controlled systems that either adjust the actual generator output, or completely shut off the ozone production when the desired ORP level is attained. In other words, generators designed using the DIN standard are normally utilized to less than 50% of their design capacity.

Under DIN 19643, all circulated water is contacted with the ozone. This will be labeled *"full flow ozonation,"* because the full filtration treatment flow is ozonated, as opposed to systems where only a fraction of the circulation flow is contacted.

The latter systems, often referred to as *side stream* or *slipstream* systems, will be called "*side stream ozonation.*" The contacting itself must be distinguished from the method of ozone injection. Almost all pool ozone

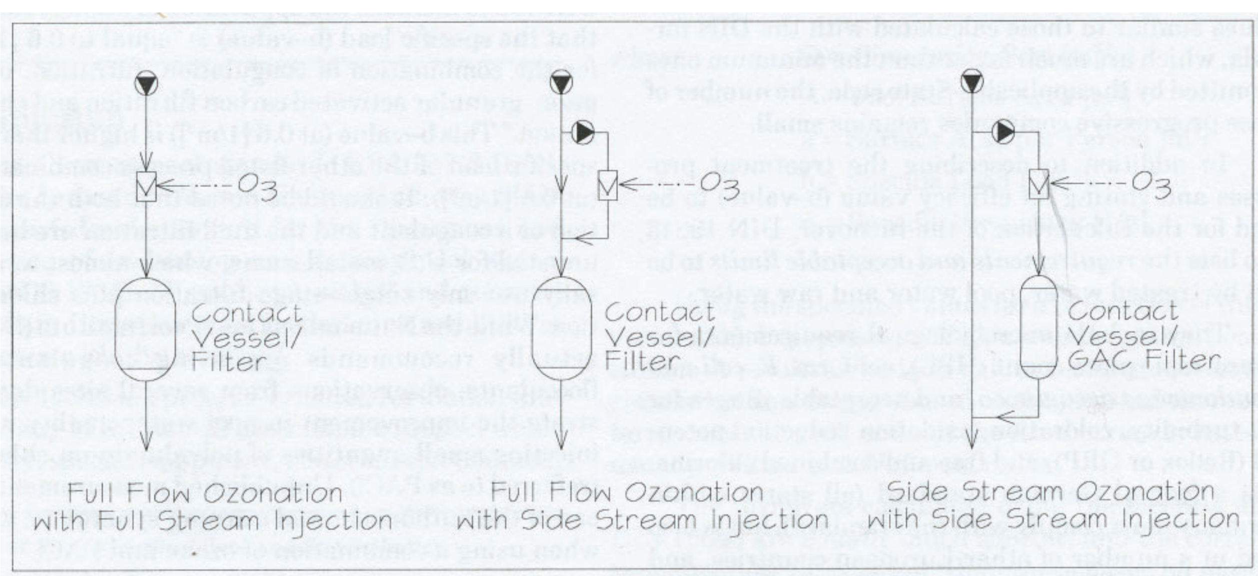

Figure 1: Treatment Alternatives for Ozonation of Pool Water

installations inject the ozone via a side stream, using a separate booster pump. A few treatment systems in large public whirlpools in the US, and the models of at least one German manufacturer, employ direct ozone injection into the full circulation flow. Figure 1 shows the possible treatment alternatives.

Design of U.S. Pool Ozonation Systems

Pool codes in the US, usually issued by the respective State Health Departments, vary widely in regulating the addition of pool water chemicals. In some states the use of ozone is not regulated at all, while others severely restrict the application of ozone. An example is the Illinois code, that currently permits "no more than one gram per day of ozone per 10 gallons per minute of flow rate" (Illinois Administrative Code 820.210). Not only is this an interesting mix of measurement units, but it restricts the applied ozone dosage to 0.018 mg/L. California proposes a limit of 0.1 mg/L dissolved ozone, but does not mention the removal of undissolved gaseous ozone (offgas destruction); it does, however, limit the concentration of ozone gas above the pool surface to "0.1 ppm above the ambient air ozone concentration" (California Health and Safety Code 20/1/24101.3).

This is equal to the OSHA eight hour limit, and, combined with ambient and smog ozone, should be cause for concern.

Some new US pools were designed using DIN 19643 as a guide, but without compliance to all requirements. This is based on the belief that the German code is in certain sections overly restrictive, or that it mandates equipment components that are oversized.

DIN 19643, in the ozone process sequence, requires that all circulated water be treated by: coagulation, filtration, ozonation, granular activated carbon filtration and chlorination. Because double filtration is almost unheard of in the US, one design alternative for full flow ozonation has been to use the main filter as contact vessel for the ozonation stage, with or without the addition of a flocculant. This is feasible

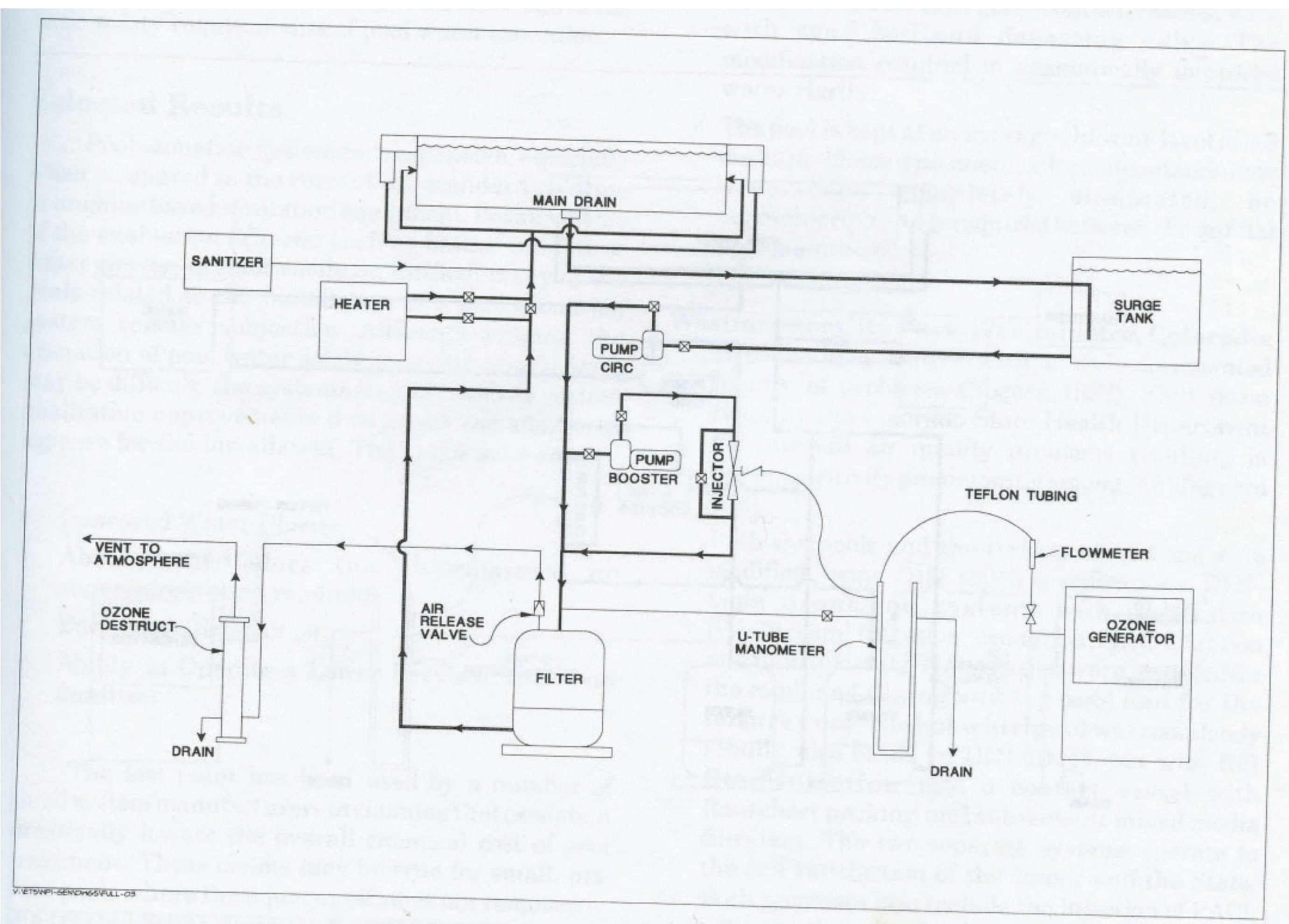

Figure 2: Full Flow Ozonation with Pre–Filter Sidestream Injection

only in new installations, because the filter interior must be resistant to gaseous and aqueous ozone. It also requires a larger freeboard than is normally available in the standard high rate sand filters. The resulting process sequence for full flow ozonation with single stage filtration is:

Flocculation (optional) ⇒ Ozonation ⇒ Mixed Media Filtration with Offgassing

This design alternative has been installed and is operating successfully in several large indoor facilities.

The major equipment modification in adapting to this process has been the re–design of the high rate sand filters. To protect the filter interior, the vessels are lined with Hypalon, or are made from stainless steel, or from fiberglass with an ozone resistant resin. The freeboard for each filter cell is extended to provide for a contact time of one minute or more. A GAC layer on top of the sand media destroys the residual aqueous ozone, while special offgassing valves allow the undissolved ozone and air or oxygen to be vented through an ozone destruct chamber. Figure 2 shows full flow ozonation, where the ozone is injected via a sidestream ahead of the filter.

Existing treatment systems with non–ozone resistant filters, or new installations with filtration equipment unsuited for ozone injection prior to filtration (such as diatomaceous earth filters) require a different approach. In this case the process sequence is:

Filtration ⇒ Ozonation ⇒ Contacting/ GAC Filtration with Offgassing

The ozone is injected after the filtration stage, and a separate vessel provides for adequate contact time, offgassing and destruction of the aqueous ozone. Because the flowrate through the GAC bed used for destruction of the dissolved ozone is limited to approximately 37 m/h (15 gpm/ft^2), the diameter of the contact vessel becomes the limiting factor. Installing a contact vessel with a diameter similar to that of a high rate sand filter (sized for the design flow) is in most cases physically difficult or impossible, and uneconomical

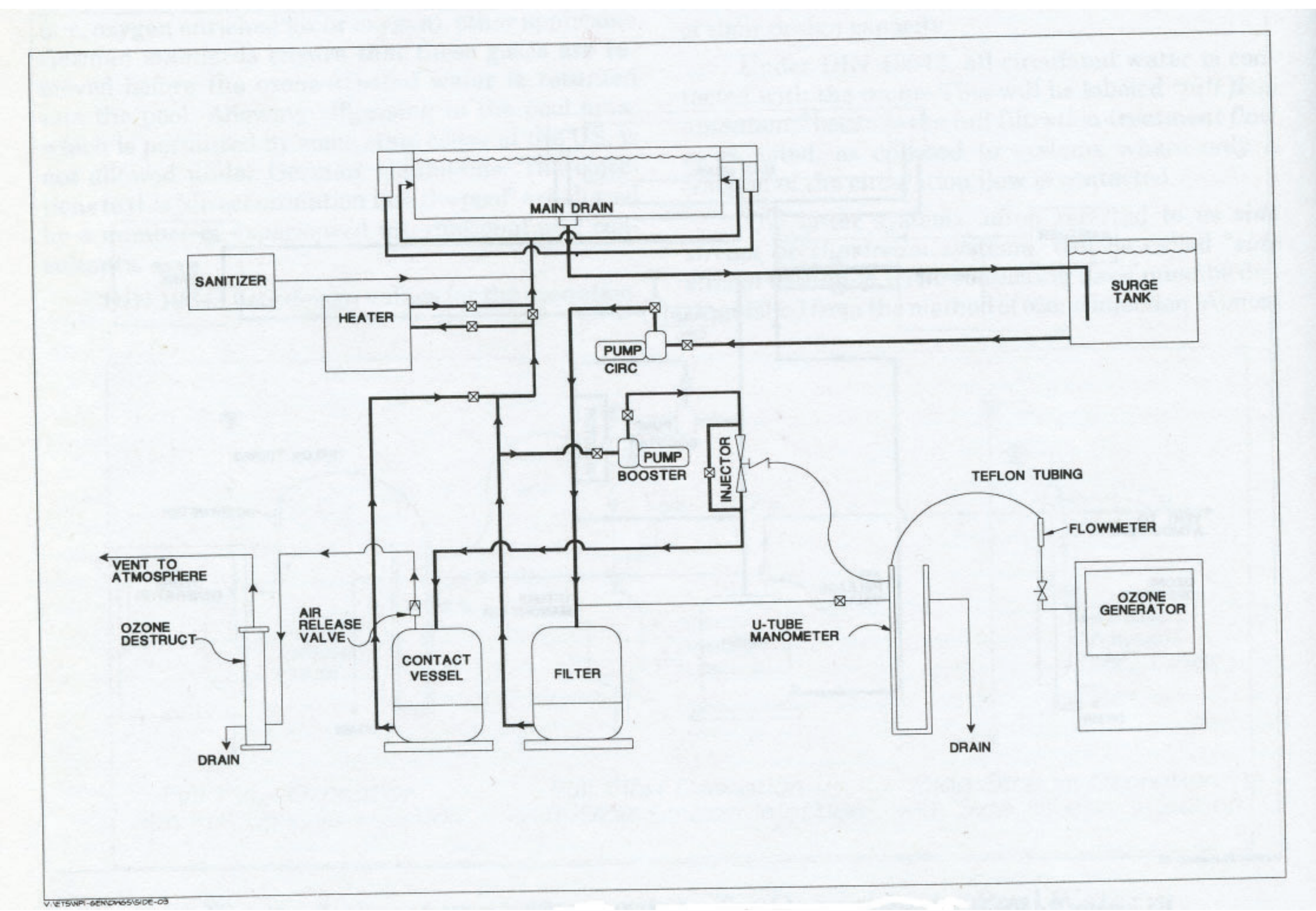

Figure 3: Post–Filter Sidestream Ozonation

as well. Systems in this design category will therefore usually treat only a portion of the full flow; they are side stream systems. The side stream fraction is a matter of discussion, and varies considerably. Some custom–designed side stream systems treat approximately one third of the full flow, while many of the commercially installed standard models are sized to ozonate only approximately 8% – 12%, a low portion. Figure 3 shows a typical retrofit installation, where a fraction of the filter flow is ozonated and contacted after the filter.

Although side stream systems could be installed upstream of the main filter, most of them are placed after the filtration stage. This avoids using the carbon in the contact vessel as a filter for the side stream, with frequent backwashing a necessity. Post–filtration contact vessels with GAC require only a few backwashes per year.

Many of the commercially available, prefabricated side stream ozonation systems do not destroy the aqueous ozone in a GAC or sand bed. Some also do not have automatic degassing of the undissolved air/ozone. Providing for destruction of both gaseous and aqueous ozone is considered by the author one of the basic safety requirements of pool water ozonation.

Selected Results

Pool ozonation systems are expensive, especially when compared to the costs of the standard chlorine or bromine based sanitation equipment. Because some of the evaluation criteria, such as bather comfort or water clarity, are not easily quantified, many of the goals related to the installation of a pool ozonation system remain subjective. Although judging the ozonation of pool water solely on a *cost benefit basis* may be difficult, the systems should result in certain qualitative improvements that justify the additional expense for the installation. The major ones are:

- Improved Water Clarity
- Absence of Odors (no chloramines; no superchlorination required)
- Enhanced Disinfection
- Ability to Operate a Lower Levels of the Main Sanitizer

The last point has been used by a number of small system manufacturers in claiming that ozonation drastically lowers the overall chemical cost of pool treatment. These claims may be true for small, private pools where the aqueous ozone is not removed in the treated water. Because the GAC used to remove the dissolved ozone also absorbs chlorine, cost reductions for the main sanitizer are usually negligible. They are certainly not the main justification for the installation of a pool ozonation system.

The achieved results in the following four examples are typical for pool ozonation.

Shoreview Community Center; Shoreview, Minnesota: An indoor facility with a large, single combination pool incorporating a shallow leisure pool, a lap pool and a slide plunge basin. Diatomaceous earth (D.E.) filtration system with final chlorination. Heavily used, averaging 750 bathers per day, and up to 1500 during holiday periods. Operating at a level of 3 – 4 mg/L (ppm) chlorine, the operator had problems with very high levels of chloramines, poor water clarity, and the resulting customer complaints.

A **post–filter side stream ozonation** system was added to treat approximately one third of the full circulation flow. The design applied ozone dosage is above 1 mg/L, but the actual operating values are considerably lower. Contacting occurs in three parallel fiberglass contact vessels, each with sand bed and degassing valve. The modification resulted in dramatically improved water clarity.

The pool is kept at an average chlorine level of 0.5 mg/L; problems with microbiological contaminants have been completely eliminated; no superchlorination is required between the annual pool maintenance.

Westminster City Park; Westminster, Colorado: A community center with a well–documented history of problems (Rogers 1993). Shut down twice by the Colorado State Health Department for internal air quality problems resulting in hypersensitivity pneumonitis among the lifeguard staff.

Both the pools and the treatment systems were modified, using DIN 19643 specifications. **DIN–type ozonation systems** with coagulation (PACl), sand filtration, ozonation, GAC filtration and final (existing) chlorination were installed for the combined **diving and lap pool and for the leisure pool**. The **hot whirlpool** was completely rebuilt, also based on DIN 19643, but with **full flow injection** into a contact vessel with Rauschert packing and subsequent mixed media filtration. The two separate systems operate to the full satisfaction of the owner and the State. Both processes also include the injection of PACl, with excellent results. The ozone generators, air feed vacuum type systems from Germany, were downrated because of the site altitude. The pool and whirlpool water treatment does not comply with all DIN requirements, but the overall design philosophy includes many DIN features.

Reba McEntire Center for Rehabilitation; Denison, Texas: A new installation for therapy use. **Post–filter side stream ozonation** (approx. 50%) for a **therapy pool and a hot whirlpool**, each with a GAC bed contact vessel and offgassing. A single ozone generator supplies both systems; the applied design dose is 1 mg/L.

Maplewood Community Center; Maplewood, Minnesota: A new community center with separate lap pool, leisure pool and whirlpool. **Pre–filter full flow ozonation**, contacting in Hypalon–lined high rate sand filters with GAC cap for the **lap and leisure pools**. **Post–filter side stream ozonation** (approximately 50% of the flow) for the **whirlpool**. Applied ozone dose (design value) is 0.65 mg/L, but all three systems are usually operated at 30% – 50% of that level.

Recommendations

Increasingly, indoor pool facilities, especially new designs featuring heavily used leisure pools with sprays and slides, select ozonation as the treatment of choice to avoid problems, and to provide optimal water quality to their patrons. The recommendations listed here are based on the experience gained in installing a number of differently configured systems.

New Installations: Choose full flow ozonation before the filtration stage, especially when using high rate sand filters. If the filters are not ozone resistant, install post–filter side stream ozonation, treating 25% – 40% of the full flow. DE filters must have ozonation after the filters, because the air/ozone bubbles interfere with the filter's DE coating.

Retrofit Installations: Design and equipment selection are dictated by the ozone compatibility of the existing equipment. Most retrofit installations will be post–filter side stream ozonation; the design is influenced by available space, power and access. Treat 25% – 40% of the full flow, if possible.

Applied Ozone Design Values: Instead of copying the DIN design values, consider the intended use. Large pools with low bather loads, such as diving, training or competitive swimming pools, don't require the same ozone dosage as leisure pools or whirlpools. Table 2 shows the design recommendations for full flow ozonation:

Type of Pool	Recommended Ozone Dosage
Training/Competition Pool	0.15–0.3 mg/L
Diving Pool (when treated separately)	0.15–0.3 mg/L
Lap/Aquatic Exercise Pool	0.3–0.5 mg/L
Leisure/Zero Depth/Wading Pool	0.5–1.0 mg/L
Hot Whirlpool	0.7–1.0 mg/L
Therapy Pool	0.7–1.0 mg/L

Table 2: Recommended Ozone Dosages for Various Types of Pools

The design values for side stream ozonation can be obtained by dividing the full flow numbers with the side stream fraction. Doses above 1.0 mg/L seem to be of little additional use when treating large side streams, so 1.0 mg/L is recommended as the upper limit for side streams in the range of 25% – 40% of full flow.

Additional Suggestions: U.S. manufacturers of pool equipment tailor their products to the applicable codes and restrictions (especially true for filters and associated components). Building a pool to DIN specifications with standard U.S. components is almost impossible. DIN 19643 may be looked at as a guide with many useful ideas and recommendations, but not as a standard to be adhered to one hundred percent.

For the use of ozone in pool water treatment, the following additional features are highly recommended for installation:

- **Mandatory offgassing, before the treated water is returned to the pool area**
- **Contact vessels with GAC and/or sand for aqueous ozone destruction**
- **Offgas ozone destruction prior to venting to the atmosphere**
- **Ambient ozone monitors when using pressurized dryers/O_3 generators**
- **Interlocking of the ozone generator with pumps and safety equipment.**

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Key Words

Ozonation of Pool Water; German Pool Code; Full Flow and Side Stream Ozonation; Turnover; Applied Ozone Dosage; Pre– and Post–Filter Ozonation; Contact Vessel; Offgas.

About the Author

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