Wastewaters from swimming pool operations

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ABSTRACT

This paper presents a chemical and physical description of various types of swimming pool wastewaters and their impacts on recipients. First, there is a brief description of the technology for public swimming pools, and the types of wastewaters that are produced. Then research results are presented for backwash waters obtained from many swimming pool operations. The results are comparable with the results obtained for various wastewaters, which can be categorized on the basis of the type of process that has been performed in swimming pool operations. Monitoredwere the wastewaters discharged from filter backwashing, when swimming pools were emptied and by swimming pool deck cleaning. Finally, in two campaigns, was studied the behavior of the stream when backwash wastewaters were discharged. Up to 17 chemical and/or physical parameters of the discharched wastewaters and stream waters were monitored, together with the technologies and other conditions for each swimming pool operation.

Key words: Discharging, stream, environment, recipient, swimming pool, wastewater.

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INTRODUCTION

Swimming pool wastewaters are one of many types of wastewaters that arise from industry and from other human activities. In comparison with industrial and sewage wastewaters, the pollution from swimming pool discharges is not heavy, but it is necessary to know the characteristics of these wastewaters if they are to be discharged into streams. Visibly clear water in swimming pools contains various chemicals, as the provision of clean water for swimming leads to the formation of unclean wastewaters[1].

The aim of this study was to provide a description of swimming pool wastewaters and of the behavior of these waters in streams and rivers. The descriptions include: types and concentrations of chemicals in swimming pool wastewaters, the flow rate of discharged waters, duration of discharging and frequency of discharging. We investigate also the length of the downstream section that is affected, which recipients are affected, and in which conditions.Swimming pool wastewaters are dependent on the technologies that are implemented in swimming pool operations. In most public swimming pool operations, the swimming pool water is directed to sand filters, where pollutants are removedfrom the water. The dirt particles are accumulated in the sand of the filters, and after acertain time it is necessary to clean the filter. This is performed by backwashing the filter. In this process, pool water is directed through the filter in the reverse direction, and the dirt particles are washed out. Higher efficient filtration is achieved by dosing with a coagulant. For the purposes of sanitary protection, doses of a chlorine-based disinfectant are released into the pool water. In order to regulate the pH levels, acidic or alkaline agents are dose usually into the pool water pipes.

This study focuses on the following types of swimming pool wastewaters:

1. Wastewaters from dischargingthe pool water – emptying pool (DPW).
2. Wastewaters from filter backwashing (BW).
3. Wastewaters from cleaning the pool and the pool decks (CPW).

This study was carried out at 14 public swimming pools in the Czech Republic. The sample included both outdoor and indoor pools. In all pool operations monitored here, coagulation, pH correction, and chlorination wasperformed. Salt chlorination used in swimming pool water treatmentwas not included in this study. All these swimming pools were equipped with sand filters. The total volume capacity of the pools ranged from 20 m^3 to 500 m^3 of water. Measurements were made in various weather conditions.

All these factors were observed,together with the wastewaters on which the tests were carried out. It is assumed that these factors have a fundamental influence on the resulting wastewaters.In addition, shortly before backwashing, measurements were made of the chlorine characteristics of the swimming pool water. We also monitored the frequency of washing and the weather conditions in the period prior to the measurements, and whether the wastewater was directed into the sewerage system or into a stream. All samples removed in deferent swimming pool operations were carried out while the pools water treatment technology was in use.The study was focused onwastewaterfrom backwashing (BW), on wastewaters from cleaning the pool and pool decks (CPW) and wastewater from pool emptying (DPW). Backwashing waters were monitored at different separateswimming pool operations. At some of thepools, the wastewaters observed over a number of backwashing processes at the same pool, in order to determine of how variable the results were. CPW were measured for8 swimming pools, but several different cleaned surfaces or cleaning technologieswere measured at each pool. At several swimming pools, we carried out measurements of water quality onthe wastewaters from pool emptying (DPW). Two campaigns were focused on measuring the waters in the recipient when backwash waters were discharged.

MATERIALS AND METHODS

Samples of discharged backwash water were taken every 30 or 60seconds throughout the time when the filter was being washed. A total of 5 to 20 samples per filter were taken. Information was simultaneously gathered about the flow rate and the discharge time. The flow rates were estimated or roughly calculatedaccording to the pump capacity data. Times were measured. These samples were mixed to form two groups per filter. The first, smaller group of samples presents the peak polluted water levels. The second, larger group presents the build-up and fade-out time. The wastewater volume for group two was about four times greater than the volume for group one. This pair of samples was gathered for each washed filterthat was measured. Some of the samples were transported to a chemical laboratory and were analyzed within 3 days after they had been collected. The samples for AOX analysis were conserved in nitric acid and sodium sulphite. Up to 13 chemical analyseswere performedon each sample. A special analysis was performed for the free and total chlorine that were formed. These parameters wereanalyzed in situ within 5 to 15 minutes after the samples were taken. A mobile colorimeter with accuracy ± 0.03 mg/l was used for this purpose.

In two cases, the behavior of the water in recipient was monitored while the washing wastewaters were being discharged. The flow rates in these recipients were 51 l/s and 1.5 l/s. In both cases, samples of the unaffected stream were taken before discharging began. During backwashing,the discharged water was measured in the same way that other backwash waters were monitored in this research. Downstream from the wastewater outlet,the flowing water was measured in each of the metering sections. Some samples were transported to the chemical laboratory in the same way as the filter backwash water. Free and total chlorine wereanalyzed in situ using a mobile colorimeter within 15 to 45 minutes after they were collected.

In the first monitored recipient, the flow rate was 1.5 l/s and the flow rate of the discharged washing waterwas 40 l/s. Downstream from the outlet,a total of six separate metering sections were placed at a distance of 40 meters to 600 meters from the outlet. Samples of water for chlorine analysis were taken every 5 minutes throughout the period of influence. The flow rate in the second monitored recipient was 51 l/s, and the flow rate of the discharged washing waterwas 55 l/s (both measured). Downstream from the outlet, two separate metering sections were placed at a distance of 40 meters and 220 meters from the outlet. Water samples were taken every 3 minutes throughout the periodof influence. About 20 sampleswere takenin each section. These samples were mixed into two groups per section, in the same way as formixing the filter samples – one group for the peak, and one group for the build-up and fade-out of the polluted water.

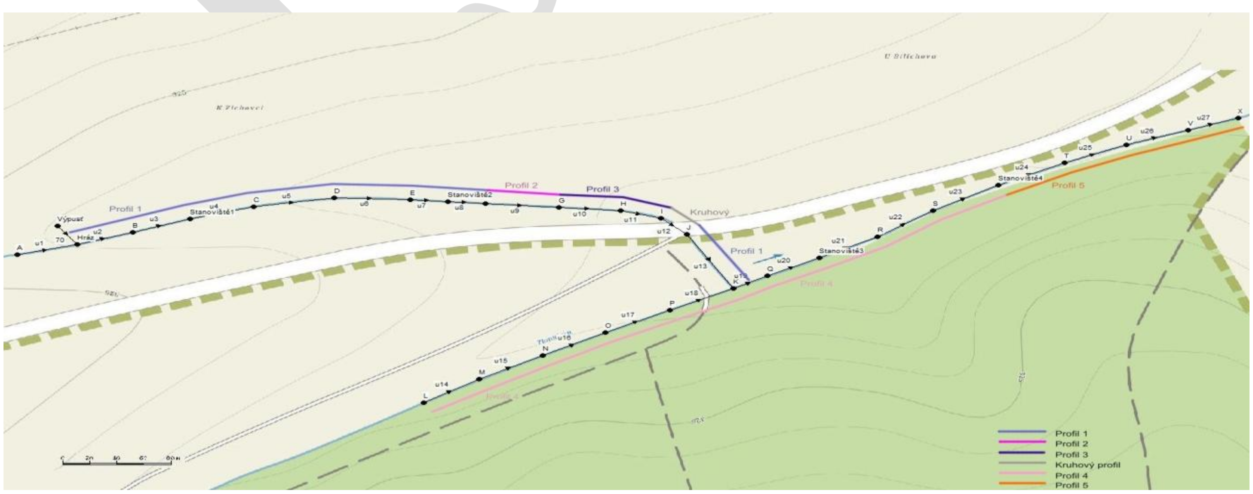

Fig 1: Measured recipient in situ

The wastewaters from swimming pool cleaning (CPW) were monitored for about 20 separate cleaned surfaces at 8 pools.Both outdoor and indoor pools were included. For each monitored cleaned surface, information was gathered about the type of surface, the area of the surface, the chemicals that were used, and the way in which the cleaning was performed. In addition, we observed the volume of chemicals that were used, the flow rate and the time taken for the wastewater to flow down. Samples were taken throughout the time when the CPWwas flowing to the sewage system. From 3 to about 20 samples were obtained for each monitored cleaning process. These partial samples were subsequently mixed into one or two overall samples for each monitored cleaned deck surface. The table below presents selected cases of cleaned surfaces.

Table1.List of all studied cleaned surfaces, with data about the area of the surface, the type of cleaning action, the chemicals used for cleaning, and the type of pool

Type of surface	***Area [m2]***	***Type of action***	***Agents used***	***Type of pool***
Tiled staircase	15	Sanitary day	Puron KD	Indoor
Tiled floor between pools	50	Sanitary day	HD Combi Clean,	Indoor
Pool walks	10	Sanitary day	4Cleaner, Kalkfjerner, CIP Acidan	Indoor
Bottom of pool	310	Annual maintenance shutdown	4Cleaner, (K1, K1 Ultra, K1 TOP)	Indoor
Footbath	6	Sanitary day	Aquabella, Savo	Outdoor
Peripheral footbath	90	Sanitary day	Blue stone (Copper sulphate)	Outdoor

Table 2. List of chemicals used for cleaning the surfaces, with a short description

Name of agent	***Short description***
Puron KD	Acidic saponaceous agent with 20% phosphoric acid and 5% cationic tenside.
HD Combi Clean	Disinfectant with 20% sodium hydroxide and 3% sodium hypochlorite.
4Cleaner	Agent for removing scale, stains and algae, with hydrochloric acid and surfactants.
Kalkfjerner	Highly acidic agent for removing scale and stains.
CIP Acidan	Highly acidic agent for removing scale and stains, with about 80% phosphoric acid, tensides and corrosion inhibitors.
K1	Cleaning agent for removing scale, stains and algae, with phosphoric acid and amidosulphonic acid
K1 Ultra	Cleaning agent with hydrochloric acid and isopropanol
K1 TOP	Agent for removing scale, with hydrochloric acid
Aquabella	Slightly alkaline cleaner with about 2% potassium hydroxide
Savo	Disinfectant agent with 5% sodium hypochlorite.

The emptying of a swimming pool was observed at two indoor pools. In the first case, the water stood for 30 days before it was discharged without any treatment. Immediately before it was discharged, three samples were taken from various parts of the pool, and the chlorine wasmeasured. At the second pool, 4 basins were discharged simultaneously: a 25m swimming pool, a whirlpool bath, a wading pool and a turbulent flow. Dosage of chemicals was stopped eight hours before the water began to be discharged. The pool water was sampled throughout the discharge period, and the free and total chlorine were measuredimmediately. From 1 to 3 samples were taken during the discharge period.

RESULTS AND DISCUSSION

The filter backwashing period was very variable from pool to pool, and also for each of the pools.The filters were washedas frequently as twice daily or as infrequently as once per 10 days. Under the individual swimming pool operations the period fluctuated roughly in range of triple.The main influence on the length of the period was the weather and the number of bathers. Backwash water was discharged mostly to the sewage system, and was discharged into a streamin only about one third of the cases. In all cases, the monitored poolsapplied doses of chlorine inthe liquid, solid or gaseous state. In most of the pools, dosesof phosphoric or sulphuric acid were applied. Doses of a coagulating agentwere applied in most cases. On rare occasions, an alkali (sodium carbonate or sodium hydroxide) was used to raise the pH value, or an algicide (copper sulphate)was applied for algae control. The free chlorine values in the pool water ranged from 0.0 to 0.7 mg/l, and were normally about 0.3 mg/l. The highest measured total chlorine value was 1.1 mg/l.

The contamination of the backwash wastewater fluctuated during the discharge period. For the first approx. 10 to 20 seconds the level of contamination was very low, equivalent to the usual level for swimming pool water. Then the values rose rapidly,and the maximum contamination value was reached after about one third of the water had been discharged. This point corresponded with approximately the second or third minute after discharging began. After that, the level of contamination declined slowly until it was almost the same as the level of contamination of the pool water. The backwash water was discharged at a flow rate from 10 l/s to 100 l/s. The total volume of discharged washing water from all washed filters ranged from less than 10 m^3 to 150 m^3. The discharge time ranged from 4 to 10 minutes per filter. The number of filters under a pool ranged between 1 and 6. The total time for discharging all the filters in the swimming pool was 45 minutes.

The qualitative values of the backwash water were alsovery variable. The biggest differences were between swimming pools. There were smaller differences within a single pool, within the backwashing processes, or between different washed filters. Higher values of chlorine in the backwash water corresponded with a higher level of chlorination of the pool water, a longer period of filter washing, or alternatively with chlorination of the filter while it was being washed. Performing chlorination before the filter seems to lead to higher levels of chlorine in the backwash water than when chlorine is added after filtering during ordinary treatment.The concentrations of free chlorine are certainly higher in the backwash waters than in the pool water. Higher levels suspended solids correspond with a longer period between washing events and larger numbers of bathers. The AOX levels are related to the chlorine content in the backwash water. Sporadic higher levels of copper corresponded with the use of copper sulphate.

The table below presents the values of the monitored parameters, divided into the maximum and minimum values that were obtained.

Table3. Measured levels of the monitored parameters in backwash waters

Parameters	*Minimum*	*Maximum*
Conductivity [mS/m]	59	897
COD(Cr) [mg/l]	1.2	216
BOD(5) [mg/l]	1	24
TOC [mg/l]	1.6	67
Suspended solids [mg/l]	6	570
Dissolved solids [mg/l]	120	6310
Free chlorine [mg/l]	0.0	6
Total chlorine [mg/l]	0.06	6.8
Chlorides [mg/l]	77	431
AOX [mg/l]	0.16	3.7
Aluminium [mg/l]	0.12	68
Copper [mg/l]	0.003	20
Iron [mg/l]	0.02	5.6
Manganese [mg/l]	0.005	0.43

In the first case, when the backwash waters were discharged into a stream, the level of free chlorine in the backwash waters was around mg/l, AOX 0.59 mg/l, copper 8.5 mg/l, and suspended solids 202 mg/l. At the metering section 40 m downstream, the discharge was observed to containup to 2.2 mg/l of free chlorine, 0.33 mg/l of AOX, 1.7 mg/l of copper and 160 mg/l of suspended solids. Raised levels of some monitored parameters, including the flow rate,were measured at least 600 meters downstream from the outlet. Free chlorine reached only the threshold value in this cross section. During the discharge, a strong increase was observedin the level of suspended solids 200 meters downstream from the outlet. The value of 530 mg/l exceeded the value in the water being discharged, probably due to erosion of the bottom sediment. The maximum flow rate 40 m downstream from the discharge was estimated to be30 l/s.

In the second case, when backwash waters were discharged into a stream, the measurements were 0.3 mg/l of free chlorine, 0.7 mg/l of total chlorine, 0.79 mg/l of AOX and 400 mg/l of suspended solids in the backwash water. 40 meters downstream from the outlet in an unaffected recipient, the measured values were 0.04 mg/l of AOX and 17 mg/l of suspended solids. During the discharge, the measured levels in this metering section were 0.22 mg/l of AOX and 220 mg/l of suspended solids as the 12-minute average at the peak of the influenced flow. In the second metering section, 220 meters downstream, the measured level was 140 mg/l of suspended solids. The free chlorine and total chlorine values in both sections did not exceed 0.05 mg/l.

The discharging backwash water from the swimming pool into a stream (BW)and free chlorine in different stands are expressedin next Fig2.

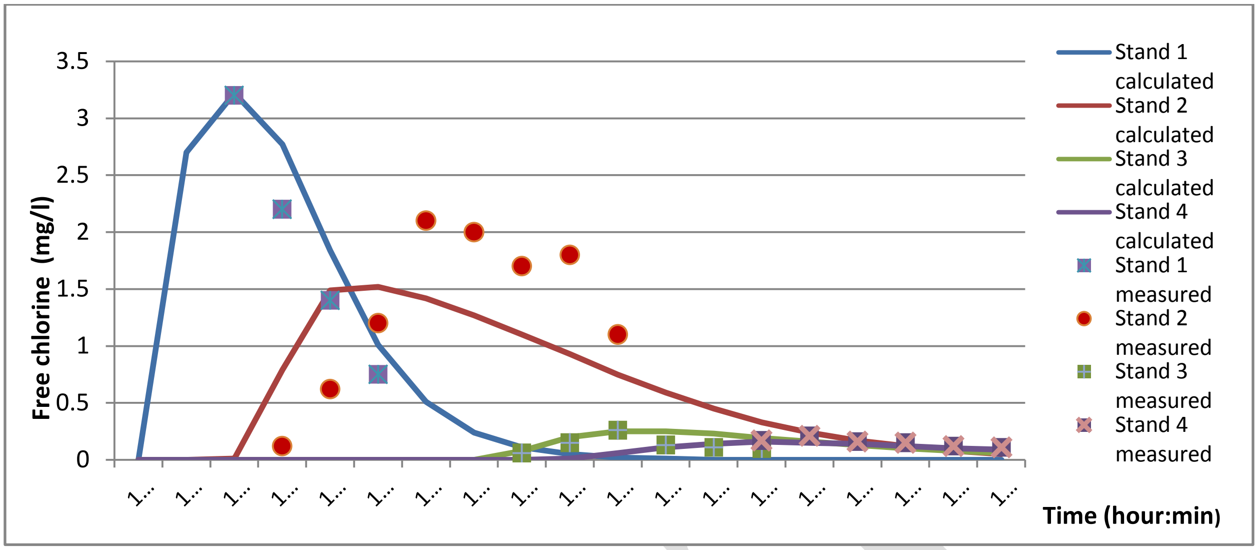

Fig 2: Free chlorine in different stands into a stream – time starts from beginning backwashing

The wastewaters from cleaning the swimming pool and pool deck (CPW) are expressedin next Table 4.

Table 4.Qualitative and quantitative parameters of cleaning the swimming pool and pool deck (CPW) under the individualcleaned surfaces. The areas of the surfaces are given in Table 1.

Parameters	***Tiled staircase (Puron KD)***	***Tiled floor decks (Combi Clean)***	***Pool walks (4 cleaners)***	***Bottom of pool (various agents)***	***Footbath (Savo)***	***Peripheral footbath (Bluestone)***
Conductivity [mS/m]	320	110	520	135 - 1700	626	-
pH [-]	< 1	4.5	2.3	< 1 - 6.2	8	7.7
COD [mg/l]	160	170	-	-	7.3	26
TOC [mg/l]	40	40	-	-	22	-
Suspended solids [mg/l]	100	140	50	50 - 2010	80	420
Dissolved solids [mg/l]	3300	1000	-	-	-	-
Anionic tensides [mg/l]	0.4	1.1	0.9	1.8 - 23	1.4	-
Free chlorine [mg/l]	-	-	-	-	750	-
Aluminium [mg/l]	-	-	31	1.6 - 20	-	-
Copper [mg/l]	-	-	0.18	0.1 - 1.0	-	95
Iron [mg/l]	-	-	0.9	4.8 - 97	-	-
Flow rate [l/s]	2	1.5	0.05	0.2	2	0.75
Duration	4 min	5 min	15 min	7 hours	7 min	5 min
Frequency	2 - 5x weekly	2 - 5x weekly	2x monthly	annually	weekly	2x monthly
Volume of chemicals[l]	0.2	0.1	0.1	10	1	-

In the first monitored case, ittook 15 hours to empty the pool and the process was divided into three days. Measurements showed no free chlorine or total chlorine in the wastewater from this pool.No significant levels of the monitored parameters were found in the wastewater. In the second case, a 25m swimming pool was emptied in 2 hours. The small basins were emptied within about 10 minutes. The free chlorine in the wastewaters from all basins varied between 0.1 and 0.2 mg/l. The total chlorine fluctuated around 0.5 mg/l in the 25m swimming pool. In the whirlpool bath, the wading pool and the turbulent flow, the total chlorine level was 0.3 mg/l. In both cases, the emptied water was discharged into the sewage system.

CONCLUSION

All measured results refer to a specific swimming pool, specific technologies and operatingprocesses. The results can be used for a general evaluation of the pollution of swimming pool wastewaters and the related damage to recipients

For backwashing wastewaters, the main pollution fingers are free chlorine, AOX, copper, suspended solids and raised flow rate. These fingers occurred at concentrations that can cause damage to stream ecosystems if the flow rates are low. The flow rate of rivers is high enough preventing damage to their ecosystems. It is not possible to establish an exact limit of the flow rate below which a stream becomes endangered, because the properties of swimming pool wastewaters are variable.

CPW are another important source of contamination. Compared to backwash waters the flow rates are low, but some quality parameters can have a major impact. The most pollution parameters of CPW are pH value, free chlorine, copper, suspended solids and dissolved solids. All of these parameters are important only in specific cases. For quality, the decisive factor is the type and the volume of the agents that are used. For the volumes of discharged water, the decisive factor is the area of the cleaned surface and the frequency of cleaning. Both of these factors are influenced by the specific approach of the maintaining operator.

The wastewaters discharged when a swimming pool is emptied are not highly hazardous. However, problems can occur especially with free chlorine and due to the large volume of wastewater that is discharged from a large pool.

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