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THE STUDY OF POSSIBILITIES FOR REUSE OF WASHINGS FROM SWIMMING POOL CIRCULATION SYSTEMS

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Abstract: Swimming pools are very expensive, in terms of operation, sports facilities. Therefore, investors and managers of these facilities are looking for methods of reducing the costs of their use. One of the proposed methods is the managing of washings previously discharged to the sanitary sewage system. The assessment of possibilities for reuse of washings from swimming pool filtration system is based on the limits of basic indicators of pollutants in wastewater discharged to water and soil (temperature, pH, TSS, BOD₅, COD, TN, TP, free chlorine). The conducted research of washings quality from 26 tested swimming pools have shown that washings quality is dependent on the operating conditions of the pool circuit, including the filter cycle duration and types of filter bed. A direct discharge to water or soil may be impossible due to excessive amounts of total suspended solids (above 35 mg/dm³) and free chlorine concentration (above 0.2 mg Cl₂/dm³). However, the quality of supernatant water of washings subjected to sedimentation in the laboratory shows that the washings are suitable for reuse. The installation of settling tanks in swimming pool facilities could relieve the sewage systems and allow for the discharge of supernatant water to surface waters or for the irrigation of green areas in an environmentally friendly way.

Keywords: washings, swimming pool water circulation system, washings reusing, sedimentation

Introduction

Technologies for recovering water from washings discharged from water treatment stations have been used in Poland and all over the world for many years [1-10].

In Poland, issues connected with the management of washings from swimming pool treatment systems have been pondered upon for about 10 years, since increasingly high prices for water and sewage started to convince swimming pool owners to look for solutions that would reduce the costs of running their facilities. One of them is the management of washings that have usually been discharged to the sewage system.

Since 2002, the Institute of Water and Wastewater Engineering of Silesian University of Technology is testing the quality of washings discharged from pools filtration systems and the possibility of their management [11, 12]. The main idea is the rational use of

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existing easy solutions, processes and devices, *eg* sedimentation tanks, settling tanks or settling tanks combined with flocculent mixing tank.

In the case of washings coming from cleaning the pools filter beds, potential is hidden in their large volume and the simplicity of methods that are used to recover the supernatant water.

The proper rinsing of a swimming pool filter requires from 4 to 6 m³ of water per m² of filter bed [13-16]. For example, swimming pool treatment system consisting of 2 filters with diameter of 1800 mm, that are usually rinsed every two days, requires from 245 to 365 m³ of water every month, just for cleaning it.

Taking into account the fact that there are 736 public indoor swimming pools in Poland [17], each with a few or several filtration systems, and that the demand of water for those facilities is high, the idea of washings reuse is certainly worth considering. The studies of the volume of washings discharged to the sewage system conducted so far showed that it is possible to reduce the costs for sewage by 20-70%. Sometimes, the volume of washings was not as important as the price for discharging 1 m³ of washings [11, 12].

With the proper quality of swimming pool water [13-16, 18] and efficient pool filtration systems [19, 20], using the supernatant water from washings for irrigating green areas, sprinkling grounds and tennis courts (very often located near a swimming pool), as well as flushing toilets is an easy solution that allows to dramatically reduce the cost of water and sewage.

If a swimming pool is located near a watercourse, washings could be discharged directly to it. It should be noted that operating an installation for discharging washings into a watercourse requires a water permit that regulates the use of water and discharge of sewage into water or soil [21-23]. Special attention should be paid to the level of washings contamination as compared to the cleanliness class of the chosen watercourse and the method of discharging wastewater into a receiving body of water [24, 25].

The simple solutions for the management of washings are gaining in popularity among the swimming pool owners. A few of the tested facilities have them already and the cost of their implementation is being recovered.

In the case of new swimming pools, the installations for washings reuse are often planned during the design stage.

The main objective of this article is to assess the basic parameters of washings quality and to determine the possibility of their management with the help of simple and environmentally friendly methods. This is achieved by analysing the results of physicochemical tests of washings samples taken from 26 filtration systems in years 2002-2015.

Research methodology

The research compares the results of physicochemical analysis against the regulations and recommendations concerning the permitted level of pollutants in wastewater discharged to water or soil [21, 23-25].

The analytical tests of basic quality parameters of washings were performed: pH, temperature, total suspended solids, COD (chemical oxygen demand), BOD₅ (the five-day biochemical oxygen demand), total nitrogen, total phosphorus, free chlorine and, in 11 samples of washings, CFU (colony forming units) of total bacterial count.

The maximum allowable values of pollutants, presented in Table 1, were considered the basis for determining if the washings could be reused by discharging them to water or soil.

The analysis covered raw washings and washings subjected to a two-hour sedimentation process in laboratory conditions.

The complete cycle of tests for determining the contamination level of washings from particular pool circuits took from 1 to 2 months. Eight basic tests were performed. These determined the sedimentation efficiency, washings contamination level and their suitability for reuse.

Table 1
Maximum allowable values of selected indicators of contaminants in wastewater discharged to water or soil by [24]

No.	Indicator	Unit	Maximum allowable value	Minimum percentage of pollution reduction [%]
1	pH	[-]	6.5-9.0	-
2	Temperature	[°C]	35	-
3	Total suspended solids	[mg/dm ³]	35	90
4	Chemical oxygen demand COD	[mg O ₂ /dm ³]	125	75
5	The five-day biochemical oxygen demand BOD ₅	[mg O ₂ /dm ³]	25	70-90
6	Total nitrogen	[mg N/dm ³]	15	-
7	Total phosphorus	[mg P/dm ³]	2	-
8	Free chlorine	[mg Cl ₂ /dm ³]	0.2	-

The washings were collected in batch during the whole cycle of filter beds rinsing (mean mixed sample) through valves installed on the pipes of individual filters.

The samples were collected and marked in accordance with applicable standards and methods [26-29]. PH was determined by potentiometric method, temperature by direct measurement method, total suspended solids by direct weigh method, COD, total phosphorus, total nitrogen and free chlorine by spectrophotometrical method (spectrophotometer DR5000 UV/VIS), BOD₅ by dilution method (measuring device Oxi Top® OC 100), the total number of organisms was determined in the accredited laboratory of District Sanitary-Epidemiological Station.

The analysis and comparison of washings test results showed that direct discharge to water or soil was impossible due to excessive amounts of total suspended solids and free chlorine concentration.

The analysis of test results of washings after the sedimentation process allowed to establish if they could be discharged into watercourses or used for the irrigation of green areas. Both manners of management required the installation of a settling tank and/or system for facilitating the sedimentation of suspended solids, and then the discharge of the condensed sewage to the sewage system.

Characteristics of swimming pool filtration cycles

The washings samples under study come from 26 pool cycles, 16 from sports pools and 10 from relaxation pools. The pool cycles (swimming pools) are marked: B1, B2, B3, etc. to B26. All of the analyzed pools are public indoor swimming pools, designed for bathing, irrespective of weather conditions. Water treatment for all cycles is based on

processes performed in close water cycles, including active overflow, and consists of: prefiltration - surface coagulation (except cycles B14 and B17 which use diatomaceous filters) - disinfection (mainly NaOCl, in a few pools supported with UV irradiation or partial water ozonization) - pH adjustment.

Among the analyzed pools, 16 are typical sports pools with dimensions of 12.5 m × 25 m, 10 are recreational pools designed mainly for children, with irregular shapes and of various sizes. Pools B14 and B17 use open vacuum filters pre-coated with diatomaceous earth. Here, the water is filtered with a speed of 2.5-4.0 m/h, and rinsing consists of removing diatomaceous earth with the help of high-pressure water from the mains. Depending on the number of filter cartridges, one rinsing requires from 3 to 7 m³ of water.

The remaining cycles are equipped with closed pressure filters that filter the cycle water with a speed of 30 m/h, and rinse the filter beds with a speed of 60-65 m/h. Rinsing requires from 4-6 m³ of water per m² of filter bed. The water for rinsing is taken from expansion tanks.

The pools under study are supplied with water from the mains water supply complying with quality requirements of water for consumption, 30 dm³ per every bathing person and per 24 hours. Sewage and washings are discharged to the external sewage system. Due to insufficient capacity of urban sewage systems to which washings from B3, B4, B5, B18, B19, B20, B21 and B26 are discharged, the water treatment systems in these facilities were equipped with buffer tanks allowing for storage and then successive discharge of washings to the sewers. In pools B4, B5, B18, B21 and B26, these tanks serve as settling tanks for washings, allowing for their partial recovery.

The characteristics of filtration cycles, from which washings samples were taken, are presented in Table 2.

Table 2

Characteristics of tested filtration cycles

Swimming pool	Number of filters [item]	Filter diameter or width × length [mm]	The height of the filter layer [mm]	Type of filter bed	Cycle time of filtration [day]
B1	1	1800	1200	sand multilayer	1
B2	3	1800	1200		2
B3	2	1800	1200	sand multilayer with a layer of anthracite	2
B4	1	1800	1500	sand multilayer	1
B5	2	1800	1500		2
B6	2	1800	1200	sand multilayer with a layer of anthracite	2
B7	2	1600	1500		3
B8	2	1800	1500		3
B9	2	765	1250		3
B10	2	1800	1350		2
B11	2	1800	1200		3
B12	2	1800	1500		2
B13	2	1600	1200	sand multilayer with a layer of anthracite	3
B14	1	2000 x 1900	2000	diatomaceous earth	7-10
B15	2	2000	1200	sand multilayer with a layer of anthracite	3
B16	2	1800	1500	sand multilayer with a layer of active carbon	2

Swimming pool	Number of filters [item]	Filter diameter or width × length [mm]	The height of the filter layer [mm]	Type of filter bed	Cycle time of filtration [day]
B17	1	2100 x 2300	2000	diatomaceous earth	6-8
B18	2	1800	1500	sand multilayer with a layer of anthracite	7
B19	2	1800	1200	sand multilayer	3
B20	1	1400	1200		2
B21	2	2200	1500	sand multilayer with a layer of anthracite	2
B22	1	1600	1200	AFG (a bed of glass)	1
B23	2	1800	1200	sand multilayer with a layer of anthracite	3
B24	2	1600	1200		3
B25	1	800	1200		1
B26	1	910	1200	sand multilayer	1

Swimming pool	Filtration surface [m ²]	Rinsing method	Circuit efficiency [m ³ /h]	The number of rinses in month	The volume of washings [m ³ /month]
B1	2.54	compressed air and water from the retention tank	76.3	12	182.9
B2	2.54		228.9	24	365.8
B3	2.54		152.6	24	365.8
B4	2.54		76.3	12	182.9
B5	2.54		152.6	24	365.8
B6	2.54		146	16	243.8
B7	2.01		120	24	289.4
B8	2.54		152.6	16	243.8
B9	0.46	water from the retention tank	46	16	44.2
B10	2.54	compressed air and water from the retention tank	146	16	243.8
B11	2.54		140	16	243.8
B12	2.54		152.6	16	243.8
B13	2.01		120	16	193.0
B14	3.60 (1 inset)	tap water	110	4	28.0
B15	3.14	compressed air and water from the retention tank	188.6	16	301.4
B16	2.54		152.6	24	365.8
B17	4.83 (1 inset)	tap water	174	5	35.0
B18	2.54	compressed air and water from the retention tank	142	4	61.0
B19	2.54		152.6	16	243.8
B20	1.54		46	15	138.6
B21	3.8		115	24	547.2
B22	2.01		60	30	361.8
B23	2.54		152.6	24	365.8
B24	2.01		120	24	289.4
B25	0.5	water from the retention tank	15	30	90.0
B26	0.65		23	30	117.0

Analysis of research results

The analysis of physicochemical properties of washings discharged from the tested swimming pools showed that these washings must not be discharged directly to water and soil due to the exceeded content of total suspended solids, COD and BOD₅ and the concentration of free chlorine.

The average content of total suspended solids in the tested washings ranged from 24 mg/dm³ in swimming pool B26 to 1615 mg/dm³ in swimming pool B17 whereas the allowed limit of suspended solids for sewage discharged into water and soil is 35 mg/dm³ (Fig. 1).

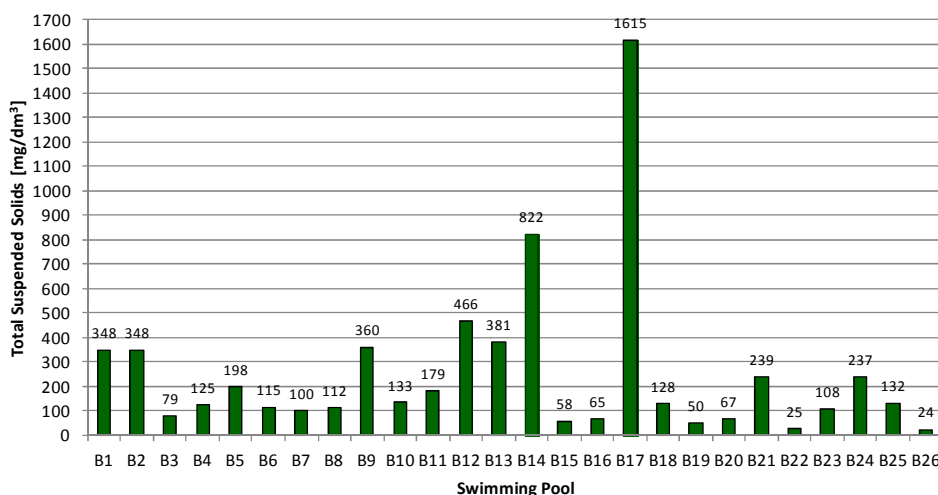


Fig. 1. The amount of total suspended solids in washings discharged from tested pools

A two-hour sedimentation process resulted in the reduction of total suspended solids in the tested washings, ranging from 24.0% in B19 to 95.4% in pool B1. As a result, the amount of settle-resistant suspended solids in supernatant water ranged from 14 mg/dm³ in B21 to 150 mg/dm³ in B14 (Fig. 2).

Washings from B14 and B17 pool circuits contained the highest amount of total suspended solids (on average: 822 and 1615 mg/dm³). Such a high level of suspended solids in the washings is caused by the filtration systems and rinsing method. Both circuits have vacuum filters with filter cloths pre-coated with powdered diatomaceous earth. The filters are cleaned by removing the contaminants together with diatomaceous earth, what is responsible for such a high content of suspended solids in washings discharged from the circuits. In both cases, despite the high reduction of suspended solids during the sedimentation process (81.7% in B14 and 95.0% in B17), the amount of settle-resistant suspended solids was still very high (80 mg/dm³ in B17 and 150 mg/dm³ in B14).

In washings from circuits B6, B10, B17, B18 and B20, the observed reduction of suspended solids ranged only between: 24.0% (B19)-58.5% (B18). Such low reduction level was caused by the low efficiency of the coagulation process. Light and very small flocs found in the washings from these swimming pools did not settle and after a two-hour sedimentation process there was on average from 38 mg/dm³ (B19) to 56 mg/dm³ (B10) of settle-resistant suspended solids in the supernatant water.

In the remaining samples of washings that were subjected to the sedimentation process, the amount of total suspended solids in the supernatant water ranged from 14 mg/dm³ in B21 to 35 mg/dm³ in B5 and B15.

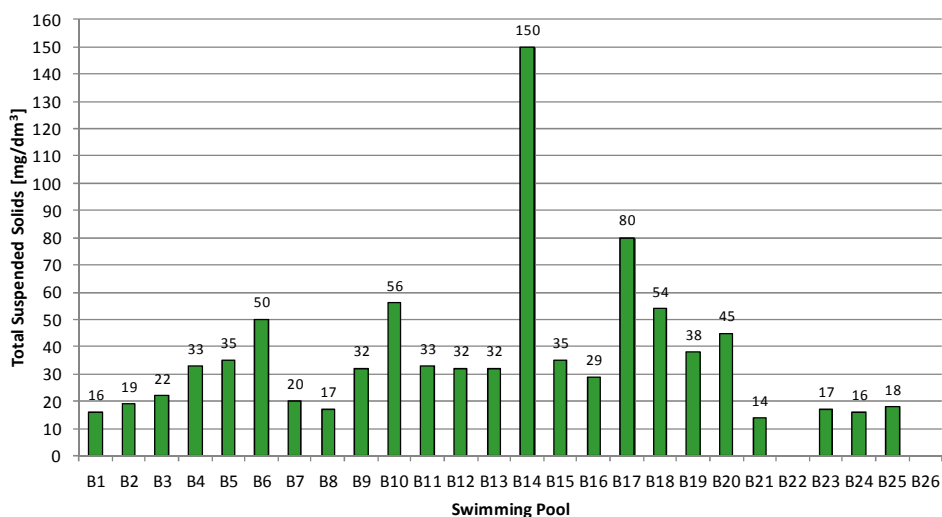


Fig. 2. The amount of total suspended solids in supernatant water after a two-hour process of washings sedimentation

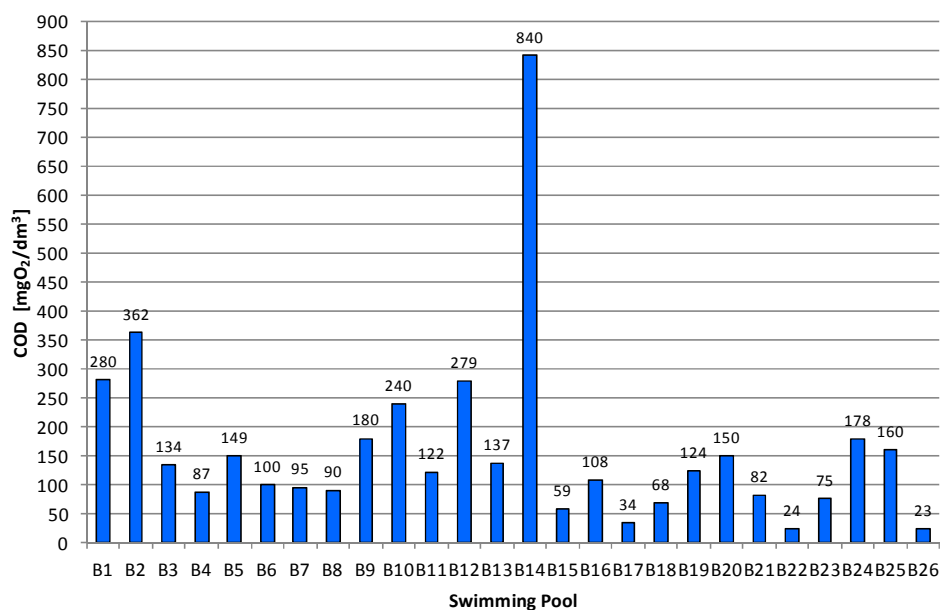


Fig. 3. COD in washings discharged from tested pools

In the tested washings, the average values of COD ranged from 23 mg O₂/dm³ in B26 pool cycle to 840 mg O₂/dm³ in B14 (Fig. 3). In the washings from 14 pools, the value of this indicator did not exceed the limit for sewage discharged to water and soil

(125 mg O₂/dm³). The sedimentation process resulted in the reduction of COD values, ranging from 29.4% in washings from B18 to 97.0% in B2. As a result, after a two-hour sedimentation process, COD values in the supernatant water did not exceed 125 mg O₂/dm³ and ranged from 11 mg O₂/dm³ in B2 and B17 to 112 mg O₂/dm³ in B14 (Fig. 4).

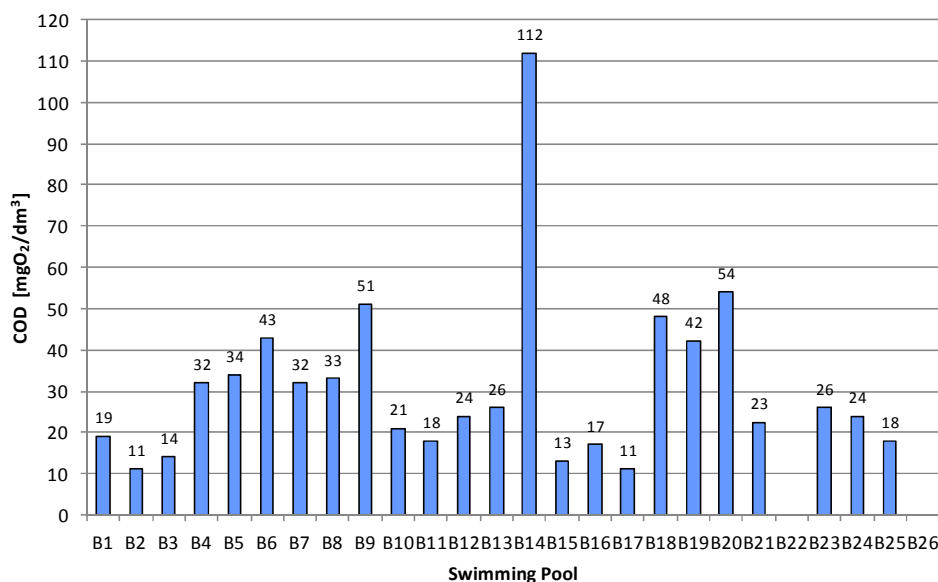


Fig. 4. COD in supernatant water after a two-hour process of washings sedimentation

The average values of BOD₅ in the tested washings ranged from 0.8 mg O₂/dm³ in B26 to 66.7 mg O₂/dm³ in B2. In the washings from 22 pools, the value of this indicator did not exceed the limit for sewage discharged to water and soil (25 mg O₂/dm³). The sedimentation process (in B1-B21) resulted in the reduction of BOD₅ values, ranging from 32.5% in pool B14 to 88.3% in pool B2, what in turn allowed to reach BOD₅ values ranging from 1.8 mg O₂/dm³ in B20 to 14.8 mg O₂/dm³ in B13 (Fig. 5).

The average values of total phosphorus in the tested washings did not exceed 2 mg P/dm³ with the exception of washings discharged from B14 and B16 in which case the average values of total phosphorus amounted to, respectively, 2.03 mg P/dm³ and 2.30 mg P/dm³ (Fig. 6).

The average values of total nitrogen in the tested washings ranged from 3.7 mg N/dm³ in B22 to 26.2 mg N/dm³ in B25. With the exception of washings discharged from B9, B14, B20 and B25, the amount of total nitrogen in washings did not exceed the limit for sewage discharged to water and soil, *ie* 15 mg N/dm³ (Fig. 7).

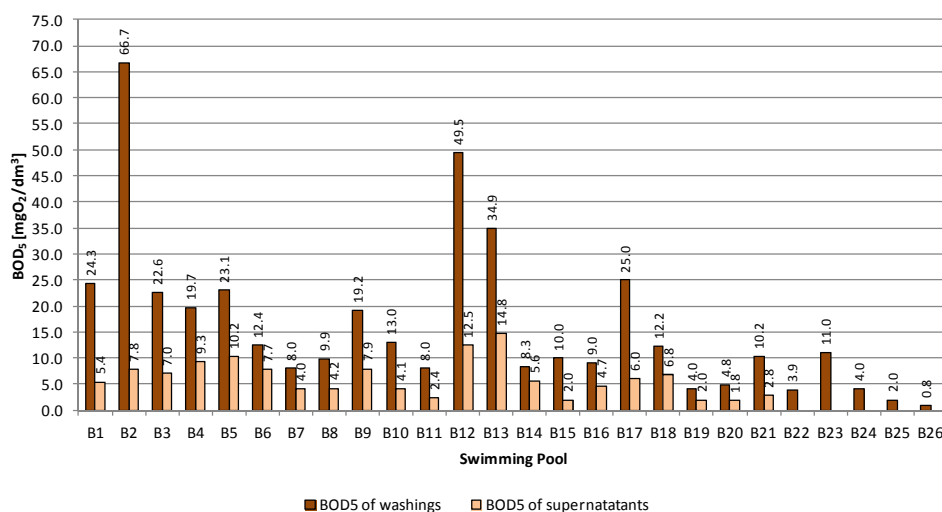


Fig. 5. BOD₅ in the washings and supernatant water after a two-hour sedimentation process

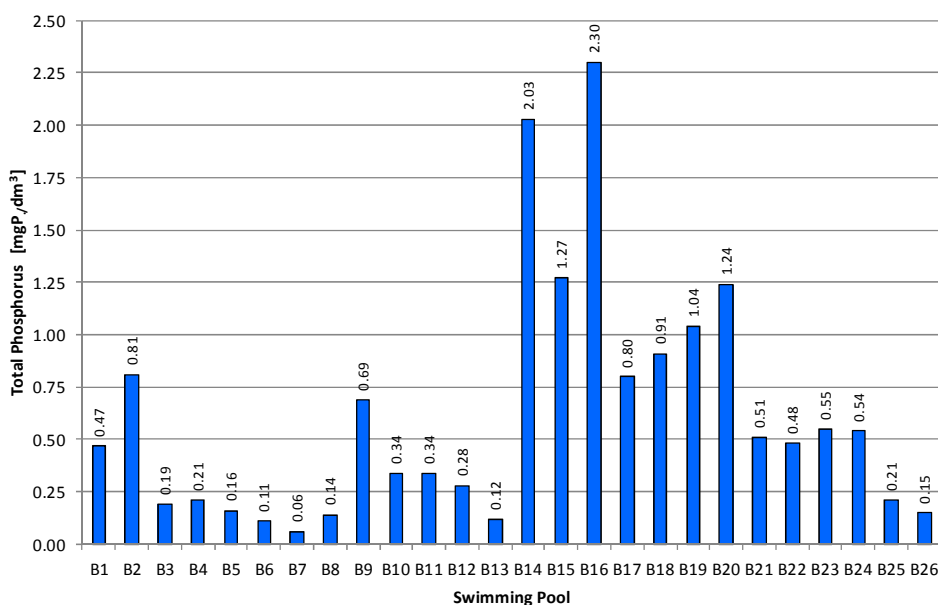


Fig. 6. The content of total phosphorus in the washings discharged from tested pools

The assessment of possibilities of washings management depends also on pH and temperature of washings. The tested washings pH values ranged from 6.74-8.59 (average value pH = 7.31). The washings temperature depended mainly on the temperature of water that was used to rinse filter beds. The beds of pressure multimedia filters (using sand or

sand and anthracite) were rinsed with water taken from pool expansion tanks, that is with water whose temperature ranged from 26-30°C (depending on the pool type). That is why the temperature of washings after rinsing of this type of beds ranged from 22.1-30.0°C (depending on the time that has elapsed since the tank was filled with water from the mains water supply). Diatomaceous filters were rinsed with water from the mains water supply, that is with water whose temperature ranged from 12-18°C. That is why the average temperature of washings coming from cleaning the filter cloths pre-coated with diatomaceous earth was 15.5°C in B14 and 16.4°C in B17.

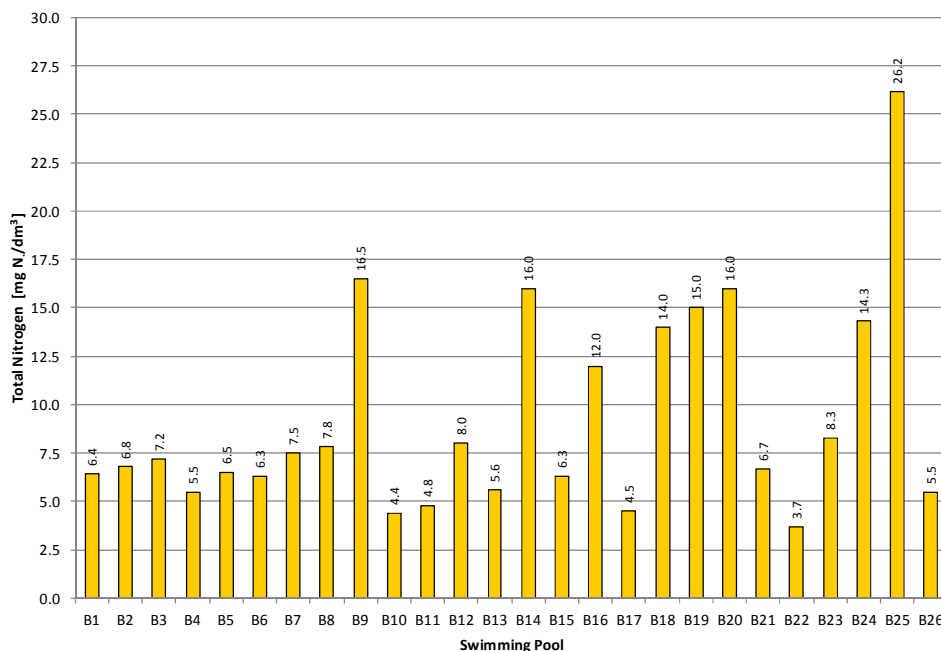


Fig. 7. The content of total nitrogen in the washings discharged from tested pools

Due to strong oxidising properties of free chlorine, its concentration in wastewater discharged to water and soil should not be higher than 0.2 mg Cl_2/dm^3 . Just like with temperature, the concentration of free chlorine in the washings depended on the type of water used for rinsing. In washings from cycles with diatomaceous earth (B14 and B17), the concentration of free chlorine was very low and amounted to, respectively, 0.16 and 0.15 mg Cl_2/dm^3 . The concentrations of free chlorine in the remaining washings were varying considerably, ranging from 0.21 mg Cl_2/dm^3 in B19 to 0.94 mg Cl_2/dm^3 in B16 (Fig. 8). Such high concentrations of free chlorine make direct discharge of washings from swimming pool circuits into water or soil impossible. Just like in the case of exceeded content of suspended solids, time is needed for the concentration of free chlorine to decrease to the acceptable level of 0.2 mg Cl_2/dm^3 . Due to the fact that the beds are rinsed during evening hours, the next determination of free chlorine in the washings samples was done after 12 hours. The reduction of free chlorine ranged from 37.9% in B3 to 94.7% in B2, and the content of chlorine in the washings samples ranged from 0.02 to

0.20 mg Cl₂/dm³. In the case of washings from B3, B10, B15 and B22, the content of free chlorine was determined after 2 hours and amounted to, respectively: 0.18; 0.15; 0.12 and 0.18 mg Cl₂/dm³ (Fig. 8).

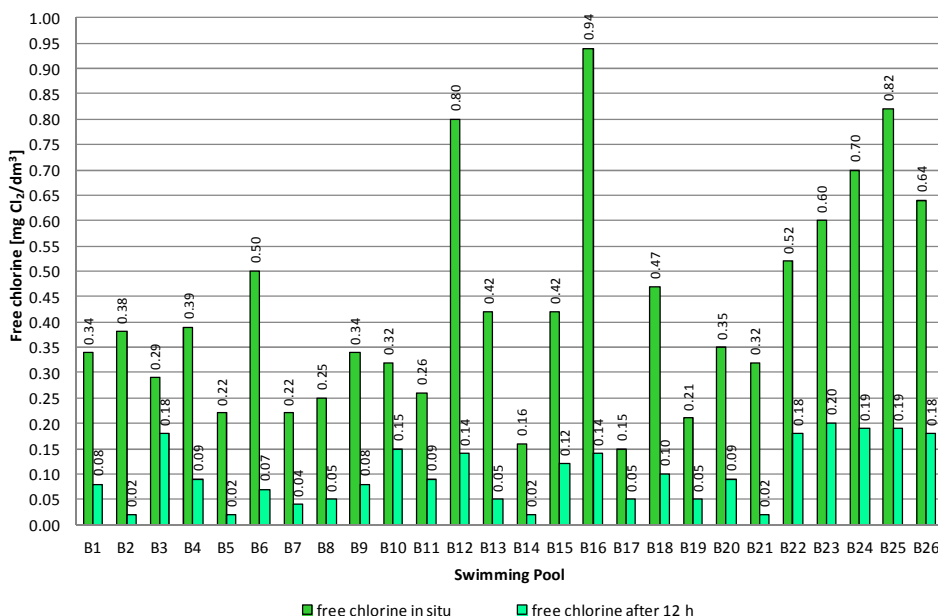


Fig. 8. The content of free chlorine in the washings during the sampling and after 12 hours

Summary and conclusions

The performed tests showed that washings discharged from swimming pools must not be directly discharged to water and soil due to the exceeded content of suspended solids and free chlorine concentration.

The results of the settling tests in Imhoff tank proved that a two-hour period of sedimentation allowed for the reuse of supernatants in 19 out of 26 tested cycles. In 7 circuits, the sedimentation process could be facilitated, for instance by dispensing and mixing washings with appropriate flocculant.

It needs to be underlined that the high efficiency of sedimentation of suspended solids in the washings in the majority of tested pool cycles was achieved by appropriate water coagulation in pool cycles and proper operation of filters.

The performed analysis of basic indicators identifying the contamination level of washings (pH, temperature, COD, BOD₅, TP, TN, free chlorine) and comparing them with the limits of contamination for sewage discharged to water and soil proved that it is possible to relieve the sewers and manage supernatant water from pool installations locally, for instance, by using it to irrigate green areas in an environmentally friendly way.

The results of the performed tests showed that:

- volume and quality of washings discharged from pools filtration circuits was varying and depended on the volume of water used for rinsing and the manner of pool circuit

- operation, *ie* on filtration cycle time, number of filters in circuits, their efficiency and bed type;
- washings discharged from tested pools installations must not be managed directly primarily due to the content of total suspended solids exceeding 35 mg/dm³ and the content of free chlorine exceeding 0.2 mg Cl₂/dm³;
 - sedimentation process allows for reuse of supernatant water, for instance, by using it to irrigate green areas or discharging it to a watercourse;
 - a two-hour sedimentation process was, in the majority of cases, enough to reduce the amount of suspended solids and the values of indicators used to determine the amount of suspended solids, *ie* COD and BOD₅, as well as the free chlorine content in supernatant water;
 - both pH and temperature of washings did not exceed the limits specified for wastewater that can be discharged to water or soil;
 - analysis of the volume of washings (from 28 m³/month in B14 to 547 m³/month in B21) and the costs of discharging them to the sewage system (from 296 PLN/month in B9 and 3818 PLN/month in B16) suggests that reusing supernatant water is reasonable and economically justifiable;
 - in every case, water recovered from washings could be used for the replenishment of water in pools circuits if appropriate processes and devices (*eg* ultrafiltration, reverse osmosis) were used after the sedimentation process [30-33].

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