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AFTERTREATMENT OF BIOCHEMICALLY TREATED WASTEWATERS BEFORE THEIR REUSE

Chemical composition of biochemically treated refinery wastewaters would allow their use as a circulating system make-up, but suspended solids should be removed prior to the water reuse.

Granular filters in which quartz sand, petroleum coke and expanded clay aggregate are used as filter media can reduce suspended matters to 6–8 mg/dm^3. Optimum results have been obtained for coarse-grained filters (expanded clay aggregate, petroleum coke) at an average filtration rate of 8 m/h. Regular treatment of filter media with biocides is needed because of biological matter adhering so strongly that its removal by washing is almost impossible.

On the basis of the laboratory model of a pressure screen filter we have studied pressure loss and filter run duration versus filtration rate as well as screen cleaning quality versus washing intensity and duration. The average efficiency of suspended matter removal at a filtration rate of 400–600 m/h amounts to 10–15% and increases to 30–40% at the rates up to 100 m/h.

Granular filters produce high-quality effluents, pressure screen filters being less efficient.

A method for biochemical treatment of industrial and storm refinery wastewaters returned to the circulating cooling water systems has been widely applied over the recent years. For biochemical treatment of these wastewaters, one-stage complete-mix activated sludge systems providing 6 to 8 h aeration are largely used. Quality of wastewaters before and after biochemical treatment is shown in tab. 1.

As is seen from tab. 1, biochemically treated wastewaters are essentially free from organic contaminants. Their chemical composition has not practically changed and, except for suspended solids, fully meet the quality standards for make-up water.

The wastage of activated sludge from activated sludge clarifiers varies mainly from 25 to 35 mg/dm^3 and in some cases (technological regime deviations) may be 100 mg/dm^3. Its reuse in circulating cooling water systems leads to undesirable phenomena. The activated sludge, passing with the reused water to condensers, settles on cooling surfaces, contributing to biological growth and reducing the heat transfer factor. In the case of 1 mm layer of deposits on tubes, the heat transfer factor is reduced by 10 to 30%.

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Table 1

Quality of wastewaters before and after biochemical treatment
Jakość ścieków przed i po oczyszczaniu biochemicznym

Analysis	Before treatment mg/dm^3	After treatment mg/dm^3
Oil products (extractable with hexane)	up to 25	3–5
COD	up to 400	70–100
BOD_5	up to 150	10–15
BOD_{total}	up to 250	15–20
Sulfides	up to 20	abs.
Phenol	up to 10	0.1
Ammonium nitrogen	up to 30	4–8
Suspended solids	up to 50	10–90
pH	6–8	6–8
Salts	—	800–1300
Chlorides (Cl^-)	—	130–210
Sulfates ($SO^=$)	—	175–280

Thus, the main task is to remove suspended solids from biochemically treated wastewaters before their return to a circulating system.

One of the promising treatment methods is filtration.

The applicability of granular and pressure screen filters has been tested. Quartz sand of 0.5 to 2 mm size (equivalent diameter 1.25 mm) and coke of a 1.5 to 3.5 mm size (equivalent diameter 2.3 mm) have been tested as a granular bed. The filter bed height is 1 m. According to the USSR standards, filtering media should meet the following requirements for mechanical strength: grindability — max 4 mass % and attrition — max 0.5 mass %. Quartz sand used in filters has a grindability of 3.6% and attrition of 0.14 mass %. Petroleum delayed coke used as filter bed has a grindability of 1.14 mass % and attrition of 0.4 mass %, which shows its applicability.

Tests were performed on pilot filters with a flow rate as high as 100 dm^3/h. Sand was used in one filter, coke in the other and the both filters were operated in parallel with the same influent. The average test results are presented in tab. 2. It can be seen from the reported data that the best treatment quality and the best filter run duration are achieved at an average filtration rate of 8 m/h (for sand 10–12 h, for coke 18–22 h).

Such a difference in filter run duration is attributed to the filter bed size composition. Coarse grained filters, which provide the optimum filter performance, are needed for after-treatment of biochemically treated wastewaters.

It should be noted that regeneration of operating pilot filters did not result from the deterioration of filtrate quality, but was rather due to the maximum pressure loss, which was indicative of a strong adherence of the retained activated sludge to the filter medium, the filtrate quality remaining good.

Table 2

Performance of granular filters
Własności eksploatacyjne filtrów ze złożem granulowanym

Average filtration rate m/h	Pressure loss, kPa		Filter run duration h	Suspended solids mg/dm³		Filter bed
	Initial	Final		Influent	Filtrate	
			Pilot filter			
7.9	4.66	86.6	12	62	3.3	Sand, 0.5–2.0 mm
8.1	5.33	86.6	10	81	4.0	Sand, 0.5–2.0 mm
8,8	2.27	87.6	18	118	5.2	Coke, 1.5–3.5 mm
8.1	2.53	86.6	22	79	4.7	Coke, 1.5–3.5 mm
			Industrial filter			
8.0	6.0	82.6	9	35	6.5	Sand, 0.5–2.0 mm
7.2	6.4	80	11	38	6.0	Sand, 0.5–2.0 mm
7.3	6.9	80	10	44	8.0	Sand, 0.5–2.0 mm
9.2	—	—	20	26	7.0	Expanded clay aggregate, 1.5–3.0 mm
8.5	—	—	18	38	5.0	

Therefore regeneration of filters is preceded with air loosening-up of the filter bed in order to destruct the contaminant clots due to the intense intermixing of filter bed and the removal of contaminants from the surface of particles. Air for loosening-up, supplied by an air blower, is fed to a separate air distribution system located in the lower filter part. Before feeding the water level in the filter is lowered by 0.3 to 0.5 m in order to prevent the filter medium wastage. Air is blown for 5 min with an intensity of 13–15 $dm^3/s \cdot m^2$. After the air blowing is completed, a conventional back washing of filter bed is performed. Water is fed to a drain distribution system located under the air system. Washing intensity is 18 $dm^3/s \cdot m^2$, washing duration being 10 min. Washings are sent to aerotanks. Washing water consumption amounts to 2–3% of the total filtered water.

It should be noted that in course of time the filter bed becomes loaded with very dense residual contaminants despite the fact that air is used for its regeneration. These contaminants consist chiefly of biological matter strongly adhering to the filter bed, hence a periodic treatment of filter bed with biocides is required.

To this chlorine water containing 100 to 200 mg of active chlorine /dm³ is recommended. To prepare chlorine water, typical chlorinators are used. Filtering media are treated after a residual pressure loss is 0.3–0.5 m for pressure filters and 0.2–0.3 m for open filters. Before the filter is treated with chlorine water, a conventional washing is performed. Water is then fully drained from the filter and the latter is filled with chlorine water. After 1 day contact of chlorine water with filter bed, the former is drained to a separate vessel where, if necessary, it is neutralized by sodium thiosulfate and sodium carbonate.

After the drainage of chlorine water, the filter is subject to a conventional washing during 2–3 min, the first portions of washings being discharged to sludge tanks.

The average data obtained for industrial filters filled with quartz sand of 0.5–2.0 mm size composition or with expanded clay aggregate of 1.5–3.0 mm are presented in tab. 2. From these data it follows that the filters provide a sufficiently high quality of aftertreated wastewater (suspended matter reduced to 6–8 mg/dm^3). Water of this quality fully meets the requirements for water returned to a circulating cooling water system (suspended matter does not exceed 25 mg/dm^3). Filters in which expanded clay aggregate is used as a filter medium have a higher dirt capacity and a longer filter run if compared with those with a quartz sand bed.

Highly efficient self-cleaning VSF type (VSF means filter with a high filtration rate) filters of a series production are intended for mechanical water treatment on screens to remove suspended matter. The filters are applied in chemical, food. paper, metallurgical, and other industries.

Filtration of biochemically treated wastewaters by means of these filters has been tested under industrial and laboratory conditions. VSF-2000 filter (fig. 1) comprises the following main parts: *1* — cylindrical shell, *2* — two filtering elements, *3* — washing device, *4* — drive. The filter is completed with a control board. Maximum flow rate — 2000 m^3/h, electric power consumption — 1.8×10^3 kJ, electric motor power — 1.7 kW: overall dimensions in mm: height — 5170, diameter — 2032; mass — 3000 kg.

Water is treated at a pressure of 1.0 MPa. The washing device is switched on automatically, washing is carried out simultaneously with filtration and, depending on the qua-

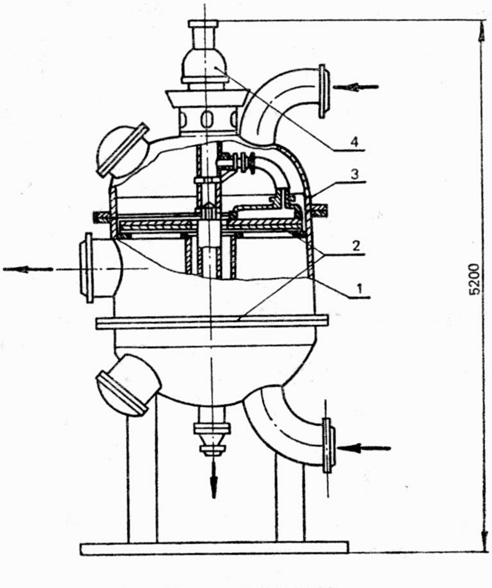

Fig. 1. VSF-2000
Rys. 1. VSF-2000

lity of water to be treated, is performed either continuously or periodically. This provides for a continuous filter performance.

On the basis of the laboratory filter model, pressure loss and filter run duration versus filtration rate, as well as screen cleaning quality versus washing intensity and duration were studied.

Pressure loss against filtration duration is plotted in figs. 2 and 3. As is seen from the curves, the filter run duration is 7–24 h for PO-0.25 screens pactet (mesh size of 200–250 μm) and 10–80 min for S-200 dense screen and it decreases with the increasing filtration rate. The curves convexity may tesify the carry-over of contaminants from screens.

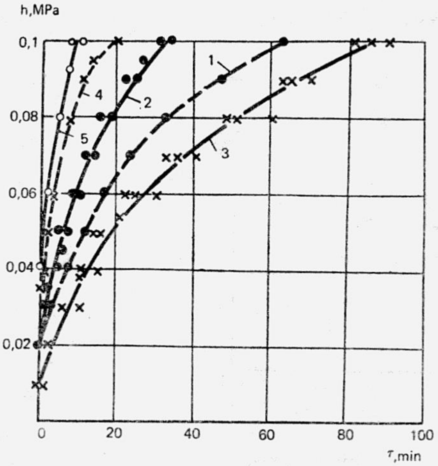

Fig. 2. Pressure drop versus filtration time (S-200 screen)

1 – filtration rate 150 m/h (clean screens), *2* – filtration rate 150 m/h (contaminated screen), *3* – 825 m/h, *4* – 300 m/h, *5* – 600 m/h

Rys. 2. Spadek ciśnienia w zależności od czasu filtracji (sito S-200)

1 – szybkość filtracji 150 m/h (czyste sita), *2* – szybkość filtracji 150 m/h (zanieczyszczone sito), *3* – 825 m/h, *4* – 300 m/h, *5* – 600 m/h

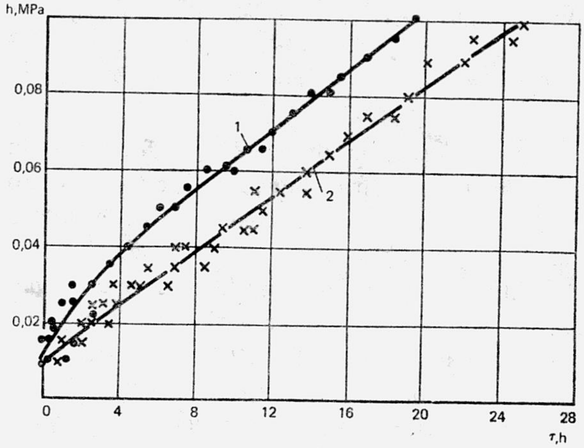

Fig. 3. Pressure drop versus filtration time (PO-025 Packet)

1 – filtration rate 300 m/h, *2* – filtration rate 150 m/h

Rys. 3. Spadek ciśnienia w zależności od czasu filtracji (Packet PO-025)

1 – szybkość filtracji 300 m/h, *2* – szybkość filtracji 150 m/h

Activated sludge settled on the screens has a density of 1.12–1.15 and ash content of about 25%. The deposit can be considered to be compressible. Due to the deformation of pressurized particles or their aggregates the deposit resistance increases with the increasing pressure difference during the filtration process.

The efficiency of back washing of the screens for their cleaning was evaluated by initial pressure drop and filtration run duration subsequent to the washing. The obtained data are presented in fig. 4. As it follows from this figure, an increase in washing intensity up to 400 dm^3/m^2 s leads to a decrease in initial pressure drop across the screen and accordingly to an increase in filter run duration. A further increase in the intensity does not improve the degree of screen cleaning. Before residual contaminants are removed, screens should be treated in order to weaken the forces of adhesion of activated sludge to the screen.

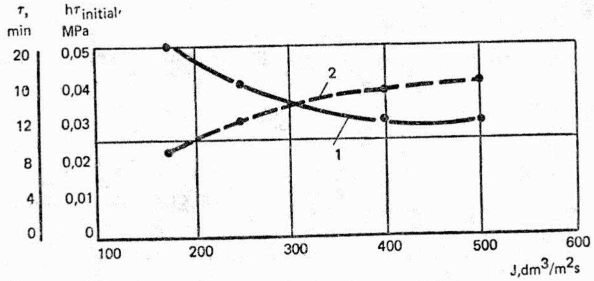

Fig. 4. Initial pressure drop and filter run duration versus washing intensity (S-200 screen)

1 — initial pressure drop, MPa, *2* — filtration duration, min

Rys. 4. Początkowy spadek ciśnienia i czas trwania pracy filtra w zależności od intensywności płukania (sito S-200)

1 — początkowy spadek ciśnienia, MPa, *2* — czas filtracji, min

Like in filtration through granular filter beds, the forces of sludge adhesion to the screen are weakened under the action of biocides. A one-day treatment of screens with chlorine water of a concentration (based on active chlorine) as high as 200 mg/dm^3 makes it possible to clean screens by a subsequent back washing. This is confirmed by an experience gained in operating VSF-2000 industrial filter in one of the petroleum refineries.

Washing quality was not affected by the variations of washing time ranging from 5–30 s, which seems to exceed the required one (the time necessary for washing one section of VSF-2000 filter is 1–2 s).

In the performed experiments, the average treatment efficiency of biochemically treated wastewaters was not higher than 10–15%; in a number of samples the content of suspended solids in filtrate, especially at high filtration rates (400–600 m/h), was even higher than that in influent which can be attributed to the carry-over of contaminants from filter screens under these conditions.

Along with tests performed on the filter model, the VSF-2000 industrial filter (used for aftertreatment of biochemically treated wastewaters before their return to the circulating system) has been studied. The filter has been mounted on the open site and operated automatically.

Effluents from activated sludge clarifiers are passed through the filter and, as make-up water, fed to circulating systems of the refinery. The filter washing water is pumped to aerotanks.

During the initial operating period, the duration of filter run amounts to 3 h and diminishes gradually to 20–30 min. The filter is switched off. The screens are treated with chlorine water for 1–2 times a month for 24 h.

The average purification efficiency of the filter is 20% at 50 mg of suspended matters/dm^3 of the influent. The filtration rate ranges from 100 to 300 m^3/h.

Table 3

Performance of VSF-2000 filters (averaged data)
Charakterystyka filtrów VSF-2000 (średnie)

	Ranges of initial contamination mg/dm^3			
	10–25	26–50	51–100	101–150
Initial content of suspended solids, mg/dm^3	21.7	38.2	56.2	117.4
Residual content of suspended solids, mg/dm^3	18.0	31.7	42	85.5
Purification degree, %	17.7	17	25	27

Average data showing the purification efficiency for different concentrations of suspended matter in the influent are presented in tab. 3. It should be noted that with the increasing content of contaminants in the influent, their residual content in the filtrate increases; the purification efficiency becomes somewhat higher but the residual contamination of filtered water remains high.

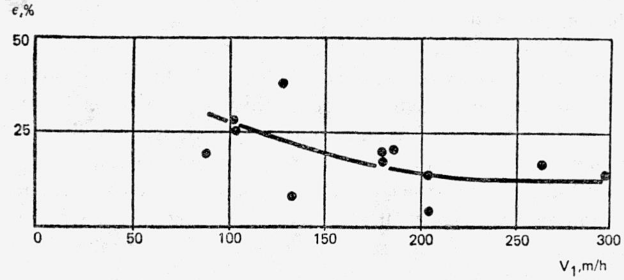

Fig. 5. Purification efficiency (*E*) versus filtration rate
Rys. 5. Efektywność oczyszczania (*E*) w zależności od szybkości filtracji

Figure 5 shows purification efficiency versus filtration rate. The diagram is based on the operating data for VSF-2000 industrial filter over a long period. As is seen from fig. 5, a decrease in filtration rate leads to an increase in purification efficiency but the latter does not exceed 30–40%. At a filtration rate higher than 200 m/h, the purification efficiency is 10 to 15%.

The performance comparison of granular and screen filters shows that despite the compactness and high filtration rates of screen filters, the efficiency of granular filters and thereby the quality of effluents are higher.

WTÓRNA OBRÓBKA BIOLOGICZNIE OCZYSZCZONYCH ŚCIEKÓW PRZED ICH POWTÓRNYM UŻYCIEM

Skład chemiczny biologicznie oczyszczonych ścieków umożliwia ponowne ich użycie do uzupełniania zamkniętych obiegów wodnych pod warunkiem, że usunięte z nich zostaną zawiesiny i substancje koloidalne.

Złoża filtrujące z piasku, koksu ponaftowego lub spulchnionego iłu redukują zawiesiny w ilości 6–8 mg/dm³. Optymalne wyniki uzyskano dla filtrów gruboziarnistych (agregaty spulchnionych iłów lub koks ponaftowy) przy średniej szybkości filtracji 8 m/h. Silna adhezja substancji biologicznych do medium filtrującego zmusza do stosowania biocydów w procesie regeneracji filtrów.

Na podstawie laboratoryjnego modelu ciśnieniowego filtra sitowego określono straty ciśnienia i czas eksploatacji filtra w zależności od szybkości filtracji, a także jakość oczyszczania sit w zależności od intensywności i czasu ich płukania. Przeciętna wydajność usuwania zawiesin w takim filtrze wynosi 10–15% przy szybkości filtracji 400–600 m/h i wzrasta do 30–40% przy szybkości 100 m/h.

Filtry granulowane okazały się wydajniejsze w usuwaniu zawiesin niż ciśnieniowe filtry sitowe.

WEITERGEHENDE BEHANDLUNG BIOLOGISCH VORGEREINIGTER ABWÄSSER

Die chemische Zusammensetzung von biologisch vorgereinigten Abwässern deutet auf die Möglichkeit deren Wiederverwendung zur Ergänzung von Wasserkreisläufen unter der Bedingung, daß alle Schwebestoffe und Kolloide vorher beseitigt werden.

Filter mit Sand, Petrolkoks oder aufgelockertem Ton gefüllt, ergeben eine Reduktion der Schwebestoffe bis zu einer Endkonzentration von 6–8 mg/dm³. Optimale Ergebnisse konnten bei grobkörnigen Filterbetten (Aggregate von aufgelockertem Ton oder Petrolkoks) und bei Filtrationsgeschwindigkeiten von 8 m/h erreicht werden. Eine starke Adhesion biologischer Substanzen an das Filtermedium, zwingt bei der Regeneration und Spülung der Filter zur Anwendung von Bioziden.

In einem Labordruck-Siebfilter wurden die Druckverluste und der Filtrationszyklus bestimmt. Sie hängen von der Filtrationsgeschwindigkeit und von der Reinigungsgüte des Siebes, wie von der Spülintensität und von der Spülzeitab. Die durchschnittliche Schwebestoffabnahme in diesem Filter war nur 10–15% bei einer $v_f = 400$–600 m/h und stieg auf 30–40% an bei $v_f = 100$ m/h.

Tiefbettfilter mit granulierter Schüttung liefern viel bessere Ergebnisse als Drucksiebfilter.

ВТОРИЧНАЯ ОБРАБОТКА БИОЛОГИЧЕСКИ ОЧИЩЕННЫХ СТОЧНЫХ ВОД ПЕРЕД ИХ ВТОРИЧНЫМ ИСПОЛЬЗОВАНИЕМ

Химический состав биологически очищенных сточных вод даёт возможность вторичного их использования для пополнения замкнутых водно-шламовых циклов, под условием, что из них будут удалены суспензии и коллоидные вещества.

Фильтрирующие слои из песка, нефтяного кокса или разрыхленного ила позволяют уменьшить количества суспензии до 6–8 мг/дм^3. Оптимальные результаты были получены для крупнозернистых фильтров (агрегаты разрыхленных илов или нефтяной кокс) при средней скорости фильтрации 8 м/ч. Сильная адгезия биологических веществ к фильтрирующей среде заставляет применять биоциды в процессе регенерации фильтров.

На основе лабораторной модели сетчатого пресс-фильтра были определены потери напора и срок эксплуатации фильтра в зависимости от скорости фильтрации, а также качество очистки сит в зависимости от интенсивности и времени их полоскания. Средняя эффективность удаления суспензий в таком фильтре составляет 10–15% при скорости фильтрации 400–600 м/ч и повышается до 30–40% при скорости 100 м/ч.

Гранулированные фильтры оказались более эффективными при удалении суспензий, чем сетчатые просс-фильтры.