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# DETECTION OF FACTORS RESPONSIBLE FOR UNSATISFACTORY QUALITY OF BIOCHEMICALLY TREATED PHENOL WASTE-WATER

The investigations have been carried out to detect the reason of poor quality of the phenolic waste-water after its biological treatment. A much advanced degradation of the mono- and polyhydroxy phenols tested has been achieved by applying acclimated activated sludge. Although in all secondary offluents low COD values and no phenolic substrates were stated, however coloured biodegradation products occured in case of four polyphenols. Next, it has been shown that monohydroxy compounds and rezorcine are resistant to chemical oxidation with atmospheric oxygen during 5 hour aeration. Partial chemical oxidation yielding coloured compounds has been stated in case of hydroquinone, pyrocatechol, pyrogallol and phloroglucinol. Chemical oxidation products of pyrocatechol and phloroglucinol were susceptible to further biodegradation, while those of hydroquinone and pyrogallol were biodegradation resistant. Hence, chemical oxidation affects molecular structure of some phenols resulting in their biodegradability decreate. The investigations have confirmed the hypothesis that chemical oxidation processes are chiefly responsible for the unsatisfactory quality of the secondary effluent. For this the oxidation of phenolic waste-water during its transport and cooling prior to biodegradation should be avoided.

## 1. INTRODUCTION

In view of the development of chemical industries involving processing of solid fuels, petrochemistry, petrol and phenol syntheses, processing of phenol products etc., the treatment of phenol waste-waters is an actual and still open problem [3, 10, 13, 20, 21]. Both experience and long-lasting investigations promoted multi-step treatment of phenol waste-water.

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It has been generally assumed that after physico-chemical regeneration, allowing the recovery of phenols, certain destructive processes of which the biodegradation is the most advantageous [4, 11, 15] should be applied. Usually, the biochemical processes based on ability of mixed acclimated microorganism populations to destruct phenol should be followed by various complementary processes. They consist in either denitrification or in phosphates removal from the treated effluent to protect the receiving water from secondary pollution [2, 12].

Despite such a tree-step treatment, the tertiary effluent is most usually characterized by a remarkably high COD and dark colour. All efforts being concentrated upon the most important problem — phenol removal — little attention is paid to the general quality of the effluent which remains unsatisfactory, though a total decay of phenols took place [11, 19].

It has been suggested that the poor quality of the treated waste-water may be due to the presence of various intermediate products, since during an intense biological treatment the degradation of phenols is not brought to its final stages. Another hypothesis is based on the readiness displayed by some phenols to be partially oxidized with oxygen, either atmospheric or dissolved in water [9, 21]. According to this hypothesis in biological treatment of phenol waste-water, especially in activated sludge process involving an intense aeration, two oxidation processes — chemical and biochemical — may occur simultaneously.

It seems that chemical oxidation products are chiefly responsible for the said disadvantageous properties of the treated phenol water. To explain the darkening effect of phenol waste-water during biodegradation and to find out a suitable treatment methods, it is necessary to analyse the following problems:

1. An extent of biodegradation of the selected phenols;
2. The changes occuring in aquaeus phenol solution aerated with atmospheric oxygen in absence of microorganisms;
3. Susceptibility to biodegradation of phenol chemical oxidation products;
4. Chemical or biochemical oxidation process responsible for the darkening of biologically treated phenol water.

The purpose of the present paper was to solve the above problems by performing a series of experiments.

## 2. MATERIAL AND METHODS

The investigations were performed on 12 types of phenols predominant in phenolic waste-water [1, 2, 5]: phenol, m- and p-cresol, 2,4- and 2,5-xylenol, thymol, $\alpha$-naphtol, resorcinol, catechol, hydroquinone, pyrogallol and phloroglucinol.

Phenol adapted activated sludge culture was seeded with raw and digested sludge taken from municipal waste treatment plants. Crude sludge was taken from primary

clarifiers, while the digested sludge came from the selected anaerobic digestion chambers.

The efficiencies of the separate technological processes were characterized by determining phenol concentrations, COD and BOD, pH, Mohlman's index, total solid and colour of waste-water. The determinations have been performed by standard methods, including:

1. Concentrations of phenols by spectrophotometric methods [22] (spectrophotometer UNICAM, model SP850B);
2. COD, after Eckenfelder [17];
3. BOD by dilution method [16];
4. Colour by determining the colour threshold number [17].

## 2.1. ACTIVATED SLUDGE GROWTH AND ACCLIMATION TO SELECTED PHENOLS

In order to obtain mixed population of microorganism, the crude and digested sludge have been converted into activated sludge by applying a direct conversion method, biomass growth and acclimation (Chmielowski [5,6]).

To complete the nourishing composition tri-basic ammonium sulphate was added to the feed, continuously introduced into the aeration tank.

## 2.2. BIODEGRADATION DYNAMICS OF THE SELECTED PHENOLS

Experiments on the dynamics of phenols degradation by acclimated activated sludge were conducted in the laboratory activated sludge units of 2.5 $dm^3$ volume equipped with aquarium compressors which promoted both good aeration and mixing.

The following batch procedure was adapted in the experiments. At the beginning of each test 1 $dm^3$ of the washed acclimated activated sludge, settled for 30 min was introduced into the aeration tank. The tank content was supplemented with the selected phenol dissolved in tap water and with solution of ammonium phosphate.

First sample of volume 150 $cm^3$ was taken after 30 s aeration of the mixed liquor. Sample weight was determined from a 50 $cm^3$ portion of the liquid, the remaining 100 $cm^3$ portion was twice filtered through the filter paper. The concentrations of phenol, $BOD_5$, COD, pH and colour have been determined in clear filtrate.

Next 100 $cm^3$ samples were extracted consecutively after 15,30, 60, 120 minutes of aeration and the final samples — at 60 minute intervals. In these samples all the parameters but solids and $BOD_5$ were determined.

As a rule the dynamics of biodegradation process was observed for 5 hrs; if necessary, however, the observation period was extended. In the last sample — like in the first one — all the parameters were determined.

### 2.3. DYNAMICS OF PHENOL CHEMICAL OXIDATION WITH ATMOSPHERIC OXYGEN

Both previously described laboratory aeration tanks and sampling technique were applied also in the study of dynamics of phenol chemical oxidation, but instead of the activated sludge and phenol mixture, 2.5 $dm^3$ of phenol solution was used as a feed.

Phenol concentration, pH, COD and colour were determined in each 60 $cm^3$ sample. The observations were conducted until the composition of the aerated medium became stabile.

### 2.4. BIODEGRADATION DYNAMICS OF PREAERATED PHENOL SOLUTIONS

This part of the investigations was identical with that concerned to biodegradability of phenols. The only exception was a 5 hr preaeration of the feed applied prior to the introduction into activated sludge unit.

## 3. RESULTS

The adapted activated sludge growth and acclimation technique allowed to obtain the acclimated biomass in a simple and fast way. The acclimation phase being accomplished the biomass was able to decompose 100–250 mg/$dm^3$ phenols from aqueous solutions; its Mohlman index ranged from 62 to 86 $cm^3/g$. Acclimation processes were conducted until parent form of phenol compounds vanished entirely and COD value was reduced to several tens mg of $O_2/dm^3$. Some operation parameters of acclimated activated sludge are given in Table 1.

Limiting concentrations of given phenol substrates, to which the sludge had to be acclimated and which ought to be kept constant throughout the experiment, appeared to be different.

This has been justified by the data concerning the concentrations of phenols in waste-water subjected to biodegradation [3, 10, 21] as well as by the solubility of individual phenols in water. It should be emphasized that the range of loads applied to all the 12 activated sludge samples was characteristic of waste-water treatment with activated sludge [7,8].

From the COD values determined in the effluents (Table 1) it follows that, despite remarkable differences in phenol concentrations in the feed, the contents of organic substances in post-biodegradation solutions were similar. An intense degradation with a complete decay of parent substrate was stated for all the phenols under investigations. At the same time low (8.6 mg $O_2/dm^3$) $BOD_5$ values of the effluent indicate the advanced course of biodegradation process, which could be recognized as being accomplished.

Table 1

Some parameters of activated sludges acclimated to biodegradation of the selected phenols.
Average values for 15 days of operation, after acclimation phase completion

Niektóre parametry pracy osadów czynnych zaaklimatyzowanych do biodegradacji wybranych fenoli.
Wyniki średnie z 15 dni pracy osadu po zakończeniu fazy aklimatyzacyjnej

| Phenolic substrate | Phenol concentration mg/dm³ | | COD $mgO_2/dm^3$ | | Colour threshold number | Hydraulic loading $m^3/m^3d.$ | Sludge content $g/m^3$ | Sludge loading | | Mohlman's index $cm^3/g$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | | | | g COD/g | g $BOD_5$/g | |
| Phenol | 250 | 0 | 650 | 36 | 0 | 1.6 | 4.9 | 0.21 | 0.16 | 76 |
| m-cresol | 145 | 0 | 340 | 42 | 0 | 1.6 | 5.1 | 0.11 | 0.05 | 69 |
| p-cresol | 130 | 0 | 325 | 55 | 0 | 1.6 | 5.1 | 0.10 | 0.05 | 70 |
| 2, 4-xylenol | 100 | 0 | 250 | 52 | 0 | 1.6 | 5.2 | 0.08 | 0.06 | 65 |
| 2, 5-xylenol | 160 | 0 | 410 | 53 | 0 | 1.6 | 5.1 | 0.13 | 0.06 | 74 |
| Thymol | 130 | 0 | 380 | 62 | 0 | 1.6 | 5.0 | 0.12 | 0.07 | 81 |
| α-naphtol | 150 | 0 | 360 | 66 | 0 | 1.6 | 3.9 | 0.15 | 0.11 | 74 |
| Pyrocatechol | 140 | 0 | 270 | 53 | 6–8 | 1.6 | 4.5 | 0.09 | 0.05 | 82 |
| Resorcinol | 240 | 0 | 520 | 53 | 0 | 1.6 | 5.1 | 0.16 | 0.09 | 86 |
| Hydroquinone | 160 | 0 | 310 | 54 | 30–40 | 1.6 | 5.3 | 0.09 | 0.06 | 69 |
| Pyrogallol | 200 | 0 | 320 | 66 | 80–100 | 1.6 | 4.9 | 0.10 | 0.06 | 62 |
| Phloroglucinol | 200 | 0 | 320 | 43 | 16–20 | 1.6 | 4.8 | 0.11 | 0.06 | 71 |

### 3.1. DYNAMICS OF BIODEGRADATION OF THE SELECTED PHENOLS

Initial concentrations of phenols applied in the experiment as well as the amounts of activated sludge have been chosen so, that the initial parameters of periodic process be similar to those kept in a continuous growth of the acclimated activated

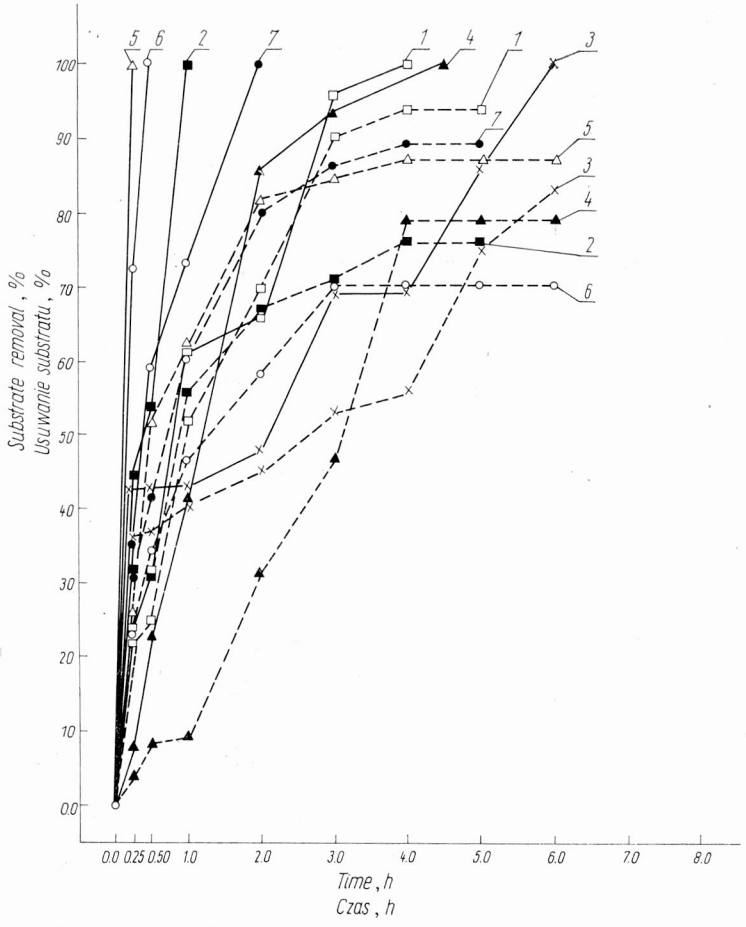


Fig. 1. Biodegradation dynamics of phenols during aeration with activated sludge. *1* — phenol; *2* — 2, 4 xylenol; *3* — α-naphtol; *4* — hydroquinone; *5* — catechol; *6* — pyrogallol; *7* — phloroglucinol; ——— phenol substrate concentration; – – – – COD

Rys. 1. Dynamika biodegradacji fenoli w procesie napowietrzania z osadem czynnym ——— stężenie substratu fenolowego; – – – – ChZT

□ — phenol,
■ — 2,4 xylenol,
× — naphtol,
▲ — hydroquinone,
△ — pyrocatechol,
○ — pyrogallol,
● — phloroglucinol

sludge. Those parameters have been checked by determining their values at the beginning of each test. The results of the investigations shown partially in Fig. 1 have confirmed opinion on similar biodegrability of the phenols. A uniform decrease in phenol substrate concentration and reduction in COD value during a few hour aeration have been stated for phenol, two cresols investigated, naphtanol, hydroquinone and resorcinol.

For catechol, phloroglucinol and pyrogallol a rapid decrease in parent substance concentration was not accompanied by a reduction in COD value. The latter occured uniformly within a few hour observation.

Slight variations in pH values (up to 0.5) occuring in the course of aeration of activated sludge have been observed in all the phenols investigated. Final concentrations of phenol compounds in all tests were equal to zero, while the COD values ranged within 40 $mgO_2/dm^3$. The observations concerning the appearence of coloured compounds were of interest. As it follows from Table 2 the coloured products of degradation appeared only in decomposition of catechol, hydroquinone, pyrogallol and phloroglucinol.

Table 2

Coloured products occurence during degradation of phenolic substrates by activated sludge

Pojawianie się barwnych produktów rozkładu fenoli

| Time | Colour threshold number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pyrocatechol | | | Hydroquinone | | | Pyrogallol | | | Phloroglucinol | | |
| h | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 0.00 | 0 | 0 | 80 | 0 | 0 | 100 | 0 | 16 | 700 | 0 | 0 | 10 |
| 0.25 | 8 | 4 | 80 | 10 | 8 | 100 | 8 | 100 | 600 | 0 | 0 | 10 |
| 0.50 | 4 | 4 | 60 | 10 | 10 | 100 | 16 | 125 | 600 | 0 | 0 | 10 |
| 1.00 | 4 | 10 | 40 | 20 | 20 | 100 | 20 | 400 | 500 | 0 | 0 | 10 |
| 2.00 | 0 | 16 | 40 | 20 | 50 | 100 | 40 | 500 | 500 | 2 | 8 | 10 |
| 3.00 | 0 | 100 | 40 | 50 | 100 | 100 | 80 | 500 | 500 | 4 | 10 | 10 |
| 4.00 | 0 | 100 | 40 | 20 | 100 | 100 | 100 | 800 | 500 | 10 | 10 | 10 |
| 5.00 | 0 | 100 | 40 | 10 | 200 | 100 | 100 | 1000 | 500 | 10 | 10 | 10 |

1. Biodegradation in activated sludge process. 2. Chemical oxidation with atmospheric oxygen. 3. Biodegradation in activated sludge process of preaerated phenolic substrates.

1. Biodegradacja w procesie osadu czynnego. 2. Chemiczne utlenianie tlenem z powietrza. 3. Biodegradacja wstępnie napowietrzonych substratów fenolowych w procesie osadu czynnego.

### 3.2. DYNAMICS OF PHENOL OXIDATION WITH ATMOSPHERIC OXYGEN

The results of series of tests on the effect of the sole aeration process (in absence of activated sludge) on phenol degradation are given in Fig. 2 and Table 2. Similar behaviour have been stated for all the monohydrobenzenes investigated, $\alpha$-naphtol

and resorcine. In the course of 5 or 6 hour aeration the concentration of the substrates did not change; no colour compounds appeared and the COD values were practically constant.

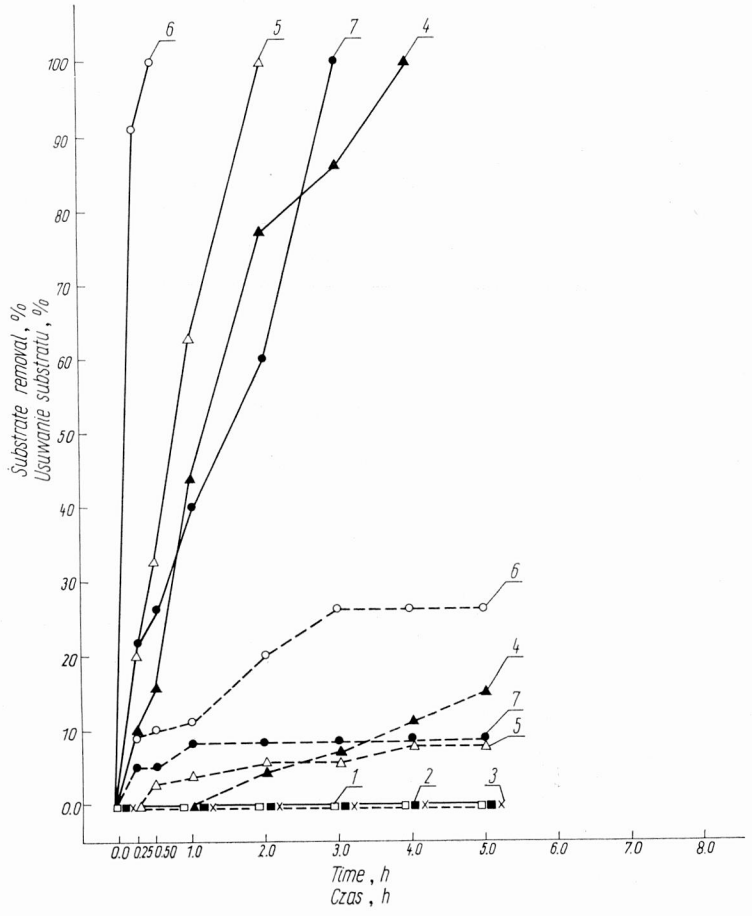


Fig. 2. Degradation dynamics of phenols during aeration in absence of activated sludge. For the legend see Fig. 1

Rys. 2. Dynamika degradacji fenoli przy napowietrzaniu bez osadu czynnego. Legenda, por. rys. 1

The behaviour of catechol, hydroquinone, pyrogallol and phloroglucinol was different. A rapid decay of parent forms of phenol compounds was accompanied by a slight reduction in COD value, which at the end of observations was at most twenty percent of the initial value (Fig. 2); at the same time the appearence of an intense colour was observed (Table 2). Slight oscillations in pH value during aeration was stated for all the phenol compounds.

### 3.3. BIODEGRADATION DYNAMICS OF THE SELECTED PHENOLS AERATED PRELIMINARILY WITH ATMOSPHERIC OXYGEN

The observations have revealed different course of chemical phenol oxidation process, depending on the type of phenol compound. The next step was to state whether the preaerated phenolic solutions are susceptible to biochemical degradation, and to determine the course of the process. This part of the experiment was conducted in the same manner as biodegradation test, except for the 5 hr preaeration of the phenolic solutions applied prior to their biodegradation phase. From the obtained results, shown for representative compounds in Fig. 3 and Table 2, it follows that the course of this process varied depending upon the type of phenol compound.

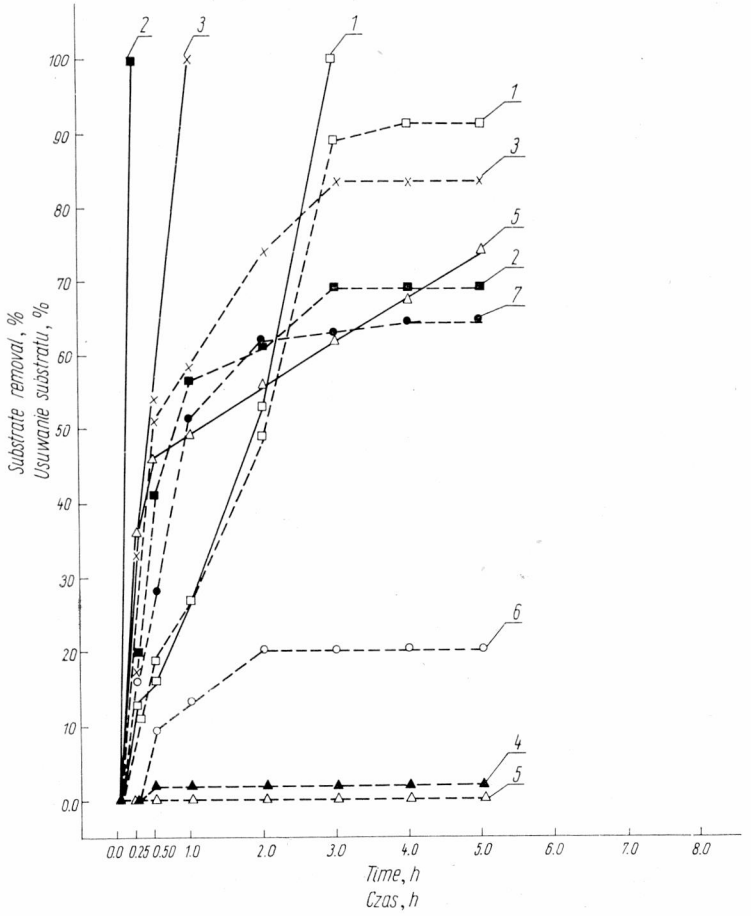


Fig. 3. Biodegradation dynamics of preaerated phenolic substrates in activated sludge process. For the legend see Fig. 1

Rys. 3. Dynamika biodegradacji wstępnie napowietrzanych substratów fenoli w procesie osadu czynnego. Legenda, patrz rys. 1

All the investigated monophenols, α-naphtol and rezorcine which had been resistant to chemical oxidation were biodegradated identically.

Preaeration did not enhance substantially biodegrability of all the investigated monophenols, α-naphtol and rezorcine, being resistant.

More profound differences have been observed in case of 4 remaining polyphenols. The products of chemical oxidation of hydroquinone and pyrogallol were resistant to biodegradation for 5 hour observation, in contrast with catechol and phloroglucinol which were susceptible to further degradation, manifested by a distinct reduction in COD (Fig. 3).

For the four polyphenols mentioned, the colour of their chemical oxidation products was stabile during the biodegradation or slightly decreased, while slight oscillations in pH values occured in case of all phenolic solutions.

## 4. DISCUSSION

### 4.1. BIODEGRABILITY OF THE SELECTED PHENOLS

Results obtained have not confirmed the supposition on the difference between volatile and non-volatile phenols in biodegradation process [11].

Similar procedures allowed to acclimate same parent activated sludges to biodegradation of the 12 different phenol compounds. The performed investigations have shown that when the selected phenols were the only source of organic carbon and the proper composition of the feeding medium as well as sludge loading range (0.05–0.16 g BOD/g MLSS·d) were maintained, then the COD values of degradation products, present in the effluent from a continuous flow system ranged from 36 to 66 mg $O_2/dm^3$ (Table 1). It has been stated that the mono and poly-hydroxy phenols did not differ significantly in COD reduction which amounted to 70–90%. The above conclusions have been also confirmed by the biodegradation dynamics of the investigated phenol substrates occuring in batch system (Fig. 1). For the separate phenols the reduction in COD value in periodically fed systems was similar to that found for activated sludge fed continuously. For most compounds the reduction in phenol concentrations and COD values occurred simultaneously. However, in case of catechol, hydroquinone, pyrogallol and phloroglucinol a slight damage in their structure (manifested by a rapid decay of the parent form of the substrate) occured at the first biodegradation stage. To achieve the next degradation stage the time required was close to that needed for the degradation of all the remaining phenols.

### 4.2. FORMATION OF COLOURED PRODUCTS IN DEGRADATION PROCESS OF THE SELECTED PHENOLS

The observations of an activated sludge continuous flow system as well as batch system have shown that coloured compounds were formed during biodegradation of only four phenol compounds (catechol, hydroquinone, pyrogallol and phloro-

glucinol, Table 2). No formation of colour in biodegradation of monophenols and rezorcine has been stated under low activated sludge loading. The above observations, however, are not contradictory to the statements saying that the degradation of monophenols may occur via the stage of coloured products [9, 18, 23]. There are numerous ways of decomposition, including transition of monophenols to polyphenols. This is also true with catechol which forms some coloured products [1].

The data obtained during aeration of aqueous solutions of phenols in absence of biomass (Table 2) have shown that chemical oxidation of four polyphenols (catechol, hydroquinone, pyrogallol and phloroglucinol) results also in formation of coloured degradation products. It may be assumed that under such conditions no biochemical processes occur practically. This can be explained e.g. by toxic phenol concentrations for not acclimated microorganisms which could enter the tanks during aeration process. In chemical oxidation of the 4 mentioned phenolic compounds the threshold colour number was several times higher than in case of biodegradation (Table 2). A slight reduction in COD values, observed during chemical oxidation (Fig. 2) shows, however, that the colour intensity is associated with a slight alterations in the structure of polyphenols, and a complete decay of their parent forms. The observations have confirmed the hypothesis that the colour is chiefly caused by chemical oxidation with atmospheric oxygen, occuring in the course of activated sludge aeration [5].

### 4.3. THE EFFECT OF PREAERATION ON BIODEGRABILITY OF THE SELECTED PHENOLIC SUBSTRATES

The results obtained have allowed to state that aqueous solutions of all monophenols, $\alpha$-naphtol, and rezorcinol are resistant to chemical oxidation during a 5 hour aeration (Fig. 2). Regardless whether or not the above compounds were preaerated the biodegradation followed a similar pattern. A high susceptibility to chemical oxidation has been stated in case of catechol, hydroquinone, pyrogallol and phloroglucinol (Fig. 2). It is, however, characteristic that a considerable amount of organic compounds, which ought to be biodegraded during aeration with the activated sludge, remained in the mixed liquor. The biodegradation tests have revealed that the products of chemical oxidation of the 4 phenols differ in properties. The products of catechol and phloroglucinol were susceptible to further decomposition via biodegradation, while these of hydroquinone and pyrogallol were resistant (Fig. 3). It seems that in case of the first two phenols the change in molecular structure occuring during chemical oxidation resembled that at the initial stage of biodegradation. As to hydroquinone and pyrogallol it seems that their resistance to biodegradation by acclimated activated sludge (which probably produced the enzymes controlling the definite way of decomposition) was due to specific changes in their

molecular structures caused by chemical oxidation. A considerable stability of the colour resulting from chemical oxidation should be emphasized (Table 2).

The performed observations have confirmed the hypothesis, that the unsatisfactory quality of biologically treated phenolic waste-water is chiefly due to chemical oxidation processes. The presence of colour products in the effluent as well as the necessity of their eventual removal should be always taken into consideration even where the minimum amounts of oxygen are allowed in the phenolic waste-water prior to its biodegradation.

## CONCLUSIONS

1. Activated sludge acclimated to the advanced biodegradation of phenols is obtained, at the stage when the decay of phenol compounds in the effluent is associated with a low COD value.
2. Some phenols show a distinct susceptibility to chemical oxidation during the aeration process. Chemical oxidation is accompanied with the formation of intensely coloured intermediate products.
3. Unsatisfactory quality of the effluent manifested by a high COD value and an intense colour is chiefly due to the presence of intermediate chemical oxidation products of phenols.
4. Phenolic waste-water preaeration should be avoided because of the biodegration resistance of the intermediate products of phenol chemical oxidation.
5. In biologically treated phenol waste-water the removal of colour and reduction of COD value are indispensable; this procedure should be the next step in phenolic waste-water treatment.

## PRZYCZYNY NIEODPOWIEDNIEJ JAKOŚCI BIOCHEMICZNIE OCZYSZCZONYCH ŚCIEKÓW FENOLOWYCH

Badanie podjęto w celu wyjaśnienia przyczyn niezadowalającej jakości biologicznie oczyszczonych ścieków fenolowych. Dzięki stosowaniu zaaklimatyzowanego osadu czynnego osiągnięto wysoki stopień rozkładu monohydroksy- i polihydroksyfenoli. Chociaż wszystkie rodzaje biologicznie oczyszczonych ścieków fenolowych charakteryzowały się niskimi wartościami ChZT oraz zawartościami fenoli, to jednak w przypadku czterech polifenoli zaobserwowano barwne produkty biodegradacji. W kolejnej fazie badań wykazano, że roztwory wodne monohydroksyfenoli i rezorcyny są odporne na utlenienie chemiczne po 5-godzinnym napowietrzaniu powietrzem atmosferycznym.

Częściowe utlenienie hydrochinonu, pirokatechiny, pirogallolu i floroglucyny w tych warunkach powoduje powstanie produktów o intensywnej barwie. W przypadku pirokatechiny i floroglucyny produkty te okazały się podatne na dalszą degradację biochemiczną, w przeciwieństwie do produ-

któw utlenienia hydrochinonu, pirogallolu — odpornych na biodegradację przez zaaklimatyzowane osady czynne. Utlenianie chemiczne może więc tak zmienić strukturę cząstek niektórych fenoli, że nastąpi spadek podatności na rozkład biochemiczny. Wykonane badania potwierdziły tezę, że utlenianie chemiczne jest główną przyczyną niezadowalającej jakości oczyszczonych biologicznie ścieków fenolowych. Dlatego należy unikać natleniania tego rodzaju ścieków podczas transportu i schładzania przed ich oczyszczaniem biologicznym.

## URSACHEN DER UNBEFRIEDIGENDER GÜTE BIOLOGISCH GEREINIGTER PHENOLABWÄSSER

Versuche wurden angestellt um die Frage zu lösen, was für Ursachen der unbefriedigender Güte biologisch gereinigter Phenolabwässer zugrunde liegen.

Ein adaptierter Belebtschlamm sorgte für den hohen Abbau von Mono-und Polyhydroxyphenolen. Obwohl alle untersuchten Arten von biologisch gereinigten Abwässer nur kleine CSB- und Phenolrestwerte aufwiesen, so sind bei vier Poliphenolen farbige Abbauprodukte festgestellt worden.

In anschliessenden Untersuchungen wurde erwiesen, daß Monohydroxyphenol und Resorzin in wässerigen Lösungen sich bei 5-stündiger Begasung resistent zum Luftsauerstoff verhalten haben. Eine partielle Oxydation unter selben Verhältnissen von Hydrochinon, Brenzkatechin, Pyrogallol Phlorogluzin, ergab Produkte mit intensiver Färbung. Bei Brenzkatechin und Phlorogluzin waren die Produkte biochemisch weiter abbaubar. Abbauprodukte von Hydrochinon und Pyrogallol verhielten sich dagegen resistent sogar zum adaptiertem Belebtschlamm.

Rein chemische Oxydation kann also eine unerwünschte Änderung der Struktur mancher Phenole nach sich ziehen, mit einem Schaden für die nachfolgende biologische Reinigung.

Die dargelegten Versuche haben die Vermutung bestätigt, daß hauptsächlich die chemische Oxydierung (als Vorbehandlungsverfahren) für die unbefriedigende Güte biologisch gereinigter Phenolabwässer verantwortlich ist. Solche Abwässer sollte man also vor der Biologischen Reinigung nicht vorbelüften; auch ist eine vorangehende Abkühlung der Abwässer zu meiden.

## ПРИЧИНЫ НЕУДОВЛЕТВОРИТЕЛЬНОГО КАЧЕСТВА БИОХИМИЧЕСКИ ОЧИЩЕННЫХ ФЕНОЛЬНЫХ СТОЧНЫХ ВОД

Цель исследований заключалась в изучении причин неудовлетворительного качества биологически очищенных фенольных сточных вод. Благодаря применению акклиматизированного активного ила достигнута высокая степень разложения моногидрокси- и поли гидроксифенолов. Несмотря на то, что все виды биологически очищенных фенольных сточных вод характеризовались низкими значениями ХПК и содержанием фенолов, в случае четырех полифенолов были обнаружены цветные продукты биодеградации. На последующей стадии исследований показано, что водные растворы моногидроксифенолов и резорцина устойчивы к химическому окислению после 5 часов аэрации атмосферным воздухом. Частичное окисление гидрохинона, пирокатехина пирогаллола и флороглюцина вызывает в этих условиях образиание продуктов яркого цвета. В случае пирокатехина и флороглюцина эти продукты показались восприимчивыми к дальнейшему биохимическому разложению в противоположность продуктам окисления гидрохинона, пирогаллола, устойчивых к биохимическому разложению акклиматизированными активными илами. Следовательно, химическое окисление может вызывать такое изменение структуры частиц некоторых фенолов, которое влечет за собой снижение восприимчивости к биохимическому разложению. Проведенные исследования подтвердили положение о том, что химическое окисление — главная

причина неудовлетворительного качества биологически очищенных фенольных сточных вод. Поэтому следует избегать окисления таких сточных вод при транспортировке их и охлаждении до момента биологической очистки.

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