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Wpływ akroleiny i hydrokrylu na dynamikę rozwoju bakterii wodnych

The influence of acrolein and hydrocryle on the development dynamics of aquatic bacteria

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Abstract — The toxic action of acrolein and hydrocryle on the *Pseudomonas Group* III and *Achromobacter-Alcaligenes* strains and on the mixed populations from a pure environment (the Trzebuńka stream) and a polluted one (the cooling system of a power plant) was evaluated. The toxicity of hydrocryle was higher than that of acrolein, while a weaker resistance of pure strains and of mixed populations of bacteria from an unpolluted environment was observed.

Excessive eutrophication of soils and waters leading to unfavourable phenomena connected with mass development of certain microorganisms presents many difficulties in both agriculture and industry. As an example, installations used for water cooling and condensers of thermal power stations may be cited, where the bacteria with the participation of unicellular algae produce tremellose coats. The development of these organisms, together with the sedimentation of mineral compounds, brings about a decrease in the inside measurement of condenser pipes, obstructs the water circulation, and reduces the heat exchange. It consequence, the turbine efficiency is reduced and the economic indices of production of 1 KWh of energy increased. The necessity of shutting off the condensers from the circulation every now and then to remove the rapidly growing jelly-like sediments from the pipes additionally increases the exploitation costs.

One of the measures of controlling or limiting the excessive development of bacteria and other aquatic organisms in industrial cooling installations is the addition of toxic substances to the water. Depending on the concentration and type of substances, their action may inhibit the growth and development of organisms up to the production of lethal effects, while the use of an unsuitable substance or dose may in consequence stimulate the life processes and bring about undesirable effects. The selective action of substances must be also considered, since they may bring about the death of some groups of organisms and more intense development and growth of others, this leading to the remodelling of water biocenosis (Stroganov 1971).

The determination of the degree of toxicity and the prevision of changes in the biocenosis require the selection of a suitable test organism or group of organisms. Most often fish are used as test organisms. However, the use of one biotest does not fully present the toxicity of a given substance, especially with systematically removed groups of organisms. Aleksandrova and Kanygina (1971) claim that in determining the toxic action of a chemical compound one has to remember that various species of organisms respond differently to the presence of the same toxic factor. These authors report that with the same concentration of a toxic substance the lethal effect depends on the density of bacterial cells in the water and that from the development of bacteria and from the biochemical processes one may draw conclusions as to the toxicity of the investigated compound.

Biological methods in determing toxicity should include three basic groups of organisms, i. e. producers, consumers, and reducers. The criterion of toxicity is the survival or death of the organism the given toxic substance is acting on. In a group of lethal tests Pawlaczyk-Szpilowa et al. (1972) found a considerable resistance of a mixed population of bacteria as compared with *Paramecium caudatum* and *Daphnia magna* against a number of toxic substances (copper sulphate, lead acetate, potassium permanganate, chlorine, arquard, and arsene). In controlling aquatic weeds and snails with acrolein in irrigation canals, Overbeck et al. (1959) found that the aquatic submersed vegetation is killed over a distance of 15—20 miles from the site of acrolein treatment at the dose of 4.54 l/1 cu. foot of flowing water. The time of treatment was 30—40 minutes. Moreover, in laboratory investigations they observed that acrolein damages the enzymes of the SH group in the cytoplasm of *Elodea densa*, a dose of 0.5 ppm being lethal for its cells.

The aim of the present work was to assay the influence of acrolein and hydrocryle on the development of bacteria occurring in the clean water of the Trzebuńka stream and in the polluted water flowing through the condensers of thermal power stations. The excessive and objectionable development of bacteria in the condenser pipes of the power station was controlled by the addition of toxic substances to the water cooling these installations.

Methods

The strains of bacteria isolated from the water of the cooling system of the power station at Blachownia Śląska (Opole province) and natural mixed populations of bacteria from the water of this system and from the water of the unpolluted Trzebuńka stream (a left-side tributary of the Raba, Kraków province) were selected for test determinations.

Using the Shewan et al. system (1960), 32 strains were isolated from the water flowing through the condensers of the power plant. Among the isolated microorganisms the following species and strains were recorded: *Achromobacter-Alcaligenes*, *Flavobacterium*, *Pseudomonas aeruginosa*, *Pseudomonas* Group III, *Pseudomonas* Group IV, *Vibrio*, *Escherichia coli*, *Proteus* sp., *Bacillus* sp., and yeasts.

The investigation included 1) checking the influence of different concentrations of acrolein on pure bacteria strains (*Pseudomonas* Group III and *Achromobacter-Alcaligenes*) and a mixture of them, 2) checking the influence of the various degrees of enrichment of the medium with nutritive compounds on the sensitivity of natural mixed populations of bacteria, 3) a comparison of the toxic action of acrolein and hydrocryle on the development of natural mixed populations of bacteria from the pure and polluted environments.

The sensitivity of strains to acrolein was assayed using tube tests, the strains selected for the investigation being *Pseudomonas* Group III (which was found to be the most sensitive) and *Achromobacter-Alcaligenes* (the least sensitive one). The concentration ranges of the investigated toxic compounds were preliminarily determined using the method of gradient plates. The following concentrations were used for both acrolein and hydrocryle: 10 000, 1000, 750, 500, 250, 125, 62 mg/l.

The influence of acrolein on the strains of *Pseudomonas* Group III and *Achromobacter-Alcaligenes* was investigated in stationary cultures using fluid broth medium. The amount of the medium together with the suitable concentration of the toxic substance was 100 ml. Separate cultures of the strain *Pseudomonas* Group III, *Achromobacter-Alcaligenes*, and of their mixture were conducted.

The cultures of natural mixed bacteria populations of rich and varied composition of species from both the aquatic environments mentioned above were carried out in 100 ml portions of water (together with the investigated toxic factor). The water was pre-filtered in order to remove the phyto- and zooplankton and then supplemented with nutritive substances for the bacteria to the amount of 10 g/l peptone and 1 g/l glucose or 1 g/l peptone and 0.1 g/l glucose.

With the isolated strains inoculation was 1 ml of the 48-hr culture and with a mixture of them 0.5 ml of the suspension of each strain was added in order to maintain the same volume. The incubation time was 120 hrs at 23°C. The rate of growth of the bacteria was investigated using the method of rubbed agar plates (Collective work 1971). In all series of experiments the initial number of bacteria was determined in the control (a culture without the toxic factor) and in the cultures with various concentrations of the investigated toxic factor. The obtained results were given as a mean from 3 parallel replications.

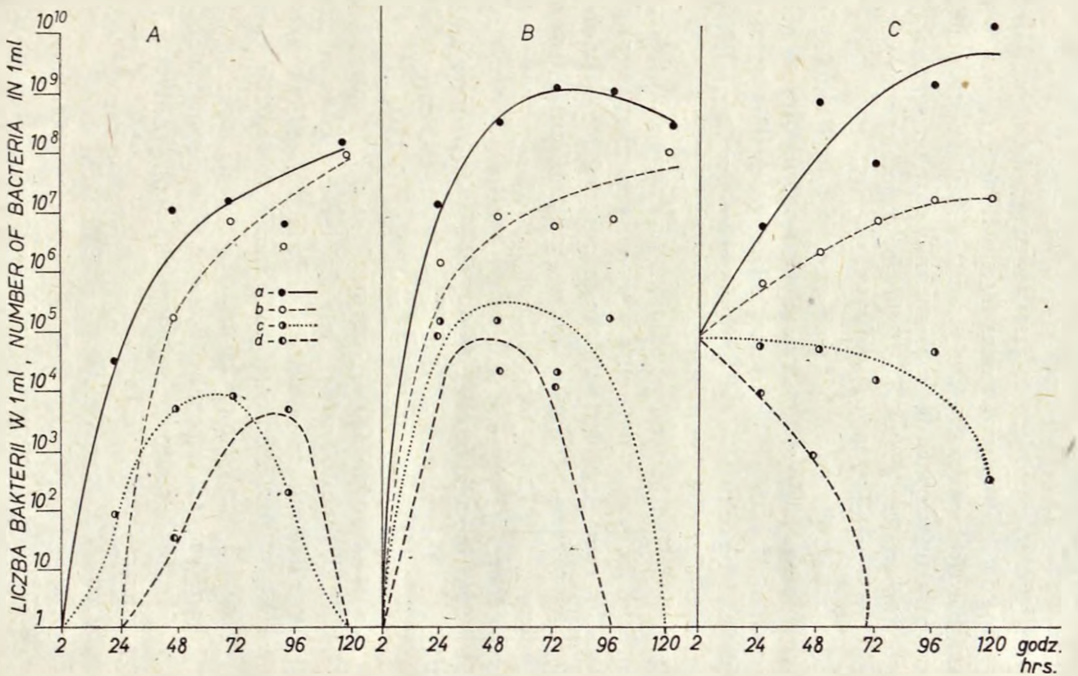
In order to present the influence of toxic substances on the development of bacteria in test cultures as compared with the control ones, a logarithmic comparative coefficient L was introduced according to the formula

$$L = \log \frac{D}{C}$$

where: C is the number of bacteria in the control culture,

D is the number of bacteria in the culture with the toxic factor.

The value of C and D were calculated at the same point of time on the basis of interpolated curves. L expresses the difference between lg D and lg C in order of magnitude. The positive value indicates an increase in the number of bacteria in the test cultures as compared with the control ones, and the negative value a decrease in that number in relation to the control.



Ryc. 1. Wpływ akroleiny na: A — szczep *Pseudomonas* Grupa III; B — szczep *Achromobacter - Alcaligenes*; C — ich mieszaninę. a — kontrola; stężenia akroleiny w pożywce: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l

Fig. 1. The influence of acrolein on: A — *Pseudomonas* strain Group III; B — *Achromobacter-Alcaligenes* strain; C — a mixture of the both; a — control; concentrations of acrolein in the medium: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l

The influence of acrolein on pure bacteria strains

In control cultures the growth of the bacteria of the strains *Pseudomonas* Group III and *Achromobacter-Alcaligenes* differed (fig. 1. A, B). The strain *Pseudomonas* Group III was characterized by a slower, prolonged up to 120 hours, logarithmic phase, while the strain *Achromobacter-Alcaligenes* showed a shorter but more dynamic growth in the logarithmic phase, which took 72 hrs, the death of cells being observed on the fifth day.

The acrolein doses of 500 mg/l and more were lethal for both strains, the death of cells occurring after 2 hours of incubation (Table I). At lower concentrations (250 and 125 mg/l) a marked inhibition in the division of cells was observed in relation to the control (L coefficient, Table I). At these concentrations in the phase

Tabela I. Wpływ akroleiny na szczepy: Pseudomonas Grupa III, Achromobacter - Alcaligenes i ich mieszaninę.
Wartości liczbowe - współczynnik L; x - efekt letalny

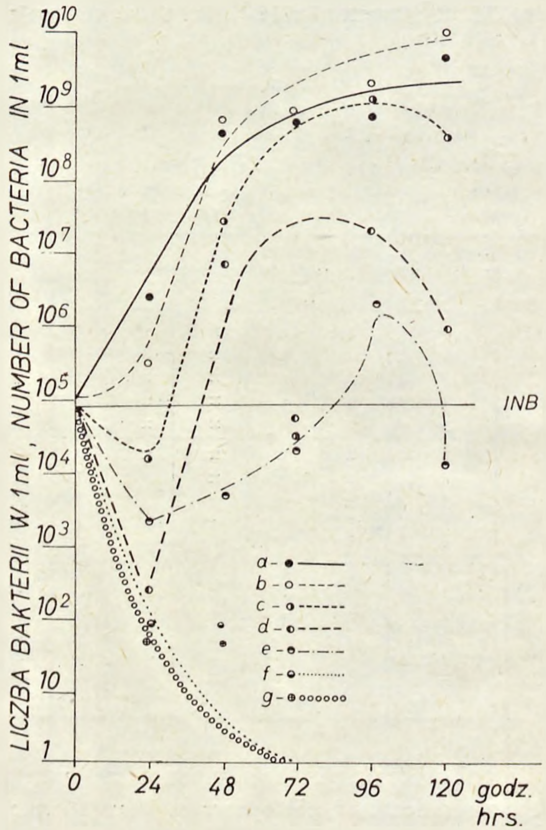
Table I. The influence of acrolein on the strains: Pseudomonas Group III, Achromobacter-Alcaligenes, and a mixture of the two.
Numbers - L coefficient; x - lethal effect

Szczep Strain	Czas w dobach Days	Stężenie w mg/l Concentration in mg/l						
		10.000	1.000	750	500	250	125	62
Pseudomonas Grupa III Pseudomonas Group III	1	x	x	x	x	-4.5	-2.5	-4.5
	2	x	x	x	x	-5.1	-3.4	-1.8
	3	x	x	x	x	-3.9	-3.2	-0.9
	4	x	x	x	x	-4.2	-5.5	-0.3
	5	x	x	x	x	x	x	-0.3
Achromobacter-Alcaligenes	1	x	x	x	x	-3.3	-3.0	-1.7
	2	x	x	x	x	-3.6	-3.0	-1.8
	3	x	x	x	x	-5.3	-3.7	-1.8
	4	x	x	x	x	x	-4.8	-1.4
	5	x	x	x	x	x	x	-0.7
Pseudomonas Grupa III + Achromobacter-Alcaligenes Pseudomonas Group III + Achromobacter-Alcaligenes	1	x	x	x	x	-2.8	-1.8	-1.1
	2	x	x	x	x	-5.1	-3.1	-1.6
	3	x	x	x	x	x	-4.3	-2.0
	4	x	x	x	x	x	-5.3	-2.3
	5	x	x	x	x	x	-7.2	-2.5

of the logarithmic growth a decrease in the number of bacteria and, after a shortened stationary phase, the rapid death of cells occurred. The stationary phases of the two strains differed and were shifted in time. The lowest acrolein concentration used (62 mg/l) brought about the death of cells in the test cultures as compared with the control ones. In the first 24 hrs of the experiment the L value was —2.6 for *Pseudomonas* Group III and —1.7 for *Achromobacter-Alcaligenes.* On the following days the L coefficient gradually increased for strain *Pseudomonas* Group III, reaching —0.3 after 120 hrs. In the case of strain *Achromobacter-Alcaligenes* on the 3rd and 4th day the greatest difference was observed in the number of bacteria as compared with the control. On the 5th day this difference distinctly decreased.

The mixture of the two strains (*Pseudomonas* Group III and *Achromobacter-Alcaligenes*) was more resistant in the adaptation phase (fig. 1 C). The death of cells occurred at the same concentrations (above 250 mg/l) but only after 24 hrs. At the concentration of 62 mg/l a decrease in the number of cells was observed as compared with the control, but on the first day the L value of —1.1 suggested greater resistance of the mixture of strains to acrolein as compared with pure strains.

The obtained results show that the monocultures (pure strains) are more sensitive to acrolein, while the greater resistance of the mixture of the two strains may probably be attributed to the reciprocal action — synergism — a phenomenon frequently encountered among the bacteria.



Ryc. 2. Wpływ akroleiny na mieszane populacje bakterii wody potoku Trzebuńka. Wzbogacenie wody: 10 g/l peptonu, 1 g/l glukozy. INB — wyjściowa liczba bakterii; a — kontrola; stężenia akroleiny w wodzie: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l; e — 500 mg/l; f — 750 mg/l; g — 1 000 mg/l

Fig. 2. The influence of acrolein on mixed populations of bacteria in the water of the Trzebuńka stream. Water enrichment: 10 g/l peptone, 1 g/l glucose. INB — initial number of bacteria; a — control; concentrations of acrolein in the water: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l; e — 500 mg/l; f — 750 mg/l; g — 1 000 mg/l

The influence of the variable enrichment of the water with nutritive substances on the resistance of natural mixed populations of bacteria

The investigation was conducted on natural mixed populations of bacteria from the water of the Trzebuńka stream, the water being enriched with 10 g/l of peptone and 1 g/l of glucose (fig. 2) and 1 g/l of peptone and 0.1 g/l of glucose (fig. 3).

At greater water enrichment the nutrients were not consumed in the control culture throughout 120 hrs. This is shown by the absence of the phase of death of cells, while at 10 times lower enrichment the phase of dying was distinctly marked in this culture.

At a higher content of nutritive compounds only the acrolein content of 10 000 mg/l brought about the death of cells. The concentrations of 1 000 mg/l and 750 mg/l inhibited the growth, the lethal effect occurring after 3 days. At the other concentrations a distinct inhibition of growth and hence a decrease in the L coefficient occurred in the first 24 hrs (Table II). The acrolein rates of 500, 250, and 125 mg/l brought about the stronger inhibition of bacterial growth in the logarithmic phase the higher was the concentration. The death of cells also increased with the increasing dose of acrolein. At the lowest concetration of acrolein (62 mg/l) the death of cells was limited to the 24-hour period while in further phases of the culture a stimulation of growth was observed, this being shown by the positive values of the L coefficient (Table II).

Tabela II. Wpływ akroleiny na mieszane populacje bakterii wody potoku Trzebuńka w zależności od wzbogacenia wody substancjami odżywczymi.
Wartości liczbowe - współczynnik L: x - efekt letalny

Table II. The influence of acrolein on mixed populations of bacteria in the water of the Trzebuńka stream depending on the enrichment of the water with nutrient substances
Numbers - coefficient L: x - lethal effect

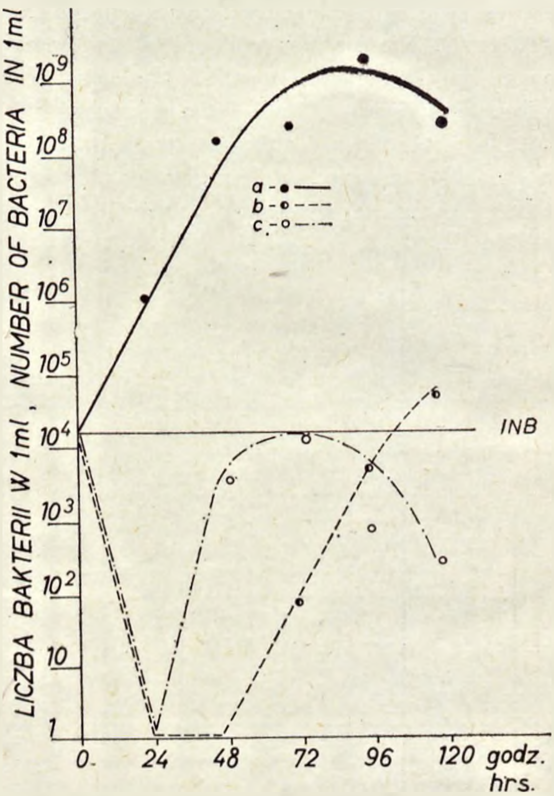
Zawartość substancji odżywczych / Content of nutrients	Czas w dobach / Days	Stężenia / Concentrations in mg/l						
		10.000	1.000	750	500	250	125	62
Pepton / Peptone 10 g/l; Glukoza / Glucose 1 g/l	1	x	-4.7	-4.5	-3.4	-4.2	-2.5	-0.7
	2	x	-7.9	-7.7	-4.6	-2.2	-0.8	+0.3
	3	x	x	x	-4.6	-1.8	-0.1	+0.3
	4	x	x	x	-3.2	-2.1	-0.1	+0.6
	5	x	x	x	-5.2	-3.4	-0.7	+0.6
Pepton / Peptone 1 g/l; Glukoza / Glucose 0.1 g/l	1	x	x	x	x	x	x	-6.0
	2	x	x	x	x	x	x	-8.0
	3	x	x	x	x	x	x	-7.2
	4	x	x	x	x	x	x	-5.4
	5	x	x	x	x	x	x	-3.8

At lower enrichment of the water with peptone and glucose all concentrations higher than 63 mg/l brought about the death of bacteria. At the concentration of 62 mg/l after a 48-hour phase of inhibition a logarithmic growth of bacteria occurred and continued to the end of the experiment (120 hrs). However, after 120-hour incubation a considerable decrease in the number of bacteria (L coefficient — 3.8) was noted as compared with the control.

To sum up one may claim that enrichment with nutrients has an essential influence on decreasing the degree of toxicity of the applied substances. The richer is the medium the less toxicity of acrolein is observed.

Comparison of the toxic effect of acrolein and hydrocryle on the development of natural mixed populations of bacteria from the pure and polluted environments

In the test investigation natural mixed populations of bacteria from the water of the Trzebuńka stream (pure environment) and from the water of the cooling installations of the power plant (polluted environment) were used. The water was enriched with peptone (1 g/l) and glucose (0.1 g/l).



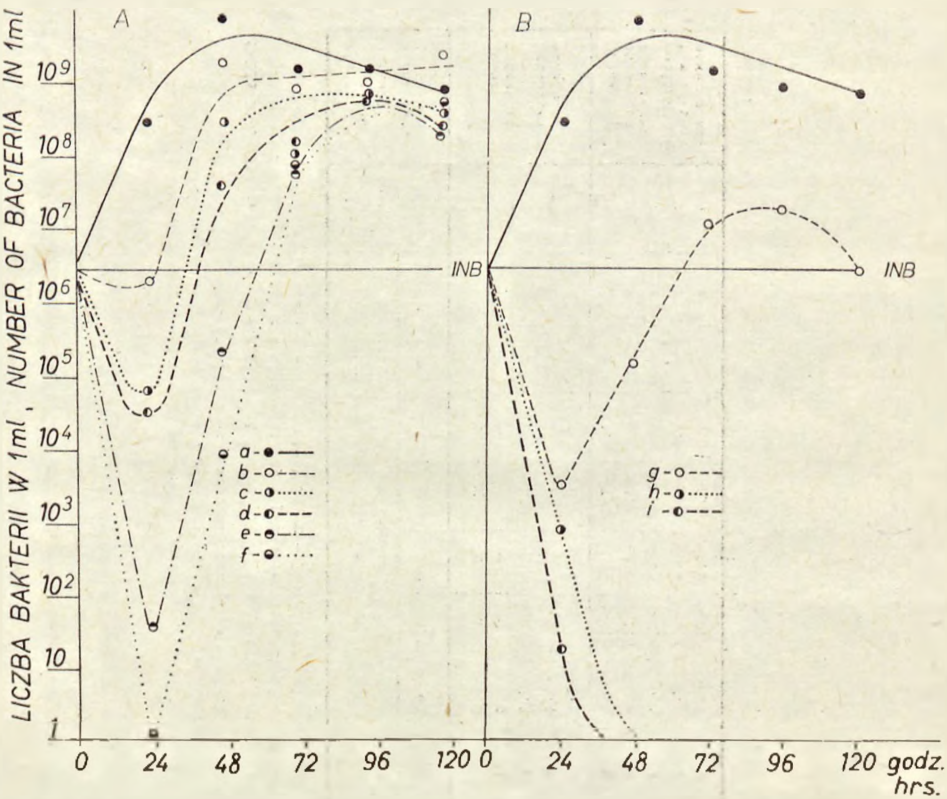
Ryc. 3. Wpływ akroleiny i hydrokrylu na mieszane populacje bakterii wody potoku Trzebuńka. Wzbogacenie wody: 1 g/l peptonu, 0,1 g/l glukozy. INB — wyjściowa liczba bakterii; a — kontrola; stężenia: b — akroleiny 62 mg/l wody; c — hydrokylu 62 mg/l wody

Fig. 3. The influence of acrolein and hydrocryle on mixed populations of bacteria in the water of the Trzebuńka stream. Enrichment of the water: 1 g/l peptone, 0.1 g/l glucose. INB — initial number of bacteria; a — control; concentrations: b — acrolein 62 mg/l of the water; c — hydrocryle 62 mg/l of the water

Tabela III. Wpływ akroleiny i hydrokrylu na wzrost mieszanych populacji bakterii wody potoku Trzebuńka i układu chłodzącego elektrowni (wzbogacenie wody: 1 g/l peptonu, 0.1 g/l glukozy).
Wartości liczbowe - współczynnik L; x - efekt letalny

Table III. The influence of acrolein and hydrooryle on the growth of mixed populations of bacteria in the Trzebuńka stream and in the cooling system of a power plant (enrichment of the water: 1 g/l peptone, 0.1 g/l glucose).
Numbers - coefficient L; x - lethal effect

Mieszane populacje bakterii / Mixed populations of bacteria	Czas w dobach / Days	Stężenie akroleiny w mg/l / Concentration of acrolein in mg/l							Stężenie hydrokrylu w mg/l / Concentration of hydrooryle in mg/l						
		10.000	1.000	750	500	250	125	62	10.000	1.000	750	500	250	125	62
Potok Trzebuńka / Trzebuńka stream	1	x	x	x	x	x	x	-6.0	x	x	x	x	x	x	-6.0
	2	x	x	x	x	x	x	-8.0	x	x	x	x	x	x	-4.4
	3	x	x	x	x	x	x	-7.2	x	x	x	x	x	x	-4.8
	4	x	x	x	x	x	x	-5.4	x	x	x	x	x	x	-5.4
	5	x	x	x	x	x	x	-3.8	x	x	x	x	x	x	-6.1
Układ chłodzący elektrowni / Cooling system of the power plant	1	x	x	-8.8	-7.6	-4.3	-4.0	-2.5	x	x	x	x	-7.5	-5.9	-5.6
	2	x	x	-5.8	-4.4	-2.2	-1.5	-0.8	x	x	x	x	x	x	-4.5
	3	x	x	-1.8	-1.7	-1.3	-0.7	-0.4	x	x	x	x	x	x	-2.4
	4	x	x	-0.6	-0.5	-0.4	-0.4	0.0	x	x	x	x	x	x	-1.9
	5	x	x	-0.1	-0.6	-0.9	-0.3	+0.4	x	x	x	x	x	x	-2.7



Ryc. 4. Wpływ akroleiny (A) i hydrokrylu (B) na mieszane populacje bakterii wody układu chłodzącego elektrowni. Wzbogacenie wody: 1 g/l peptonu, 0,1 g/l glukozy. INB — wyjściowa liczba bakterii; a — kontrola; stężenia akroleiny w wodzie: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l; e — 500 mg/l; f — 750 mg/l; stężenia hydrokrylu w wodzie: g — 62 mg/l; h — 125 mg/l; i — 250 mg/l

Fig. 4. The influence of acrolein (A) and hydrocryle (B) on mixed populations of bacteria in the water of the cooling system of a power plant. Enrichment of the water: 1 g/l peptone, 0.1 g/l glucose. INB — initial number of bacteria; a — control; concentrations of acrolein in the water: b — 62 mg/l; c — 125 mg/l; d — 250 mg/l; e — 500 mg/l; f — 750 mg/l; concentrations of hydrocryle in the water: g — 62 mg/l; h — 125 mg/l; i — 250 mg/l

Mixed bacterial populations of the Trzebunka stream were very sensitive to the action of both acrolein and hydrocryle (fig. 3). The growth of bacteria was found only at the lowest concentration (62 mg/l) of the two toxic substances, temporary inhibition of bacterial growth being longer with acrolein (48 hrs) than with hydrocryle (24 hrs). Throughout the first 24 hours the L value was the same for the two substances and amounted to —6.0 (Table III). Nevertheless, in the case of acrolein after a lengthened phase of the inhibition (two days), an increase in the number of bacteria was already found on the third day. At the end of the experiment (120 hours) the number of bacteria was greater than the initial one, the L value being —3.8 (Table III).

As compared with acrolein, the same concentration of hydrocryle (62 mg/l) was more toxic for the bacterial population of the Trzebuńka stream. After a shorter phase of the inhibition in the growth of bacteria (one day) and a more dynamic logarithmic phase, the number of bacteria became smaller than the initial one, the L value being —6.1 after 120 hrs (Table III).

The populations of the bacteria from the cooling installations of the power plant were more resistant than those from the Trzebuńka stream to the toxic substances applied in the experiment (fig. 4, A, B).

The acrolein concentrations of 1 000 mg/l and more were decisively lethal, killing the cells already in the first 24 hrs of the culture (Table III). In the case of hydrocryle the same effect was already observed from the concentration of 500 mg/l. The acrolein rates of 750 mg/l and lower inhibited the growth of the bacteria only throughout the first 24 hrs, the inhibition being proportional to the rates (fig. 4, A). However, independently of the recorded degree of inhibition and the acrolein concentration used, after 4 days of the incubation, the number of bacteria in the cultures with acrolein was actually similar to the control and the values of the L coefficient were lower than 1 (Table III).

The hydrocryle doses of 500 mg/l and higher had a lethal effect in the first 24 hrs and the concentrations of 250 mg/l and 125 mg/l on the second day (fig. 4 B); only the dose of 62 mg/l brought about a temporary inhibition in the growth of the bacteria in the first 24 hrs of the culture. On the following days an increase in the number of bacteria was observed at this concentration and on the third and fourth day this number was slightly higher than the initial one. At the end of the investigation period (120 hrs) an equalization with the initial level occurred, the value of the L coefficient being —2.7.

The sensitivity of the mixed populations of bacteria to the same rates of a given toxic factor is variable, depending on the quantitative and qualitative composition of the populations formed in different environments. The mixed populations of bacteria were less sensitive to the action of acrolein than to that of hydrocryle. This was especially visible in the case of the population from the cooling system of the power plant, where after 96 hrs at relatively high rates of acrolein (750 mg/l) the number of bacteria practically equalled that of the control. Even the lowest rate of hydrocryle (62 mg/l) resulted in a significant decrease in the number of bacteria as compared with the control.

Conclusions

1) Pure strains of bacteria are less resistant to the action of acrolein than are mixed populations.

2) The enrichment of the water with nutritive compounds decreases the toxic influence of acrolein and hydrocryle on the bacteria. Thus it may be expected

that in natural water environments poor in nutrients the degree of toxicity of the two compounds will be higher.

3) The bacteria from a pure environment show greater sensitivity to the investigated toxic substances (acrolein and hydrocryle) than do the populations from a polluted environment.

4) Hydrocryle is more toxic to bacteria than acrolein.

5) The experiments conducted suggest that in an aquatic environment acrolein not only undergoes a chemical but also a biological degradation and loses its toxic properties. It is decomposed by some species of bacteria and used in the metabolic processes, this being indicated by the growth stimulation at the concentration of 62 mg/l in the final period of the culture of the mixed populations of bacteria.

6) For the mixed populations of bacteria from the cooling system of the power plant the doses of 1 000 mg/l of acrolein and 500 mg/l of hydrocryle cause a lethal effect after 24 hrs. Lower rates of hydrocryle (250 and 125 mg/l) also bring a lethal effect after 48 hrs, this not being found with acrolein.

7) Concentrations lower than the lethal ones (for acrolein 750 mg/l — 62 mg/l, for hydrocryle 62 mg/l only) induce a temporary inhibition of the bacterial growth in the first 24 hours. On the following days of the experiment the development of bacteria occurs, the maximum number being noted after 3 days. It should be noted that the degreee of the inhibition in the growth of bacteria, as compared with the control, is variable, depending on the concentration and the type of the toxic compound.

8) When using toxic substances in a concentration lower than the lethal one, they should be applied every 24 hours in order to obtain a decreased number of bacteria in the water of the cooling system of a power plant.

9) The use of too low concentrations of toxic substances is dangerous since it may induce the formation of populations resistant to a given toxic factor.

STRESZCZENIE

Przeprowadzono ocenę toksycznego wpływu akroleiny i hydrokrylu na dynamikę rozwoju bakterii *Pseudomonas* Grupa III i *Achromobacter-Alcaligenes* wyizolowanych z wody układu chłodzącego elektrowni w Blachowni Śląskiej (woj. Opolskie) oraz na mieszane populacje bakterii wody tego układu i nie zanieczyszczonego potoku Trzebuńka, lewobrzeżnego dopływu Raby (woj. krakowskie).

Toksyczny wpływ wymienionych związków w stężeniach: 10 000, 1000, 750, 500, 125 i 62 mg/l określono na podstawie wzrostu bakterii w hodowlach płynnych, stacjonarnych, przy czym liczbę bakterii oznaczono metodą płytek agarowych tartych. Dla zobrazowania wpływu substancji toksycznych na hodowle testowe w porównaniu z kontrolnymi wprowadzono logarytmiczny współczynnik porównawczy L.

Stwierdzono, że hodowle szczepów *Pseudomonas* Grupa III i *Achromobacter-Alcaligenes* w porównaniu do hodowli mieszaniny obu szczepów były bardziej wrażliwe na działanie akroleiny w fazie adaptacyjnej wzrostu. Dawka akroleiny 500 mg/l była letalna dla poszczególnych szczepów już po 2 godzinach, a dla ich mieszaniny po 24 godzinach.

Większe wzbogacenie wody substancjami odżywczymi dla bakterii (pepton, glukoza) obniżało wrażliwość drobnoustrojów na toksyczne działanie akroleiny. Przy wzbogaceniu wody peptonem

10 g/l i glukozą 1 g/l, dawka akroleiny 750 mg/l była letalna dla mieszanych populacji bakterii wody potoku Trzebuńka po 3 dobach. Natomiast przy 10-krotnie mniejszym wzbogaceniu wody substancjami odżywczymi stężenie akroleiny 125 mg/l było letalne już po jednej dobie.

Mieszane populacje bakterii czystej wody potoku Trzebuńka w porównaniu z mieszanymi populacjami bakterii zanieczyszczonej wody układu chłodzącego elektrowni były bardziej wrażliwe na stosowane w doświadczeniach substancje toksyczne.

Stwierdzono, że dla mieszanych populacji bakterii hydrokryl jest bardziej toksyczny niż akroleina.

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