

Harmful factors in wastewater treatment plant – knowledge and awareness of workers about hazards

Szkodliwe czynniki w oczyszczalni ścieków – wiedza i świadomość pracowników o zagrożeniach

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Wprowadzenie. Pracownicy oczyszczalni ścieków nie zawsze zdają sobie sprawę z tego, że w ich środowisku pracy występuje szereg rozmaitych czynników biologicznych i chemicznych, które mogą zagrażać ich zdrowiu i życiu. Szczególnie niebezpieczny jest bezpośredni kontakt ze ściekami, ale również narażenie na bioaerol i odory emitowane podczas procesów oczyszczania ścieków.

Cel. Ocena wiedzy i świadomości pracowników oczyszczalni ścieków na temat narażenia na szkodliwe czynniki podczas wykonywania swoich obowiązków zawodowych.

Materiały i metody. Przeprowadzono anonimowe badanie ankietowe z pracownikami 15 oczyszczalni ścieków na Dolnym Śląsku. Kwestionariusz zawierał pytania sprawdzające poziom wiedzy oraz świadomość na temat zagrożeń związanych z obecnością czynników biologicznych i chemicznych w oczyszczalni ścieków.

Wyniki. Ankietowani wykazali się średnią znajomością zagadnień dotyczących szkodliwych czynników, choć zdawali sobie sprawę z niebezpieczeństw, wynikających z pracy przy oczyszczaniu ścieków. Wiedzieli również z jakich metod ochrony powinni korzystać i je stosowali. Na wiedzę pracowników znaczący wpływ miało ich wykształcenie (OR=1,86; CI 1,06-3,28) oraz wielkość oczyszczalni (OR=2,47; CI 1,09-5,59).

Wnioski. Należałoby zwiększyć częstość oraz zakres materiału szkoleń pracowniczych dotyczących szkodliwych czynników w ich miejscu pracy. Istotne jest również wprowadzenie nowocześniejszych metod ochrony pracowników oraz większe egzekwowanie obowiązków szczepień ochronnych od osób zatrudnionych w oczyszczalniach ścieków.

Słowa kluczowe: *biologiczne czynniki, niebezpieczne substancje, wiedza o zdrowiu, narażenie zawodowe, ścieki*

Introduction. Wastewater treatment plant workers are not always aware that biological and chemical factors present at their workplace can have harmful impact on their health. Especially dangerous is the direct contact with wastewater, but also exposure to bioaerosol and odors emitted during the wastewater treatment processes.

Aim. To assess the knowledge and awareness of wastewater treatment plant workers about exposure to harmful health factors during performance of professional duties.

Material & method. The anonymous survey was conducted among workers of 15 wastewater treatment plants in Lower Silesia (Poland). The survey included questions assessing the awareness and knowledge about hazards associated with the presence of biological and chemical factors in wastewater treatment plant.

Results. Although the level of knowledge workers about harmful risk factors was assessed as average, the study participants were aware of hazards related to work in the wastewater treatment plant. They also knew about the methods of protection and used them. Their knowledge was correlated with the level of education (OR=1.86, CI 1.06-3.28) and the size of the wastewater treatment plant (OR=2.47, CI 1.09-5.59).

Conclusion. The extension of the material range and frequency of professional trainings about harmful factors at workplace are necessary. Moreover, it is important to introduce modern protective measures of workers and enforce obligatory vaccinations in the wastewater treatment plant workers.

Key words: *biological factors, hazardous substances, health knowledge, occupational exposure, wastewater*

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Introduction

Work in the wastewater treatment plant is related to exposure to biological and chemical factors that may be a serious threat for worker's health and life. But still, too little attention is paid to such issues in the work environment [1-4]. Established standards for the permitted concentrations of microorganisms in the air in the area of bioaerosol emissions from wastewater

are lacking [5]. The bioaerosol may contain bacteria, viruses, fungal spores, their fragments, by-products. They can have allergenic and toxic impact on human health. They may initiate inflammatory reactions, most commonly in the respiratory and digestive system, skin and mucous membranes of the eyes. Workers at the wastewater treatment plant also complain of tiredness and headaches [6]. Especially dangerous

is the direct contact with wastewater, therefore the employer is obliged to provide workers vaccination against: tetanus, typhoid and hepatitis A [7].

Even though the concentrations of chemical factors are often standardized, only a few substances are monitored in the workplace. Exposure of employees to odors (even at low concentrations) may result in symptoms from central nervous system (headache, dizziness), irritation of the mucous membranes of the eyes and respiratory tract. There are also cases of fatal poisoning, e.g. with hydrogen sulphide [8, 9]. Why is this happening? Are the wastewater treatment plant workers sufficiently aware of the risks associated with exposure to these factors? What is their knowledge about it? Do they comply with occupational health and safety rules?

Aim

To assess the knowledge of wastewater treatment plant workers about exposure and awareness of the hazards associated with the presence of harmful biological and chemical factors in their occupational environment. This study can contribute to initiate activities that expand knowledge in the area of occupational health and safety in wastewater treatment plant workers and minimize or eliminate workplace hazards. As a result, to protect wastewater workers' health more effectively.

Material and method

Questionnaire

A questionnaire was designed after a detailed review of the literature on biological and chemical risks at wastewater environment. It was anonymous and included questions assessing workers' knowledge about harmful factors, hazards and work safety in wastewater treatment plant. In the last question the respondents were asked about the complaints due to the exposure to harmful factors in the workplace ("Do you feel any health problems caused by exposure to biological and chemical factors present in the workplace?"). The questions checking employees' knowledge constituted the main part of the questionnaire subject to reliability assessment (validation of the questionnaire). The Cronbach's alpha coefficient was 0.71, indicating the cohesion of respondents' answers to questions from the knowledge contained in the survey.

A request to perform the study was sent to the management of selected wastewater treatment plants in Lower Silesia. We obtained the agreement to conduct the study in 15 wastewater treatment plants (3 large – wastewater capacity $>10,000\text{ m}^3/24\text{ h}$ and 12 small – wastewater capacity $<10,000\text{ m}^3/24\text{ h}$).

The study group consisted of 107 employees of the wastewater treatment plants in Lower Silesia, who

agreed to participate in the study. Data were collected through face-to-face interviews.

After collecting the data we created a computer database containing the information from the questionnaires. Statistical analysis was performed according to the purpose of the survey.

The workers' knowledge was assessed on the basis of the percentage of correct answers.

The study was approved by the Bioethics Committee of the Wroclaw Medical University (Approval No: KB 385/2016).

Data analysis

Statistical analysis was performed using Statistica 12.0 for Windows. Logistic regression (multi-factor and single-factor models) was applied to investigate the influence of various factors on the workers' knowledge. Odds ratios (OR) with 95% confidence intervals (CI) were calculated. The analysis included the following factors: workplace (type and size of wastewater treatment plant), gender, age, work experience, education. We used $p < 0.05$ as a criterion for statistical significance.

Results

Demographic characteristics

The characteristic of the study population is presented in Table I. The majority of respondents were employed in the mechanical-biological wastewater treatment plants. Chemical methods of wastewater treatment were used only in 12.1% of the respondents' workplaces. Over 50% of the workers worked in small wastewater treatment plants with capacity $<10,000\text{ m}^3/24\text{ h}$. The majority of the workers were men between 53 and 68 years old with over 15 years of working experience. The majority of workers completed vocational or secondary education.

According to the regulations, the employees had undergone training in the field of occupational health and safety (about health hazards in their workplace and possible protective measures) before taking a job and during work.

Workers' knowledge about hazards in their occupational environment

When asked about the biological and chemical factors present in their occupational environment 79.4% of the respondents had over 50% correct answers; 44.9% of the respondents had over 75% correct answers. Correct answers of the respondents were as follows:

- is direct contact with wastewater harmful to human health? (yes) – 104 indications (97.2%);
- to which biological factors are you exposed in your workplace at the wastewater treatment plant? (bac-

Table I. Characteristics of studied population of employees in wastewater treatment plants
Tabela I. Charakterystyka badanej populacji pracowników oczyszczalni ścieków

Characteristics /Charakterystyka		Employees /Pracownicy	
		N=107	%
workplace – type of wastewater treatment plant /miejsce pracy – rodzaj oczyszczalni ścieków	mechanical-biological /mechaniczno-biologiczna	94	87.9
	mechanical-biological-chemical /mechaniczno-biologiczno-chemiczna	13	12.1
size of a wastewater treatment plant – capacity /wielkość oczyszczalni ścieków – przepustowość (m ³ /24 h)	< 10,000	68	63.6
	≥ 10,000	39	36.4
sex /płeć	men /mężczyzna	101	94.4
	women /kobieta	6	5.6
age (years) /wiek (lata)	21-36	16	15.0
	37-52	37	34.6
	53-68	54	50.4
education /wykształcenie	primary school /podstawowe	7	6.5
	vocational school /średnie	46	43.0
	comprehensive school /zawodowe	39	36.5
	university /wyższe	15	14.0
work experience (years) /staż pracy (lata)	<1	6	5.6
	1-5	12	11.2
	6-15	32	29.9
	>15	57	53.3

- teria, viruses, parasites, protozoa, insects, secretions and excretions of human/animal, pathogenic fungi) – 70 indications (65.4%)^a;
- to which chemicals are you exposed in your workplace at the wastewater treatment plant? (heavy metals, aromatic hydrocarbons, dioxins and furans, degradation of organic substances with a sharp odor, organic solvents) – 41 indications (38.3%)^b;
 - which gases are produced in decomposition of substances of plant and animal origin? (hydrogen sulfide, ammonia, methane, carbon dioxide) – 70 indications (65.4%)^c;
 - in which period of the year are you the most exposed to biological factors in the workplace? (4 seasons of the year) – 84 indications (78.5%)^c;
 - in which period of the year are you the most exposed to chemicals in the workplace? (4 seasons of the year) – 93 indications (86.9%)^c;
 - which wastewater treatment processes pose the greatest risk of exposure to biological and chemical factors? (during all steps of wastewater treatment: mechanical, biological, chemical wastewater treatment, sludge treatment) – 77 indications (72.0%)^c;
 - which are routes of entry of pathogens (biological and chemical) into the human body in your workplace? (via the respiratory tract, the gastrointestinal tract, the mucous membranes and skin) – 75 indications (70.1%)^c;
 - what is bioaerosol? (Microbes, their toxins and fragments of microorganisms suspended in the air in the form of drops or solid particles) – 53 indications (49.5%)^c;
 - is exposure to bioaerosol dangerous to the employee's health? (yes) – 81 indications (75.7%)^c;
 - when is bioaerosol emitted in your workplace? (during all technological processes of wastewater treatment: near the objects associated with the

sludge, during mechanical treatment wastewater, near the biological reactor) – 61 indications (57.0%)^d;

- which health problems may be the result of exposure to harmful biological factors in your workplace? (hepatitis A, hepatitis B i C, gastric diseases, food poisoning, asthma, skin allergies, eye irritation, irritations and infections of the upper respiratory tract, giardiasis, mycosis) – 57 indications (53.3%)^e;
- which health problems may be the result of exposure to chemicals in your workplace? (organs damage, eye irritation, irritations and inflammation of the upper respiratory tract, headache and dizziness, cancers) – 82 indications (76.6%)^b.

Proportion of employees indicating at least: ^a – 5 out of 7 correct answers; ^b – 3 out of 5 correct answers; ^c – 3 out of 4 correct answers; ^d – 2 out of 3 correct answers; ^e – 8 out of 10 correct answers.

Almost all the workers were aware that direct contact with wastewater was dangerous to health. Approximately 70-87% of the respondents were able to indicate the period of greatest exposure to these factors, health problems that may be the result of exposure to chemicals, health hazards related to exposure to bioaerosol, routes of entry of pathogens into the human body and wastewater treatment processes posing the greatest exposure risk to these factors. 'The most difficult' were the questions about the definition of the term 'bioaerosol' and about the chemicals that wastewater treatment plant workers are exposed to – less than 50% of the respondents reported correct answers. For the other questions, the percentage of respondents indicating correct answers was: 53.3-65.4%.

According to the respondents, their knowledge of biological and chemical factors came mainly from OSH (occupational safety and health) training.

The employees' answers to the question: "How do you assess your knowledge about biological and chemical factors in the workplace and methods of protection against them?", indicated that self-assessments of their level of knowledge (5-point scale) differed significantly from the actual one (also 5-point scale) calculated on the basis of percentage of correct answers: less than 31% – insufficient {1}; 31-50% – poor {2}; 51-74% – satisfactory {3}; 75-90% – good {4}; over 90% – very good {5}. Only 24.3% of the respondents (26 persons) correctly assessed their knowledge. The employees most often assessed their knowledge as 'satisfactory' (29.0%; 31 respondents) or 'good' (54.2%; 58 respondents), which in some cases was overstated. On the other hand, only in 15.8% of the employees with the highest level of knowledge (over 90% of correct answers) assessed their knowledge as 'very good' (3/19 persons).

Workers' safety practices to prevent exposure to recognized hazards

To the questions: "Have you been informed about any risk of exposure to biological and chemical factors associated with working in a wastewater treatment plant?" and "Have you been informed about the basic rules of conduct in case of risk of infection in the workplace?" – respectively: 98.1% (105 workers) and 96.3% of the respondents (103 workers) answered in the affirmative. However, 28.0% of the workers (30 persons) were not aware of exposure to bioaerosol on their workplace ("Is there a risk of bioaerosol exposure in your workplace?"). The workers were also asked about situations of particular exposure to biological or chemical factors in the workplace – 22.4% of the respondents (24 workers) reported the following situations: fall into the cesspit, eye irritation with lime, staphylococcal poisoning during handling of the compactor, symptoms of hydrogen sulphide poisoning during the repair of the press.

The employees' answers to the question: "Which methods of protection against biological and chemical factors do you use in your workplace?", indicate that the most commonly used are: personal protective equipment (PPE) – 100.0% (107 persons); personal hygiene – 95.3% (102 persons); periodic medical examinations – 94.4% (101 persons) and following occupational safety and health (OSH) rules – 94.4% (101 persons), a little less often: vaccination – 77.6% (83 persons) and ventilation of rooms – 66.4% (71 persons), while the least often: disinfection of rooms – 25.2% (27 persons).

The workers were also asked about their propositions to increase safety and protection from harmful biological and chemical factors in workplace. Their suggestions were as follows: safer technologies to minimize harmful emissions – 57.9% (62 persons);

more frequent training on worker health protection methods – 51.4% (55 persons); modern PPE – 38.3% (41 persons) such as forced air respirators; established restrictive standards for the concentrations of harmful substances in the air – 27.1% (29 workers); there is sufficient protection against harmful risk factors at my workplace – 23.4% (25 workers); others – 3.7% (4 workers): e.g. disinfection of equipment, enforcement of standards and use of PPE.

The respondents also indicated against which diseases they had been vaccinated due to the occupation. Most of the workers were vaccinated against tetanus – 69.2% (74 persons), a little less often – against: hepatitis A – 49.5% (53 persons), typhoid fever – 44.9% (48 persons) and hepatitis B – 36.4% (39 persons). 9.3% (10 persons) of the workers had also been vaccinated against influenza and borreliosis, while 1.9% (2 persons) – against rabies. Some of them were vaccinated on their own – 8.4% (9 persons). Surprisingly, about one quarter of the employees were not vaccinated at all at work – 24.3% (26 persons).

In the question: "How do you assess the employee's safety policy in the workplace?" (5-point scale), the employees most often (47.7%; 51 persons) put in a 'good' grade {4}; rarely (in 0.9-1.9%; 1-2 persons) – 'insufficient' {1} and 'poor' {2}. The frequency of other ratings ('satisfactory' {3} and 'very good' {5}) was in the range of 20.5-29.0% (22-31 workers).

Factors related to workers' knowledge

A multi-factor analysis indicated only a significant influence of education on the employees' knowledge (Table II). For single-factor analyses, the correlation was demonstrated between the size of the wastewater treatment plant and the respondents' knowledge. The larger the wastewater treatment plant, the greater the workers' knowledge about the occupational hazards in wastewater treatment plants and their effects on human health (OR = 2.47; CI 1.09-5.59).

There were no evident relationships between the knowledge of the workers and the protection methods used and the occurrence of exposure situations to harmful factors. There was also no significant impact of the respondents' knowledge and the protection methods used on their health (only 1/4 of employees (27 persons) reported frequent complaints related with work in wastewater treatment plants: upper respiratory tract infections, cough attacks, eye irritation, skin irritation, onychomycosis, staphylococcal infections, gastrointestinal complaints).

Discussion

The number of wastewater treatment plants in Poland is constantly rising. From 2000 to 2015, the number of urban wastewater treatment plants increased by 14% (913 of plants). Polish villages are

Table II. Analysis of impact of various factors on knowledge of employees in wastewater treatment plants

Tabela II. Analiza wpływu różnych czynników na wiedzę pracowników oczyszczalni ścieków

Factors	OR	95% CI	p
workplace – type of a wastewater treatment plant /miejsce pracy – rodzaj oczyszczalni ścieków	0.94	0.24, 3.72	0.925
size of a wastewater treatment plant /wielkość oczyszczalni ścieków	2.26	0.92, 5.54	0.071
gender /płeć	2.05	0.33, 12.79	0.438
age /wiek	0.99	0.95, 1.03	0.733
education /wykształcenie	1.86	1.06, 3.28	0.029
work experience /staż pracy	1.30	0.76, 2.21	0.327

served by 2563 treatment plants. This increase is due to the environmental action from the EU guidelines (mostly the Water Framework Directive). Of the 227 wastewater treatment plants localized in Lower Silesia – 15 participated in the study [10].

In Poland, over ten thousand workers are employed in the wastewater industry, with an average of 10 employees in wastewater treatment plants with capacity of about 5000 m³/24 h. Most of the participants of the study (63.6%) were employed in small wastewater treatment plants (capacity <10,000 m³/24 h). According to this probably their exposure to biological and chemical factors is lower than in larger wastewater treatment plants. However, the exposure to occupational hazards is also determined by the level of technical progress of the purification process. In the modern wastewater treatment plants fewer employees work manually, because more often they supervise the automated processes. In our study the majority of respondents were employed in the new treatment plants or the modernized older treatment plants [11].

Various pathogens may be present in wastewater. Thus, the wastewater treatment plants' workers should be aware of the hazards arising from direct contact with wastewater and from the emission of pollutants into the air. The respondents' level of knowledge was not satisfactory. Only 44.9% of the respondents correctly answered over 75% of the questions. There is not much research in this field. However, in the THESEIS project the analyses of knowledge and skills related to wastewater infrastructure revealed that over 60% of the respondents were sufficiently informed about the biological hazards and aware of their effects [12]. Differences in the results may be related to the fact that our study was carried out using the face-to-face method. The THESEIS project research was conducted by sending out questionnaires, which means there is uncertainty that the respondents had completed the questionnaires themselves.

The respondents proved better knowledge of harmful biological factors than of the chemicals present in the occupational environment. The most com-

monly mentioned were biological factors such as bacteria, parasites, viruses, while among chemicals: heavy metals, organic substances with a sharp odor. Similar results were also obtained by Zielińska-Jankiewicz, et al. [3, 4], except that the respondents more often mentioned pathogenic fungi instead of parasites. For heavy metals, their source in wastewater is both industry and households (laundry effluents containing chromium, lead that are present in dyes) [13]. Organic substances with an acute odor are also an inherent part of the wastewater treatment plants, because they are formed in the rotting process [14]. An unpleasant odor was noticeable in almost every examined wastewater treatment plant. However, it was more intensive and had a greater reach in larger plants – it often exceeded the area of the wastewater treatment plant.

Approximately 65% of the respondents knew which gases were generated during the decomposition process. They most often mentioned: hydrogen sulphide, odorless methane and ammonia. Less than half of the respondents indicated carbon dioxide, probably because of its odorlessness and common occurrence in the atmosphere (it is also produced in processes such as breathing and burning) [15].

The periods of occurrence of the highest concentrations of both chemical and biological factors may be different in individual plants [16]. The respondents most frequently answered that they were exposed to these factors throughout the year. The majority of workers claimed also that during most processes there was a similar risk of exposure to them. The studies of Korzeniewska [6], Michałkiewicz, et al. [2] and Sanchez-Monedero, et al. [17] confirm that the highest concentrations of harmful factors were reported at the objects associated with both pre-treatment of wastewater, biological treatment and treatment of sludge.

Although only about half of the surveyed employees correctly answered the question “What is bioaerosol?” and “When (where) is it emitted?”, three fourth of the respondents realized that it was dangerous to health. The harmful effects of bioaerosol are confirmed by the studies of Malakootian, et al. [18] and Haldal, et al. [19]. It is one of the main health hazard of wastewater treatment plants workers. It may cause respiratory system symptoms, headaches, unusual tiredness [19] and also dizziness, abdominal pain, eye irritation [18].

Most of the respondents indicated all possible routes of entry of pathogens into the human body (via the respiratory tract, the gastrointestinal tract, the mucous membranes and skin). *Actinobacteria*, *Escherichia coli* and endotoxins may enter human body via respiratory tract; *Salmonella*, *Shigella* – via gastrointestinal tract; *Staphylococcus aureus* – through the mucous membranes of the eyes [6]; viruses, such as e.g. HBV, HCV – through damaged skin [16].

53.3% of the respondents were aware of the health effects related to the exposure to harmful biological factors. They most commonly mentioned: food poisoning, skin allergies, hepatitis A, eye irritation, upper respiratory tract irritation, mycosis and gastric diseases (e.g. gastritis induced by *Helicobacter pylori*). In our study each of the employees pointed out at least one of these diseases. In contrast, in the study of Zielńska-Jankiewicz, et al. – 38.0% of the respondents did not mention any disease caused by exposure to biological factors in the workplace (wastewater treatment plant, waste dump) [4]. However, both in our and their studies, viral hepatitis was at the forefront of listed health disorders. This finding suggests that probably employees are aware of the recommendations for vaccination against hepatitis A.

In our study, the respondents claimed that exposure to harmful chemicals might cause upper respiratory tract irritation, headache, dizziness, damage to organs (e.g. kidney, liver). Irritation of the upper respiratory tract is related with substances with acute irritating odor, such as ammonia and hydrogen sulphide [20]. Moreover, hydrogen sulphide can lead to headaches, dizziness, and even sudden death (at very high concentrations in the air) [8]. Chemicals such as heavy metals, organic solvents, aromatic hydrocarbons may cause damage to kidneys and liver [21].

Very important finding is that the participants of our study were aware that direct contact with wastewater was dangerous to their health. Moreover they proved knowledge on methods of protection against hazards present in their workplace. 100.0% of the respondents reported that they used PPE. This findings agree with the study about the knowledge of workers in three occupational groups: health services, wastewater treatment plants and foresters [3, 4]. Moreover the participants of our study followed the rules of occupational safety and hygiene. They were regularly examined during periodic medical examinations. Furthermore 77.6% of the respondents were vaccinated. Most often they were vaccination against: tetanus, hepatitis A and typhoid fever. Unfortunately, not all of the employees benefited from this form of protection (approximately 20% of the respondents were not vaccinated).

The respondents most often assessed the health policy realized in their workplaces as 'good', which proves their satisfaction and sense of safety at work. Nevertheless, most of them were aware what could be improved. According to the employees the strategies to increase safety and protection against the harmful factors in their workplace include: safer technologies to minimize harmful emissions, more frequent training on worker health protection methods, modern PPE

such as forced air respirators. The employees surveyed by the Institute for Environmental Protection – PIB (THESEIS project) also pointed out the need for more frequent and more detailed OSH training [2]. An important implication of these findings can be the creation of an innovative model of employee training (regular training providing better knowledge of occupational health and safety, harmful risk factors present at work, including practical exercises – examples of risky situations and proper behavior. It seems important to point out that the employees appreciate modern solutions (safer technologies and modern PPE). They realize that the automation of cleaning processes and the minimization of activities which require direct contact with wastewater increase the safety at work. If modernization of the purification processes is impossible, modern PPE should be used to minimize the absorption of harmful factors.

The logistic regression analysis showed that education and the size of the wastewater treatment plant in which workers were employed, were significantly impact on their knowledge. Our observations about the role of education in educating employees are not new [22]. The higher the education, the better knowledge of issues related to exposure to harmful factors in the workplace. While according to the employees, the main source of their knowledge was OSH training.

It seems important to add that workers from larger wastewater treatment plants had better knowledge. Perhaps it could be related to more frequent occupational health and safety training due to greater exposure to harmful factors in large plants.

Most employees (54.2%) assessed their level of knowledge as 'good', but it was not always reflected in the correctness of the responses. Because of the differences between the self-reported level of knowledge and the level of knowledge (assessed on the basis of the percentage of correct answers), there is a need for further training of the employees.

Most of the studies in which the health status of wastewater treatment workers was examined revealed that the employees had a high incidence of diseases of respiratory tract, gastrointestinal tract, infections of skin and mucosal membrane of the eye (work-related symptoms). In our study the respondents reported similar disorders, but the percentage of complaining workers was lower (only 25.2% of the respondents) than in other plants [19, 23]. Perhaps it is related to the use of sufficient protection against exposure to harmful factors in the wastewater treatment plants in Lower Silesia. Besides, it is also possible that the workplaces analyzed in our study emitted less pollution, because most of them had a wastewater capacity $<10,000 \text{ m}^3/24 \text{ h}$.

Conclusion

From the outcomes of our investigation it is possible to conclude that the knowledge of the wastewater treatment plant workers about the biological and chemical factors present in their occupational environment is at an average level. However, they are aware of the danger related with the exposure and the possibilities of protection. Nevertheless, especially in smaller plants it would be worthwhile to increase the frequency of training and pay more attention to the topics about the harmful factors. Although not all respondents reported work-related symptoms, it is necessary to introduce more modern technologies to improve occupational safety to minimize the risk of health problems. It is also important to introduce

strategies to strengthen enforcement mechanisms to follow recommendations for immunization – to vaccinate workers against hepatitis A, tetanus and typhoid. Some workers do not realize the role of vaccinations, because they are not aware that the vaccines provide the most effective protection for human health. It would also be useful to pay attention to immunization against hepatitis B, because direct contact with wastewater poses a risk of transmission of the virus through damaged skin.

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