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ACTUAL PROBLEMS OF OCCUPATIONAL HEALTH AT AGRICULTURAL ENTERPRISES

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The aim of the work was to review the studies on biological factors, having been conducted in the following branches of agricultural industry in Ukraine: cattle-breeding enterprises (farms) for cows and pigs, animal feed facilities, production of biofuel from rape and pellets of the agricultural waste (wood and straw). In all facilities there have been determined: concentrations of the dust and microorganisms in the air and species composition of microflora. The dust concentrations in animal farms ranged from 6–218 mg/m³, while in animal feed facilities they ranged from 30–260 mg/m³. The dust concentrations in the facilities, producing biofuel from rape, were in the range of 4,0–28,0 mg/m³, in agricultural waste (wood and straw) – 4,8–16,0 mg/m³. The determined values exceeded the maximal available concentration (MAC) in most cases, which were 4 mg/m³. The concentrations of microorganisms in animal farms were $5,8 \cdot 10^4$ – $1,9 \cdot 10^7$ cfu/m³ and $4,8 \cdot 10^4$ – $1,6 \cdot 10^6$ cfu/m³, respectively, while in animal feed facilities they ranged from $2,8 \cdot 10^4$ to $2,9 \cdot 10^9$ cfu/m³ and from $1,9 \cdot 10^3$ to $2,2 \cdot 10^6$ cfu/m³, respectively. The concentrations of microorganisms in the facilities, producing biofuel from rape, were in the range of $1,6 \cdot 10^3$ – $5,8 \cdot 10^6$ cfu/m³, in agricultural waste (wood and straw – $1,7 \cdot 10^4$ – $1,8 \cdot 10^5$ cfu/m³). The results of microbiological investigations, conducted in various kinds of agricultural settings, indicate clearly that the airborne biological factors play a primary role among occupational risk factors, which can exert harmful effects on the state of health of the exposed workers. The formation of the harmful biological factor depends on the specificity of the setting, kind of technological operations, degree of mechanization, properties of the processed materials, temperature and humidity, and the concentration of the dust in the air.

Key words: biological factor, agriculture, dust, microorganisms, bacteria, fungi

Introduction

There are many agricultural facilities in which biological factors is a main occupational hazard. These facilities cover both small farms and great industrial complexes, such as animal feed factories. Recently, there has been found a number of facilities, processing genetically modified plants, for production of diesel biofuel from rape and agricultural waste, using wood and straw as pellets [24].

In the present time there are known constituents of agricultural bioaerosols, which can cause such infectious diseases as: anthrax, Q fever, ornithosis, tularemia, brucellosis, salmonellosis, aspergillosis and many others [4]. Pathogenic properties of «saprophytic» bacteria and fungi are known by their ability to produce allergens and toxins (endotoxins, mycotoxins). They play an important role in etiology and pathogenesis of different human work-related respiratory diseases, such as extrinsic allergic alveolitis (hypersensitivity pneumonitis), allergic rhinitis, bronchial asthma, organic dust toxic syndrome (ODTS, toxic pneumonitis), and pulmonary mycoses [10].

So, the *aim of the present work* was to review the results of studies on biological factors, which have

been conducted in some important branches of agricultural industry.

Subjects and methods

The studies were performed in 10 animal houses, 5 animal feed facilities, 6 factories, producing diesel biofuel from rape and agricultural waste from wood and straw as pellets.

The hygienic estimation of microclimate and dust was conducted according to the State Standard. The dust concentration was determined by a gravimetric method. In general, there have been examined 1400 dust samples.

The microbiological samples were collected by the method of impaction on agar media, using a Krotov impactor. Bacterial samples were detected by microscopic and biochemical methods, as recommended in the Bergey's Manual. Fungi were determined by microscopic and biochemical methods, according to Bilay & Pidoplitchko [1], and Pidoplitchko [15].

The microbiological air pollution was assessed basing on the GOST (Standard) 12.1.005-88 [18]. In general, there have been analyzed 2400 microbiological samples.

Technological processes. Investigations of the technological processes in the examined facilities showed that they included similar operations: transportation, unloading and loading, weighting, and storage of materials and the final products. In animal farms the most important operations are feeding and sweeping the rooms, while in animal feed facilities and in other facilities when processing plant materials the operations included drying, sieving, grinding and granulation of the product.

Microclimate. In formation of bioaerosols, temperature and relative air humidity in production rooms and in the outside environment play a significant role. It was found that changes of microclimate parameters in all examined facilities showed similar trends and distinguished itself by the marked fluctuations, depending on production specificity, construction failures, operation of the ventilation system and on the season of the year.

In animal houses, the mean air temperature varied in the cold period between 8–18 °C and in the warm period – between 15–27 °C. The relative humidity was between 52–83 % [19].

When processing plant materials for biofuel, the air temperatures were 15–19 °C in the cold period and in the warm period – 20–30 °C. The relative air humidity varied from 60 to 75 %. The high temperatures up to 30 °C were recorded when drying the plant material [24].

In animal feed facilities, the air temperatures varied in the cold period from 15 to 20 °C and in the warm period – 22–35 °C. The relative humidity was between 60–80 %. High air temperatures were recorded in the rooms for thermal processing, grinding and granulating the plant material [19].

Dust. In agricultural settings, most of technological operations are accompanied by the dust emissions into the breathing zone of workers. This is an organic dust, consisting of many components. It contains silica, biologically active plant and animal substances with allergenic properties, wide spectrum of microorganisms and their products (toxins, enzymes), and other biological agents, such as particles of mites and insects.

It has been found that the dust concentration in animal houses was 6–208 mg/m³. High dust concentrations were found in loading the fodder, feeding animals and when removing the manure. The dust concentration in the air (4 mg/m³) exceeded the MAC by up to 50 times [17].

In facilities, processing the rape for biofuel, the dust concentration in the air ranged between 3,6–28,0 mg/m³ [24]. High dust concentrations were

recorded in transportation, sieving and drying of the rape, wood and straw. The MAC was exceeded up to 7 times, less than in other agricultural settings. The relatively low dust concentrations could be explained by high humidity of the processed plant material, significantly decreasing the dustiness.

In animal feed producing facilities, the dust concentrations in the air were between 35–306 mg/m³. High dust concentrations were recorded in grinding and granulating the feed and in distribution of the final product. The MAC was exceeded by 8–75 times.

In all examined facilities the dust emissions depended on the level of mechanization, equipment, proportion of the operations taken manually, and of properties and the degree of dustiness of the materials being processed.

The organic dust presents a favorable medium for numerous species of bacteria and microscopic fungi, able to produce allergens and toxins, depending on the temperature and air humidity [7, 8, 16].

In all examined facilities there was found a direct positive correlation between the concentrations of dust and microorganisms in the air of working zone. The correlation coefficients (r) ranged from 0,7 to 0,8, at $p < 0,01$.

Microorganisms. The concentrations of microorganisms in the air of the working zone in animal houses ranged from $5,8 \cdot 10^4$ to $1,9 \cdot 10^7$ cfu/m³. The maximum allowable concentration (MAC, equal to $5,0 \cdot 10^4$ cfu/m³) was exceeded by up to 380 times. The highest concentrations were recorded in unloading the plant materials, when feeding animals and cleaning animal rooms.

In processing the rape for diesel biofuel, the concentrations of microorganisms in the air ranged from $1,5 \cdot 10^3$ to $5,8 \cdot 10^6$ cfu/m³. The greatest concentrations were found in loading, transportation and drying the rape. The microbiological component included a wide range of bacteria, microscopic fungi and their metabolic products – endo- and mycotoxins. It was found that straw samples were significantly more contaminated with bacteria than wood sawdust, wood pellets and briquettes; the concentrations of endotoxins in the straw were significantly higher than in other types of the material. The excess was from 2 to 50 times and, in some cases, by 100 times. The concentrations of microscopic fungi in straw were significantly higher than in other raw materials.

High concentrations of fungi and endotoxins were recorded in the mechanical processing of straw. In wooden and straw dust there were also found mycotoxins, produced by fungi *A. fumigatus*, which could

produce infectious, allergenic and carcinogenic effects on the working environment [8, 9, 11].

In animal feed facilities, the concentrations of microorganisms in the air ranged from $2,7 \cdot 10^4$ to $2,6 \cdot 10^9$ cfu/m³. The marked excess of the MAC value was noted in unloading, grinding, drying, and granulation of the raw material and in distribution of the finished products [7]. In these facilities there was studied the dynamics of the microbial pollution in the course of the work shift by determining concentrations of microorganisms in washings from the technological equipment, protective clothing and skin on the hands of workers, which were distinctly greater in the middle of the work shift than at its beginning. The species composition of the microflora, taken from the washings, showed a close identity with that determined in the air samples taken in animal feed facilities. The concentrations of microorganisms in samples, washed off from the surface of the skin, showed a significant correlation with the concentrations of the dust in all production departments ($r = 0,7$, $p < 0,05$), and in non-production rooms ($r = 0,9$, $p < 0,01$).

For determination of the sources of microbial pollution in the working zone, numerous samples were taken from various raw materials and animal foods. It was found that all kinds of the raw materials, as well as animal foods and the finished products, were highly polluted with a wide spectrum of microorganisms. All these materials represent a good nutrient medium for preservation of the vital functions of microorganisms and their propagation. A species composition of the microflora, polluted by these materials, corresponded to that found in the air of agricultural facilities, in washings from the equipment, clothes and hands of workers.

Thus, a large number of microorganisms, contaminating the air of the breathing zone and other elements of working environment, come from the processed raw materials. In animal houses – an additional source of microbial contamination are animals themselves and products of their metabolism (feces, urine, saliva, milk).

The analysis of the species composition of the microflora in the air of agricultural settings showed that bio-aerosol in all those settings contained a wide range of microorganisms. In those settings there were recorded high concentrations of Gram-positive spore-forming bacilli of the genus *Bacillus*. These bacteria made up 10–24 % of the total microbial pollution in animal farms, 12–66 % – in animal feed facilities and 0,2–12,0 % in

facilities, processing rape for biofuel. The most popular species were: *Bacillus subtilis*, *B. cereus*, *B. alvei*, *B. laterosporus*, *B. circulans*, *B. megaterium*, *B. pumilus*, *B. stearothermophilus*, *Clostridium tetani*. According to some reports, these bacteria may be hazardous for human respiratory system. It has been shown that the aerosol, containing spores of *B. subtilis* and *B. licheniformis*, can cause extrinsic allergic alveolitis [3, 5, 6, 9].

The other Gram-positive bacteria, mostly cocci, made up 5–35 % of the total microbial pollution in animal farms, 0,2–14,0 % in animal feed facilities and 0,5–8,0 % in facilities, processing rape for fuel. The most popular cocci were: *Staphylococcus aureus*, *S. epidermidis*, *S. saprophyticus*, *Streptococcus faecalis*, *S. faecium*, *S. mitis*. These species may cause infections and inflammatory processes. Other Gram-positive bacteria, found in the examined settings, were thermophilic actinomycetes, producing small spores which may penetrate into deep parts of lungs and cause extrinsic allergic alveolitis. Of these bacteria there were distinguished: *Saccharopolyspora rectivirgula*, *Thermoactinomyces vulgaris*, *T. thalophilus* and *Saccharomonospora viridis*.

The other group of potentially pathogenic microorganisms is Gram-negative bacteria. They made up 16–45 % of the total microbial samples in animal farms, 4,4–23,1 % in animal feed facilities and 0,2–5,0 % in facilities, processing rape for fuel. The prevailing species were: *Proteus vulgaris*, *P. mirabilis*, *Pantoea agglomerans* (synonyms: *Erwinia herbicola*, *Enterobacter agglomerans*), *Escherichia coli*, *Citrobacter spp.*, *Pseudomonas spp.*, *Klebsiella spp.*, *Alcaligenes spp.*, *Acinetobacter spp.*

Microscopic fungi formed a large part of the microflora, available in the air of agricultural settings. They made up 12–28 % of the total microbial samples in animal farms, 20–44 % in animal feed facilities and 15–85 % in facilities, processing rape for fuel and agricultural waste from wood and straw as pellets. [13, 14, 24, 25].

Discussion

The presented results show that in the various branches of agricultural industry in Ukraine the levels of the airborne dust and microorganisms exceeded the safe levels in most cases and that they can be a potential cause of work-related respiratory diseases.

The airborne microflora of agricultural settings includes Gram-positive bacteria, Gram-negative

bacteria and fungi. On the average, Gram-positive bacteria, composed of corynebacteria, cocci, bacilli and actinomycetes, present a prevailing part of the microflora. These bacteria produce peptidoglycan, a cell wall component with inflammatory properties, and some species (such as thermophilic actinomycetes, *Arthrobacter spp.*) can be a cause of allergic alveolitis [12, 21]. Gram-negative bacteria were less numerous, but were present in the air.

Gram-negative bacteria, which have been found from most places, can be a cause of allergic alveolitis and produce a biologically potent endotoxin [9] with a high molecular weight – lipopolysaccharide (LPS), resistant to high temperatures. Endotoxin is produced in the outer membrane of the Gram-negative bacteria as a heteropolymer of LPS with proteins and phospholipids and is released in large quantities in the dust [2, 6]. When inhaled by workers endotoxin activates alveolar macrophages and causes inflammatory reactions in the lung.

The concentration of bacterial endotoxin in the air, polluted with herb dust, ranged 10^{-3} – 10^3 $\mu\text{g}/\text{m}^3$ and was comparable with concentrations, found in organic dusts from grain, cotton, grasses and other plant materials [6, 8]. In animal farms the endotoxin concentration was within the range of 10^{-3} – 10^1 $\mu\text{g}/\text{m}^3$ [3], and in animal feed facilities it was in the range of 10^{-3} – 10^2 $\mu\text{g}/\text{m}^3$ [5]. In most cases the threshold limit value of $2 \cdot 10^{-1}$ $\mu\text{g}/\text{m}^3$ was exceeded.

Fungi were found in the air of agricultural settings. Their concentration and the proportion in the whole microflora created a potential hazard to the exposed workers. It has been documented by numerous studies that fungi classified earlier as «non-pathogenic saprophytes», in fact, can cause allergic diseases of lungs, allergic rhinitis, allergic conjunctivitis, allergic dermatitis and mycoses [19]. The concentrations of fungal sporules in the air of various agricultural settings can attain large concentrations, for example in animal feed facilities the concentrations were 10^6 – 10^9 cfu/ m^3 in the air.

Microscopic fungi may produce mycotoxins – low-molecular secondary metabolites, which cause severe

diseases in humans and animals. To the important producers of mycotoxins belong the general *Aspergillus*, *Penicillium*, *Fusarium*, *Cladosporium*, *Alternaria*, *Candida*, *Helminthosporium*. The list of mycotoxin-producing fungi is steadily increasing. The fungal species, identified in the air of animal feed facilities in Ukraine, can produce such mycotoxins as: aflatoxins, ochratoxins, sterigmatocystin, trichothecens and a large combination of metabolites produced by *Alternaria spp.* Among these mycotoxins there are carcinogens, mutagens, substances inhibiting protein synthesis and substances exerting harmful effects on the nervous system. It is assumed that, according to the literature data, mycotoxins can be a potential cause of malignant neoplasm in the exposed workers [2].

In conclusion, the results of microbiological investigations, performed in various kinds of agricultural settings in Ukraine, clearly indicate that the airborne biological factors play a significant part as occupational risk factors in these settings, exerting harmful effects on the state of health of the exposed workers. The presence of harmful bioaerosols depend on the specificity of the setting, kind of technological operations, degree of mechanization, and properties of the processed materials.

Also, the occurrence of bioaerosol depends on the temperature and humidity and is highly proportional to the concentration of the dust in the air. The concentration and species composition of bioaerosol is related on the microflora of the processed materials or on the microflora released by bred animals. The presence of high concentrations and wide spectrum of microorganisms in the work environment, showing infectious, allergenic, toxic and carcinogenic effects, can be a cause of work-related diseases in the exposed agricultural workers [23].

Thus, monitoring of biological factors in agricultural settings is a necessary step in developing hygienic recommendations, aiming to improve work conditions and to protect workers from dangerous health hazards.

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АКТУАЛЬНІ ПРОБЛЕМИ ГІГІЄНИ ПРАЦІ НА СІЛЬСЬКОГОСПОДАРСЬКИХ ПІДПРИЄМСТВАХ

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Мета дослідження – ознайомитись з дослідженнями біологічного фактора, що проводилися в галузях аграрної промисловості в Україні: тваринницькі підприємства (ферми) для корів та свиней, підприємства з виробництва кормів для тваринництва, виробництво біопалива з ріпака та пелетів з сільськогосподарських відходів (деревини та соломи). У всіх підприємствах були визначені: концентрація пилу та мікроорганізмів у повітрі та видовий склад мікрофлори. Концентрація пилу у тваринницьких господарствах коливалася в межах 6–218 мг/м³, тоді як у приміщеннях для тварин вона коливалась від 30–260 мг/м³. Концентрація пилу на об'єктах виробництва біопалива з ріпака була в межах 3,6–28,0 мг/м³, сільськогосподарські відходи (деревина та солома) 4,8–16,0 мг/м³. Визначені величини у більшості випадків перевищували гранично допустиму концентрацію (ГДК), яка становила 4 мг/м³. Концентрація

мікроорганізмів на тваринницьких фермах коливалася від $5,8 \cdot 10^4 - 1,9 \cdot 10^7$ КУО/м³, тоді як у кормах від $4,8 \cdot 10^4 - 1,9 \cdot 10^7$ КУО/м³ до $4,8 \cdot 10^4 - 1,6 \cdot 10^6$ КУО/м³, для тварин вона коливалася від $2,8 \cdot 10^4 - 2,9 \cdot 10^9$ КУО/м³. Концентрації мікроорганізмів на об'єктах, що виробляють біопаливо з ріпака, перебували в діапазоні $1,6 \cdot 10^3 - 5,8 \cdot 10^6$ КУО/м³. При виробництві пелетів з відходів деревини та соломи – $1,7 \cdot 10^4 - 1,8 \cdot 10^5$ КУО/м³. Результати мікробіологічних досліджень, що виконуються в різних сільськогосподарських умовах, чітко вказують на те, що біологічні чинники повітря в цих умовах відіграють основну роль як професійні фактори ризику, які можуть надавати шкідливий вплив на здоров'я працівників. Формування шкідливого біологічного фактора залежить від специфіки підприємства, виду технологічних операцій, ступеня механізації, властивостей оброблюваних матеріалів, температури та вологості, а також концентрації пилу в повітрі.

Ключові слова: біологічний фактор, сільське господарство, пил, мікроорганізми, бактерії, гриби

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АКТУАЛЬНЫЕ ПРОБЛЕМЫ ГИГИЕНЫ ТРУДА НА СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПРЕДПРИЯТИЯХ

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Цель исследования – изучение исследований биологического фактора, которые были проведены в следующих отраслях сельскохозяйственной промышленности Украины: животноводческие фермы (фермерские хозяйства) для коров и свиней, объекты животноводства, производство биотоплива из рапса и пеллет из сельскохозяйственных отходов (древесина и солома). На всех объектах были определены: концентрация пыли и микроорганизмов в воздухе и видовой состав микрофлоры. Концентрация пыли в животноводческих фермах составляла 6–214 мг/м³, тогда как в кормах для животных они составляли от 35 до 260 мг/м³. Концентрация пыли на объектах, производящих биотопливо из рапса, находилась в диапазоне 3,6–28 мг/м³, сельскохозяйственные отходы (древесина и солома) 4,8–16,0 мг/м³. Определенные значения в большинстве случаев превышали максимально допустимую концентрацию (МАС), которая составляла 4 мг/м³. Концентрация микроорганизмов на животноводческих фермах составляла от $5,8 \cdot 10^4 - 1,9 \cdot 10^7$ КУО/м³, в то время как в кормах для животных она составляла от $4,8 \cdot 10^4 - 1,9 \cdot 10^7$ КУО/м³ до $4,8 \cdot 10^4 - 1,6 \cdot 10^6$ КУО/м³ соответственно. Концентрации микроорганизмов на предприятиях, производящих биотопливо из рапса, находились в пределах $1,6 \cdot 10^3 - 5,8 \cdot 10^6$ КУО/м³. При производстве пеллет из древесных отходов и соломы – $1,7 \cdot 10^4 - 1,8 \cdot 10^5$ КУО/м³. Результаты микробиологических исследований, выполненных в различных сельскохозяйственных предприятиях, ясно указывают на то, что биологический фактор воздуха играет в этих условиях первичную роль для профессионального риска, может оказывать вредное воздействие на состояние здоровья работников. Формирование вредного биологического фактора зависит от специфики предприятия, вида технологических операций, степени механизации, свойств обработанных материалов, температуры и влажности, а также концентрации пыли в воздухе.

Ключевые слова: биологический фактор, сельское хозяйство, пыль, микроорганизмы, бактерии, грибы

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