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STUDY ON EXPOSURE OF PIG FARM WORKERS TO BIOAEROSOLS, IMMUNOLOGIC REACTIVITY AND HEALTH EFFECTS

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Abstract: Occupational inhalation of organic dust may be a cause of numerous symptoms and diseases. Organic dust consists of various biological compounds which induce inflammatory reactions in the lungs on an immunotoxic or allergic basis. Bacteria and their metabolites, moulds and their spores, mycotoxins, glucans, and other still unidentified substances, can be potential aetiologic factors of diseases caused by organic dust. The aim of this study was to determine the concentration and composition of airborne microflora in typical Polish swine buildings and to assess the health conditions of the workers employed within them. Total concentration of microorganisms in the air of five examined swine breeding farms ranged from 613.7-1246.7 × 10^3 cfu/m^3 (mean value 930.6 × 10^3 cfu/ m^3).The examination of 53 employees working in the swine buildings included their medical history, physical examination, spirometry, and allergological tests. Work-related symptoms were reported by 31 (58.5%) of the subjects. No abnormal findings were present upon physical and spirometric examinations. The results suggest the common occurrence of work-related respiratory disease in swine workers, mostly corresponding to the Organic Dust Toxic Syndrome (ODTS).

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Key words: organic dust, swine buildings, bioaerosols, bacteria, fungi, allergological tests, work –related symptoms, respiratory tract, ODTS.

INTRODUCTION

Exposure to organic dust can occur in different environments, broadly speaking in an agricultural or industrial environment, in houses and offices. In each of these surroundings, organic dust is released from miscellaneous sources and is also created by different mechanical processes, which result in the collection, concentration and distribution of dust.

Worldwide, hundreds of millions of agriculture sector, food, textile and timber industry employees are exposed to constant inhalation of heterogeneous organic dust, which could possibly alter their state of health. The effects of organic dust on human health were described for the first time in 1555 by the Danish bishop Olaus Magnus, in his book "Historia de Gentibus Septentrionalibus" in which is presented the influence of dust released during threshing on workers' health and the name for this condition is proposed as "the illness of thresh workers" [24].

Contemporary research has proved, that exposure to organic dust inhalation can generate many different groups of diseases connected with the respiratory tract, including: allergic alveolitis, organic dust toxic syndrome, bronchial asthma, chronic bronchitis and bissynosis [12, 22, 28]. The main reasons provoking the above-mentioned changes are, as is presently believed, biological factors existing in animal or plant dust, which can stimulate allergic and toxic reactions in organisms of exposed people [13, 14, 22, 33].

For the first time, Donham *et al.* in 1977 observed the harmful effects of work with swine on the respiratory tract of employees [11]. In the mid-eighties more studies on harmful influence of work in pig farms have appeared [5, 7, 8].

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In Poland, up to now, epidemiological studies concerning the influence of organic dust in swine-breeding farms on the health state of local employees have not been performed.

The aim of this study was to estimate the degree of exposure of swine-breeding farm employees to dust and microbial air contaminants, clinical evaluation of the state of health of workers exposed to organic dust, and an attempt to find a relation between exposure to aerogenic biological factors and the state of the respiratory tract among workers of swine farms.

MATERIAL AND METHODS

Examined group. The study was carried out on a group of 53 people, working in pigsties in the eastern part of Poland. Thoroughly examined were 15 workers from swine buildings in village "S" of the Lublin region, 17 workers from village "K", Chełm region, and 21 workers from village "P", Zamość region. The group consisted of 18 men and 35 women, aged between 21–60 (mean age 38.9 ± 8.06 years). As much as 35 persons were cigarette smokers, 2 were former smokers and 16 have never smoked.

Control group. The control group consisted of 53 workers of an industrial factory (machinery industry), located in the city of Lublin, with no exposure to organic dust. This group consisted of 19 men and 34 women, aged between 25–56 (mean age 40.0 ± 7.43 years). As much as 21 persons were active smokers, 32 have never smoked.

Environmental studies. Studies were performed in 3 state owned farms located in the following villages: "S" in Lublin region, "K" in Chełm region, and "P" in Zamość region.

Methods of air examination. Air samples were collected in the very centre of an examined piggery, at a height of 145 cm. Microbiological samples were collected directly on agar plates, with the use of a custom designed slit sampler, so called "selective aerobioscope" [15], which enables the determination of a total number of microorganisms in the air and its respirable fraction, i.e. that part of microbial aerosol, which has the ability to penetrate into alveoli.

In order to determine the concentration of dust and bacterial endotoxin, air samples were collected with the use of a AS-50 aspirator (TWO-MET, Zgierz, Poland) on preweighted polyvinyl chloride filters. Concentration of endotoxin was determined using Limulus test by Levine and Bang [23].

Allergological examinations. Microbial antigens were prepared from the potentially allergenic [14, 16] strains commonly found in the air of swine buildings. The antigens were selected for the research based on own results and literature data. The lyophilised extracts of bacterial and fungal mass were used, prepared as described by Milanowski *et al.* [28].

Skin prick test was done with the use of 5 environmental allergens (*Acinetobacter calcoaceticus*, *Arthrobacter globiformis*, *Corynebacterium xerosis*, *Endomycopsis capsularis* and swine serum protein). Agar gel double diffusion test was carried out according to Ouchterlony [29], with 12 environmental allergens (Tab. 5).

Clinical examination. A thorough medical history was taken, with the application of two types of questionnaires:

- ATS standard questionnaire, evolved by Ferris (1978) [18], recommended by the American Thoracic Society (ATS).
- Questionnaire evolved at the Institute of Agricultural Medicine in Lublin, concerning exposure to organic dust and evoked symptoms and signs. Several features were defined in this questionnaire: the kind of exposure (plant and/or animal dust), different types of symptoms and signs (both respiratory and general), time intervals between exposure and the onset of illness, duration of sickness.

The nature of auscultatory phenomenon over lung fields was evaluated by auscultation. Respiratory system functional tests were performed with the use of a spirometer type Vitalograph Eutest 2 L (VT–16), produced by Medicor, Budapest. The following parameters were estimated: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), index $FEV_{1\%}FVC$ according to the American Association for Respiratory Care (AARC), 1991 [1]. Results were displayed as absolute values and as a percentage of due value, according to the standards of the European Community of Coal and Steel (ECCS) [31].

X-ray examination of chest was also done in all subjects.

Statistical analysis. Statistical analysis was made by Student's t-test and analysis of variance ANOVA, using Statistica ver. 4.3. package.

RESULTS

Air pollution in piggeries. Total concentration of microorganisms in the air of five examined swine farms was in the range of 613.7–1246.7 × 10^3 cfu/m^3 (mean value 930.6 × 10^3 cfu/m^3). Qualitative composition of mesophilic bacteria in swine farms located in villages "S" and "K" was characteristic by frequent occurrence of *Corynebacterium* spp. and *Arthrobacter* spp., whereas in swine farms located in village "P" prevailed Gram-positive micrococci. Qualitative composition of microorganisms in the air of above described places is presented in Figure 1.

Concentration of mesophilic bacteria in the respirable fraction of microbial aerosol made up 22.5–49.1% of the total concentration of these microorganisms in the air. In the case of Gram-negative bacteria, fungi and thermophilic actinomycetes, respirable fraction made up respectively 37.5–52.7%; 31.1–100.0%; and 0–49.2% of the total concentration in the air.

Concentration of dust in the air of examined piggeries was between 3.03–14.05 mg/m^3 (mean value 8.76 mg/m^3).

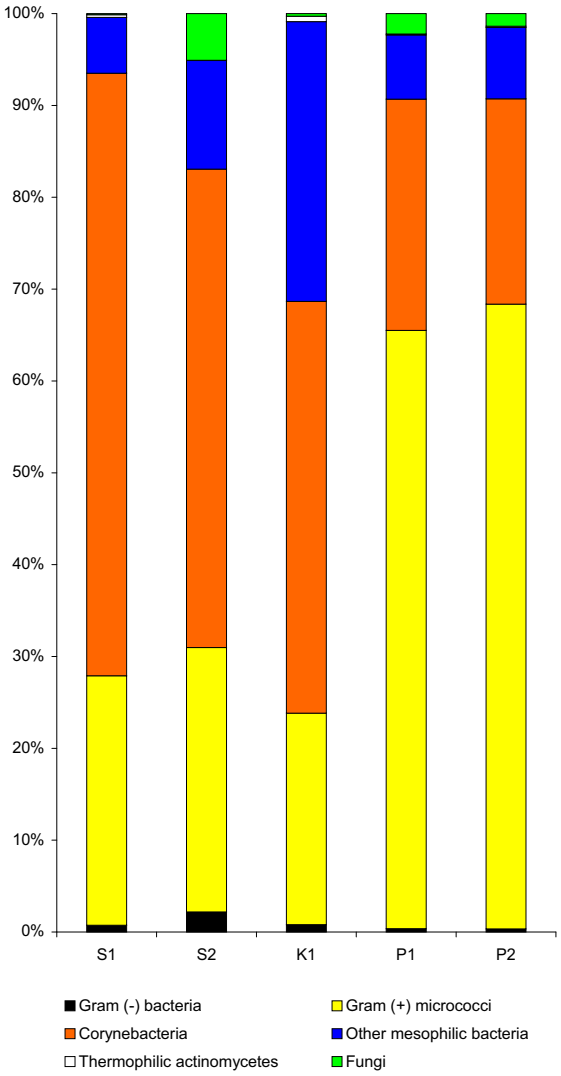

Figure 1. Composition of microflora in the air of examined piggeries.
S1 - fattening-building in village "S", S2- farrowing-building in village "S"
K1 - fattening building in village "K"
P1 - fattening-building in village "P", P2- farrowing-building in village "P"

Table 1. Frequency of positive skin reactions in piggery workers and control group.

Allergens	Piggery workers			Control group	
	n	%		n	%
Acinetobacter calcoaceticus	22	41.5	***	5	9.4
Arthrobacter globiformis	18	33.9	***	2	3.8
Corynebacterium xerosis	22	41.5	**	7	13.2
Endomycopsis capsularis	19	35.8	***	4	7.5
Swine serum protein	11	20.7	*	2	3.8

*–*** Significantly greater compared to control group; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Concentration of bacterial endotoxin in the air of examined swine buildings was within the range 1.88–31.25 µg/m^3, with the mean value 22.8 µg/m^3.

Skin test. Statistically significant differences were found in the occurrence of positive skin reactions between swine farm workers and control group ($p < 0.05$), as shown in Table 1. The workers reporting signs reacted more frequently with microbial allergens, but the differences were not significant ($p > 0.05$). A significantly higher frequency of positive skin reactions was found in swine building workers with symptoms of chronic bronchitis (84.6%) compared to those free of symptoms (52.5%).

Analyzing the frequency of occurrence of positive skin reactions with particular allergens among swine buildings workers with signs of chronic bronchitis, a significant correlation between positive skin reactions to *Corynebacterium xerosis* and the presence of signs of chronic bronchitis was found ($p < 0.05$). In the subgroup with signs of chronic bronchitis, positive skin reactions to *Corynebacterium xerosis* were present in 69.2%, while in a subgroup with no signs they were present only in 30.8%. No such relationship was proved in the case of other allergens.

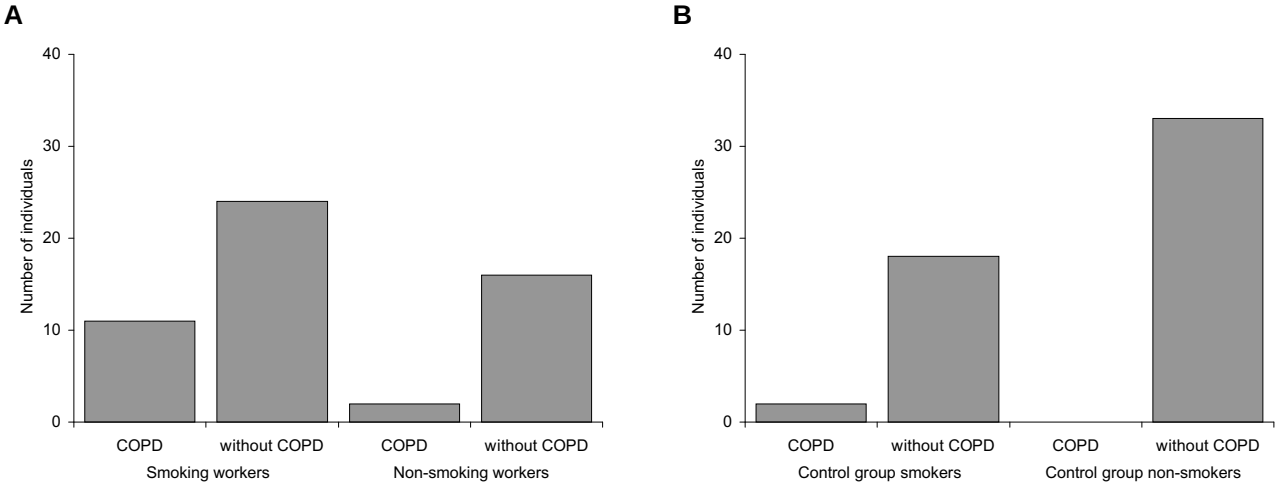

Figure 2. Frequency of COPD signs in swine buildings employees (A) and in control group (B), with recognition of smoking habits.

Table 2. Frequency of positive precipitation reactions in piggery workers and control group.

Antigens	Piggery workers			Control group	
	n	%		n	%
Erwinia herbicola	21	39.6	***	1	1.8
Escherichia coli	19	35.8	***	4	7.5
Klebsiella pneumoniae	15	28.3	***	0	0
Acinetobacter calcoaceticus	0	0		0	0
Alternaria tenuis	0	0		0	0
Arthrobacter globiformis	0	0		0	0
Aspergillus fumigatus	0	0		0	0
Corynebacterium xerosis	0	0		0	0
Endomycopsis capsularis	0	0		0	0
Micropolyspora faeni	0	0		0	0
Thermoactinomyces thalpophilus	0	0		1	1.9
Swine serum protein	0	0		0	0

*** $p < 0.001$, compared to the control group

Precipitation test. The majority of positive precipitation reactions occurred among swine buildings workers with the antigens of Gram-negative rods, of the family *Enterobacteriaceae*. In the control group, much less positive precipitation reactions were observed and the differences were statistically significant ($p < 0.001$) as it is shown in Table 2.

No statistically significant relationship was found between the occurrence of positive precipitation reactions and work-related symptoms in the examined piggery workers.

State of health of swine farm workers. Among swine buildings workers, 13 individuals (24.5%) suffered from symptoms characteristic for chronic bronchitis: cough with expectoration on a daily basis, for at least 3 months a year during successive 2 years. Among the control group, only 2 persons (3.8%) suffered these symptoms.

Table 3. Frequent symptoms related to work in piggeries.

Symptoms	Number of individuals reporting symptoms	Percent of individuals reporting symptoms
Dry cough	25	80.6
Headache	14	45.1
Conjunctivitis	14	45.1
Itching	14	45.1
Tiredness	13	41.9
Dyspnea	12	38.7
Cutaneous rash	12	38.7
Chest tightness	10	32.2
Hyperhidrosis	10	32.2
Hoarseness	9	29.0

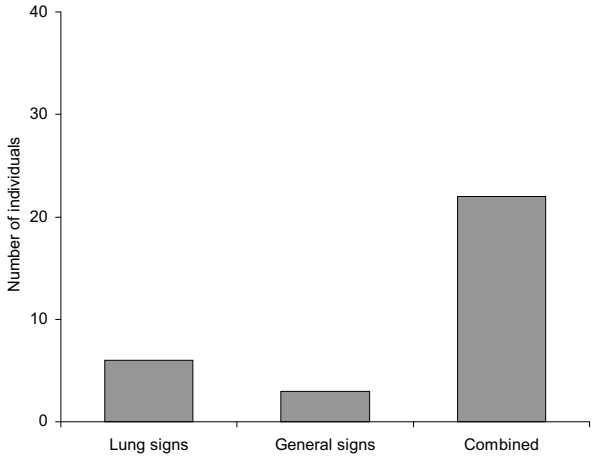

Figure 3. Frequency of the occurrence of particular groups of signs in 31 individuals showing work-related sings.

As much as 25 swine workers (47.1%) reported susceptibility to respiratory tract infections. In the control group, only 3 persons (5.7%) reported such susceptibility. The difference in the frequency of occurrence of respiratory tract chronic illnesses between swine workers and the control group was statistically significant ($p < 0.05$).

Analyzing the frequency of the occurrence of chronic bronchitis in swine farm workers and in the control group, with recognition of smoking habits it was found that the occurrence of chronic bronchitis in smokers' group working in exposure to organic dust proved to be statistically more frequent in comparison to the group of non-smokers without exposure to organic dust ($p < 0.05$). This relationship is presented in Figure 2.

In a questionnaire, concerning exposure to organic dust and evoked signs, 31 persons (58.5%) working in swine buildings reported the following symptoms directly associated with their job: dry cough in 25 persons, headache, burning sensations of conjunctivitis, and itching in 14 persons each, tiredness in 13, dyspnea in 12, cutaneous rash in 12, chest tightness in 10, hyperhidrosis in 10 and hoarseness in 9 persons. Other symptoms occurred less frequently. They included: malaise in 6 persons, rhinostegnosis in 5 persons, muscle and joints pain in 3 persons, fever in 2 persons, cough with expectoration in 2 persons and nausea in 1 person. Frequent symptoms are presented in Table 3.

Nobody in control group reported symptoms associated with job or incidental exposure to organic dust, e.g. during work in a house garden, at contact with domestic animals, or at occasional contact with stock-raising.

On analyzing the frequency of occurrence of signs solely from respiratory tract and entirely general signs, it was concluded that symptoms characteristic for respiratory tract were present in only 6 cases and general signs in only 3 cases. In the remaining 22 individuals out of 31 reporting signs associated with their job, both symptoms from respiratory tract and general ones were present. Results of this analysis are demonstrated in Figure 3.

On auscultation, single dry rales over lung fields were detected in 4 piggery workers (7.5%). Among the remaining 49 workers, physiological vesicular murmurs were detected. In the control group, pathological vesicular murmurs over lung fields were not detected.

Respiratory function tests did not show statistically significant differences between piggery workers and the control group. Spirometric results, in percentages of due values, are presented in Table 4.

Respiratory function test did not demonstrate statistically significant differences in estimated spirometric values between subgroups of swine buildings workers reporting the presence of symptoms associated with job and not reporting these symptoms ($p > 0.05$). Mean spirometric values for these subgroups are shown in Table 5.

On chest X-ray examination, only in one piggery worker (1.8%) were found intensive bronchial and peribronchial markings in lower fields of both lungs, with features of chronic bronchitis. The remaining workers did not show abnormalities in chest X-ray examination. In the control group, chest X-ray picture was normal in all cases.

Table 4. Results of respiratory function tests of system in piggery workers and control group ($\bar{x} \pm$ S.D.).

Spirometric value	Mean value in piggery workers group (%)	Mean value in control group (%)
FVC% pv	89.5 ± 9.7	86.6 ± 8.0
FEV_1 % pv	90.5 ± 9.6	89.4 ± 9.7
FEV_1 % FVC	85.8 ± 6.3	87.6 ± 6.7

Explanations: %pv = % of predicted value

Table 5. Results of respiratory function tests in subgroups with work-related symptoms and without these symptoms.

Spirometric value in % pv	Subgroup of piggery workers			
	showing symptoms (%)		free of symptoms (%)	
	mean ($\bar{x}$)	± S.D.	mean ($\bar{x}$)	± S.D.
FVC	91.2	9.0	87.2	10.3
FEV_1	92.0	10.3	88.5	8.5
$FEV_{1\%}$ FVC	85.9	6.8	85.8	5.7

Explanations: %pv = % of predicted value

DISCUSSION

Tactile contact with the natural environment, contact with plants and animals, were always thought to be beneficial for health and general well-being. In spite of the fact that first reports about the possibility of the harmful effects of organic dust on human organism go back as far the XVIth century [24], for many years attention was mainly paid to the endangering effects of industry and big city development. Health hazards associated with the work in agriculture have become of special interest among research workers yet in recent times (second part of XXth century). The harmful effects on human health of many plant and animal dust has been proved [17, 21, 26, 27].

Lately, great importance has been placed on risk caused by work in the close neighbourhood of stock-raising places, because of the exposure to particularly high concentrations of organic dust and microorganisms [2, 6, 20, 34, 35]. The stock-breeding farms are additionally contaminated by toxic gases, which undoubtedly damage mucous membrane of the bronchial tree [2, 10, 20, 30].

Air examination in swine buildings. Results of this study show that air in pigsties was contaminated by bacteria and endotoxin to a very high degree. Total concentration of microorganisms in the air of all buildings exceeded many times the Polish proposals of occupational exposure limits (OEL) [14, 19] and similar proposals elaborated in other countries [7, 9].

Qualitative composition of microflora in the air of swine buildings characterized itself by the frequent occurrence of Gram-positive mesophilic bacteria, similarly as in the studies by Crook *et al.* [5], and Clark *et al.* [3].

Endotoxin concentration in the air of swine buildings was very high. The mean concentration of bacterial endotoxin was as large as 22.8 $\mu g/m^3$, exceeding over 200 times the suggested safe level [14].

High level of microbial contamination in the examined piggeries can be potentially dangerous for employees' health. Numerous epidemiological studies on the influence of work at the exposure to organic dust accompanying swine-rearing on the state of health of employees, and also experimental research on animals e.g. that by Donham *et al.* [8], support this conclusion.

Allergological examination. Positive skin reactions in pig workers were observed significantly more frequently compared to the control subjects. Out of 53 examined pig workers, 22 (41.5%) showed positive skin reactions. Pig farmers showed the presence of serum precipitins only against three antigens of Gram-negative bacteria: *Erwinia herbicola* (synonyms: *Pantoea agglomerans, Enterobacter agglomerans*), *E. coli*, and *Klebsiella pneumoniae.* Among the controls, the response rates to these antigens were significantly lower. No significant relationship was found between the response to particular antigens and occurrence of work-related symptoms.

In general, the results obtained show that farmers are highly exposed to microbial allergens present in dust at workplaces. It suggests that there is a potential risk of occupational respiratory diseases of allergic and immunotoxic background in this group.

Clinical examination. Compared to control group of healthy urban dwellers, the group of swine buildings employees showed greater susceptibility to chronic disorders of respiratory tract such as: signs characteristic for chronic bronchitis, frequent respiratory tract infections and other diseases (e.g. pneumonia). This difference was

statistically significant, even when taking into account cigarettes smoking, which was more frequent among swine buildings employees. It indicates the existence of other factors, apart from tobacco smoke, harming the respiratory system in the environment of pig farms.

More than half of the swine buildings employees suffered from work-related symptoms. Both the character of these signs and the lack of a significant relationship between their occurrence and chest X-ray image, spirometric values and allergic reactions, suggest the presence of relatively mildly pronounced syndrome called the Organic Dust Toxic Syndrome (ODTS). This disease results from unspecific stimulation of the immune system by a high concentration of bio-active substances, mostly microorganisms and their products such as endotoxins, to which farm employees are constantly exposed. Bearing in mind that ODTS syndrome was described quite recently [32], and that its consequences are not precisely known (these could be possibly: chronic respiratory diseases, i.e. chronic bronchitis) [8, 20, 33], it would be wise to undertake actions to reduce frequency of its appearance. Among these actions are: quantitative and qualitative examination of microbiological air pollution in pig farms (as an index of exposure risk level in work environment), setting air pollution standards, improving breeding technology and organization, promotion of health education and prophylaxis among employees exposed to high risk (including individual safety measures), and providing health care services for high risk employees.

CONCLUSIONS

- Concentration of microorganisms and bacterial endotoxins in the air of pig farms was very high and exceeded levels proposed as occupational exposure limits. Respirable fraction constituted up to half of the airborne microorganisms, what considerably increases a risk to exposed farm workers.
- People employed in pigsties showed signs of chronic bronchitis significantly more often than people not exposed to organic dust. This is probably connected with high microbiological air pollution in work environment.
- Work-related symptoms were present in more than half of examined employees. The character of these symptoms indicated the common occurrence of Organic Dust Toxic Syndrome (ODTS) among this population.
- Results of this study show that work in pigsties endangers the health of employees and requests an appropriate prophylaxis (decreasing exposure risk level, promotion of individual safety measures, health education, specialist health care).

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