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Department of Hygiene, Medical University of Lublin

ALICJA WÓJCIK, IWONA LUTEREK

The analysis of occupational risk due to the exposure to some carcinogenic factors in the working environment in a chemical plant

Working environment may strongly affect the health of employees. Employees are often affected by physical, chemical, biological, psychological and social factors, including psychological stress at their workplace. Environmentally unfriendly working conditions often have a harmful and damaging effect on human body exceeding individual adaptability, which results in pathological changes.

A considerable number of carcinogens has been identified in the working environment. The best recognised among carcinogens is a group of factors of chemical origin and the occupational risk connected with the incidence of these substances is high. Harmful chemical substances may affect different systems resulting in morphological and functional changes in particular organs. There may also be after-effects of exposure to toxic substances that may develop in exposed organisms or manifest themselves in next generations. These changes often manifest themselves as a cancerous growth.

The incidence of cancer of occupational origin has been the subject of controversial opinions about its extent and importance. It is belived that environmental factors contribute to 3–5% to 30% of the total number of cases of cancer registered in one year. Multileveled etiology of cancer, its complicated and not fully recognised mechanism of development make the evaluation of the role of particular factors and their origin very difficult (1,3,4,6,7).

The aim of this study is the evaluation of exposure of employees to carcinogenic factors at some departments of a chemical plant.

MATERIAL AND METHODS

The study was carried out at different workplaces in some departments of Caprolactam Plant, which was a part of Nitrogen Plant (Zakłady Azotowe) in the years 1999–2002. The aim of the study was evaluation of the occupational risk due to the exposure to some carcinogenic factors or factors considered carcinogenic, e.g. benzene, mist of sulphuric acid, chromium compounds and formaldehyde. In the studied plant caprolactam is produced using the method of oximation of inositol followed by the rearrangement of inositol oxime to caprolactam.

The process of production consists of the following stages: production of sulphuric acid and oleum, production of cyclohexanon tetrified, production of hydroxylamine sulphate, production of caprolactam (synthesis and purification), auxiliary stage crystallization of ammonium sulphate.

Evaluation of the concentration of chemical substances was carried out according to the recommended standards: a) determination of sulphuric acid and sulphur trioxide was carried out using turbidimetric method according to PN-91/Z-04056/02; b) determination of chromium and its compounds was carried out using calorimetric method according to PN-87/Z-04126/03; c) determination of benzene at workplaces was carried out using nitration method with acetone according to PN-73/Z-04033/03.

The study included the following departments of the Caprolactam Plant: *PK – Managing director, *PKT – Vice-director, production manager, *PK-1 – Department for Inorganic Processes, *PK-2 – Department for Cyclohexanon Production, *PK-4 – Department for Hydroxylamine Production, *PKTL – Quality Testing Laboratory, *PKTB – Laboratory for Biological Water Treatment, *PKTT – Technicians, *PKU – Maintenance workers for the Caprolactam Plant. The study also included the analysis of the condition of the working population.

RESULTS

The results of measurements of the concentration of benzene, mist of sulphuric acid, chromium compounds and formaldehyde measured at particular workplaces in the Caprolactam Plant are presented in the tables. The exposure of respiratory tract and skin to chemical substances was found at all studied workplaces. Maximum and minimum values of benzene concentration in the studied departments in the years 2000-2001 are presented in Table 1. After analyzing the values of benzene concentration in the studied departments it was found that the recommended standards were not exceeded. Maximum values of benzene concentration was found in 2000 at the department PK-2 at three workplaces (1,2,3) and at the department PKU

Table 1. Values of maximum and minimum benzene concentration at the departments in the years 2000–2001

Department	Workplace	Benzene concentration max mg/m^3		Benzene concentration min mg/m^3	
		2000	2001	2000	2001
PK-2	1	2.98	1.28	0.29	0.24
	2	2.98	1.28	0.29	0.24
	3	2.98	1.28	0.29	0.299
	4	0.74	1.28	0.29	0.24
	5	0.74	1.09	0.29	0.608
PKTL	2	0.56	0.142	0.33	0.09
	3	0.56	0.142	0.33	0.09
	6	0.56	0.142	0.33	0.09
	7	0.56	1.09	0.33	0.142
PKTT	8	2.98	1.28	0.298	0.24
PKU	9	2.98	1.28	0.298	0.24
	10	2.98	1.28	0.298	0.24
	3	2.98	1.28	0.298	0.24
	11	2.98	1.28	0.298	0.24
	12	2.98	1.28	0.298	0.24
	13	2.98	1.28	0.298	0.24

NDS = 10.0 mg/m^3

Table 2. Values of maximum and minimum concentration of H_2SO_4 mist at studied departments in the years 2000–2001

Department	Workplace	Max concentration of H_2SO_4 mist in mg/m^3		Min concentration of H_2SO_4 mist in mg/m^3	
		2000	2001	2000	2001
PK-1	1	1.7	0.51	0.3	0.22
	2	1.7	0.51	0.3	0.06
	3	1.7	0.68	0.3	0.23
	4	1.7	0.51	0.3	0.38
	5	1.7	0.51	0.3	0.00
PKTL	2	0.36	1.0	0.1	0.55
	3	0.36	1.0	0.1	0.55
	6	0.36	1.0	0.1	0.55
	7	0.36	0.95	0.1	0.55
PKTB	15	0.5	1.0	0.0	1.0
	16	0.5	1.0	0.0	1.0
PKTT	8	0.05	0.51	0.31	0.045
PKU	9	1.7	0.51	0.31	0.00
	10	1.7	0.51	0.31	0.00
	3	1.7	0.51	0.31	0.00
	14	1.7	0.51	0.31	0.00
	11	1.7	0.51	0.31	0.00
	12	1.7	0.51	0.31	0.00
	13	1.7	0.51	0.31	0.00

NDS=1.0 mg/m^3

at all studied workplaces, and it was 2.98 mg/m^3. In the year 2001 maximum values of benzene concentration at the same departments and workplaces was 1.28 mg/m^3 (Tab.1). Minimum values of benzene concentration were found at the department PKTL at all studied workplaces in 2000 and it was 0.29 mg/m^3. In 2001 the minimum concentration of 0.09 mg/m^3 was found at the department PKTL.

Maximum and minimum values of concentration of the mist of sulphuric acid at the studied departments in the years 2000–2001 are presented in Table 2. The analysis of values of concentration of the mist of sulphuric acid in the year 2000 at the departments PK-1 and PKU revealed that the maximum concentration limit was exceeded. The maximum concentration of the mist of sulphuric acid was found in the year 2000 at the departments PK-1 and PKU, and it was 1.7 mg/m^3, while NDS = 1.0 mg/m^3. The maximum value of concentration in 2001 was found at the department PKTB and PKTL and it was 1.0 mg/m^3, except workplace 7, where it was 0.95 mg/m^3. At the departments PK-1, PKTT and PKU the concentration was 0.51 mg/m^3, except workplace of 3 at PK-1. Minimum values of concentration were found in 2000 at the department PKTB and in 2001 at the department PKU and they were under the detection threshold for a particular method of investigation.

Values of concentration of Cr (VI) compounds at workplaces at the Laboratory for Biological Water Treatment in the years 2000–2001 are presented in Table 3. The analysis of concentration of chromium compounds in the year 2000 and 2001 at the studied department revealed that the maximum concentration limit was not exceeded. Values of formaldehyde concentration at the

Laboratory for Biological Water Treatment in the years 2000–2001 are presented in Table 4. The analysis of values of formaldehyde concentration at the Laboratory for Biological Water Treatment revealed that concentration limits were not exceeded.

Table 3. Values of maximum and minimum concentration of chromium compounds in the years 2000 – 2001

Department	Workplace	Max concentration of chromium compounds mg/m^3		Min concentration of chromium compounds mg/m^3	
		2000	2001	2000	2001
PKTB	15	0.002	0.06	0.00	0.00
	16	0.002	0.06	0.00	0.00

NDS = 0.1 mg/m^3

Table 4. Maximum and minimum values for concentration of formaldehyde in the years 2000 – 2001

Department	Workplace	Max formaldehyde concentration mg/m^3		Min formaldehyde concentration mg/ m^3	
		2000	2001	2000	2001
PKTB	15	0,17	0,175	0,00	0,00
	16	0,17	0,175	0,00	0,00

NDS = 0.5 mg/m^3

Qualitative and quantitative evaluation of the occupational risk at particular workplaces in the Caprolactane Plant taking into account the values of concentration of carcinogenic and seemingly carcinogenic substances in the years 2000–2001 is presented in Tables 5 and 6. In 2000 a qualitative risk of exposure to benzene in the Caprolactam Department in the Cyclohexanone Department was small and it was negligible in the Quality Testing Laboratory, and in 2001 in both Departments the risk was small. In 2000 the risk of exposure to mist of sulphuric acid in the Quality Testing Laboratory and the Department for Inorganic Compound was negligible apart from the workplace called steering and equipment for chemical processes, and the Laboratory for Biological Water Treatment, where the risk was small. In 2001 in the Quality Testing Laboratory as well as in the Department for Inorganic Compound the risk increased, except two workplaces of skilled workers where the risk was negligible. The risk of exposure to chromium compounds and formaldehyde found only in the Laboratory for Biological Water Treatment has not changed over the studied years and is small, while the occupational risk of exposure to formaldehyde is negligible.

The register of the occupational diseases and suspected occupational diseases was kept in the plant from 1966 to 2001. Only 9 out of 98 registered patients worked in the Caprolactam Department. There were 4 females in this group: 3 laboratory technicians (1 from the Laboratory for Biological Water Treatment and 2 from the Quality Testing Laboratory, who were exposed to mist of sulphuric acid, benzene and Cr compounds (VI). 1 female worked in the Inorganic Department PK-1 as an operator. Males working in the Inorganic Department PK-1 and in maintenance services in the Caprolactam Department PKU were mainly exposed to the mist of sulphuric acid. The most common occupational disease is occupational eczema diagnosed in 6 patients. In 2 females it was generalized occupational eczema and in 1 female (a laboratory technician) it was contact dermatitis.

Table 5. Qualitative and quantitative evaluation of the occupational risk at particular workplaces in the Caprolactam Department in 2000

Department	Workplace	A list of carcinogenic and seemingly carcenogenic factors					
		factor	index of exposure (mg/m^3) max.	multiplicity of exceeding	index of exposure (mg/m^3) min.	multiplicity of exceeding	risk
Caprolactam PK	The Cycloheksanone Department						
	1	benzene					
	2	benzene	2.98	0.298	0.74	0.074	small
	3	benzene	2.98	0.298	0.74	0.074	small
	Laboratory of Caprolactam						
	4	benzene					
	5	benzene	0.56	0.056	0.33	0.033	negligible
	Laboratory for Biological Water Treatment						
	6	chromium compounds	0.002	0.02	0.00	0.00	small
	6	mist of H_2SO_4	0.50	0.50	0.00	0.00	small
	6	formaldehyde	0.17	0.34	0.05	0.10	negligible
	Laboratory of sulphuric acid						
	7	mist of H_2SO_4	0.36	0.36	0.10	0.10	negligible
	Department for Inorganic Compounds						
	1	mist of H_2SO_4	1.70	1.70	0.31	0.31	small
	2	mist of H_2SO_4	1.70	1.70	0.31	0.31	small
	3	mist of H_2SO_4	0.36	0.36	0.10	0.10	negligible
	4	mist of H_2SO_4	0.22	0.22	0.06	0.06	negligible
	5	mist of H_2SO_4	0.36	0.36	0.10	0.10	negligible
	6	mist of H_2SO_4	0.28	0.28	0.22	0.22	negligible

Table 6. Qualitative and quantitative evaluation of the occupational risk at particular workplaces in the Caprolactam Department in 2001

Department	Workplace	A list of carcinogenic and seemingly carcenogenic factors					
		factor	index of exposure (mg/m^3) max.	multiplicity of exceeding	index of exposure (mg/m^3) min.	multiplicity of exceeding	risk
Caprolactam PK	The Cycloheksanone Department	benzene					
	1						
	2		1.28	0.128	0.24	0.024	negligible
	3		1.09	0.109	0.608	0.0608	negligible
	Laboratory of Caprolactam						
	4	benzene					
	5		1.09	0.109	0.828	0.0828	negligible
	Laboratory for Biological Water Treatment						
	6	chromium compounds	0.0065	0.065	0.0003	0.003	small
		mist of H_2SO_4	1.0	1.0	0.74	0.74	small
		formaldehyde	0.175	0.350	0.07	0.14	negligible
	Laboratory of sulphuric acid						
	7	mist of H_2SO_4	0.95	0.95	0.55	0.55	small
	Department for Inorganic Compounds						
	1	mist of H_2SO_4	0.17	0.17			negligible
	2		0.51	0.51	0.138	0.138	small
	3		0.68	0.68	0.23	0.23	small
	4		0.22	0.22	0.06	0.06	negligible
	5		0.49	0.49	0.045	0.045	small
	6		0.28	0.28	0.22	0.22	negligible

DISCUSSION

Monitoring risk factors and recognizing them in the working environment is mandatory by law as a part of prophylactic campaign for protecting the health of employees. The exposure to harmful environmental factors in the working environment over the years may result in various diseases, including cancer. Continuous exposure to some chemical substances may cause unrestricted growth of cells, resulting in a cancerous growth. These cancerous changes may appear after many years from the time of the first exposure to chemical substances. Latency period may range from 4 to 40 years.

The cancerous growth resulting from occupational exposure may develop at various sites, not only at the site of contact with carcinogenic substances. The carcinogenic effect of chemical compounds depends in a high degree on the structure and physical and chemical properties of these substances. The final carcinogenic effect – the formation of the cancerous growth – is the result of many reactions in the body (3, 5, 6, 9, 10, 11, 12, 14).

Krajewska et al. who studied carcinogenic proteins in blood serum of employees exposed to polycyclic aromatic hydrocarbons (WWA) based their study on the assumption of one of the theories that activation of protooncogenes and deactivation of suppressor genes is connected with point mutation of these genes induced by such carcinogens as WWA, which may result in changes in oncoprotein content and antioncoprotein content in cells, which may be determined in body fluids. It has been found that the increased concentration of the studied proteins in blood serum may lead to the incidence of cancer. Performing tests and measurements and monitoring the conditions threatening occupational cancer proved useful in making the diagnosis (8). Wąsowicz et al. studied employees of a tannery to evaluate the effect of Cr (VI) on the intensity of peroxidatic processes and on the concentration of some antioxidants, e.g. selenium. Selenium concentration in blood and urine was lower in employees than in a control group (15). Gromadzińska et al. revealed that lower concentration of selenium in blood and urine in patients exposed to chromium results from interactions in the body between selenium and chromium (2). Wójcik et al. studied the level of some carcinogenic substances including sulphuric acid, benzene, chromium, formaldehyde, nickel and cadmium at workplaces with various degrees of harmful effect in a car factory and no toxicologic threat was found (16). In the studied chemical plant in some individual cases the concentration of carcinogenic and seemingly carcinogenic substances exceeded the value of the accepted concentration, but this fact did not pose a toxicologic threat to the studied working population. Continuous biomonitoring of threats at workplaces done by safety inspectors and medical services contributes to the elimination of occupational threats and protection of health of employees.

In order to prevent adverse effects of occupational exposure to carcinogenic factors at the workplace a continuous environmental and biological monitoring is carried out, enabling the control of threat and study its effects on human body. Occupational health service deals with promotion of healthy lifestyle among employees, education and occupational responsibility.

CONCLUSIONS

1. The concentration of benzene at a workplace did not exceed the maximum acceptable limit.
2. The exposure to mist of sulphuric acid in 2001 was low. In 2000 the values of concentration exceeded acceptable standards in the Inorganic Department (PK-1) and in the Maintenance Services Department in Caprolactam Plant (PKU).

3. The exposure to Cr compounds (VI) and formaldehyde was low and negligible.

4. The greatest risk of exposure to carcinogenic and seemingly carcinogenic substances was found in Cyclohexanon Department (PK-2) and Maintenance Services Department in Caprolactam Department (PKU).

5. No direct causative effect was found between the exposure to the studied substances and the incidence of cancer in employees.

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SUMMARY

The evaluation of exposure to some carcinogenic chemicals and seemingly carcinogenic chemicals, e.g. mist of sulphuric acid, benzene, chromium (VI) and formaldehyde among employees of some departments of a chemical plant was carried out. The study was carried out in the years 1999–2002. The analysis of concentration of the studied substances revealed the highest risk of exposure in the Cyclohexanon Department and The Maintenance Services Department in Caprolactam department. No direct relationship between the exposure to the studied chemicals and the development of cancer in the working population was found.

Analiza ryzyka zawodowego związanego z ekspozycją na wybrane czynniki rakotwórcze w środowisku pracy zakładu chemicznego

Przeprowadzono ocenę narażenia pracowników wybranych wydziałów zakładu przemysłu chemicznego na niektóre substancje o charakterze rakotwórczym i prawdopodobnie rakotwórczym, m. in. mgły kwasu siarkowego, benzen, chrom (VI) oraz formaldehyd. Badania przeprowadzono w latach 1999–2002. Oceniając uzyskane wartości stężeń badanych substancji, największe narażenie wykazano na Wydziale Cykloheksanonu i Wydziale Utrzymania Ruchu Zakładu Kaprolaktamu. Nie stwierdzono bezpośredniego związku przyczynowego pomiędzy ekspozycją a zapadalnością na choroby nowotworowe populacji pracującej.