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INDUSTRIAL HYGIENE OF WORKERS HEALTH CONDITION IN THE MANUFACTURE OF LEAD CRYSTAL

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Armenia has been a center of glass production and use for several millennia [1]. Excavations at the prehistoric burial site known as Lchashen, located on the western shore of Lake Sevan, have revealed glass beads dating to 1500 BC. Glass artifacts such as blown flasks and bowls over 2000 years old, including both objects imported from nearby countries and wares of local manufacture, have been discovered during excavation of ancient Armenian sites such as Karmir bloor, Artashat and Garni near the city of Yerevan. During the middle ages glass manufactures gained an importance, and the medieval cities of Dvin and Ani, in particular, were noted centers of production. Due to their diversity of shapes, harmony of colors and broad applied use, Armenian handicrafts were in constant demand in neighboring countries.

Armenia is rich in the raw materials needed for glass manufacture, and has prospects for further development of this branch of industry. Presently, factories in the Armenian Republic fabricate glass for windows, electric insulation, optical applications, lighting, fiberglass, and lead crystal. Crystal products designed for light fixture are made at the Armenian Electric Light Plant near Yerevan. The manufacture of decorative lead crystal glassware in Armenia began about 25 years ago at the Armenian Lead Crystal Factory located near the town of Arzni.

Taking into account the fact that lead is a highly toxic substance, and that human lead exposure as well as lead contamination of the environment are matters of international importance for public health [2], the Environment Committee of the Armenian Engineers and Scientists of America, Inc. in collaboration with the Laboratory of Industrial Toxicology of the Armenian Institute of General Hygiene and Occupational Diseases, and with the financial support of benefactor Mr. Lemyel Amirian, is presently conducting a comprehensive research program to investigate lead exposure in Armenia. This article presents the results of a portion of this study pertaining to the industrial manufacture of leaded crystal glassware at the Arzni Lead Crystal Factory.

Material and methods

Concentrations of lead oxide, quarts, potassium, potassium nitrate, soda ash, zinc oxide, arsenic and nickel in air were measured in 188 samples taken from the raw material preparation workshop. Additional samples for lead (40 samples) and carbon monoxide (30 samples) were obtained from the melting workshop, and for lead (20 samples), sulfuric acid (10 samples), and hydrofluoric acids (10 samples) from the engraving workshops. These determinations were performed using methods accepted by the Ministry of Health of the former USSR [3].

Samples of settled dust (24 wipes) were obtained from floors and machinery surfaces in the raw material mixing shop, casting shop, artistic and regular engraving shops, office, and from the hands of some workers using soap- impregnated wipers. Wipers were digested in hot nitric acid and lead was determined by flame atomic absorption spectrometry using a modification of United States national Institute of Occupational Safety and Health method 7082 [4]. Quality assurance was established by successful participation in the Armenian Industrial Hygiene Association environmental lead proficiency analytical testing program.

Samples of the whole blood from factory workers in various workshops were collected into evacuated tubes containing sodium heparin, and analyzed for lead, hemoglobin, and erythrocyte protoporphyrin in 38 workers and subsequently in 19 workers, according to well-established, previously described methods [5]. Quality assurance for blood lead and protophorpyrin determinations was established by successful participation in several external proficiency testing programs, including the quarterly blood lead program of the United State College of American Pathologists.

Results and discussion

The manufacture of lead crystal products creates conditions in which workers come into contact with a wide ranges of harmful factors which are hazardous to their health. Accordingly, this study was undertaken to investigate working conditions during lead crystal manufacture, and to evaluate the health of workers exposed to lead and other harmful agents.

We should begin with a brief description of the technological peculiarities of the manufacture of crystal products, pointing out those factors which influence hygienic conditions. The production scheme requires the use of free-flowing bulk raw materials in approximately the following composition; quartz sand, 49.2%; lead oxides 21.9%; potassium carbonate 15.7%; potassium nitrate 7.4%; sodium carbonate 2.9%; zinc oxide 0.8%; arsenic compounds 0.4% and nickel compounds 0.003%.

The powdered constituents of the glass are measured, mixed and melted at approximately 1400 degrees Celsius: molten glass is removed from the furnace and cast or hand-blown into the desired shape; when cool, each object is individually engraved and polished using grinding wheels.

In the mixture preparation shop, workers are subject to pneumoconiosis, and may inhale chemical aerosols, foremost among these being lead oxide. Table 1 presents data on the content of lead oxide and quartz aerosol in the working zone air of the mixture preparation shop

This area is highly contaminated by dusts rich in lead and silica. The airborne lead concentration was found to be as high as 18.6 milligrams per cubic meter, and quartz dust as high as 200 milligrams per cubic meter. These concentrations exceed the TL values and maximum permissible concentrations recognized in the USA and in Armenia several fold. The concentrations of other chemical aerosols, such as arsenic and nickel, are lower, but exceed applicable standards in some instances.

Operations at the beginning of the process, including loading and unloading, pacing, measurement, mixing, grinding and transport of raw materials, result in the dispersal of harmful dusts which, because of poor housekeeping, ineffective ventilation, and absence of other methods of dust suppression, may be inhaled and/or ingested by workers. Furthermore, dusts are transported to clean areas on the soles of shoes and by the tires of forklifts. Gross contamination of the shop floor and machinery by red lead oxide dust was observed. Because of a lack of effective housekeeping, this material poses not only a threat to the health of the worker and his family, but also may be responsible for more general environmental contamination.

Table 1

Aerosol content of harmful substance in the air zone at the shop of raw material preparation for melting (*mg/m³*)

Substance	N of samples	Concentrations	MAC in the air of the working zone
lead oxide	28	2.95-18.6	0.01
quartz	30	118.2-200.0	1.0
potassium	30	2.3-3.9	2.0
potassium nitrate	28	2.9-5.3	5.0
soda-ash	30	0.95-3.4	2.0
zinc oxide	20	0.2-0.8	0.5
arsenic	12	0.09-0.2	0.2
nickel	10	0.006-0.035	0.05

Besides exposure to chemical factors, workers are subject to heavy physical exertion, sometimes under adverse climatic conditions. Several operations in this department are poorly mechanized or demand the use of manual labor in the case of the conveyor equipment malfunction.

Occasionally, a worker may be required to carry several tons of material in a shift, which can be quite taxing especially in the summer months when the ambient temperature is 30 to 34 degrees Celsius.

Working conditions are similarly unfavorable in the furnace area, where sift blend and crystal wastes are melted (Table 2).Furnace loading with the powder mixture is accompanied by the release of polycomponent dust into the workroom air. Here too, air concentrations of lead oxide and silica dust exceed the TLV by more than ten fold.

At the next stage of production, the furnace and glassblowing operations, workers are subject to multiple harmful factors, including chemical exposures as described previously; occupational accidents such as burns from molten glass and cuts from broken glass shards; heavy physical loads; high temperature working condition; and significant thermal radiation. The air temperature at the opening of the furnace during rabbing or poking of the glass melt can reach 40 to 42 degrees Celsius in the summer. Though this operation is of short duration, it must be repeated often, sometimes dozens of times in one shift. Air temperatures adjacent to the furnace, where the glass blowers are stationed, are also quite high.

Table 2

The level of physical and chemical industrial factors in the working zone of the melting shop. (Summer time)

The place of determination	Air t° (°C)	Thermal radiation (*cal/cm2*)	Relative humidity (*%*)	Air speed (*m/sec*)	Air content (*mg/m³*)		
					mixture	lead fumes	CO
Melting furnace loading place	33-36	-	20-23	0.8-1.4	18.5-66.5	-	0.3-0.6
At the furnace	40-42	2.4-4.1	16-18	1.1-1.5	-	8.2-29.5	0.7-1.6
On the working place of the press operator	35-39	1.8-2.6	16-19	0.6-1.0	-	3.0-16.9	-
On the working place of the glass blowing worker	37-40	2.2-3.4	16-20	1.0-1.3	-	6.4-20.3	0.6-0.8

The final stages of lead crystal production involve the faceting, engraving, and polishing of semi-finished crystal products. Lead dust emissions are significant but mitigated somewhat by the use of watersuffused grinding wheels (Table 3). During these processes, in addition to lead dust aerosols, vapors of sulfuric and hydrofluoric acids penetrate the working zone air. Concentration of these acids in some cases exceed their MAC levels as much as 12 and 14 times respectively.

Table 3

The contents toxic substance in the air of the working zone at the plots-bays of semifinished crystal products (in mg/m^3)

The plots	Lead	Sulfuric acid fumes	Hydrofluoric acid fumes
Cutting and faceting	0.23-0.49	-	-
Engraving, grinding, polishing	0.11-0.18	0.7-12.1	2.1-7.0

Only at the stage of packaging of the finished products are workers not subject to harmful environment factors.

During a walk-through tour of the lead crystal factory made in September of 1993, we obtained several one square foot (approximately 900 cm^2) wipe samples taken from the floors and machinery surface at working height in the principal workshops. These samples were analyzed for lead content (Table 4). In comparison to the 200 microgram per square foot post-abatement residential floor cleanup interim standard which is applied in the United States, all of these readings indicate gross contamination of the working area by lead dust. The lowest of nineteen working area samples read nearly 4000 micrograms lead per square foot. Workers' hands showed contamination at an average of about 500 micrograms per wipe, and even floors in the presumably clean office area were significantly contaminated at levels of about 750 micrograms per square foot.

Table 4

Lead in dust Arzni lead crystal factory (9-93)

Department Area	Lead, mcg/square foot	n
Lead oxide mixing area	66.000-415.000	4
Quartz sand mixing area	5.200-19.800	4
KNO_3 mixing area	11.000-15.500	2
Casting area	7.000-13.700	2
Artistic engraving	10.800-18.200	3
Regular engraving	3.800-51.400	4
Office hallway floor	606 - 879	2
Hands of casting workers	288 - 852 mcg/wipe	3

In order to evaluate the absorption of lead and health status of workers in this facility, biological monitoring and medical examination of workers was conducted. Table 5 summarizes the results of biological monitoring for blood lead and erythrocyte (zinc) protoporphyrin conducted in November 1991.

Table 5

Biological monitoring at Arzni lead Crystal factory (11-91)

Job classification	n	Blood lead value (*mcg/dL*)		ZPP (*mcg/dL*)
		range	mean±SD	mean±SD
Mixers, melters, and glass casters	7	42-89	63±19	259±166
Glass engravers	9	19-53	34±15	52±21
General labor (QC, forklift, mtnce., inventory, etc.)	9	15-50	32±12	85±72
Administration, office, guards	8	10-20	14±4	35±19
Chemists, chemical engineers	5	4-10	7±3	30±4

Workers were divided into five categories based on their usual job duties, as follows; mixers, melters, and casters; engravers and polishers; general labor, such as maintenance, quality control, inventory control, and worklift transport; administrative workers such as chemists. Among workers in the mixing, melting, and casting areas blood lead values exceeded permissible norms applied in the USA and Europe; values up to 89 micrograms lead per deciliter whole blood were observed for workers in this group, with a mean of 63 micrograms per deciliter for 7 workers tested. Engravers and general laborers were found to have lower values on average, between about 15 and 53 *mcg/dl*, in these two groups, blood lead values of some workers reached the maximum levels allowed by the United States Occupational Safety and Health Administration lead standard. Administrative workers and chemists had very low blood lead levels and are in the lowest risk category.

Follow-up blood lead sampling was performed in September of 1993 (Table 6). Nearly two years later, blood lead levels remained excessively high, especially among workers in the mixing, melting, and casting shops. The highest erythrocyte protophyrin values were observed among mixers, melters and casters. Hemoglobin levels were acceptable except for a single worker, who had extremely high blood lead. The hemoglobin of 13.9 grams per deciliter and erythrocyte protophyrin of approximately 400 micrograms per deciliter in this worker suggest developing anemia due to lead intoxication.

Table 6

Biological monitoring at Arzni lead Crystal factory (9-93)

Job classification	n	Blood lead value (*mcg/dl*)		ZPP (*mcg/dl*)
		range	mean ± SD	mean ± Sd
Mixers, melters, and glass casters	7	36-82	64±15	227±143
Glass engravers	1	20	–	44
General labor (QC, forklift, mtnce., inventory, etc.)	6	8-47	29±14	48±22
Administration, office, guards	3	6-8	7±1	31±8
Chemists, chemical engineers	2	5-8	6±2	46±11

Medical examinations were conducted by occupational physicians on sixteen workers with the highest blood lead levels. The examination revealed signs of chronic lead intoxication in four workers, dust bronchitis in three workers and early manifestation of pneumoconiosis in one worker.

Conclusion

This study demonstrates that the manufacture of lead crystal is fraught with several occupational hazards of which lead intoxication is one of most serious and prominent. Extreme conditions such as these require urgent improvement in work practices, ventilation, process mechanization and sealing, housekeeping, worker education and hygiene, protective clothing and changes of clothing, and if possible, respiratory protection. A comprehensive list of these measures has been presented to the management of the factory for implementation.

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Կապար պարունակող բյուրեղապակու արտադրությունը կապված է մասնագիտական բազմաթիվ վտանգավոր գործոնների վնասակար ազդեցության, հատկապես կապարով թունավորվելու հնարավորության հետ: Բյուրեղապակու արտադրությունում աշխատող բանվորների օրգանիզմում կապարի և մնացած նյութերի ազդեցությունը գնահատելու համար ուսումնասիրվել է օդում և նստած փոշու մեջ վերջիններիս պարունակությունը, արյան մեջ կապարի քանակությունը և բանվորների առողջական վիճակը: Օդում և նստած փոշու մեջ կապարի պարունակությունը խիստ գերազանցում է թույլատրելի նորմաները, իսկ խառնուրդ պատրաստողների, ձուլողների և կաղապարողների արյան մեջ այն բարձրացած է և հասնում է վտանգավոր չափերի (մինչև 89 մկգ/դլ): Կապարով թունավորման նշաններ են հայտնաբերվել արյան մեջ այդ մետաղի բարձր պարունակություն ունեցող 16 բանվորներից չորսի մոտ:

ГИГИЕНА ТРУДА И СОСТОЯНИЕ ЗДОРОВЬЯ РАБОЧИХ, ЗАНЯТЫХ НА ПРОИЗВОДСТВЕ СВИНЕЦСОДЕРЖАЩЕГО ХРУСТАЛЯ

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Производство свинецсодержащего хрусталя связано с воздействием многочисленных вредных факторов и, в частности, риском отравления свинцом.

С целью оценки воздействия отравляющих веществ на организм изучалось их содержание в воздухе, пыли, а также в крови у рабочих различных цехов Арзнинского хрустального завода.

Исследования показали, что содержание свинца в воздухе и пыли сильно превышает допустимую норму, а в крови обследуемых – повышено и достигает угрожающих пределов (до 89 *мкг/дл*) у рабочих некоторых цехов. У 4 из 16 обследованных отмечались признаки свинцового отравления.

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