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WORKPLACE MONITORING AND OCCUPATIONAL HEALTH STUDIES AT THE CENTRE FOR PRODUCTION OF PHOSPHORUS MINERAL FERTILIZERS, VOSKRESENSK (MOSCOW REGION, RUSSIA), USING NUCLEAR AND RELATED ANALYTICAL TECHNIQUES. Part I

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1. Introduction

Intensive production of phosphorus fertilizers requires a thorough investigation of the deterioration of the environment, including its pathological impact on occupational staff. Nuclear and related analytical techniques enable relationships to be established between the concentrations of elemental pollutants (Cr, Ni, Cu, Zn, As, Se, Sr, Mo, Ag, Cd, Sb, Pb, (REE), Th, U, and other) in raw material, byproducts, humans and the workplace.

The goal of this study is to determine how man's biosubstrates can be used to follow the rate of pathological changes in the organism as it is exposed to intense technogenic environments.

As a rule, the degree of pollution of the environment is determined by studying the amount of sulfur and nitrogen compounds and fluorine in the air. In the early 1980s, specialists of the Institute of Mineralogy, Geochemistry and Crystallochemistry of RAS used emission spectrography to provisionally study of geochemistry of soils and snow around the "Mineral Fertilizers" plant in Voskresensk (Moscow region) and Apatity (Kola Peninsula). This study revealed another, previously unknown, type of pollution: increased REE, zinc, and strontium [1]. The potential environmental hazard of phosphorus fertilizers and their byproduct is a well established fact now [2-5]. Investigation [1] stimulated further studies [6-8] in 1985-1989 by M.V. Frontasyeva, A.V. Gorbunov and B.A. Revich, the authors of the present IAEA project, using the more precise methods of X-ray fluorescence (XRF) and neutron activation analysis (NAA). At that time the task was to assess the eco-geochemical situation in the northern part of the town of Voskresensk (see **Fig. 1**).

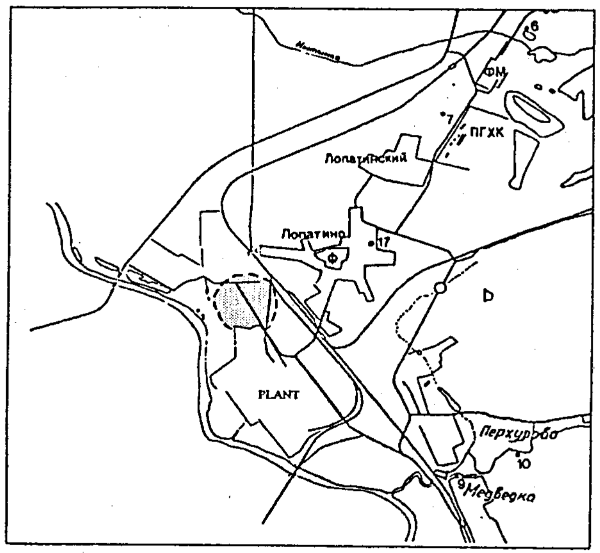


Fig. 1. The "Mineral Fertilizers" plant in Voskresensk. The dashed area was examined in the previous studies [6-8].

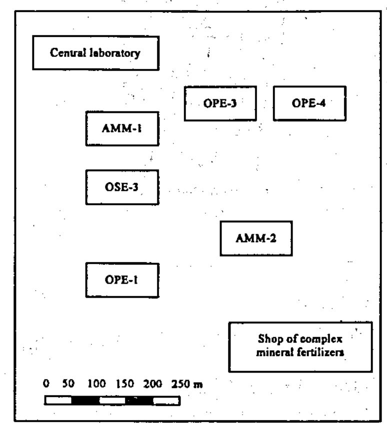
We studied the main anthropogenic streams blown into the air, which then fall back to the earth's surface (soil, snow), as well as their uptake into agricultural plants nearby and into local residents. The impact of technogenic flows on man's organism was examined by comparing the concentrations and associations of various elements in hair from relatively normal and impacted subjects [9].

From 1989 to 1993, the plant was rebuilt to more efficiently utilize phosphogypsum ($CaSO_4 \cdot 2H_2O$ + 0.6-1.0% P_2O_5). As a result of the oleum sulphate extraction process (the most common one in the production of phosphorus fertilizer), approximately 5 *t* of phosphogypsum are precipitated per 1 *t* of final product (ammophos, or ammonium phosphate: 47-60% P_2O_5, 11-13% N, 1-2% Ca). There are several ways of disposing of phosphogypsum: to use it as an agricultural meliorant, as a building material (tile, filling and binding components), etc. Practically all of the methods of phosphogypsum disposal were developed without taking into account the increase in pollution levels caused by element-impurities in the phosphate raw material. For this and other objective reasons, the byproduct goods did not find a market, and the shop for reprocessing the main disposal waste (phosphogypsum) was shut down. The production of complex mineral fertilizers was shut down also, as well as the production of oleum phosphate in one of the shops, specifically, OPS-2. In addition, the technology of oleum sulfate extraction was changed. These activities must have altered the environmental situation in and around the plant, and, in turn, its effects on humans. The present-day products of the "Mineral Fertilizers" plant in Voskresensk are summarized in **Table 1**.

Table 1. Present-day production and element associations most typical for the relevant shops of the "Mineral Fertilizers" plant in Voskresensk.

No.	Type of production	Shop	Association of chemical elements
1	Ammonium phosphate fertilizers	AMM-1, AMM-2	Sr, Y, Bi, REE
2	Oleum phosphate extraction	OPS-1, OPS-3, OPS-4	Sr, Y, Mo, Zn, REE
3	Oleum sulphate extraction	OSE-3	Sr

Allocation of the main shops under consideration on the premises of the plant is shown in **Fig. 2**.



To clarify the present-day situation at the "Mineral Fertilizers" plant it was necessary to:

- determine the content and level of air pollution of the working areas and the drinking water;
- determine the normal and abnormal concentrations of elements in biosubstrates (hair, nails, bone tissue – teeth) of the occupational staff.

Fig. 2. "Mineral Fertilizers" plant premises

2. Methodology

2.1 *Sampling*

The sampling strategy is based on the assumption that, at the workplace, the main sources of the technogenic impact on the human organism are the air of the workplace and drinking water consumed in the shops.

2.1.1. Environmental samples

Atmospheric aerosols and pollution streams (dust) blown into the air and which then fell back around were collected in the workplace. To collect aerosols on filters (AFA-XA-20, Russia), the aspirator (model 822 and AC-1, Russia) was used continuously during the working time (6-8 hours) [10]. Dust samples were collected directly in the workplace from an area 10 sq. cm by means of a fur brush, taking into consideration the whole area examined and its dustness. Tap water was collected from the drinking fountains at the shops in clean plastic bottles 1.5 liter in volume. As the central water supply system provides the shops with fresh water, water samples were collected in only two shops (OSE-3 and OPE-3) and were conserved as required elsewhere [11].

To estimate the most probable sources of the air pollution in the working area, samples of the main type of industrial raw material (apatite concentrate), the final product (ammophos), and its byproduct (phosphogypsum) were collected.

2.1.2 Human biosubstrates

Diagnostic samples of human biosubstrates were collected in all operating shops. The list of occupations and relevant shops are given in **Table 6.**

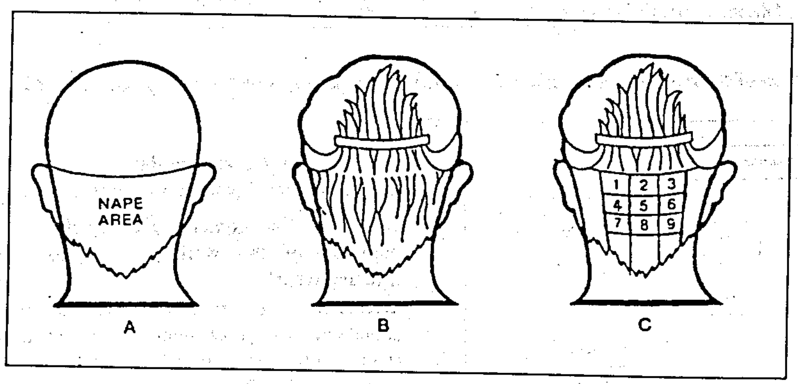


Fig. 3. Collecting hair samples.

- Locate a region on the scalp between the top of the ears and the nape of the neck (see figure A)
- Fasten the hair not to be cut out of the way with plastic clips (see figure B)
- Cut 10-20 strands of hair from 5-10 different sites in the occipital region of the scalp with stainless steel surgical scissors (see figure C). Save only the 5 cm of hair growing next to the scalp (if the hair is longer than 5 cm).

1) Collection of hair samples from the occupational staff was carried out in accordance with the scheme shown in **Fig. 3** [12] as adopted by the World Health Organization. Not less than 500 mg of hair for each sample was collected.
2) Simultaneously with the collection of the hair samples, nail samples were collected from some of the examined employees.
3) Samples of bone-tissue (teeth) were obtained from the stomatological medical clinic of the plant. These samples were not differentiated by shop or occupation.

Age, sex, the total length of service in the shop, and at the plant, was fixed in a protocol (see APPENDIX I). To avoid surface contamination prior to analysis of the biosubstrate samples the hair, nails, and teeth were subjected to a special cleaning procedure described elsewhere [13]. All of the collected samples were stored in hermetic zip-lock type plastic bags.

Thus, 23 samples of atmospheric aerosols, 15 samples of dust, 2 samples of drinking water, 3 technological samples, 36 samples of hair, 5 samples of nails and 5 samples of teeth were collected. The total number of samples subjected to analysis during the first year of the project was 89.

2.2 *Analysis*

The element concentrations of samples collected during the first year of the project were determined by means of NAA, XRF, and AAS.

The XRFA of the aerosol filters, dust, and technological samples for Ti, Mn, Cu, As, Rb, Sr, Y, Zr, Nb, Ba, Pb determination was carried out using a MECA-1044A (XR-500) analyzer (LINC SYSTEMS, Great Britain) with a pulsed X-ray tube and a silver target as a source of excitation. The detection energy resolution at the 5.9 keV K-line of Mn was 160 eV. A double-channel spectrometer XRF-WD (ARF-6, Russia) was also used [6, 14].

Heavy metals in the drinking water were determined by the method of preconcentration sorption filters with grafted chelate groups. The sorption filters were measured then by XRFA [15]. The rare-earth elements in the drinking water were determined in the salt residuals after evaporation by means of neutron activation analysis. Individual elements in the drinking water were determined with the atomic absorption spectrometer FAAS-3 (Germany) [14], the sample being placed directly into the flame (acetylene-air mixture) after preliminary sample preparation.

Neutron activation analysis of the biosubstrates, aerosol filters, dust and technological samples was used to determine Na, Ca, Sc, Cr, Fe, Co, Zn, As, Br, Cd, Sb, Ba, REE, Au, Hg, Th, and U. The analysis was performed at IBR-2 reactor in Dubna and at IRT research reactor at Moscow Technical University (MIPhI) as described in [14]. The integral flux of epithermal neutrons was 10^{16}–10^{17} neutron/cm^2. The temperature of the container with the samples during irradiation did not exceed 70 °C. The induced activity was measured with the using ORTEC γ-spectrometer of energy resolution 1.9 keV at the 1333 keV line of ^{60}Co.

3. Results and discussion

The data on the trace element concentrations in the air of the premises of the plant and dust collected in the shops are given in **Table 2** and **Table 3**, respectively.

The analysis showed that the maximum permissible levels for trace elements in the workplaces have never been exceeded. The maximum air pollution with airborne particulate matter as well as the maximum concentrations of Na, Ca, Cr, Fe, As, Sb, Sr, REE, and Th occur at the loading-unloading sites. One should note relatively high, but not exceeding the maximum permissible, levels of As in the air of the Central Laboratory premises.

Table 2

TRACE ELEMENTS IN THE AIR OF THE PREMISES OF THE "MINERAL FERTILIZERS" PLANT, NG/M3

Plant premises	Dust imp. мg/м³	Na μg/м³	Ca μg/м³	Sc	Cr	Fe μg/м³	Co	As	Br	Sr μg/м³	Y μg/м³	Sb	La	Ce	Sm	Eu	Au	Hg	Th	U	Pb μg/м³	Lu
Shop for oleum phosphate extraction (OPE-1)																						
Turn-around tanks	0.7	1	100	0.3	140	4.7	<0.1	15	<0.1	15	0.12	1.5	680	1100	55	14	0.3	<1	6.9	<15	0.04	0.8
Extractors	0.4	0.5	75	0.08	570	3.1	0.4	<0.1	<0.1	1.5	<0.1	0.8	210	370	18	4	0.06	<1	3.3	<15	<0.02	<0.2
Dozers	1.1	<0.1	260	0.7	550	9.6	2.7	10	<0.1	11	0.09	0.6	1800	3600	140	30	0.08	<1	15	<15	0.03	1
Shop for oleum phosphate extraction (OPE-3)																						
Operational, unloading	37	54.9	9600	23	1500	380	96	23	43	620	12	<0.5	64000	112000	4600	1200	2.1	<1	690	<15	0.6	18
Platform, unloading	20	21	5900	7.8	1500	160	180	33	13	150	3.3	<0.5	37000	64000	2600	680	0.7	<1	423	<15	<0.2	18
Bunker, unloading	71	105	12000	8.4	1200	430	140	30	20	880	16	120	113000	194000	8000	1900	1.3	<1	870	<15	<0.2	55
Evapourating dept.	1	0.3	70	0.6	160	6.6	<0.3	<0.1	12	4	<0.1	1.2	160	220	15	4	0.2	<1	2.2	<15	0.05	0.2
Extracting dept.	0.4	0.1	20	0.3	7	0.2	<0.1	<0.1	<0.1	1	<0.1	<0.5	140	250	13	3	<0.01	<1	1.4	<15	<0.02	0.3
Shop for oleum phosphate extraction (OPE-4)																						
Transporter loading	1	1.1	230	0.2	100	14	2.2	6	<0.1	9.9	0.09	90	1600	2500	120	33	0.08	<1	17	<15	0.02	0.7
Separators	0.8	0.3	100	0.3	100	7	0.7	4.8	5	11	0.08	56	670	1200	46	15	0.16	<1	9	<15	0.02	0.5
Unloading platform	65	32	8200	4.5	1100	210	120	50	18	1100	19	<0.5	53000	93000	4300	1000	1	<1	460	<15	0.2	18.3
Shop for production of ammophos (AMM-1)																						
Wet-dust collectors	17	6.7	190	2.9	220	79	25	17	<0.1	4.3	0.8	<0.5	1400	2100	570	70	0.16	<1	190	<15	<0.05	6.4
Crushers	14	5.6	100	2.1	48	78	7.1	10	<0.1	2.3	0.3	<0.5	1000	1300	140	30	0.1	<1	130	13	<0.05	3.3
Loading	7.8	2.1	210	1.9	250	100	15	35	<0.1	-		1000	3400	5000	300	80	0.26	<1	80	<15		3.2
Shop for production of ammophos (AMM-2)																						
Fine crusher	2	1.2	52	0.5	220	37	2.7	15	6	2.6	0.3	1.9	310	570	48	12	0.06	<1	28	23	0.04	1.7
Drum-dryer	0.5	0.1	<10	0.08	40	<1	<0.1	12	<0.1	0.6	0.1	<0.5	28	70	5	1	0.06	<1	1.4	<15	0.03	0.4
Coarse crusher	0.8	1.4	<10	0.05	50	5.2	<0.1	11	<0.1	1.1	0.1	<0.5	54	130	8	2	0.13	<1	1.6	<15	<0.02	0.8
Shop for production of oleum sulfate extraction (OSE)																						
Oleum absorption	<0.2	<0.1	<10	0.3	7.4	2.9	1.1	2.2	3.7	0.4	0.06	<0.5	27	46	3	0.5	0.146	<1	0.2	<15	<0.02	<0.2
Site of oleum mixture	0.6	0.7	<10	0.7	240	4	<0.1	5.5	14	0.3	<0.1	0.7	20	51	3	0.7	0.04	<1	<0.1	<15	<0.02	0.4
Water vapour purification	0.6	0.2	<10	0.7	7.2	4.3	2.8	36	4.1	0.04	<0.1	1.1	23	65	4	0.5	0.08	<1	<0.1	<15	<0.02	<0.2
Central Laboratory CL																						
Room No.132 (09.06.97)	1.6	0.6	<10	2.5	270	66	3.7	85	8.1	1.3	0.4	24	100	240	11	1	0.08	<1	<0.1	<15	0.15	0.6
Room No.132 (10.06.97)	0.7	1.1	<10	2.2	240	73	2.9	53	11	2.5	<0.1	17	70	160	10	0.9	0.07	<1	<0.1	<15	0.16	<0.2
Room No.128 (10.06.97)	0.7	0.5	<10	2.1	230	46	<0.1	85	7	1.4	<0.1	18	60	130	7	1	0.07	<1	<0.1	<15	1.3	<0.2
Max. permis. level [16,17]	-	-	-	-	$1\cdot10^6$	4000	$5\cdot10^5$	$1\cdot10^4$	-	-	-	$5\cdot10^5$	-	-	-	-	-	$1\cdot10^4$	7500	8800	10	

Table 3

TRACE ELEMENT CONCENTRATIONS IN DUST COLLECTED IN THE SHOPS OF THE "MINERAL FERTILIZERS" PLANT, μG/G

Shop	Sampling site	As	Pb	U	Th	Y	Sr %
OPE-1	Site of dozators	<3	41	<1	21	220	1.6
	Site of extractors	<3	76	<1	13	140	1
OPE-3	Operational, unloading	5	3.6	<1	27	310	2.2
	Evapourating department	<3	70	2.9	5.8	7.6	2.3
	Extracting department	<3	30	<1	14	170	1.2
OPE-4	Transporter	<3	10	2.1	8.5	94	1
	Separators	<3	18	4	16	160	1.3
	Unloading shop	<3	3.5	<1	26	310	2.2
AMM-1	Wet-dust collectors	<3	3.2	1.9	10	99	0.04
	Site of loading	<3	24	0.9	12	120	0.6
	Crushers	<3	4.5	2.5	11	120	0.04
AMM-2	Drum -dryer	6.9	110	1	8.5	68	0.06
	Coarse crusher	<3	12	1.7	13	140	0.06
	Crushers	<3	6.8	2.1	13	120	0.04
OSE-3	Site of oleum mixture	7.9	92	<1	1.7	4	0.006

Table 4

ELEMENTAL COMPOSITION OF RAW MATERIAL, FINAL PRODUCT, AND BYPRODUCT, μG/G

Type	F %	Na %	P2O5 %	Ca %	Sc	Ti %	Cr	Mn	Fe %	Co	Cu	Zn	As	Br	Rb
Raw material (apatite concentrate)	2.3	0.25	40.7	30	0.1	0.6	<5	500	0.7	1.2	100	70	1	<1	50
Final product (ammophos)		0.15	65	1.5	0.3	0.27	<5	650	0.7	3.5	50	50	<0.1	3	15
Byproduct phosphogypsum	0.14	0.07	1.4	19	1.3	<0.2	28	30	<0.01	<1	<20	<10	<0.1	<1	<5

Type	Sr %	Y	Zr	Nb	Sb	Ba	La	Ce	Nd	Sm	Au	Th	U	Pb
Raw material (apatite concentrate)	2	230	650	50	8.7	800	1900	3000	550	150	<0.05	23	9.4	1.2
Final product (ammophos)	0.04	180	65	35	<1	40	110	210	<50	20	<0.05	12	<5	<1
Byproduct (phosphogypsum)	1.4	190	380	<20	<1	550	1000	1400		80		6	10	1

Table 5

TRACE ELEMENT CONCENTRATIONS IN DRINKING WATER AT THE "MINERAL FERTILIZERS" PLANT, μG/L

No	SHOP	Na Mg/l	Ca Mg/l	Sc	Cr	Fe	Co	Zn	As	Se	Cd	Sb	I	Ba	La	Ce	Nd	Eu	Au	Hg	Th	U	Pb
1	OPE-3	16.7	50.9	0	1.1	140	0.8	70	<0.1	0.9	<0.1	<0.06	1.3	330	4.2	7.9	5.9	0.1	0.01	<0.1	0.2	<1	<1
2	OSE-3	16.8	52.8	0	1.8	100	0.7	25	<0.1	0.9	<0.1	<0.06	1.1	310	3.9	7.5	3.4	0.1	0	<0.1	0.2	<1	<1
	Max.PL [16]	200	-	-	50	300	100	3000	10	10	1	50	-	100	-	-	-	-	-	0.5	500	1800	30

Table 4 presents the elemental content of mineral raw material (apatite concentrate), final product (ammophos), and industrial waste byproduct (phosphogypsum). It follows from this data that F, As, Sb, REE, Th, and U are of the highest potential hazard for the given environment.

The data obtained for the drinking water consumed at the plant (**Table 5**) do not exceed the relevant maximum permissible levels.

The information on occupations and shops of the examined personnel of the plant is given in **Table 6**. To study the environmental impact on the population health such diagnostic biosubstrates as blood, urine, hair and nails are most often used. Human hair are responsible for the release of chemical elements from the organism, the rate of this release through hair varies from $1 \cdot 10^{-3}$ to $1 \cdot 10^{2}$ μg per day [9]. Accumulation of trace elements in hair allows one to characterize the sustainable and systematic impact of pollutants, which is of special importance for our study.

Table 6

OCCUPATIONS OF THE EMPLOYEES EXAMINED AT THE "MINERAL FERTILIZERS" PLANT

Shop	Occupation	Shop	Occupation
OPE-1 OPE-3 OPE-4	Shop chief Chief deputy Foreman Central Control Desk operator Power supply operator Mechanic Electrician Measuring devices mechanic Installation operator Mechanic-repairman Apparatus mechanic Conveyor mechanic Electrical welding mechanic Driver Cleaner	AMM-1 AMM-2	Chief deputy Foreman Shipment foreman Hopper - operator Installation operator Quality control dept. supervisor Conveyor mechanic Furnace fireman Electrical engineer Mechanic
		OSE-3	Quality control dept. supervisor Installation operator Mechanic-repairman Electrical engineer
		CL	Engineer technologist Installation operator Technician Head engineer technologist Quality control technician

The trace element concentrations in the hair of the occupational staff are given in **Table 7**. Biochemical association of trace elements accumulated in the hair fully correlate with the specific features of the content of atmospheric aerosols. For example, the results obtained allow the shop OPE-3 to be distinguished as a source of increased concentrations of Ca, Cr, Fe, As, REE, Th, and U. However, it is evident that for a reliable statistical analysis with account of shops, occupations, age, length of service, etc. the experimental material under consideration is insufficient.

Table 7

TRACE ELEMENTS IN HAIR OF THE OCCUPATIONAL STAFF FROM THE "MINERAL FERTILIZERS" PLANT, µG/G

No.	Occupation	Na	Ca	Sc	Cr	Fe	Co	Zn
	Shop for oleum phosphate extraction (OPE-1)							
1	Responsible for power supply	26	760	0.03	0.6	92	0.3	195
2	Shop chief	34	1500	0.03	1.1	65	0.3	190
3	Mechanic	30	480	0.04	2	96	0.3	220
4	Electrician	36	1700	0.03	1.2	43	0.2	160
5	Cleaner	21	5200	0.03	1.9	50	0.3	230
	Shop for oleum phosphate extraction (OPE-3)							
6	Mechanic	40	1300	0.02	5.2	110	0.3	165
7	Mechanic	70	1100	0.01	3.4	150	0.4	180
8	Apparatus mechanic	280	11000	0.01	1.9	180	0.2	175
9	Mechanic	66	2400	0.01	1.3	100	0.3	290
10	Mechanic	38	460	0.01	1.3	130	0.4	175
	Shop for oleum phosphate extraction (OPE-4)							
11	Hopper-operator	70	3700	0.03	0.7	46	0.2	150
12	Apparatus mechanic	32	1200	0.04	1.9	92	0.3	165
13	Hopper-operator	23	3900	0.02	1.1	77	0.2	130
14	Conveyor mechanic	25	4000	0.04	1.2	60	0.3	195
	Shop for production of ammophos (AMM-1)							
15	Shipment foreman	20	790	0.03	1.4	93	0.2	120
16	Hopper - operator	31	2800	0.03	1.5	100	0.2	180
17	Installation operator	35	5100	0.04	2.3	100	0.2	170
18	Quality control technician	39	1400	0.03	1.2	67	0.1	140
19	Conveyor mechanic	41	3400	0.03	2.1	110	0.2	160
	Shop for production of ammophos (AMM-2)							
20	Conveyor mechanic	18	2600	0.01	2.2	28	0.4	155
21	Quality control technician	29	680	0.01	1.1	77	0.4	220
22	Master	23	780	0.02	2.1	100	0.4	210
23	Master	23	360	0.02	1.4	55	0.3	180
24	Installation operator	37	<200	0.05	1.5	52	0.2	185
25	Head master	25	1300	0.03	1.6	85	0.3	225
	Shop for oleum sulfate extraction (OSE-3)							
26	Installation operator	46	9200	0.03	4.1	160	0.6	480
27	Mechanic	142	3800	0.19	3.5	360	0.2	200
28	Installation operator	31	7900	0.03	1.4	83	0.2	180
29	Quality control technician	33	6500	0.04	0.9	170	0.3	140
30	Installation operator	42	1900	0.03	1.3	120	0.1	160
	Central Laboratory CL							
31	Engineer technologist	36	970	0.04	1.5	84	0.2	140
32	Technician	36	1100	0.04	1.4	53	0.2	220
33	Quality control technician	19	4300	0.02	0.7	32	0.3	210
34	Engineer technologist	47	400	0.01	0.4	30	0.1	50
35	Head engineer	43	290	0.04	2	40	0.3	190
36	Background sample	35	1500	0.04	1.5	170	0.2	160

(Con't) Table 7

No.	As	Se	Br	Ag	Cd	Sb	La	Ce	Sm	Eu	Au	Hg	Th	U
					Shop for oleum phosphate extraction (OPE-1)									
1	<0.1	0.8	2.8	<0.5	<0.5	0.05	0.5	1.1	0.05	0.03	0.009	0.1	<0.1	0.3
2	0.1	<0.5	1.1	<0.5	<0.5	0.09	0.4	1	0.05		0.065	0.3	<0.1	0.9
3	0.1	<0.5	0.5	<0.5	<0.5	0.04	1.2	2.3	0.07	0.03	0.009	0.2	0.1	<0.1
4	<0.1	<0.5	0.7	<0.5	<0.5	0.02	0.5	0.9	0.05		0.016	0.3	<0.1	0.4
5	<0.1	<0.5	0.5	0.7	<0.5	0.02	0.7	1.5	0.06	0.03	0.008	0.1	<0.1	0.4
					Shop for oleum phosphate extraction (OPE-3)									
6	0.5	1.1	1.7	0.6	<0.5	0.05	2.2	3.4	0.2	0.14	0.018	0.3	0.2	<0.1
7	0.5	0.8	0.7	0.7	<0.5	0.05	4.2	6.5	0.4	0.17	0.008	0.4	0.3	0.2
8	0.5	0.9	0.8	<0.5	<0.5	0.18	4.1	6.1	0.4	0.15	0.015	0.5	0.3	0.8
9	0.2	<0.5	1	<0.5	<0.5	0.04	2.4	3.6	0.2	0.06	0.014	0.4	0.2	0.4
10	0.2	1.2	2.6	3.5	<0.5	0.09	2.1	3.8	0.2	0.09	0.024	0.5	0.2	0.5
					Shop for oleum phosphate extraction (OPE-4)									
11	0.1	0.6	0.4	<0.5	<0.5	0.04	0.6	1.2	0.06	0.04	0.069	0.4	<0.1	0.6
12	<0.1	0.6	0.4	0.2	<0.5	1.1	2.1	3.8	0.16	0.08	0.17	0.7	0.1	0.4
13	<0.1	<0.5	0.3	6.5	<0.5	0.04	0.4	0.9	0.06		0.079	0.2	<0.1	0.7
14	0.1	<0.5	0.3	<0.5	<0.5	0.24	2.2	4.1	0.1	0.05	0.048	<0.1	<0.1	0.2
					Shop for production of ammophos (AMM-1)									
15	<0.1	<0.5	2.1	<0.5	<0.5	0.07	1.2	1.7	0.1	0.06	0.006	0.2	0.2	0.3
16	<0.1	<0.5	1	<0.5	<0.5	0.03	0.7	1.8	0.05	0.03	0.009	0.1	<0.1	<0.1
17	0.2	<0.5	0.6	<0.5	<0.5	0.03	0.7	1.1	0.05	0.06	0.009	0.1	<0.1	<0.1
18	<0.1	0.5	1.4	<0.5	<0.5	0.05	0.5	0.7	0.04	0.02	0.008	0.4	<0.1	0.5
19	<0.1	<0.5	0.6	<0.5	<0.5	0.04	0.6	0.9	0.07	0.07	0.032	0.3	<0.1	<0.1
					Shop for production of ammophos AMM-2									
20	0.1	<0.5	0.8	<0.5	<0.5	0.04	0.2	0.7	0.06	0.03	0.007	0.3	0.1	0.4
21	0.1	<0.5	0.7	<0.5	<0.5	0.06	0.3	0.7	0.05	0.02	0.054	0.1	0.2	0.7
22	0.4	0.5	1.1	<0.5	<0.5	0.06	1.2	2.5	0.09	0.02	0.008	0.2	0.3	0.6
23	<0,1	<0.5	1.1	<0.5	<0.5	0.02	0.3	0.8	0.04	0.03	0.015	0.7	<0.1	0.6
24	0.1	1.1	1.3	0.8	<0.5	0.04	0.5	1.1	0.04	0.02	0.014	0.5	<0.1	<0.1
25	<0,1	<0.5	0.6	<0.5	<0.5	0.22	0.4	0.7	0.06		0.01	0.5	<0.1	0.4
					Shop for oleum sulfate extraction OSE-3									
26	<0.1	<0.5	0.6	<0.5	<0.5	0.03	0.7	1	0.07	0.03	0.37	0.2	0.1	0.6
27	<0.1	<0.5	2.7	<0.5	<0.5	0.22	1.4	2.5	0.1	0.15	0.063	0.5	<0.1	<0.1
28	<0.1	<0.5	0.6	<0.5	<0.5	0.06	0.4	1.1	0.02	0.05	0.048	0.2	<0.1	0.3
29	0.3	<0.5	1	<0.5	<0.5	0.03	2.8	4.6	0.15	0.06	0.049	0.2	<0.1	0.4
30	<0.1	<0.5	1.4	<0.5	<0.5	<0.01	0.6	0.9	0.04	0.05	0.14	0.4	<0.1	<0.1
					Central Laboratory CL									
31	0.09	<0.5	1.1	<0.5	<0.5	0.05	0.5	1	0.1	0.03	0.02	0.6	0.04	0.6
32	0.05	<0.5	1.7	<0.5	<0.5	0.02	0.6	1.3	0.05	0.03	0.022	0.5	<0.1	0.3
33	<0.1	<0.5	0.5	<0.5	<0.5	0.02	1.3	3	0.06	0.05	0.005	0.3	<0.1	<0.1
34	0.08	<0.5	1.7	0.4	<0.5	0.05	0.8	1	0.05	0.01	0.073	0.1	<0.1	1.1
35	<0.1	<0.5	1.9	2.2	<0.5	0.11	0.2	0.5	0.04		0.027	0.4	<0.1	0.2
36	<0.1	<0.5	0.4	<0.5	<0.5	<0.01	0.6	1	0.03	0.04	0.018	0.2	<0.1	<0.1

Table 8

TRACE ELEMENTS IN NAILS OF THE OCCUPATIONAL STAFF OF THE "MINERAL FERTILIZERS" PLANT, μG/G

No	Occupation	Shop	Na	Ca	Sc	Cr	Fe	Co	Zn	As	Br	Sb	La	Ce	Sm	Eu	Au	Th
1	Mechanic-repairman	OPE-3	140	3000	0.13	8.5	430	0.9	145	<0.1	1.8	<0.05	2	3.3	0.12	0.16	0.04	0.2
2	Mechanic-repairman	OPE-3	130	3600	0.14	13	360	0.8	170	<0.1	2.7	<0.05	10	14	0.74	0.42	0.02	0.4
3	Conveyor mechanic	AMM-2	130	5700	0.14	4.4	270	0.8	170	<0.1	0.8	<0.05	1.2	2.9	0.06	0.1	0.01	<0.1
4	Quality control technician	AMM-2	240	5900	0.2	5.9	470	0.9	200	<0.1	0.9	<0.05	6	10	0.18	0.12	0.06	<0.1
5	Foreman	AMM-2	540	15 000	0.7	30	3300	3.3	330	<0.1	6	<0.05	7.3	19	0.43	0.8	0.07	1.2
6	Background sample		74	3400	0.16	6.8	160	0.4	110	<0.1	1.8	<0.05	1.6	2.6	0.12	0.16	0.02	<0.1

Table 9

TRACE ELEMENTS IN TEETH OF THE OCCUPATIONAL STAFF OF THE "MINERAL FERTILIZERS" PLANT

No.	Na	Ca (%)	Sc	Fe	Co	Zn	La	Ce	Sm	Eu	Yb	Lu	Au
1	4,900	10.7	0.08	400	0.45	200	0.23	0.74	0.052	0.041	0.067	0.0086	0.52
2	7,600	9.8	0.14	470	0.6	1,700	-	-	-	-	-	-	48.7
3	4,500	11.1	0.08	510	0.9	200	-	-	-	-	-	-	0.05
4	8,100	7.3	0.67	2,600	1.8	57,000	-	-	-	-	-	-	0.2
5	3,400	10	0.08	500	0.5	140	0.1	0.38	0.014	0.012	0.026	0.0041	0.03
6*	-	-	-	-	-	-	0.12	0.39	0.017	0.013	0.028	0.0069	-

6 - the background sample.

The employee nails (**Table 8**) show the same identity with hair in accumulating the trace elements. However, there is always a possibility that nails are not cleaned enough from the surface contamination.

The results of the analysis of the bone tissue (teeth) of the occupational staff are presented in **Table 9**. The difference in the level of element concentrations in individual samples is quite substantial. Perhaps it could be explained by the presence or absence of the artificial dental protheses in the mouth and by the material they are produced from. One should note the differential distribution of REE (Sm/Eu ratio) obtained from the radiochemical analysis.

4. Conclusions

1. The main chemical pollutants at the plant are F, Ca, As, Sb, REE, Th, and U, which is confirmed by the analysis of the atmospheric aerosols and the hair of the occupational staff. The main source of pollution is the raw material (apatite concentrate).

2. The drinking water consumed at the plant could not be considered as a source of the uptake of the above-mentioned elements into a human organism.

3. Due to atmochemical network the workplaces characterized by the increased level of trace element pollution in air are revealed.

4. The trace element content of the hair of the occupational staff reflects the pollution of the workplaces.

5 There is a hope that more thorough study of the trace element content of teeth could help to reveal the interrelation between the concentration of Ca on the one hand, and of F, Sr, and REE, on the other.

6. One should note that the further sampling of dust and nails is not reasonable.

We plan to repeat the workplace monitoring of the fertilizer plant at a large scale and the extending the study to the occupational staff and local residents of the phosphate ore of the phosphate ore open-cast mining enterprise, situated 3-7 km from the main plant.

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Фронтасьева М.В. и др. E14-98-392

Мониторинг на рабочих местах
и изучение влияния производства фосфорных минеральных удобрений
на здоровье персонала, занятого в этом производстве
(завод «Минеральные удобрения», Воскресенск, Московская область, Россия),
с использованием ядерно-физических аналитических методов.
Часть I

В работе содержатся данные первого этапа мониторинга на рабочих местах завода «Минеральные удобрения» в Воскресенске (Московская область), одного из крупнейших центров по производству фосфорных минеральных удобрений в России. Определены типичные ассоциации элементов-загрязнителей в цехах завода с использованием рентгено-флюоресцентного анализа (ХРФА), метода атомной абсорбции (АА) и нейтронного активационного анализа (НАА). Максимальное загрязнение частицами пыли и наивысшие концентрации Na, Ca, Sc, Cr, Fe, As, Sb, Sr, РЗЭ и Th были выявлены в загрузочно-разгрузочных помещениях соответствующих цехов. Уровень концентрации микроэлементов в биосубстратах (волосы, ногти, зубы) отражает длительное и систематическое воздействие загрязнителей воздуха на рабочие места и на персонал, занятый в производстве. Наличие в технологии производства выделения фтора показывает необходимость проведения дополнительного объема работ для оценки его воздействия на рабочий персонал предприятия.

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Frontasyeva M.V. et al. E14-98-392

Workplace Monitoring and Occupational Health Studies at the Centre for Production
of Phosphorus Mineral Fertilizers, Voskresensk (Moscow Region, Russia),
Using Nuclear and Related Analytical Techniques.
Part I

This paper contains the preliminary data obtained while monitoring the workplaces of the «Mineral Fertilizers» plant in Voskresensk (Moscow Region), one of the largest centres for producting phosphorus mineral fertilizers in Russia. The most typical associations of element-pollutants in the shops of the plant were determined by means of XRF, AAS and NAA. The maximal pollution by dust particulates and the highest concentrations for Na, Ca, Sc, Cr, Fe, As, Sb, Sr, REE, and Th at the loading-unloading sites of the shops were revealed. The level of trace element concentrations in the biosubstrates of the occupational staff (hair, nails, teeth) reflects the sustained and systematic impact of air pollutants in the working area of the plant on its occupational staff. Due to the considerable emissions of fluorine in the technological process, the necessity of assessing the fluorine accumulation in the occupational staff is emphasized.

The investigation has been performed at the Frank Laboratory of Neutron Physics, JINR.

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