E.P. Yanin

ELECTRICAL ENGINEERING INDUSTRY
and
THE URBAN ENVIRONMENT

(man-made pollution and ecological effects)

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Yanin E.P.

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This paper displays geoenvironmental aspects of supply and distribution of chemical elements in urban environments related to activities of the electrical engineering enterprises. The paper is based upon the data obtained during the course of studies conducted in Saransk, Republic of Mordovia, Russia. In the methodical aspect, this is a favorable object representing an industrial urban area. Its ecology is dominated by the electrical engineering plants.

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Dr. Evgeny P. Yanin
Leading Scientist, Department of Geoecological and Geochemical Cartography, Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements (IMGRE), Russian Academy of Sciences,
15 Veresaeva ul., Moscow, 121357, Russia; e-mail: kva@imgre.ittp.ru (for Yanin).

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Introduction

Philosophy of geoecological studies aimed at the anthropogenic impact effects are based upon revealing of relationships between the pollution sources (industrial enterprises), the pollutant distribution along the pathways of atmospheric and aquatic flows, and deposition of the pollutants in the accumulating media (soil, stream sediments, and living organisms) [2]. Principal objective of the urban pollution studies is revealing of the man-made geochemical anomalies as areas where the landscape constituents bear concentrations of chemical elements and compounds that exceed the background level. Such levels are inherent in the natural bodies (i.e., soil, water, air, stream sediment) that remain intact of productive human activities. Anomalies could be mono- or polyelemental. In the former case, content of only one element is above the threshold; in the latter case it is presumed that several components are above the background.

Arbitrary units serve as a contrast measure of the anthropogenic geochemical anomalies, i.e., the observed values are compared to the normative environmental parameters. This approach enables estimation of the pollution level (the hazardousness grade). To date, ecological and sanitary normatives and the maximum permissible concentrations, MPC, are the parameters. However, values of these characteristics are not available for every existing landscape component. In such cases, the background-normalized values, or K_c, are used, i.e., $K_c=C_{(observed)}/C_{(background)}$. Key characteristics of an anomaly are its geochemical spectrum, i.e., an assemblage of the anomaly-forming elements, and its contrast, K_c . Usually, the elements are included into the assemblage in cases when K_c is greater or equal to 1.5 (a normative error below 50%). The multi-component geochemical anomalies are characterized by the net pollution index, Zc, defined as:

$$Z_c=\sum_{\iota=1}^{n} K_c - (n-1)$$

where n is a number of the chemical elements with the background-normalized concentration values, K_c, greater than or equal to 1.5.

In compliance with the methods of the urbanized territories' studies accepted in Russia, geochemical soil anomalies are used as the atmospheric pollution indication. Soil is the depositing medium for the pollutants and reflects indirectly the geochemical situation in the ambient air. Real level of the atmospheric pollution is estimated by the results of direct geochemical observations in the atmosphere. Additional information could be obtained from studies of the chemical elements' distribution in the industrial waste and vegetation of the urbanized territories. Ecological estimation of the water courses requires data on chemistries of water, stream sediments, suspensates, and water-living plants. Increased contents of pollutants in human organism, as well as morphological and functional health disorders are major indications of the ecological impact for the urban residents.

1. Saransk: Major features of the city territory

Saransk (population about 360,000) is a capital of the Mordovian Republic and an important center of the Russian electrical engineering industry. Enterprises of this industry employ more than 33,000 persons. Taking into account the family members, every other resident is related to this industry. Up to 70% of the illumination sources are made in Saransk. Saransk is an area of heavy anthropogenic impact. Essential features of the city to be considered when estimating relative influence grade of the health situation controls are: (1) multi-component character of geochemical anomalies (pollution zones that carry heavy metals, organic toxicants, etc.) existing in various components of the urban environment, (2) high contents of antibiotics emitted by a pharmaceutical factory, (3) intensive lead pollution, (4) special features of the potable water that is rich in F and some other undesirable components, (5) use of ecologically hazardous technologies and techniques at the city industrial enterprises [1; 4-8].

Saransk is well above the average in existing pollution level of the ambient air among the Russian cities. It takes the same undesirable position in the *per capita* liquid waste production and the under-treated refuse water dumping into the watercourses. Annual domestic waste output is about 230,000 m^3, and that of industrial refuse exceeds 5600 tons, including approx. 400 tons of toxic substances. From 14,000 to 15,000 women are employed at hazardous and health-risky jobs; the professional disease rate among them is about 64% of the total case histories number. Electrical engineering enterprises are among the major pollution sources at the city territory (Table 1).

This industry requires significant amounts of base and ferrous metals, acids, organic reagents, polymers, paint and varnish materials. Practically all these enterprises use etching and galvanic techniques; key technologic operations are tinplating, soldering, fat removal, cutting, and painting. All these processes are accompanied by intensive emission of pollutants. Electric engineering enterprises, especially the lamp plants, emit significant amounts of gaseous and liquid refuse. Besides, the plants give rise to great volumes of solid waste, trapped dust and sludge settled by the local liquid dump treatment units. Greater part of the waste, i.e., litter, sludge, dust, and solids, is either transported to the municipal dumps, or remains stored at the plant territories.

Table 1. Major characteristics of the electric engineering enterprises, Saransk

Full name of an enterprise	Abbrevia-tion	Year of founda-tion	Number of em-ployees	Atmospheric discharge, tons per year			Sludge, tons per year	Waste water, m^3/year
				Total	incl. dust	Scav-enged dust		
Electric lamp plant	SELZ	1955	4374	965.2	68.8	239.6	300	1750000
Special illumination equipment and vacuum glass plant	SIS-EVS	1965	15039	492.1	241.9	70.17	3100	1755360
R&D Institute of the Illumination Equipment	VNIIIS	1958	1662	nd	nd	nd	nd	208000
Rectifier plant	EV	1941	7900	85	8.8	7.3	917	461500
Experimental power line electronics plant	OZSE	1985	1030	3.32	0.16	2.83	nd	43766
Special power line converter plant	ZSSP	1979	1842	40.6	14	45.8	nd	52353
Cable plant	SK	1955	1350	3.6	0.07	nd	25	364000

Note: data are valid for early 1990s; nd here and elsewhere - no data.

Significant contents of heavy metals, organic compounds and inorganic acids in refuse are typical of the electric engineering enterprises. Some categories of gaseous discharge, as well as solid and liquid waste carry cancerogenes, e.g., benzo-[a]-pyrene, soot, vinyl chloride, formaldehyde, polychlorobenzene, mineral oils, and Cd, As, Be, Ni, Cr compounds. Technologic processes that comprise spraying of strong mineral acids are also dangerous in this aspect. Minor amounts of radioactive waste is reported as a possibility for these enterprises.

The Saransk electrical lamp plant, SELZ, produces incandescent lamps and gas discharge low-pressure mercury lamps, including the luminescent varieties. The most hazardous technologies are those related to the luminescent lamp production, etching , galvanic and spiral making. Presently ecological impact has decreased significantly, as controlled by decreased production rate. Nevertheless, existing discharge still carries numerous pollutants (Table 2). SELZ is a major heavy metal pollution source of the city [1, 8]. The luminescent lamps have been produced here since 1961. After 1965, the production rate of the luminescent lamps was about 30-35 million per year that required about 5.5 tons of mercury. By 1990, about one billion lamps has been produced here. Total amount of Hg supplied to the urban environment during the period was 10-12 tons.

The special illumination sources and vacuum glass plant, SIS-EVS, produces light sources, vacuum glass and other illumination equipment. The most hazardous techniques used here are lead glass production (terminated in mid-90s), along with gas discharge lamps, chemical polishing and galvanic techniques. Source waste waters treated by the city sewage are rich in Fe, Cu, Ni, Zn, Mo, Pb, Cr, fluorides, and detergents. About 450 tons of graphite, 400 tons of galvanic sludge and 12 tons of defective mercury lamps are stored annually at the city dump among other kinds of solid refuse. Recently, the total output of pollutants has reduced (Table 3) due to the environment protection measures taken and general decrease in the production rate.

R&D Institute of the Illumination Sources (VNIIIS) comprises several productive units that manufacture various types of incandescent lamps, halogen quartz lamps, low-pressure luminescent lamps, and gas discharge UV lamps. Luminescent lamp production and operations that use galvanic techniques are the most hazardous ones. Solid refuse annually produced by VNIIIS comprises litter (25 t), unpolluted cullet (22 t), luminophore-polluted cullet (7 t), demercurized luminescent lamps (2.5 t). Besides, the following items are stored immediately at the territory of the institute (tons per year): thoriated tungsten (0.2), oil-polluted tricloroethylene (0.24), luminophore-polluted butile acetate (0.48), and hard rubber shaving (0.3).

The experimental power line electronics plant (OZSE) produces the power line converters, the converter substations, welding equipment, etc. Technologies require ferrous and base metal rolled materials, paint and varnish materials (approx. 0.5 tons p.y.) and various cables.

Table 2. Discharge of pollutants to the atmosphere from SELZ, tons per year

Pollutant	Year	
	1995	1996
TOTAL	413.790	347.214
Solid components, including:	49.173	29.521
Inorganic dust	21.865	13.628
Organic dust	2.357	1.469
Pb	0.002	0.002
Mn and its compounds	0.001	0.001
Na and its compounds	17.708	7.606
Si and its compounds	0.002	0.002
K and its compounds	6.086	6.457
Fluoride	0.002	0.002
Soot	0.320	0.042
Gaseous and liquid components, including	364.617	317.693
SO_2	210.889	179.526
CO_2	70.971	66.543
No_x	51.213	44.904
Hydrocarbons (volatile species excluded)	0.681	0.774
Volatile organic compounds,	25.483	21.190
including:		
Xylene	0.446	0.283
Toluene	0.002	0.002
Butyl acetate	11.100	7.756
Ethanol	2.579	2.523
Benzine	0.177	0.476
Acetone	0.640	5.624
Trichloroethylene	4.425	4.425
Dichlordifluoromethane	0.040	0.040
Methane	0.030	0.024
Kerosene	0.007	0.007
White spirit	0.027	0.034
Acetic acid	0.003	0.003
Other gaseous and liquid components, incuding:	5.380	4.756
Ammonia	0.001	0.001
Hydrogen chloride	3.198	2.574
Hydrogen fluoride	0.001	0.001
Alkali	0.217	0.217
Sulfuric acid	0.105	0.105
Nitric acid	1.848	1.848
Phosphoric acid	0.003	0.003
Hg	0.007	0.007

Table 3 Discharge of pollutants to the atmosphere from SIS-EVS, tons per year

Pollutant	Year	
	1995	1996
TOTAL	326.933	264.775
Solid components, including:	104.863	91.863
Inorganic dust	46.629	46.985
Organic dust	5.533	5.302
Pb and its compounds	1.497	0.978
Mn and its compounds	1.689	1.051
Zn and its compounds	1.363	0.006
Al and its compounds	0.333	0.333
Cr and its compounds	0.009	0.006
Na and its compounds	13.465	23.095
Si and its compounds	0.830	nd
P and its compounds	0.020	0.022
K and its compounds	30.208	8.051
B and its compounds	3.281	6.051
Sb and its compounds	0.002	0.002
Ni and its compounds	0.003	0.0094
Fluoride	0.001	0.0017
Gaseous and liquid components, including:	222.961	172.912
SO_2	9.582	8.359
CO	59.941	30.899
No_x	131.283	116.743
Hydrocarbons (volatile species excluded)	3.230	3.235
Volatile organic compounds, including:	10.136	7.903
Butanol	0.054	0.027
Formaldehyde	0.086	0.084
Butyl acetate	4.469	1.964
Benzine	0.011	0.011
Chloroform	0.013	0.013
Acetone	2.609	3.952
Solvent	2.800	1.778
Perchloroethylene	0.046	0.040
Ethylbenzene	nd	0.0002
Ethylcellosolve	0.043	0.027
Other gaseous and liquid components, including:	7.959	5.773
Ammonia	0.175	0.186
Hydrogen chloride	6.600	4.712
Hydrogen fluoride	0.300	0.268
Alkali	0.563	0.427
Sulfuric acid	0.295	0.144
Hg	0.0016	0.0007
Ozone	0.024	0.021

The Saransk cable plant (SK) produces a wide range of cables, along with polyethylene and polychlorovynile items. Conducting materials are presented by Cu and Al, whereas insulators and protective covers - by lead, polyethylene and polyvinyl chloride. The most ecologically hazardous operations are etching, tinning, metal cutting, coloring, drawing of wire through thermoplastic, bitumen or lead (aluminium) melt, accumulator charging. Atmospheric discharge of the enterprise carry Pb, Sn, Cu, Al, hydrogen chloride, chlorovinyle, inorganic acid spray, carbon monoxide, polyethylene and polyvinyl chloride dust, triethanol amine, hydrocarbons, benzo-[a]-pyrene, butyl acetate, acetone, spirit, toluene, etc. Waste water of the enterprise are rich in Fe, Pb, Cu, and oil products. Solid residual of the local purification unit is used as the construction material.

The EV (electric rectifier) plant produces electronic devices, power line transducers, and domestic electronics. The most hazardous technologic operations are galvanics, coloring, HF-etching, and operations with phosphorus compounds in production of semiconductors. Waste waters are rich in Cu, Ni, Zn, Cr, Fe, F, oil products, etc. Annual production of solid waste subsequently transported to the city dump includes: thermosetting plastics (up to 12 t), fluoroplactics (up to 5 t) and litter (up to 15 m^3 per day).

The special power line converter plant (ZSSP) produces the power line converters and related equipment, along with domestic devices. Liquid and gaseous refuse of this plant is rich in xylene, tholuene, benzene, white spirit, kerosene, spirits, carbon monoxide, nitrogen oxides, etc. Solid waste includes (tons per year): paper (10), oil-impregnated timber cutting (44), the fiber glass dust (>30).

The following areas that differ in functional and environmental features, constitute the city infrastructure: (1) ‘Svetotekhnika’ (NW part of the city, a ’dormitory’ area influenced by the Northern industrial zone), (2) the Northern industrial zone (SIS-EVS, ZSSP, TV making plant, the construction materials plant; from south, the dump truck making plant, the cable plant, the tool making plant, and some others adjoin the area; (3) ‘Northern’ area (a residential zone that lies NE of the Northern zone; a large power plant is located nearby; (4) ‘Zarechnyi’ , a residential area in the western part of the city; the technologic rubber plant is the main industrial enterprise; (5) downtown (the major and oldest part of the city; SELZ, EV, OZSE, pharmaceutical factory and tool making plant occur here; (6) ‘Oktyabr’skii’, the SW part of the city, a residential area; (7) ‘Parkovyi’, the SE part of the city, a residential area, and (8) ‘the Southern industrial zone’ that comprises food , medical equipment and electronic plants.

The Insar river is a major city water course. Along with its tributaries, it takes up waters dumped from local and city water treatment stations, as well as surface runoff produced in the urban area and surroundings. Approximately 70 km downstream of Saransk, the Insar flows into the Alatyr, a left tributary of the Sura river.

The sewage and liquid refuse treatment units supply about 20 per cent of the Insar river runoff; additionally, pollutants enter the Insar river with the surface runoff.

2. Electrical engineering enterprises: Effects on the ambient air and urban ecology

2.1. Chemical elements abundance in the industrial dust discharge

The industrial dust discharge is a key source of chemical elements in the urban environments. The dust chemistry studies enable establishment of the pollutants’ assemblages and identification of their source(s). Required sampling and analytical operations are a complicated procedure. Probably, this is the reason for scarcity of this kind of information in Russian publications.

The author have organized dust chemistry studies at various industrial enterprises of Saransk. The following varieties of dust are sampled: (i) the ‘technologic’ dust collected from traps, i.e., cyclones and filters, (ii) the ‘vent’ dust collected from inside of the ventilating units of the industrial buildings, and (iii) the ‘wipeable’ dust collected from various surfaces (e.g., sills, ramps, tables) located inside the industrial buildings.

Chemistry of the ‘technologic’ dust characterizes the pollutants transported with the canalized (specially designed) waste flow, whereas the two latter categories represent leakages and immediately indicate quality of the working zones’ environment.

Sharp spatial variations are characteristic of chemical elements’ distribution, even when measured within an individual room. This fact is due to inhomogeneity of the materials sampled, and, probably, different speciation of chemical elements. Normally, contents of chemical elements in all types of dust are much higher relatively to the background soil (Tables 4 and 5).

Table 4. Chemical element contents (ppm) in dust produced by the electric lamp-producing plants.

№	Element	Enterprise									Background in soils
		SELZ			SIS-EVS			VNIIIS			
		1	2	3	1	2	3	1	2	3	
1	B	40	nd	nd	2800	50	100	2600	130	45	20
2	Sc	7	nd	nd	8	<1	5	3	nd	4	7
3	Ti	700	nd	nd	8400	7600	8000	650	1200	2200	5000
4	V	175	nd	nd	200	200	300	20	150	125	90
5	Cr	450	50	46	700	6000	100	55	400	5000	70
6	Mn	8500	290	5300	3700	3400	100	680	3400	900	1000
7	Co	20	nd	nd	50	54	30	14	100	175	8
8	Ni	80	65	56	480	640	100	48	270	1600	50
9	Cu	470	120	4700	9200	9600	150	5000	1400	500	30
10	Zn	2200	710	2600	4400	4600	600	1300	24000	5000	90
11	Ga	2	nd	nd	15	2	80	2	nd	8	20
12	Ge	12	nd	nd	3	3	5	<3	25	3	1,2
13	As	280	nd	nd	7	6	7	11	nd	5	6
14	Sr	3000	nd	nd	<30	100	30	30	nd	90	250
15	Y	40	nd	nd	3	<1	5	<3	nd	6	40
16	Zr	10	nd	nd	100	30	100	100	nd	65	400
17	Nb	3	nd	nd	3	<3	<3	<3	nd	30	10
18	Mo	20	nd	nd	8	20	3	7	600	17	1.2
19	Ag	0.2	nd	nd	6.4	9	0.15	0.1	2.5	0.2	0.05
20	Cd	1800	2	1700	3	3	<3	3	190	55	0.35
21	Sn	250	nd	nd	7	25	8	550	140	19	4
22	Sb	>1000	nd	nd	27	19	28	<3	5	10	1
23	Ba	25000	nd	nd	300	8000	100	100	nd	700	500
24	W	200	nd	nd	30	10	60	25	900	330	1.5
25	Hg	12	2	nd	0.3	0.5	0.3	4	1	2	0.06
26	Pb	1200	450	4200	1200	1500	5000	60	1400	1000	15
27	Bi	<3	nd	nd	3	<3	5	3	<3	3	0.2

Note: 1 - ‘technologic’ dust, 2 - ‘vent’ dust, 3 - ‘wipeable’ dust; analytical techniques used:AAS (№№ 5-10, 18-20, 25-27), quantitative OESA (№№ 1, 3, 4, 12-14, 21-24, 27), semi-quantitative OESA (others); the values given here represent analytical data on combined samples obtained from 3 to 5 subsamples of morphologically identical material collected at the territoties of the above mentioned enterprises.

Table 5. Chemical element contents (ppm) in dust produced by the electric engineering plants

Element	Plant								Background in soil
	EV		OZSE		ZSSP		SK		
	1	3	1	3	1	3	2	3	
B	nd	nd	nd	nd	nd	nd	22	50	20
Sc	nd	nd	nd	nd	nd	nd	5	3	7
Ti	nd	nd	nd	nd	nd	nd	3000	1500	5000
V	nd	nd	nd	nd	nd	nd	35	100	90
Cr	1800	390	680	400	250	110	240	150	70
Mn	1600	440	790	530	790	270	650	800	1000
Co	130	15	14	12	14	9	10	20	8
Ni	690	50	470	130	470	34	160	30	50
Cu	960	230	190	420	190	89	44000	6000	30
Zn	290	3200	550	4700	550	520	3600	2000	90
Ga	nd	nd	nd	nd	nd	nd	10	6	20
Ge	nd	nd	nd	nd	nd	nd	<3	3	1,2
As	nd	nd	nd	nd	nd	nd	5	5	6
Sr	nd	nd	nd	nd	nd	nd	100	100	250
Y	nd	nd	nd	nd	nd	nd	10	3	40
Zr	nd	nd	nd	nd	nd	nd	100	50	400
Nb	nd	nd	nd	nd	nd	nd	3	3	10
Mo	38	50	60	260	5	nd	11	6	1.2
Ag	0.2	nd	0.2	16	0.5	nd	1.3	0.6	0.05
Cd	28	11	220	21	10	23	40	<3	0.35
Sn	nd	nd	nd	nd	nd	nd	4600	500	4
Sb	nd	nd	nd	nd	nd	nd	200	35	1
Ba	nd	nd	nd	nd	nd	nd	800	800	500
W	nd	nd	nd	nd	nd	nd	20	200	1.5
Hg	nd	nd	nd	nd	nd	nd	0.4	0.3	0.06
Pb	290	760	1200	480	40	690	3300	2000	15
Bi	<3	nd	<3	nd	<3	nd	3	5	0.2

Note: See Table 4.

Heavy metals (Pb, Hg, Cd, Cu, Zn, Sb, Mo, W, Sn, Ag, Cr, Bi) set the example. As a rule, the metal loading of the ‘technologic’ dust is the greatest. The exceptions are maximum Cu, Zn and Pb contents found in the ‘wipeable’ dust at SELZ, and peak Cr, Ni, Zn, Mo, Sn, and Ba contents in the ‘vent’ dust at SIS-EVS. In a majority of cases, low Ti (SIS-EVS excluded) and Zr concentrations, as compared to those in the background soil, are typical of the industrial dust. Similar tendency is observed for Sc, Y, and Ga (except for the ‘wipeable’ dust at SIS-EVS), Sr (the ‘technologic’ dust at SELZ excluded), and Nb (minus the ‘wipeable dust at VNIIIS). Presumably, individual technologic features and source materials used are responsible for these facts. Thus, in the SIS-EVS and VNIIIS cases, where the source materials (soda, sand, dolomite, etc.) for the glass manufacturing are different, the dust is more rich in lithofile elements (e.g., Ti and Zr).

As calculated, the canalized dust flow (the ‘technologic’ dust) carries from SELZ into the environment more than 3 tons p.y. of metals; in case of SIS-EVS the value exceeds 7.7 tons p.y. More than 11 tons of metals is annually deposited by the liquid waste treatment units at SELZ with subsequent transportation to the city dump. Considerable output of metals with dust are controlled both by high metal contents in solid particles and high total dust discharge to the ambient atmosphere. Our data demonstrate that the dust leakages (the ‘vent’ dust) also represents a major pollution source. Notably, such sources skip existing ecological statistics. High metal contents in the ‘wipeable’ and ‘vent’ dust increase the health risk for employees of the enterprises studied. Dust produced at an individual enterprise preserves its original geochemical signature. The latter is best demonstrated by proportions between the K_c values of the components and, to a lesser degree, as presence of the indicator elements inherent in a given enterprise in the geochemical assemblage (Table 6).

Table 6. Assemblages of chemical elements in 'technologic' dust.

Plant	Type of dust	K_c of the elements in dust (observed values for the dust are normalized by backgroun values for soil)					
		> 300	300-100	100-30	30-10	10-3	< 3
SELZ	1	Sb-Cd	Hg-W	Pb-Sn-Ba-As	Zn-Mo-Cu-Sr-Ge	Mn-Cr-Ag	Co-B-V-Ni
	2			Pb	Hg	Zn-Cd-Cu	
	3	Cd	Pb-Cu	Hg	Zn	Mn	
SIS-EVS	1	Cu	B-Ag	Pb-Zn-	Sb-W-Bi-Cr	Ni-Cd-Mo-Co-Hg-Mn-	Ge-V-Sn-Ti-
	2	Cu	Ag-Pb	Cr-Zn	Sb-Ba-Mo-Ni	Hg-Cd-Co-W-Sn-Mn	B-V-Ge-Ti-
	3	Pb		W	Sb-Bi	Zn-Hg-B-Cu-Ga-Co-Ag-V	Mo-Sn-Ni-Ti-Cr
EV	1			Cd-Mo-Cu	Cr-Pb-Co-Ni	Ag-Zn	Mn
	3			Pb-Mo-Zn-Cd		Cu-Cr-Fe	Co
OZSE	1	Cd		Pb-Mo		Cr-Cu-Zn-Ag	Co
	3	Ag	Mo	Cd-Zn-Pb	Cu	Cr-Fe	Co
ZSSP	1			Cu	Cd-Ag	Zn-Ni-Co-Mo-Cr-Mn	Pb
	3			Cd-Pb		Zn	Cu-Fe-Cr
SK	2	Cu-Sn	Pb-Sb-Cd	Zn	Ag-Bi-W	Mo-Hg-Cr-Ni	Ba
	3		Cu-W-Pb-Sn-	Sb	Bi-Zn-Ag	Mo-Hg	Co-Cr-Ba
Instrument making	2	W	Mo	Co-Cr-Cu-Pb-Zn	Ni-Ag-Sn	V	Ti-Mn
	3	W	Co-Cd-Zn	Pb-Cu-Cr	Sn-Bi-Ag-Ni-Mo-Hg	B	V
Precise tools making	3			Cd-Pb-Zn	Fe-Cu	Co	Ni-Mn

Note: Dust types:1 - 'technologic', 2 - 'vent' 3 - 'wipeable'.

Studies of proportions between the so-called 'mobile' metal species (ammonia acetate-extractable, pH 4.2) and the 'residual', or 'immobile' ones in the 'technologic' dust collected at SIS-EVS demonstrate that the latter category prevails. Possibly, these are oxides or fine metal particles (Table 7). The 'vent' dust carries higher proportion of the 'mobile' species, especially for Zn, Pb, Cd, Cr, and Cu. Condensates of the vapor and gaseous phases could be responsible for the fact, along with carbonates, sulfates, and other forms easily extractable with ammonia acetate. This is an indication of the sanitary hazardousness of the dust leakages that occur in the working zones.

Thus, the dust discharge of the electric engineering enterprises is rich in many chemical elements. The electrical lamp plants are the worst case: high total dust output is combined here with high pollutant contents. Normally, geochemical signature of an individual enterprise is also individual, as reflected by different concentration levels for individual elements and, less frequently, by pollutants specific for a given enterprise or dust type. The plant that manufactures luminescent and incandescent lamps (SELZ) is marked by maximum Sb, Cd, Hg, W, Pb, and concentrations in dust; Cu, B, Ag, and Pb are typical of SIS-EVS where the illumination sources, related equipment and glass are produced. The dust generated at the power line electronics plant is rich in Cd, Mo, Cu, Pb, Ag, and Zn (at lower levels comparatively to the illumination equipment plants). Dust of the cable plant is rich in Cu, Sn, Pb, Sb, and Cd. All the elements listed constitute either source materials, or reagents. It is especially important that the air of the working zones at any electric engineering enterprise is rich in toxic dust.

Table 7. Speciation of metals in 'technologic' (1) and 'vent' dust, SIS-EVS

Me-tal	Characteristics					
	Total content, ppm		Ammonia acetate-extractable, ppm		(EXTRACTABLE) / (TOTAL), %	
	1	2	1	2	1	2
Cu	5300	85	2.86	9.2	0.05	10.8
Co	31	nd	2	nd	6.45	nd
Ni	260	31	16.2	1.2	6.23	3.9
Zn	3200	460	89.2	271	2.79	58.9
Mn	1000	660	104.4	16.6	10.44	4.8
Cr	190	92	4.05	16.6	2.13	18
Ag	nd	9	nd	0.02	nd	0.22
Cd	nd	3	nd	2.78	nd	92.6
Pb	nd	1200	nd	690	nd	57.5

Note: Analytical technique used : AAS

2.2 Chemical elements in urban soils

First of all, intensity of the anthropogenic impact of the industrial enterprises is indicated by contents of chemical elements in soil of industrial zones (Table 8), whereas individuality and hazardousness grade - by the elemental composition of the soil anomalies and proportions between the constituents (Table 9).

Soils of industrialized areas carry high amounts of numerous chemical elements at content grades usually well above the background. Values of the net pollution index, Z_c, contrast of the chemical element accumulation in soil and number of chemical elements that constitute the anomaly are directly related to duration and rate of the dust discharge. Each production unit is marked by an individual set of anomalous elements and, what is more important, by proportions between the elements that form the anomalies. Maximum intensity of the anthropogenic impact is established at SELZ.

Chemical elements typical of the source materials and techniques used dominate here among pollutants (Hg, Sb, Ag, Pb, Mo, Cd, Tl, W, Zn). Soil at the territory of SIS-EVS is marked , first of all, by Pb, Hg, Mo, W, Cu, F, Zn, Sb, whereas soil of the EV area is rich in Mo, Cd, W, Cu, Ag, along with characteristically high levels of Sn, Ge, Bi, Be, and F.

Contrast of anomalies at the territories of OZSE, ZSSP and the precise tool plant is much lower than in the previous cases. Mo is the most typical component of the OZSE area, with low-contrast W, Pb, F, Be, Cu, and Bi anomalies. This set of the indicator elements resembles that of the EV. Assemblages of chemical elements observed in soils of ZSSP and the precise tool plant are practically identical, with Pb, Be, F and Bi as dominants, probably due to similarity in technologic processes and source materials. High levels of Pb, Bi, Cu, Sn, Mo, P, and Sr are found at the territory of SK. Qualitatively, soil and dust anomalies are quite similar. Naturally, it should be noted that the dust chemistry reflects the situation for the moment of observation, whereas soils accumulate and average the lasting pollution effects. Low content of lithofiles (Sc, Ti, Zr, Ga, Y, Sr, Nb), as it is found in the industrial dust case, is also typical of the urban soils. This feature favors participation of the industrial dust discharge in formation of the urban soil chemistry.

Table 8. Chemical element content in soil of industrial zones, average values, ppm

№	Ele-ment	Plant						Background in soils
		SELZ	SIS-EVS	EV	OZSE	ZSSP	Precise tools	
1	Li	31	45	39	39	40	38	28
2	Be	0.5	0.4	1	1	1	1.5	0.3
3	B	22	30	49	34	37	34	20
4	F	760	980	870	770	750	800	200
5	Sc	3	4	3	3	3	4	7
6	Ti	2000	3000	3900	2800	3300	3300	5000
7	V	202	345	150	130	140	140	90
8	Cr	199	136	100	130	67	63	70
9	Mn	320	600	540	2300	450	430	1000
10	Co	18	10	22	13	14	13	8
11	Ni	83	49	64	36	38	31	50
12	Cu	198	186	310	92	80	62	30
13	Zn	950	280	270	140	150	100	90
14	Ga	10	12	15	20	15	15	20
15	Ge	5	3	7	3	3	3	1.2
16	As	10	9	7	6	7	6	6
17	Sr	225	75	50	50	80	40	250
18	Y	8	10	8	9	10	9	40
19	Zr	150	110	90	80	80	80	400
20	Nb	5	4	3	4	6	5	10
21	Mo	35	9	39	15	2	2	1.2
22	Ag	1.8	0.08	0.5	0.08	<0.1	0.05	0.05
23	Cd	9	1	1	0.7	0.5	<1	0.35
24	Sn	15	6	35	5	4	4	4
25	Sb	60	3	<3	<3	<3	<3	1
26	Ba	2530	380	150	100	100	100	500
27	W	25	11	25	10	<1	2	1.5
28	Hg	28.3	0.84	0.39	0.076	0.105	0.099	0.06
29	Tl	4	nd	nd	nd	nd	nd	0.2
30	Pb	480	920	100	71	72	60	15
31	Bi	0.4	0.3	1	0.6	0.7	0.8	0.2

Note: 30 samples for SELZ and SIS-EVS, 10 samples for other zones; analytical techniques used: AAS (№№ 8-13, 21-23, 28, 30, 31), quantitative OESA (№№ 3, 4, 6, 7, 15-17, 24, 26, 27), extraction photometry (29), semi-quantitative OESA (others).

Table 9. Assemblages of chemical elements in soils of the industrial zones

Plant	K_c (background-normalized analytical values)					
	>100	100-30	30-10	10-3	< 3	Z_c
SELZ	Hg	Sb-Ag-Pb	Mo-Cd-Tl-W-Zn	Cu-Ba-Ge-F-Sn	Cr-Co-V-Ni-Bi-As-Be-	664
SIS-EVS		Pb	Hg	Mo-W-Cu-F-V-Zn-Sb	Cd-Ge-Cr-Li-Ag-Bi-As-Sn-B	108
EV		Mo	Cd-W-Cu-Ag	Sn-Hg-Pb-Ge-Bi-F-Be-Zn	B-Co-V	132
OZSE			Mo-	W-Pb-F-Be-Cu-Bi	Ge-Mn-Cr-Cd-Co-B-Zn-Ag-	38
ZSSP				Pb-F-Bi-Be	Cu-Ge-B-Co-Mo-Hg-Zn-V-Li	20
Precise tools				Be-F-Pb-Bi	Ge-Cu-Hg-Mo-B-V-Co	19
SK				Pb-Bi-Cu-Sn-Mo-P-Sr	Zn-V-Cr	31

Note: data for SK are presented for individual samples collected immediately near the industrial zone.

High spatial variability is typical of the chemical elements in the industrial zone soils, as reflected by high variability index (the range divided by the average value, Table 10). Contents of Hg, Pb, V, and Sb are many times greater than MPC of these elements. Maximal values of the variability index are observed at the SELZ territory. The exceptions are Pb, W, Cu, and Cr with maxima at the SIS-EVS industrial zone. Industrial dust of this plant carries maximum contents of these elements. High variability is quite typical of the anthropogenically polluted soils. This feature could be controlled by discrete supply of pollutants with gaseous discharge and solids, presence of numerous local metal sources at the plant territory, inhomogeneousness of the wind transport, granulometric composition and chemistry of the urban soils. Duration and productivity of the pollution sources are also important.

Tendencies that show distribution of chemical elements in soil with depth related to duration of productive activities of the enterprise studied, are very demonstrative. For example, high Zn, Hg, Mo, Pb, Cu, Ag contents are traceable to 60-80 cm at SELZ territory. At the same time, at the SIS-EVS territory the pollution depth for a greater part of the chemical elements does not exceed 15 cm. However, the glass works with related Pb pollution enabled the downward migration of Pb to 90-100 cm.

Table 10. Chemical elements in soils of SELZ and SIS-EVS territories

Ele-ment	SELZ			SIS-EVS		
	Average, ppm	Range, ppm	Oscillation index, %	Average, ppm	Range, ppm	Oscillation index, %
Hg	28.3	0.08-300	1059	0.84	0.015-5	593
Sb	60	30-300	450	3	1.5-5	116
Ag	1.8	0.05-50	2775	0,08	0.05-0.3	312
Tl	4	3-5	50	nd	nd	nd
Ba	2530	100-30000	1181	380	100-1500	368
Cd	6	3-50	783	1	0.3-3	270
Pb	213	10-1000	464	20	10-10000	49950
Zn	950	80-6000	623	280	50-1000	339
Sr	225	30-1000	431	75	30-300	360
Mo	8.7	0.5-100	1143	6.6	1-100	1500
W	9	5-30	277	11	5-70	590
Sn	11.7	1-60	504	5.4	3-30	500
Cu	198	30-300	136	186	30-1000	522
Cr	199	30-2000	990	136	30-2000	1448
Ni	63	20-300	444	49	20-150	265
V	202	70-600	262	345	80-600	150

In order to reveal spatial features and dimensions of pollution across the city area, soil geochemical sampling was carried out. Topsoil was sampled at density 16 samples per square kilometer [1]. Table 11 displays the pollution signature revealed. When calculating areas of different pollution grade, the city industrial zones, except for SELZ and SIS-EVS, were excluded because of technical reasons. Thus, real dimensions of highly polluted areas are greater than those specified, for most of soils underlying the industrial areas are rich in pollutants. As a result of the survey, vast high-contrast anthropogenic anomalies of Hg, Zn, Sn are contoured in the city soils; Ni, Mo and Cu anomalies are less pronounced. However, lead is a key pollutant at the city territory. High Pb contents are found in soils underlying practically every industrial zone of the city (Tables 8 and 12).

Lead content exceeds MPC (32 ppm) at more than 80% of the city area. Local zones with Pb>500 ppm are widely scattered across the territory studied; maxima are as high as 10,000 ppm. The maxima are not limited by industrial zones and highways, some of them occur in residential areas. Such Pb content when occurring in the children playground soil, may cause infant psychoneurosis [3]. High Pb pollution level is confirmed by data on the metal distribution in the soil profile: maximum accumulation takes place in topsoil, and evident downward migration of the metal is established. Close correlation is found between Pb content in topsoil, its downward migration range, and distance of the observation point from the nearest industrial zone. Three major soil pollution zones are contoured within the city territory: the Northern industrial zone, downtown, and the Southern industrial zone. The metal accumulation grade notably grows from the Southern zone northward.

Table 11. Soils of Saransk: Metal pollution structure (% of total city area)

Element	K_c grade					
	< 1,5	1,5-3	3-10	10-30	30-100	> 100
Cu	92.8	6.6	0.5	0.1	nd	nd
Zn	52.5	43.3	3.9	0.2	0.1	nd
Ni	81.9	17.1	1.0	nd	nd	nd
Sr	83.0	13.8	2.8	0.4	nd	nd
Mo	88.6	9.8	1.5	0.3	nd	nd
Sn	56.2	42.4	1.4	nd	nd	nd
Pb	23.6	29.9	41.9	4.2	0.4	nd
Hg	82.0	9.2	6.9	1.5	0.3	0.1

Table 12. Pb content in soil of industrial zones

Enterprise	Major production (service type)	Range , ppm
Dump truck plant	Dump trucks	30-100
Traffic company ATP-1	Cargo delivery	60-1000
Biokhimik farmaceutical factory	Antibiotics, farmaceutical items	20-100
Tool plant	Saws, files	35-90
Medical equipment plant	Medical equipment	20-100
Mechanics plant	Bicycles	35-100
Mordovavtotrans company	Bus communications	35-250
Keramik company	Ceramics, bricks	20-500
Panel construction plant	Gravel, reinforced concrete	25-100
Foundry	Pig iron, steel, cast materials	40-200
Semiconductor plant	Microchips and related items	20-150
Industrial rubber plant	Industrial rubber	45-250
Locomotive repairs plant	Repairs of diesel and electric engines	50-600
Heat insulator plant	Heat-isulating panels	30-350
Typography	Printed matter	150 - >10000
Precise tool plant	Microchips and related items	20-690
Central boiler house	Heat supply	40-250
Central refrigerator store	Storage of frozen food	20-100

Note: 10 samples per each object; analytical technique used: AAS.

High degree of anthropogenic pollution over the urban area studied is reflected by our data on the 'mobile' (ammonia acetate-extractable) heavy metal species in soils (Tables 13 and 14).

Anthropogenic geochemical anomalies carry concentrations of these species that locally exceed the MPC level (e.g., Pb, Cu and Zn). It should be noted that soil of the SELZ industrial zone carries higher proportion of the 'mobile' species relatively to other industrial objects studied. The phenomenon is explainable by individuality of the industrial discharge chemistries combined with duration of the impact. During the course of the latter the 'parent' constituents could have been transformed into 'secondary' products of greater mobility. Probably, the 'vent' dust with its normally high proportion of 'mobile' metal compounds is responsible in the SELZ case. Besides, this is the soil of SELZ that carries the highest metal content. Direct proportionality is usually observable between the total metal content and that of 'mobile' species. This tendency explains relatively lower contents of both total and 'mobile' metal contents in soils of the power line electronics plant and the high voltage converter plant territories. The soil survey data and results obtained from studies of the pollutant distribution in the industrial objects' soil served as a basis for ecological hazardousness zoning of the urban territory (Table 15).

Table 13. Ammonia acetate-extractable ('mobile') metal species in soils of Saransk.

City area	Contents of ammonia acetate-extractable species, ppm					
	Cr	Co	Ni	Cu	Zn	Pb
SIS-EVS	0.9 (1.2)	1.4 (1.5)	1.8 (3)	2.23 (5.7)	66 (111)	85 (254)
Downtown	0.8 (1.1)	0.82 (0.9)	1 (1.2)	0.4 (0.7)	34 (58)	4.4 (11)
Zarechnyi	0.8 (0.9)	0.7 (0.8)	1 (2)	0.2 (0.3)	59 (65)	1 (1.5)
Svetotekhnika	0.8 (0.9)	0.8 (0.9)	1 (1.2)	0.2 (0.3)	42 (45)	1 (1.5)
Yuzhnyi (Southern area)	0.7 (0.8)	1.1 (1.2)	1 (1.2)	0.6 (0.7)	13 (15)	9 (10)
Local background	0.7	0.6	1	0.2	5	1
MPC	6	5	4	3	23	11

Note: figures in brackets - maximum values; ammonia acetate solution (pH 4.2) was used for the the 'mobile' species' extraction; analytical technique used: AAS.

Table 14. Metal speciation in soils of the industrial zones

Metal	Industrial zones											
	SELZ			EV			OZSE			ZSSP		
	1	2	3	1	2	3	1	2	3	1	2	3
Cu	160	8.4	5.3	100	1.7	1.7	26	0.8	3.1	26	0.1	0.4
Zn	300	10.5	3.5	220	32	14.5	82	1.9	2.3	160	1.6	1
Ni	73	9.6	13.2	75	2	2.7	46	0.7	1.5	37	0.2	0.5
Cr	80	2.3	2.9	260	2.5	1	80	0.2	0.3	80	0,1	0.1
Cd	5	1.2	24	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pb	480	36.4	7.6	60	3.9	6.5	30	0.9	3	30	0.2	0.7

Note: 1 - total content, ppm; 2 - contents of 'mobile' metal species (ammonia acetate-extractable, pH 4.2), ppm;
3- ('MOBILE') / (TOTAL), %; analytical technique used: AAS.

Table 15. Pollution hazardousness grade at the city territory: $\mathbf{Z_c}$ intervals *vs.* percentage of areas

Pollution hazardousness grade	$\mathbf{Z_c}$ (soils)	Approximate percentage of the total city territory
Acceptable	< 16	25
Moderately hazardous	16-32	50
Hazardous	32-128	20
Extremely hazardous	> 128	5

Moderate hazardousness level is characteristic of approximately 50% of the city territory. At this pollution level, total sickness rate of the urban population increases [2]. About 20% of the urban area is ecologically hazardous, as expressed by increased total sickness rate, infant sickness rate, infant chronic sickness rate, and functional cardiovascular irregularities rate. Extremely hazardous pollution level is established for areas covering about 5% of the urban territories with population about 15,000. Infant sickness rate, the female reproductivity dysfunctions, and other health disorders are characteristic of such areas.

2.3 Metals and organic compounds in atmospheric air

Retrospective data available on the influence areas of the industrial objects from the local meteorological and sanitary services demonstrate that during the past periods intensive pollution has been observed in the ambient air. Lead and Hg contents systematically exceeded MPC here (Table 16).

Table 16. Temporal variations of Pb and Pb contents in atmospheric air within the SELZ influence area

Month, Year	Me-tal	Distance from a plant, km	Number of the observation points		Concentration, mg/m^3	
			Total	Including the above-MPC points	Average	Maximum
April 1969	Hg	1	12	10	0.0006	0.0010
	Pb	1	12	11	0.0016	0.0041
August 1969	Hg	0.5	8	8	0.0008	0.0011
		1	8	7	0.0006	0.0014
	Pb	0.5	8	8	0.0020	0.0026
		1	8	7	0.0011	0.0018
Septem-ber 1969	Hg	0.5	3	3	0.0008	0.0009
		1	3	2	0.0004	0.0005
	Pb	0.5	3	3	0.0027	0.0030
		1	3	3	0.0016	0.0018
October 1969	Hg	0.5	3	3	0.08	0.09
		1	3	3	0.06	0.07
	Pb	0.5	3	3	0.0019	0.0026
		1	3	3	0.0017	0.0022

Note: MPC, mg/m^3: 0.0003 (Hg), 0.0007 (Pb).

Technologic improvements, along with introduction of local waste treatment systems in late 80's and early 90's resulted in significant reduction of the technogenic environmental impact. Thus, results obtained in 1990 demonstrate only local Hg pollution zones (Table 17). Concentrations of the metal equal to or greater than MPC were found only within the SELZ sanitary protection area; near the heat power station Hg contents were above the background. In summer Hg vapor content level in the atmospheric air was higher than in the fall what is quite understandable.

Table 17. Hg vapor content in ambient air, ng/m^3[1]

City area	Period of observations	
	Summer	Fall
SIS-EVS	<50-70	<50
SELZ	250-350	70-80
Power plant	150-250	100-200
Downtown	<50-80	<50-60
Dwelling zones	<50-70	<50
Background	<50	<50
MPC	300	300

Note: analytical technique used: flameless AAS (the AGP-01 analyzer)

Since Hg is currently used in production of various types of lamps, content of the metal in air of the industrial edifices remains high, well above the existing sanitary norm. For example, in 1994, despite the decreased production rate of the plant, Hg vapor content in the air of the luminescent lamp assemblage shop was up to 6 times greater than MPC, while in the gas discharge lamp shop the value ranged from 1.5 to 2 [4].

As the stationary observation data demonstrate (at observations for a period from 10 to 25 days, with cumulative daily sampling of the atmospheric aerosols), three zones of metal atmospheric pollution exist at the city territory (Table 18). These are: (i) the Northern industrial zone where Pb, Cr, Cd, Ni, and V contents are at least occasionally above the MPC level, (ii) the downtown (Pb and Ni levels are permanently above the MPC, whereas other pollutants studied are below MPC and above the background), and (iii) the Southern industrial zone (Pb content permanently above the MPC, and Ni occasionally above it). The pollution level existing in other parts of the city exhibits occasional heights for Pb, Ni, Zn, and V. Usually, the illumination equipment plants are responsible for the maximum air pollution level. Significant temporal variations inherent in the metal content level in the air tend to the zones of maximum soil pollution, as revealed by total metal content in soil .

Table 18. Assemblages of the aerosol metal species in ambient air [1]

City area	K_c , background-normalized data				
	> 100	30-100	10-30	3-10	1.5-3
SIS-EVS	Pb-V-Cd	Cr-Ni-W	Mo	Mn-Zn-Sn	nd
SELZ	Sn-Pb-Ni	Zn-Cd	V-Cr	nd	Mn
Oktyabr'skii			V	Pb-Ni-Zn-Cr	Mn-Sn
Southern industrial area			Pb	Ni-Cr-V	Mn-Zn-Cd
Zarechnyi				Cr	Ni-Pb-Sn-Zn-V-Mn

Distribution of chemical elements in the outer wall covers of the industrial buildings is quite demonstrative (Table 19). Naturally, the metal budget of the wall covers is composed by 'natural' presence of some components of pigments, plaster, etc. (e.g., Pb, Zn, Sn, Cd, Cu). Still, chemical assemblages of the wall covers resemble those of the industrial dust discharges. Presence of relatively 'volatile' chemical elements, i.e., Hg, As, and Sb, are quite indicative. Recent publications bring data on gaseous forms of the metal occurrence (the so-called 'molecular vapor') in the industrial discharges and atmospheric air. In particular, it was reported that the gas-and-vapor species of Sb, As, Hg, Ni, and Cd may occur in the atmospheric air. Thus, it could not be excluded that scavenging of these compounds by the wall cover materials is responsible for very high contents of chemical elements there.

Table 19. Assemblages of chemical elements in the outer wall lining materials

Enterprize	Z_c intervals of chemical elements (the soil background-normalized data)				
	> 100	30-100	10-30	3-10	1.5-3
SIS-EVS	Zn	Cr-Pb-Mo	Cd-W-Bi-Ni	Hg-Ag-Sb	Cu-V-B-As
VNIIIS	Sn	Cu-Cd-W	Pb-Sb-Bi	Hg-Mo-Ag	As-B-Cr
EV		Cr		Pb-Bi-Zn-Sb	
SK		Pb-Zn	Cd-Bi	Hg-As-Sn-V-Sb	Cu-Mo-Co-W-Ag-B
Tool plant		Zn	Pb-Cr	W-Sn-Sb	Mo-Cu-Hg-V-Ag-As-B

The electric engineering plants discharge into the environment a great variety of organic compounds. Publications on the abundance of the organic pollutants related to these enterprises are practically absent. The author carried out a reconnaissance study on the organic pollutants in the influence areas of the electric engineering enterprises in Saransk. The results display a wide spectrum of the organic pollutants present in the atmospheric air near the plants (Table 20). The content level is above the local background in a majority of cases. The SIS-EVS area demonstrates maximum contents and the widest range of the compounds. It should be noted that during the sampling procedures conducted near the plant, the wind was blowing from the territory of the latter to the observation point, whereas in all other cases the still conditions occurred.

Table 20. Organic compounds in ambient atmosphere, μg/m^3

Compound	Plant				
	SIS-EVS	SELZ	SK	EV	Background
C_1-C_3	122	40	150	95	30
Butane	63	20	12	5	3
Pentane	753	54	8	17	5
2-methylbutane	393	17	18	22	15
2- methylpentane	3613	51	17	15	13
3- methylpentane	605	15	0.3	0.4	0.2
2- methylhexane	13	4	2	3	1
3- methylhexane	1348	11	16	5	3
2,4-di methylpentane	1020	27	3	9	14
2-hexene	36	nd	1	nd	nd
1-heptene	16	nd	1	3	0.5
Cyclohexane	1560	90	nd	2	0.4
Methylcyclohexane	5	nd	nd	nd	nd
Methylcyclopentane	43	13	3	1	1
Toluene	11	nd	nd	nd	nd
Ethylbenzene	1	nd	nd	nd	nd
2,4- dimethylhexane	1.5	nd	nd	nd	nd
2,5- dimethylhexane	0.8	nd	nd	nd	nd
2,3- dimethylhexane	0.7	nd	nd	nd	nd
C_7 isomeres	185	77	10	8	3
C_7-diene	17	nd	nd	nd	nd
3-methyl-1-buthanole	17	nd	nd	nd	nd
1,2-propanediol	1.3	nd	nd	nd	nd
3-methyl-2-pentanone	3	nd	nd	nd	nd
2- methylheptane	1.2	nd	nd	nd	nd
3- methylheptane	40	12	9	15	8
3-hexanone	1.4	nd	nd	nd	nd

Note: Sampling technique used: air pumping duration (microaspirator) 20 min, air discharge rate 200 mL/min; TENAX sorbent was used for pre-concentration; analytical technique: chromatography (the Tsvet-500 and Ecokhrom devices).

2.4 Chemical elements in the urban vegetation

As it follows from analysis of the birch leaves, twigs and bark samples collected in various parts of the city, Pb is a leading pollutant of the urban environment [1]. Anomalous contents of Mo, Zn, Cu, and Ni, i.e., the chemical elements typical of the soil and air pollution in Saransk. The highest levels of the pollutants in vegetation were found in the downtown and in the industrial areas (Table 21). Significant Hg contents in vegetation were observed only in areas immediately adjoining the SELZ territory (about 0.05-0.07 ppm in dry mass). Territories of the electric lamp factories displayed high Pb, Cd, and Mo levels in vegetation. High Cu level is inherent in plants at the territory of the cable plant, Cd, Cu, and Zn - at the EV territory, and Pb - at the territory of a typography, i.e., vegetation first of all accumulates metals that the industrial enterprises supply to the atmosphere.

Table 21. Chemical element contents in birch leaves (ppm, dry mass)

Industrial areas	Ni	Cu	Zn	Mo	Cd	Pb
SELZ	5	9	150	1.3	0.9	7
SIS-EVS	5	5	130	0.9	0.4	12
EV	9	20	380	0.6	1.7	3
SK	5	21	110	0.5	0.2	7
Foundry	7	11	200	0.6	<0.05	3
Typography	3	8	130	0.5	<0.05	12
Dump truck plant	3	7	130	0.4	0.2	4
Tool plant	3	17	70	0.5	<0.05	11
Semiconductor plant	10	32	240	0.5	<0.05	3
Precise tool plant	3	9	380	0.5	<0.05	8
Background	4	4.4	35	0.4	0.05	2.5

Note: Analytical technique used: AAS

3. Chemical elements in watercourses

It seems rather difficult to estimate a share of the electrical engineering enterprises in the total pollution budget of the urban watercourses. Numerous plants and factories dump their waste there. Larger part of the liquid waste is treated at the city sewage station. Individual features of the electrical engineering industry could be disclosed when comparing chemistries of the city sewage sludge, deposits of the local purification units at individual enterprises, and anthropogenic stream sediments of the Insar river, the latter sampled downstream of Saransk (Table 22).

Deposits of the electrical engineering enterprises' purification units are rich in B, F, Ni, Cu, Zn, Mo, Cd, Sb, Ba, W, and Hg. Tonnage of the toxic chemical elements here is significant: SELZ -4.5 Ni, Cu 2.5, F 1.1, Mo 0.6; SIS-EVS - F280, EV - Zn 12, Cu 7.4, Ni 3.4, Sn 1.6, Mo 1.5, Cd 0.4, Ag 0.02; the precise tool plant - Cr 9, Cu 1, Sn 0.8. For a long period, the deposits are transported to the city dump where the tonnage figures are probably measured in hundreds.

Table 22 favors the notion on the electrical engineering enterprises as major pollutant sources for the city waste waters. Sampling of anthropogenic stream sediments of the Insar river revealed high-contrast continuos Cd, F, Hg, Cu, Zn, Mo, Sb, W, and Bi anomalies, i.e., the sediments inherit some features of their geochemical signature from that of the electrical engineering enterprises.

Individuality of the chemical element assemblages and, especially, proportions between the concentration indices ($\boldsymbol{Z_c}$) calculated for each element is a key feature of the industrial sludge (Table 23). Higher $\boldsymbol{Z_c}$ values typical of the electric engineering plants differ them from enterprises of different technologic orientation. The technologic rubber plant is an exception in this aspect; however, quantities of sludge produced here are relatively small.

Table 24 shows that along with a general decrease in total metal contents in the anthropogenic stream sediments, proportion of the mobile forms increases. This feature is especially characteristic of Cd, Zn, Ni, and Cr. Higher proportion of the 'mobile' species in anthropogenic stream sediments distinctly separates them from the background alluvium (Table 25).

Concentrations of mercury in water of the Insar river and its tributaries were below MPC (0.5 ppb) for dissolved species. Mercury was transported to the watercourses by suspended solids. Suspensates retained by macrophytes display Hg anomalies of the highest contrast (Table 26). Water of the Insar river downstream of Saransk carries anomalous concentrations of dissolved Cu, Zn, Ni, Cd, F, Hg, Sr, Fe, and Li.

Table 22. Chemical elements in industrial sludges (ppm, dry mass)

№	Element	Plant								City sew-age station	Back-ground in soils
		SELZ	SIS-EVS		EV	Precise tool	Instrumental	Mechanics	Techno-logic rubber plant		
			№ 1	№ 2							
1	B	300	30	6	100	14	36	28	34	35	20
2	F	3700	90000	90000	8000	41200	4100	5000	700	3300	200
3	Sc	<1	<3	<3	<1	<1	<1	<1	<1	2.6	7
4	Ti	170	30	50	320	280	370	2500	1200	2500	5000
5	V	3	10	5	12	6	23	52	26	56	90
6	Cr	1400	1500	20	870	20	23000	24000	1200	1900	70
7	Mn	2000	310	94	300	300	400	480	960	610	1000
8	Fe	4800	28500	100	8900	2000	nd	nd	145000	21040	nd
9	Co	<3	6	1,5	7	<3	10	<3	12	8.4	8
10	Ni	15000	8000	10	3700	820	500	900	600	690	50
11	Cu	8300	13000	330	8000	200	2400	3400	50000	1700	30
12	Zn	620	84800	320	13000	100	100	5000	13000	4500	90
13	Ga	<1	10	<10	2	<1	2	3	3	5	20
14	Ge	<3	<3	<3	<3	<3	<3	<3	13	<3	nd
15	As	<5	5	<5	<5	<5	<5	<5	6	9	6
16	Sr	3000	590	190	600	80	30	50	11000	796	250
17	Y	3	10	<10	10	3	<3	<3	<3	12.6	40
18	Zr	10	30	<30	10	10	<10	30	20	100	400
19	Nb	13	3	3	3	6	3	4	3	4.5	10
20	Mo	1900	130	1	1600	10	130	100	14	56	1.2
21	Ag	7	0.3	<0.1	20	0.1	0.3	8.4	0.5	7.6	0.05
22	Cd	200	2	1	400	<2	<2	80	7.5	40	0.35
23	Sn	180	6	<3	1700	1000	2000	>1000	84	400	4
24	Sb	600	3	30	<3	5	<3	30	3	16	1
25	Ba	1000	<100	<100	100	<100	<100	400	<100	270	500
26	W	390	20	<10	100	380	<10	40	<10	54	1.5
27	Au	<3	<3	<3	<3	10	<3	<3	<3	<3	0.002
28	Hg	300	0.063	0.12	<0.3	<0.3	<0.3	<0.3	<0.3	4	0.06
29	Pb	530	500	100	70	30	100	4700	240	240	15
30	Bi	190	<3	<3	160	<3	<3	16	750	15.2	0.2
Sludge output, tons per year		300	3100		917	2.6	400	12	2.4	25000	

Note: Analytical techniques used: AAS (№№ 6-12, 20-22, 28-30), qualitative OESA (№№ 1, 2, 4, 5, 14, 15, 23-27), semi-quantitative OESA (others);

As demonstrated by geochemical studies of the Penzyatka river that takes up the surface runoff from the SIS-EVS territory, the river water is rich in F (up to 20 ppm) and Li (up to 0.06 ppm). The fact is attributed to technologic usage of these elements, as well as Zn, Cu, Ni, Sr, and As. Stream sediments of the river are rich in Zn, B, Cu, Pb, Bi, W, F, Ni, Li, and Sr (2 to 11 times above the background). These chemical elements are typical of the industrial sludge of SIS-EVS.

Table 23. Assemblages of chemical elements in the sewage station sediments, sludge and anthropogenic stream sediments

Object		K_c (background-normalized data)						
		> 300	100-300	30-100	10-30	3-10	1,5-3	Z_c
City	Sewage station		Ag-Cd-Sn	Bi-Hg-Cu-Zn-Mo-W	Cr-Be-F-Sb-Pb-Ni-Sr		B-As-U-Tl-Ba-Nb	760
SIS-EVS	Sludge	Zn-F-Cu	Ni-Mo	Pb	Cr-W	Ag-Cd-Sb	Sn-B-Sr	2750
SELZ	Sludge	Hg-Mo-Bi-Sb-Cd-	Ni-Cu-W-Ag	Sn-Pb	Cr-F-B	Zn	Mn-Sr	9800
EV	Sludge	Mo-Cd-Bi-Sn-Ag	Cu-Zn	Ni-W-F	Cr	B-Pb		4650
Precise tool plant	Sludge	Au	W-Sn-F		Ni-	Mo-Cu-Sb	Ag-Pb	730
Tools plant	Sludge	Sn-Cr	Mo	Cu	N-Fi	Pb-Ag	B-Co	1020
Mechanics plant	Sludge	Sn-Cr-Pb	Cd-Ag-Cu	Mo-Bi-Zn-Sb	W-F-Ni		B	1450
Technical rubber plant	Sludge	Bi-Cu	Zn	Sr	Cd-Sn-Cr-Pb-Ni-Mo	Ag-F-Sb	B-Co	5620
The Insar river	Tech-noge-nic sedi-ments	Cd	Hg-Mo	Zn-Sn	Cu-W-Ag	Ni-Pb-Cr-Sr-Bi-B	F-V-Fe-Tl-Ga-P-Be	810

Table 24. Heavy metal speciation in anthropogenic sediments

Metal	SELZ sludge			EV sludge			Sewage sludge			Anthropogenic stream sediments		
	1	2	3	1	2	3	1	2	3	1	2	3
Cu	6500	3270	50	6600	1283	19	866	28	3	530	14.4	2.7
Zn	620	199	32	8200	2094	26	2080	866	42	360	162	45
Ni	14000	7458	53	3700	720	19	320	178	56	185	131	71
Cr	1500	8	0,5	870	39	4,5	1338	9	0,7	270	27	10
Cd	200	38	19	nd	nd	nd	37	19	51	24	13.2	55
Pb	530	5	1	70	2	2.9	166	3	1.8	140	16.8	12
Mo	670	40	6	1600	152	9.5	72	0.4	0.6	120	2	1.7
Ag	7	0.02	0.3	20	0.02	0,1	6.4	0.1	1.6	nd	nd	nd
Bi	190	40	21	160	24	15	nd	nd	nd	nd	nd	nd
Fe	4800	10	0.2	8900	548	6	21040	73	0.4	nd	nd	nd
Mn	1500	242	16	200	33	16.5	252	82	32	420	120	29

Note: 1 - total content, ppm; 2 - ammonia acetate-extractable (pH 4.8), or 'mobile' species, ppm; 3 - (MOBILE) / (TOTAL), %; analytical method used: AAS

Table 25. 'Mobile' metal species in anthropogenic stream sediments and background alluvium of the Insar river [1;8]

Metal	Anthropogenic stream sediments (downstream of the city)		Background alluvium (upstream of the city)	
	ppm	% of total	ppm	% of total
Cr	270	10	31	3
Co	10	36	8	6
Ni	185	71	15	8
Cu	530	2.7	12.4	2
Zn	360	45	33	13
Cd	24	55	0.13	5
Pb	140	12	19	7

Table 26. Hg in various components of the river system

Sam-pling site	Epyphite-retained suspensates		Macrophytes		Anthropogenic stream sediments		Suspensates in the river water		Dissolved species in the river water	
	ppm	@Kc	ppm	Kc	ppm	Kc	μg/L	Kc	μg/L	Kc
I	15	500	0.3	6	4.8	240	0.41	5	0.10	2
II	5	170	0.2	4	0.9	45	0.25	3	0.06	1.2
III	1	33	0.1	2	0.05	2,5	0.08	1	0.05	1
IV	0.15	5	0.05	1	0.03	1,5	0.08	1	0.05	1
V	0.03		0.05		0.02		0.08		0.05	

Note: contents in dry mass are given for epyphite-retained suspensates, macrophytes and anthropogenic stream sediments; location of the sampling sites: I - mouth of a brook that drains an industrial zone in the Sasansk downtown, II - the Insar river, 1 km downstream of (I), III - the Insar river, 50 km downstream of (I), IV - the Alatyr river, 160 km downstream of (I), V - local background.

Thus, the electrical engineering enterprises are among the major controls of chemistry and intensity of the urban watercourse pollution. The influence area of the city that is marked by high contents of heavy metals (first of all, Cd, Hg, Mo, Zn, Sn, Cu, W, Ag, Ni, and Pb) in the stream sediments , suspended solids, and the epiphyte-retained suspensates is traceable for scores of kilometers downstream, and passes further into the Alatyr, a river of higher order.

4. Sanitary response to pollution

Complicated migratory chains typical of pollutants in the urban environment inevitably involve human organism and cause negative health effects. In case of an urbanized industrial territory it is difficult to measure the ‘weight’ of an individual enterprise in deterioration of the human health. Generally, health of an individual or a group is influenced by a combination of natural, anthropogenic and social factors. In urbanized areas, inhalation is responsible for uptake of hazardous substances. Atmospheric pollution should be considered as not just the immediate cause of the increased sickness rate of the urban population. Along with that, the factor controls the general resistance of an organism which, when hampered, results in increased sickness rate, along with other negative tendencies in human health. Increased pollutant contents in human organisms, along with various functional disorders, indicate negative response for pollution [2]. Children are especially sensitive to anthropogenic pollution. The data we obtained enable estimation of possible health influence caused by the electrical engineering plants of Saransk.

The worst situation was revealed for the group of industrial workers who immediately contact with hazardous substances. In more than 505 cases, Hg content in hair of SELZ and SIS-EVS workers was 1.5 times higher relatively to the background group. In approx. 30% cases, the background level was exceeded by a factor of 3 and greater. Maximum observed values for Pb in hair of SIS-EVS were about 50 ppm. Negative health effects typical of lasting Hg impact were observed for the SELZ personnel. The most pronounced effects were related for women (80% of the luminescent lamp shop staff). In particular, general health studies and observations carried out during the course of pregnancy and termination, revealed that complications occurred more frequently for SELTZ personnel relatively to the background group (Table 27). In particular, the parturition, on the average, lasted longer by 2.5 hours for the first-birth women from SELTZ than for women from the background group. Late toxicoses rate was significantly higher in the former category.

Besides, women that professionally contacted with Hg, suffered from the following negative effects: premature confinement (twice as high as in the background group), pronounced anemia (2 to 4 times), negative tendencies in composition of peripheral blood (high leukocytes, low erythrocyte sedimentation rate), significantly more frequent fetal hypotrophy, and the twin birth cases (Table 28).

Women workers of the luminescent lamp shop with record length beyond 5 years suffer from the menstrual dysfunctions (23.3 *vs.* 16.1% in the background population) and uterus fibroma (7.8 vs. 5.6%). Direct proportionality was observed between the record length and the uterus-placenta malfunction rate. Mercury was found in biosubstrates of women. More than 270 cases of the professional mercury intoxication have been registered during the period of the luminescent lamp production, and women constitute about 90% of the victims (Guseva, 1989, 1994). Infants of SELZ workers suffer from retarded mental development more frequently than those of the background group.

Table 27. Pregnancy and termination complication frequencies in Saransk, (%) [1].

Complications	Categories of women		
	SELZ staff	Women living in the SELZ protection zone	Background group
Possible premature termination	10.4	10.6	8.8
Late toxicosis	9.5	4.1	2.2
Premature termination	9.5	6.5	4.2
Kidney pathologies	8.5	5.3	6.9
Anaemia	7.5	10.5	3.8
Inopportune amniotic fluid discharge	21.7	21.8	23.3
Weak termination activivties	15.0	12.9	10.4

Luminophores are widely used in the electric lamp production. When sprayed, the luminophore dust could leak from the working zones. Chemical elements, especially metals that constitute the luminophores, are potentially hazardous for human health. For example, it were the luminophore studies conducted in 1933 that had revealed toxicity of Be. Experimental and sanitary studies conducted at the luminophore-consuming enterprises, revealed the following negative effects of the luminophore dust: gonadotropy and teratogeny (Cd-based luminophores), pancreas damages (Cd-Zn-based luminophores), specific bronchitis (halophosphate luminophores).

The professional disease frequency in Saransk is up to 70 p.a. During 1994, the sickness rate in Saransk was 5.60 per 10,000 (cf. 2.02 per 10,000 as the average value for Russia). All professional diseases diagnosed during 1994 turned out to be chronical and caused professional restrictions or invalidness. Chronical Hg intoxications dominate among the professional diseases (93% case histories). The highest professional disease rate was registered at the electrical lamp plants (35 cases of chronical Hg intoxication, [4]).

Table 28. Health state of babies born from female residents of various areas, Saransk [1]

Index	Mothers are SELZ staff members	Mothers are residents of the SELZ sanitary protection area	Background group
% of babies with the anharmo-nicity index value below 9	21.7	19.5	12.2
Twin cases, %	1.0	1.2	0.4
Foetus hypotrophy cases (%)	25.5	23.2	14.4
Foetus hypertrophy cases (%)	15.1	10.1	8.4
Weight, g: boys girls	3323 3289	3361 3302	3423 3333
Height, cm: boys girls	50.2 50.0	50.7 50.4	50.9 50.6

In 1995 maximum frequency of the first-diagnosed malignant tumors was observed at SELZ and SIS-EVS. Note that EV follows, and several cases were observed at the cable plant. At OZSE the sick leave rate was 83.6% p.a. with net sick leave duration 1013 days. This is an absolute maximum for Saransk. Thus, working conditions at the electrical engineering plants are especially unfavorable, as controlled by a vast range of toxic substances, heavy metals included.

Results of Hg measurements in the infant hair (650 samples taken from children living in different parts of the city) demonstrated that in 50% cases Hg content was below 0.1 ppm (background level 0.26 ppm, critical level 2 ppm). Mercury content that exceeded the background by 50% (above 0.4 ppm) was registered in 13% cases. In 7% cases, the level was 3 times higher than the background (>0.78 ppm).

In case of Pb (the background value 3.58), the proportion of cases of values that exceeded the background by a factor of 1.5 was 50 per cent; 20% samples carried more than 8 ppm (the MPC level), and 5% contained more than 24 ppm Pb (the latter value is above the critical level). Some authors believe that the critical level for Pb in the infant hair should be 3 ppm [3]. If so, 805 samples studied carried abnormally high Pb content.

Cd concentration in 32% samples was above the background (0.19 ppm) by a factor from 2 to 5, and 7% samples contained more than 1 ppm of the metal (critical level). The above mentioned data indicate that Pb and Cd dominate among the pollutants studied in Saransk. Along with it, accumulation of Hg is also a troublesome fact [1, 6]. Electrical engineering enterprises (SELZ, SIS-EVS, EV, SK) are among major sources of these chemical elements.

Additionally, high Ni and Cu levels , 3 to 5 times above the background, were found in the downtown that lies within the influence area of SELZ and EV; elsewhere across the city only rare outstretches were recorded at this level.

The children who reside in the downtown more frequently suffer from endocrine and blood diseases, while ocular diseases, dermatitis. and malignant tumors are the ‘leaders’ among the adults of the area (Table 29, [4]). The downtown area with its high Hg, Pb and Cd contents in soils and ambient air is marked by high rate of specific diseases, pyelonephritis and cystitis (Table 30). Mass-scale (4000 pre-school age children) nephrologic studies demonstrated that within the SELZ territory, the urinary disease rate is 3 times as high as in the background areas of Saransk [3].

Table 29. Sickness rate per 1000, two areas of Saransk, 1991

Categories of diseases	Area			
	Downtown		Sowth-eastern area	
	Infants	Adults	Infants	Adults
Malignant tumors	nd	3.00	nd	3.12
Endocrine system diseases	0.70	3.96	nd	2.88
Blood diseases	8.53	0.66	0.94	0.57
Ocular diseases	12.48	0.18	11.11	4.80
Otic diseases	21.60	4.80	22.80	8.16
Rheumatism and related diseases	0.12	0.67	0.13	0.86
Hypertonia	nd	16.68	nd	11.88
Ischemia	nd	18.12	nd	10.32
Gill and tracheal diseases	649.80	76.68	557.04	81.72
Other respiratory organ diseases	199.56	36.36	164.52	34.20
Digestion diseases	14.04	34.32	5.16	18.00
Urinogenital system diseases	5.88	2.28	1.92	4.08
Dermatoses	18.72	6.96	40.20	13.80
TOTAL	931.56	204.12	804.00	194.38

Table 30. Frequency of the infant pyelonephritis and cystitis cases in Saransk [6]

Area of the city	Cases per 1000
SELZ influence area	18
Downtown	21
Other areas	0.9-4.8

Hair samples collected from children (5 to 7 years old) born from the electric lamp plant workers much more frequently carry high Hg contents relatively to the background population (Table 31). Similar situation was revealed for Pb. Maximum observed Pb content was observed for children of the electric engineering plant workers and the traffic company staff members (Table 32). This fact could be attributed to pollutants transported into living apartments on wear and exposed parts of body [5].

This special transport mechanism could be dangerous, especially for children. Further Hg-related problems for the urban population are attributed to Hg spills, sometimes intentional. This circumstance increases a risk of Hg uptake by human organism.

Table 31. Hg content in infant hair [10]

Affiliation of parents	Range, ppm
SELZ and (or) SIS-EVS	0.1 - 1.6
EV	< 0.1 - 0.5
Mechanics and (or) tool making	< 0.1 - 0.4
SK	0.1 - 0.2
Foundry	< 0.1 - 0.1

Table 32. Pb content in hair of children: (1) of pre-school age, (2) of school age

Affiliation of parents	Sample number		Average, ppm	
	(1)	(2)	(1)	(2)
SELZ	7	24	13.77	5.36
SIS-EVS	4	10	8.23	7.47
EV	3	9	11.67	5.80
SK	-	2	nd	4.0
Dump truck plant	3	-	3.73	nd
Mechanics plant	2	6	7.55	2.72
Excavator plant	2	nd	8.00	nd
Instrument making	-	6	nd	4.83
Pharmaceutical factory	1	3	10.00	4.00
Technologic rubber plant	-	4	nd	17.3
Tool making plant	-	2	nd	2.8
Typography	1	nd	5.00	nd
Traffic companies	7	7	21.49	5.71
Other non-industrial enterprises	14	17	3.65	2.84
Background			3.58	
MPC			8	
Critical level			24	

Note: the ‘traffic companies’ category includes parents who work as drivers, traffic policemen, automobile mechanics, etc.

Conclusions

The electrical engineering plants are sources of numerous pollutants for the urban territories. Chemical signature of these enterprises is characterized by significant amounts of heavy metals (Hg, Cd, Pb, Zn, Mo, W, Cu, Sb, Ag, Sn, Mn), organic components (especially, thinners), fluorine, nitrogen and carbon oxides, etc. Gaseous, liquid and solid refuse of the plants contains cancerogenes , e.g., benzo-[a]-pyrene, soot, vinyl chloride, Cd, As, Be, Ni, and Cr compounds, formaldehyde, polychlorobenzene, and mineral oils. Minor amounts of radioactive materials are reported to occur in the waste. In most cases, the industrial refuse (dust, sludge, etc) is transported to the city dump, either stored at the plant territories, thus presenting the pollution sources.

The electrical engineering plants are characterized by presence of hazardous technologies and permanent presence of high contents of various pollutants in the ambient air of the working zones. As a result, professional intoxications and high professional disease rate take place. Among the industrial workers of Saransk, those of the electric engineering plants most frequently suffer from malignant tumors. Women constitute a greater part of the hazardous productive units’ staff; high sickness rate is established here. Children born from women that work in the mercury lamp production, are frequently retarded mentally, and the sick rate among them is high.

High-contrast anomalies of heavy metals, trace elements and organic compounds occur within the influence areas of the electrical engineering enterprises in air, soil, vegetation, and stream sediments. Dimensions of the polluted areas are significant; concentrations of pollutants within the areas exceed the background and normative values.

Permanent presence of various pollutants in the urban environment causes uptake of these substances by human organisms. In Saransk, major pollutants, as indicated by analysis of the infant hair, are Pb and Cd; role of Hg, Zn, and Ni is relatively of minor importance. High sickness rate, along with frequent cases of special diseases (pyelonephritis, cystitis, endocrynal, hematological and urinal diseases) are typical of the infant residents of the influence areas of the electric engineering enterprises.

Transport of pollutants on the clothes, footwear and exposed parts of the bodies of workers is an important control of the metal supply to the living apartments. This factor is responsible for additional uptake of pollutants by children whose parents work at the electric engineering plants.

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