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PECULIARITIES OF COMBINED SPINAL COLUMN AND PELVIS PATHOLOGY IN CHILDREN BEING EXPOSED TO HARMFUL FACTORS OF ALUMINIUM PRODUCTION

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We have accomplished orthopedic and X-ray examination of children from various age groups. The children have combined spinal column and pelvis pathologies and live under constant exposure to aluminium production's harmful emissions into air in an industrial center in Irkutsk region. Fluoride compounds are seen as primary environmental health risk factor. We have detected that pelvis asymmetry holds the 1^{st} place among combined pathology; the 2^{nd} place belongs to scoliosis; and the 3^{rd} place is taken by whirlbone aseptic necrosis. According to assessment of combined pathology age structure we have concluded that scoliosis, Spina bifida, retrospondylolisthesis and pelvis asymmetry are evenly spread among examined children; still, aseptic necrosis prevails in children aged 11-15, and coxarthrosis occurs in age group of 16-21. We have statistically proved strong authentic dependence of aseptic necrosis on children's age and gender: Pearson chi-square criterion amounts to 15.821 and 21.228 correspondingly at $p<0.01$. This pathology is detected in 100% examined boys and only in 35.5% girls. We have also statistically proved dependence of diseases prevalence on ecological factors (Pearson chi-square is equal to 5.264, $p<0.05$): the greatest specific weight of necrosis is detected in children living within 5 km range from an industrial object (75% of all cases). We have seen prevalence of clinical and radiologic abnormalities indicating combined spinal column and pelvis pathology of the 1^{st} and 2^{nd} degree of severity. We consider further search for evidence proving correlation between chemical risk factors and locomotor apparatus diseases as a very promising and vital research trend. We recommend regular medical check-ups for children living in polluted areas as it helps early diagnostics of combined orthopedic pathology, including premorbid period of its evolvement.

Key words: *ecology, harmful factors of aluminium production, combined spinal column and pelvis pathology, whirlbone aseptic necrosis, children, age, sex.*

Introduction. In Russia when primary aluminium is produced air pollution becomes one of the gravest problems; this pollution is mainly caused by use of self-backing anodes technology as well as impurities dispersion in atmosphere [15]. "IrkAz-SUAL" Public company (Irkutskiy aluminium plant) located in Shelekhov industrial zone (south-east outskirts of Shelekhov) manufactures semi-finished aluminium. Its main production divisions are electrolysis workshop, fluorine salts production, and anode weight workshop. Aluminium elec trolysis process involves pollutants emissions; such pollutants include fluoride hydrogen, fluorides, dust, sulfur dioxide, carbon oxide, resins, and benzpyrene. Sanitary-hygienic zone of the enterprise is 1700 m.

According to the data provided by the Federal State Public Health Institution "Irkutsk Regional Hygiene and Epidemiology Center" and presented in the dissertation by T.I. Shalina, harmful substances polluting air in Shelekhov include: benzpy-

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rene (maximum permissible concentration) $1*10^{-6}$, average annual concentrations mgr/m^3 $4.2*10^{-6}$), suspended substances (maximum permissible concentration daily average 0.15, average annual concentrations mgr/m^3 00124), carbon oxide (maximum permissible concentration daily average 3.0, average annual concentrations mgr/m^3 1.78), formaldehyde (maximum permissible concentration daily average 0.003, average annual concentrations mgr/m^3 0.007), fluoride gaseous compounds (maximum permissible concentration daily average 0.005, average annual concentrations mgr/m^3 0.004), poorly soluble fluorides (maximum permissible concentration daily average 0.03, average annual concentrations mgr/m^3 0.12) [20]. And here we noted that in 2000s maximum single concentrations of fluoride hydrogen exceeded maximum permissible levels 6-8 times; and maximum single concentrations of non-organics fluorides were 1.6-2 times higher than maximum permissible concentration. At the same time in 2001-2004 average annual concentrations of gaseous fluorine were 6.2 – 4.8 times higher than maximum permissible concentration daily average, and in 2005-2007 they exceeded maximum permissible concentration daily average 2.4-1.4 times. We have calculated potentiation coefficient for fluorine-containing substances; it amounts to 3.6 and the values exceeds admissible level 4.5 times.

N.V. Sirina accomplished some research work [15] which included dispersion modeling for pollutants emitted into atmosphere by Irkutskiy aluminium plant; the research proved that harmful substances concentration exceeded maximum permissible levels on the territory of production site and beyond its limits for a period from 24 to 744 hours during a year. And influence of all specific substances in increased concentrations emitted by the plant's electrolysis workshops occur beyond the limits of the sanitary-hygienic zone. Thus, benzpyrene occurrence range is 15 km; fluoride hydrogen can be found at 7 km distance away from the plant; as for solid fluorides and resins their occurrence range is 2.5 and 1.5 km correspondingly. It is also defined that the most hazardous effect of aluminium production emissions is exerted at the distance of 0.5 – 1.5 km from the plant; but gaseous compounds occur 30 km away from this industrial object [3]. Pollutants distribution has its vector and it is stretched south-east to north-west; the direction coincides with prevailing wind directions [15]. The aluminium plant influences city living blocks, agricultural grounds, surface waters and country houses; it creates pre-conditions for negative changes in nature and population health.

At the same time, the correlation between population morbidity and technogenic impact on the atmosphere has been profoundly proved in the research works [1, 2, 8, 9, 19]. It has been determined that aluminium production's harmful factors exert negative influence on people leading to greater risks of locomotor apparatus diseases in adults and children [4, 22]. S.A. Syurin shows in his work that despite constant development of production technologies when considering health disorders structure for aluminium plants workers in North European part of Russia we see that the greatest specific weight in it belongs to musculoskeletal apparatus pathology of dystrophic and degenerative character (29.8%), and the most frequently diagnosed disease is osteoarthrosis deformans (8.6%) [16]. To further prove high risks of such pathology evolvement we can mention that over the period 1992-2003 there was an increasing trend for musculoskeletal system diseases in Shelekhov and Shelekhov district for all age groups; children's morbidity grew 7 times; teenagers' morbidity, 6 times; and adults' morbidity went up 5 times [15]. In 2007 in comparison with 90ties musculoskeletal system morbidity increased 5.6 times in children and 12 times in adults; respiratory system morbidity grew 2 and 7.7 times correspondingly in these age groups [20].

As bones morphogenesis under fluoride compounds was examined in children and adults in Shelekhov, researchers worked out a concept of fluorine toxic effect on bones morphogenesis in fetal and postembryonic periods of human ontogenesis. According to this concept fluorine compounds are able to penetrate into a fetus through placenta and modify plastic processes in developing bones; it leads to resorption processes stimulation and slowing down synthetic and proliferative processes; during postembryonic period it results in unbalanced and disproportional bone growth thus creating the ground for bone pathology evolvement [20]. The authors proved that osteogenesis disorders caused impaired blood supply, suppressed multiplication of growth plate cells, osteoresorption activation, and osteogenesis weakening; all these disorders can lead to dysplastic changes in bones which are usually found in 76% of teenagers.

At the same time, we should note that clinical signs of spine column and pelvis diseases as independent nosologic forms among all locomotor apparatus diseases are studied quite sufficiently [7, 11, 17, 24]. On the other hand, researchers often have to deal with combined orthopedic pathology

[10, 18]. Thus, in accordance with authoring technique which gives the possibility to apply multi-factor analysis of combined locomotor system disorders, we have accomplished orthopedic examination of 801 children and teenagers living in an industrial city [5]. We have detected combined pathology (two and more nosologic forms) in most of them, namely in 389 (55.4%). To confirm cause-and-effect relations between combined deformations of spinal column and pelvis researchers outline the necessity to study their age dynamics [13, 23]. In spite of well-known achievements, issues of combined orthopedic pathology in children and its correlation with the impact of adverse technogenic factors are not studied as they should be and therefore they remain vital.

Research goal was to determine peculiarities of combined orthopedic pathology in children and teenagers being exposed to technogenic impact of aluminium production.

Data and methods. We examined 51 children aged from 8 to 21 suffering from combined spinal column diseases who lived in an industrial center in Irkutsk region and on the territory around it. 31 were female and 20 were male. As per age periodization, we divided all examined children into 3 groups [26]. The 1st group included 10 children: 5 girls and 5 boys aged 8-10. The 2nd group consisted of teenagers, 13 girls and 7 boys aged 11-15. And 13 girls and 8 boys (21 totally) aged 16-21 made up the 3rd group. 28 children and teenagers were living in close proximity to the industrial object (up to 5 km away); 23 examined children and teenagers were living more than 5 km away from the plant.

To accomplish orthopedic examination we used check-up technique taking ecological factors into account and a multi-factor analysis scheme [6]. To make a more precise diagnosis we conducted X-ray examinations of thoracic spine, lumbar spine, and pelvis. We also applied clinical classification, in particular, for dimensional disorders in pelvis bones orientation. We assessed spinal curvature degree as per value of Kobb angle.

In our statistical research we used Pearson chi-square criterion to analyze correlation between two constellations and to determine effective sign dependence on various factors (age, sex, proximity to an industrial object). Such method provides good results in determining frequency of a disease evolvement depending on risk factors. Determined risk factors parameters are measured mainly in a nominal scale. In case of sex we used two groups, male and female one. As for proximity to the industrial object we used a nominal scale consisting of two quantiles: “up to 5 km” and “more than 5 km away”. When we analyzed dependence of diseases evolvement on age we also used a nominal scale; all examined children and teenagers were divided into three quantiles: “8-10 years”, “11-15 years”, “16-21 years”. As some subgroups in our sample contained less than 10 patients, we applied Yates’ correction. To analyze correlation between the industrial object, children’s place of living and whirlbone aseptic necrosis morbidity we applied a hypothesis stating risk factor occurrence in proximity of 5 km. Danger coefficient for chemicals’ impact caused by inhalation intake was calculated according to **P 2.1.10.1920-04.** Guidelines on assessment of population health risk under exposure to chemicals which pollute environment [27].

Results and discussion. At the moment of our examination 42 children had no complaints; 9 patients of older age reported having insignificant periodical pains in lumbar area and pelvis joints. Nosologic forms of spinal column and pelvis pathology depending on children’s age are presented in table 1, as well as on cumulative bar graph (Picture 1).

Distribution of combined orthopedic pathology as per sex is shown on Picture.

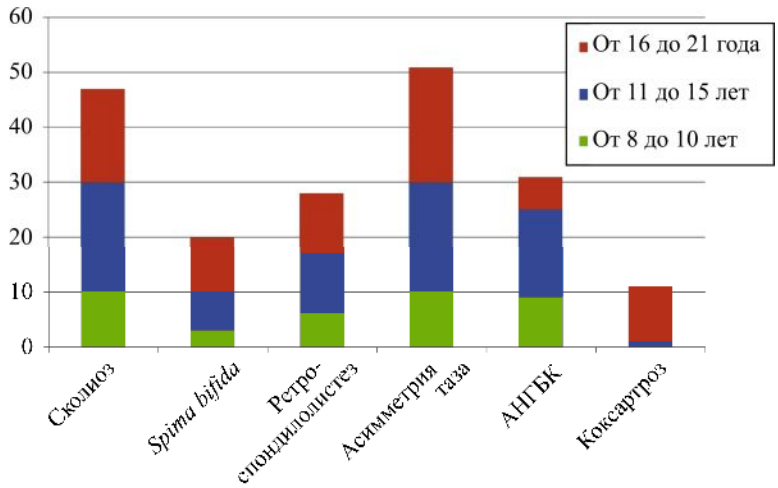
Pathology nosologic forms and their manifestation severity depending on proximity of children’s place of residence to an industrial object are given in Table 2.

Manifestation severity for combined spinal column and pelvis pathology depending on age is shown in Tables 3-5. 55% of children in the 1st subgroup had 1st severity degree scoliosis of thoracic spine and lumbar spine (table 3). 36% of the examined children had thoracic scoliokyphosis, thoracic and thoracic-lumbar scoliosis, and all the diseases of the 2nd severity degree. One third of children (6 out of 21) had poly-segmented retrospondylolisthesis of L_{II}-S_I, L_{III}-S_I spinal bones and retrospondylolisthesis of L_V-S_I spinal bone.

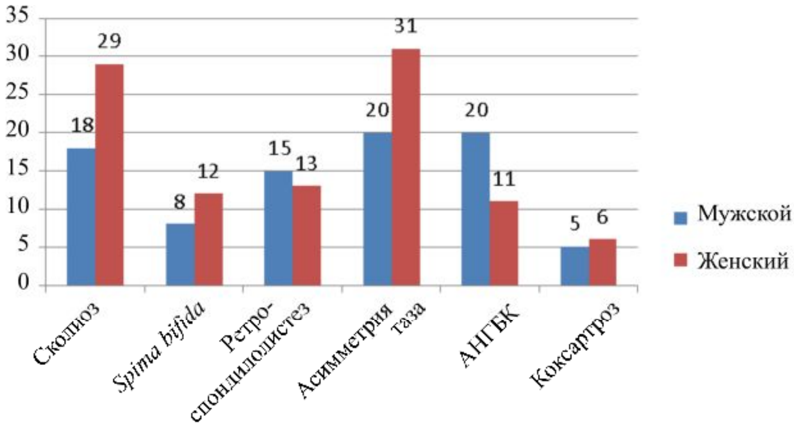
Table 1

Age structure of combined spinal column and pelvis pathology

Group	Age (years)	Number of children	Orthopedic pathology types, share (%)					
			Scoliosis	Spina bifida	Retrospondylolisthesis	Pelvis asymmetry	WAN*	Coxarthrosis
I	8–10	10	100,0	30,0	60,0	100,0	90,0	0,0
II	11–15	20	100,0	35,0	55,0	100,0	80,0	5,0
III	16–21	21	81,0	47,6	52,4	100,0	28,6	47,6
Total		51	92,2	92,2	39,2	54,9	100,0	60,8



Picture.1. Combined bar graph showing patients' distribution as per age
From left to right: scoliosis, retrospondylolisthesis, pelvis asymmetry, WAN, Coxarthrosis
Age groups: from 8 to 10, from 11 to 15, from 16 to 21



Picture 2. Patients' distribution as per age
From left to right: scoliosis, retrospondylolisthesis, pelvis asymmetry, WAN, Coxarthrosis
Sex groups: red – female, blue - male

Table 2

Specific weight of orthopedic pathology types and their manifestation severity depending on proximity of children's and teenagers' place of living to an industrial object

Place of living proximity to an industrial object (km)	Number of children	Share of orthopedic pathology types and severity degree, %								
		Scoliosis		Pelvis asymmetry			WAN		Coxarthrosis	
		1 severity	2 severity	1 severity	2 severity	3 severity	1,1-2 severity	3 severity	1-2 severity	3 severity
Less than 5	28	35,0	60,0	35,0	45,0	60,0	40,0	15,0	0,0	35,0
Farther than 5	23	53,8	69,2	69,2	38,5	38,5	38,5	46,2	15,4	53,8

Table 3

Manifestation degree for combined spinal column and pelvis pathology in children aged 8-10 (1st subgroup, N=11)

Orthopedic pathology types	Share of various degrees of severity (%:)		
	1st degree	2nd degree	3rd degree
Scoliosis	54,5	36,4	0,0
Pelvis asymmetry	18,2	36,4	36,4
WAN	27,3	54,5	0,0
Coxarthrosis	0,0	0,0	0,0
Total	100,0	90,9	36,4

70% of teenagers in the 2nd subgroup had thoracic and thoracic-lumbar scoliosis of the 1st severity degree (table 4); 30% of the examined patients in this subgroup had thoracic scoliokyphosis; and thoracic and lumbar-thoracic scoliosis of the 2nd severity degree as well (5%, 5% and 20% correspondingly). Also 55% of teenagers had poly-segmented retrospondylolisthesis of L_{IV}-S_I, L_{II}-L_V, L_{IV}-S_I, L_{III}-S_I, L_I-S_I, L_I-L_V, L_{IV}-S_I spinal bones.

Table 4

Severity degree of combined spinal column and pelvis pathology in teenagers aged 11-15 (2nd subgroup, N=20)

Orthopedic pathology types	Share of various degrees of severity (%:)		
	1st degree	2nd degree	3rd degree
Scoliosis	70,0	30,0	0,0
Pelvis asymmetry	35,0	35,0	30,0
WAN	50,0	30,0	0,0
Coxarthrosis	5,0	0,0	0,0

62% of patients in the 3rd subgroup had thoracic and thoracic-lumbar scoliosis of the 1st severity degree (table 5). 4 examined patients had thoracic scoliokyphosis, thoracic and thoracic-lumbar scoliosis of the 2nd severity degree. Here 19% had poly-segmented retrospondylolisthesis of L_{III}-S_I, L_I-S_I, Th_{XII}-S_I spinal bones and retrospondylolisthesis of L_V-S_I spinal bone. 48% of young people (male and female) suffered from dysplastic coxarthrosis; 28.5% had two-sided coxarthrosis of the 1st-2nd severity degree, and as for one-sided coxarthrosis of the 1st and 3rd degree, 9.5% and 9.5% correspondingly had such type of pathology.

We included all the obtained data into “Peculiarities of combined orthopedic pathology and assessment of its probable evolvement in children and teenagers living in an industrial city in Irkutsk region” database [12, 25].

Table 5

Severity degree of combined spinal column and pelvis pathology in teenagers aged 11-15 (2nd subgroup, N=20)

Orthopedic pathology types	Share of various degrees of severity (%:)		
	1st degree	2nd degree	1st degree
Scoliosis	61,9	19,0	0,0
Pelvis asymmetry	57,1	19,0	23,8
WAN	14,3	14,3	0,0
Coxarthrosis	38,1	9,5	0,0

Research results analysis has revealed that pelvis asymmetry holds the 1st place in the structure of combined spinal column and pelvis pathology; the 2nd place belongs to scoliosis, and the 3rd place belongs to whirlbone aseptic necrosis. All 51 examined patients have pelvis asymmetry and it coincides with the data presented in the literature [14]. Pelvis asymmetry prevalence over number of cases of dystrophic changes in whirlbones proves its leading role in the further development of hip joints deformations [6]. If we assess age structure for combined pathology determined in the 2nd and 3rd groups of the examined patients we can conclude that scoliosis, Spina bifida, retrospondylolisthesis and pelvis asymmetry manifestations are practically the same; but whirlbone aseptic necrosis prevails in children aged 11-15, while its specific weight lowers in 16-21 age group, and coxarthrosis in this group becomes more common. The primary statistically significant results are given in table 6.

Table 6

Statistic analysis of correlation between effective disease sign and factorial disease signs: criteria and results

Effective and factorial disease signs	Statistic analysis criteria			Correlation statistic significance
	Criterion value $\chi2$	Criterion value $\chi2$	Critical value $\chi2$	
WAN and age	2	15,821	9.21 at $p<0.01$	significant at $p<0.01$
WAN and sex	1	21,228	6.635 at $p<0.01$	significant at $p<0.01$
WAN and an industrial object*	1	5,264	3.841 at $p<0.05$	significant at $p<0.05$

As per statistic analysis results for the sample they have helped us to detect strong dependence of WAN morbidity on children’s age, sex and their place of living proximity to the industrial object. Within 5 km distance from the industrial object WAN specific weight is the biggest (21 case out of

31 examined), and as the distance grows it tends to go down; our data coincide with those presented in the literature [3, 6]. Then, as for dependence on sex, WAN is diagnosed in all examined boys, and only in 35.5 cases among girls. At the same time, 1st and 2nd degrees of evidence of clinical and X-ray abnormalities as signs of combined spinal column and pelvis pathology prevail over 3rd degree of abnormalities (77 and 43 cases correspondingly against 15 cases).

We applied reference concentration rates for chronic inhalant impact [26] and average annual substances concentrations [20] in our analysis in order to determine danger coefficients (HQ_i); some of them are: HQ_i 4,2 for benzpyrene, HQ_i 9,2 for poorly soluble fluorides, HQ_i 2,3 for formaldehyde, HQ_i 1,65 для for suspended substances. The outlined danger coefficients cause body development risks and morbidity risks, in particular, respiratory organs diseases and locomotor apparatus diseases. If we correlate our research results with danger coefficients we can assume that chronic inhalant impact of harmful substances, particularly, fluoride compounds, causes locomotor system pathology risk.

Conclusion. Our research confirms that long-lasting living on territories where air is polluted with harmful emissions of aluminium production which contain fluorine impurities leads to combined spinal column and pelvis pathology evolvement in children and teenagers. We have determined clinical, age, sex and ecologic peculiarities of combined orthopedic pathology. We have statistically proved correlation between particular factorial and effective diseases signs. At the same time, we have detected the necessity to continue searching for other significant proofs of correlation between chemical risk factors and locomotor apparatus diseases. Therefore we recommend accomplishing further research, early diagnostics and regular check-ups of children living in polluted places; all these measures allow us to assess combined orthopedic pathology objectively, including premorbid period of its evolvement.

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