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The influence of heavy metals on cataracts

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ABSTRACT

Currently, much attention is paid to the search for the etiology of many eye diseases. It has been shown that environmental pollution with heavy metals (cadmium, lead, mercury) is of significant importance. One of these diseases is cataract, i.e. clouding of the lens of the eye. It turns out that heavy metals are deposited in the tissues of the eyes, damaging them and accelerating the disease. This work is aimed at presenting the problem of the influence of heavy metals on cataracts. The study compares the concentration of heavy metals between the control group (81 healthy volunteers) and the group of cataract patients (72 sick). Plasma was used in the research and the ICP-MS method was used.

Keywords: eye, heavy metals, cataract, cadmium, lead, mercury

1. INTRODUCTION

Cataract research and the search for its treatment interested scientists several thousand years ago. Cataracts are clouding of the lens of the eye. A cataract is a disease that affects the lens of the eye and is responsible for the breaking of light rays that reach it and accompanying pathophysiological abnormalities. Another name for this disease entity is cataract, because it was once believed that inflammation "flows" from the brain to the eye like a waterfall. The clouding of the lens affects visual acuity [1, 2].

Nowadays, much attention is paid to the role that environmental conditions can play during the formation of a cataract [3].

2. LENS

A transparent, biconvex structure whose main task is to break incoming light rays. It is located between the iris and the vitreous body. It takes an active part in the eye accommodation, i.e. the setting ability of the lens depending on the distance between the eye and the object. The lens increases with age. Its weight in a 20-years-old person is about 0.2 g, diameter 9 mm and thickness 4 mm [4, 5].

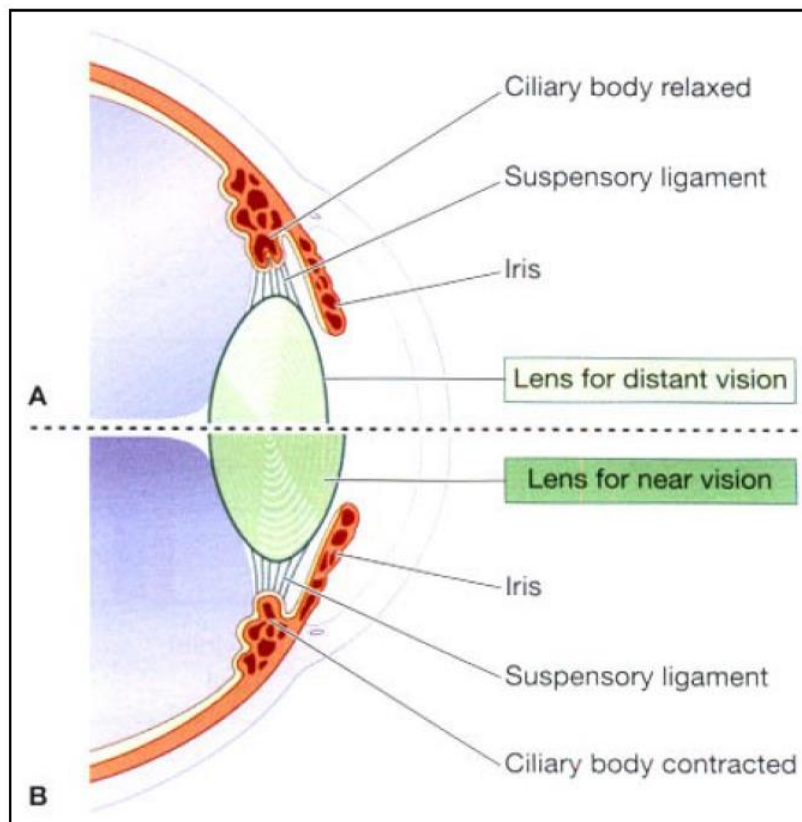


Fig. 1. Change the shape of the lens depending on the distance of the object. A - objects far away, B - objects close. Source: Waugh, Grant 2001

The lens can change its shape as a result of changes in the voltage of the ciliary fringe. This in turn is regulated by the muscles of the ciliary body. These changes make the lens shape more convex or flatter. The different shape of the lens changes the focal length, and thus at the same time transforms the focusing ability, thanks to which, during the correct operation of the lens, you can clearly see near and far objects. When looking at distant objects, the ciliary muscle relaxes, the effect of which is the simultaneous change in the tension of the ligaments connected to the edge of the lens. The lens takes a flattened shape. On the other hand, when looking at close objects, the ciliary muscle contracts and the ligaments are released, and the lens itself becomes rounded [5, 6].

3. PATHOPHYSIOLOGY OF THE LENS – CATARACT

A cataract is a congenital or degenerative condition that causes the lens of the eye to become cloudy. From a clinical point of view, cataracts represent clouding of the pupil. This cloudiness also affects visual acuity. According to various statistics, cataracts are the most common cause of blindness in the world. Initially, the symptoms observed were blurring and visual disturbances. The degree and extent of cataract visual impairment depends on the size and location of cataracts. The location varies from subcapsular, cortical or nuclear, to the anterior, possibly posterior. Cataracts can develop very quickly or slowly and, as research shows, it is impossible to determine the cause at this time. Additional changes that occur during cataracts are the change of the lens color to yellow or amber [2, 3].

4. HEAVY METALS AND THEIR INFLUENCE ON THE FORMATION OF CATARACTS

It turns out that chemical elements influence the pathophysiological changes in the human body. Environmental pollution and contamination with heavy metals directly affect the changes in the body [7, 8]. Trace metals (Fe, Zn, Cu) play an important role in both the physiology and pathophysiology of the retina. They are involved in a variety of functions in the body, such as the phototransduction mechanisms and in the process of neurotransmission. Elevated levels of the free ions of these metals may cause a toxic effect [9].

The results of a study by the Korean team of Park et al. suggests that toxic heavy metals such as lead, mercury and cadmium can adversely affect human vision [11]. Heavy metals have been shown to accumulate in the eyes. According to current reports, the most accurate indicator of lead poisoning is δ -aminolevulinic acid dehydratase (ALAD), its activity decreases with increasing lead. Lead is one of the most known toxic elements in the biomedical field [11, 12]. Research has shown that lead can also build up in the lens of the eye. It acts as a protoplasmic poison. Due to its accumulation in a given tissue, it acts slowly, often causing many symptoms that may not be related to its effect. Lead toxicity is a major health question [12-14].

Due to the competition with zinc and selenium, cadmium leads to a lower concentration of antioxidants [15]. Based on the results of experimental studies on rabbits that were administered high doses of cadmium via the oral route, it was shown that cadmium accumulated in quite high concentrations in the tissues of the eye. Adverse effects of cadmium on the lens of the eye were observed, presumably due to its effect on sodium-potassium disturbances.

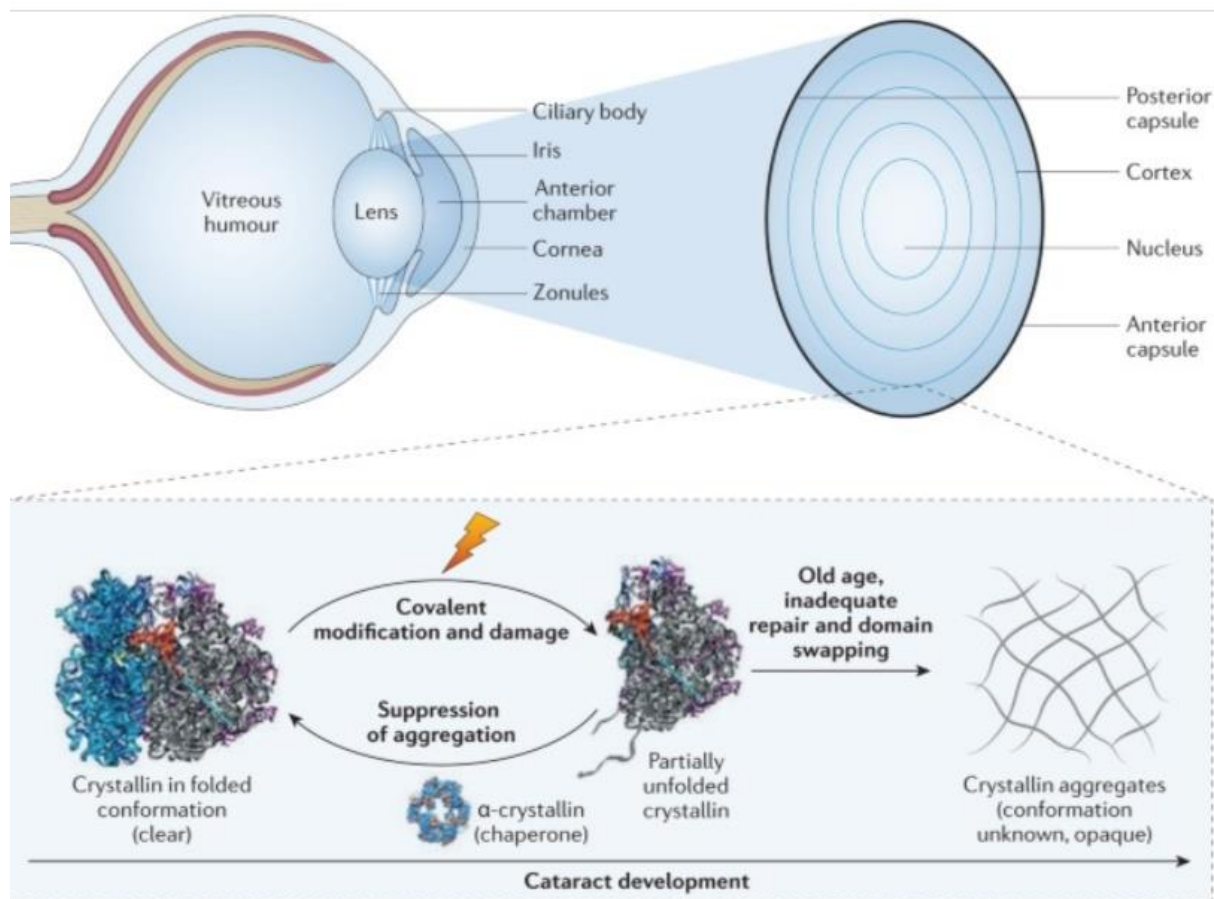


Fig. 2. Cataract; source: [10]

Cadmium exposure can also cause conjunctivitis and damage the cornea. People chronically exposed to high concentrations of cadmium may develop changes characteristic of hypertensive retinopathy. Cadmium increases blood pressure [16]. It turns out, however, that cadmium, and more precisely its Cd^{2+} ions, can also accumulate in mitochondria, which are directly responsible for intracellular respiration and contribute to the formation of ROS. In addition, these ions damage other organelles that may have the effect of creating "weaker" lenses that are not resistant to photooxidation. The above-mentioned factors as a result, they may contribute to cataracts. It has also been proven that long-term cadmium exposure contributes to damage to the intracellular structures of the lens, resulting in lens opacification. Other results of studies conducted on cadmium prove that it also accumulates directly in the eye tissues, primarily in the nervous retina, pigments of the retinal epithelium and in the choroid. However, its concentration depends on the age and general health of the patient [17, 18]. Mercury is also a highly toxic element. In vivo studies using monkeys have shown that mercury crosses the blood-retinal barrier. There is visual impairment, including blindness, as a result of acute mercury poisoning, which primarily causes damage to the visual cortex [11].

The results of the studies carried out so far have shown that mercury, like other heavy metals, can accumulate in the eye tissues, primarily in the choroid, epithelium and in the

pigments of the retina. It has also been shown to bind with calcium. This way it gets to the individual tissues more easily. It also turned out that Hg can accumulate in the eyes through epithelial melanosomes, i.e. pigments contained in in the retina of the eye [10, 11].

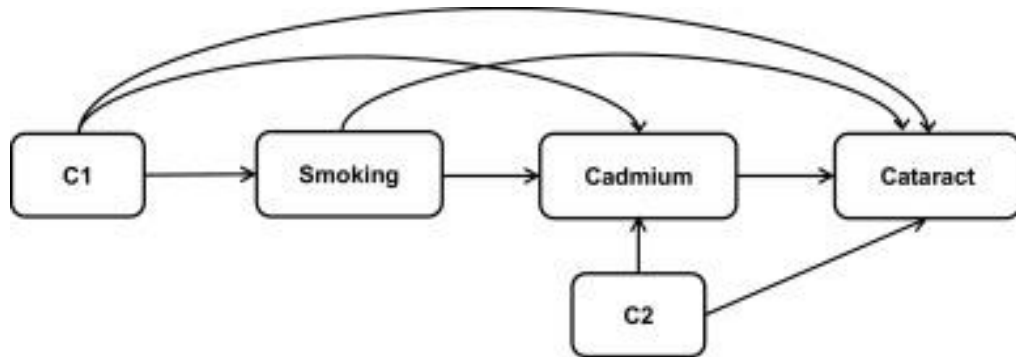


Fig. 3. Cataract and cadmium; source: [20]

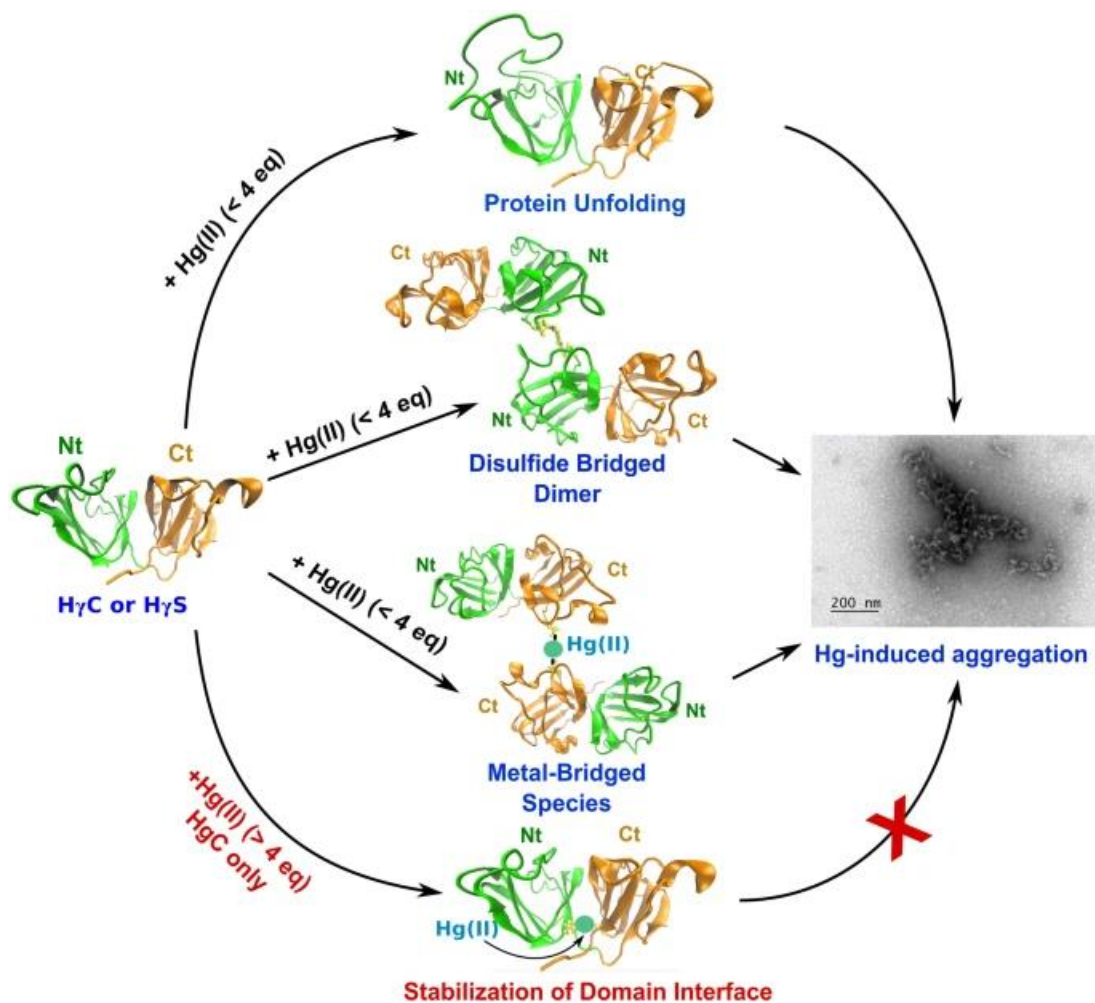


Fig. 4. The action of mercury; source: [19]

Accumulation of mercury in the tissues of the eye has not been proven, however, many studies show that mercury, through its proven toxic effect, can actively influence the progression of cataracts. Protection against it is the protein metallothionein, whose task is to bind and detoxify heavy metals, mainly mercury and cadmium. In addition to this function, it also participates in the storage and metabolism of zinc and copper [12, 13].

5. MATERIALS

The material for the research was whole blood collected in a heparin-lithium tube in the amount 4 ml, from which plasma was obtained.



Fig. 5. Lithium heparin tube

Blood collection was consistent with the guidelines recommended by the bioethics committee. The obtained material had to be centrifuged in accordance with the established parameters:

- Spin speed: 2 thousand turnover/min.
- Spin time: 15 min.
- Cooling temperature during spinning: +4 °C

The obtained plasma was transferred to sterile Eppendorf tubes and stored at -80 °C until analysis. As a result, it was obtained:

- 81 healthy volunteers from Zielona Góra (control)
- 72 cataract patients from the Ophthalmology Clinic in Bydgoszcz (study group)

6. METHODS

The tests were performed as a quantitative analysis of chemical elements using the ICP-MS method (mass spectrometry with excitation in inductively coupled plasma). The ICP-MS Agilent 7500 CE apparatus was used, equipped with a micro-mist nebulizer, thermoelectrically cooled with the Peltier effect, a double-pass fog chamber. To maintain instrument stability and minimize matrix effects, all determinations were made in the presence of ^{45}Sc , ^{89}Y , ^{159}Tb as an internal standard.

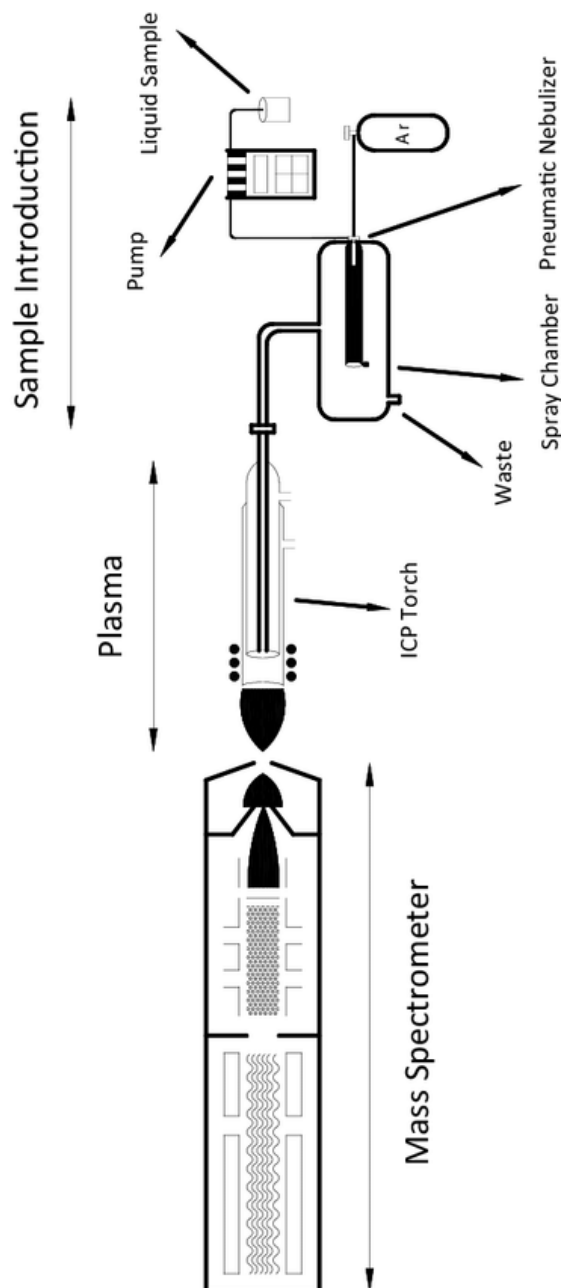


Fig. 6. ICP-MS scheme of operation; source: [20]

7. RESULTS

The concentration of elements from 81 healthy volunteers (control group) and 72 volunteers with cataracts (cataract group) were tested. The distribution of the concentration of chemical elements in the blood did not differ for: Cd, Pb, Hg.

Table 1. Descriptive statistics of data from the concentration of elements in the control and cataract groups. Count (n), arithmetic means (median (Me), minimum values (min), maximum values (max) and standard deviation (SD).

Descriptive statistic	Group	n	\bar{x}	Me	min	max	SD
Cd [mg·kg ⁻¹]	control	72	0.0001	0.0000	0.0000	0.0004	0.0001
Pb [mg·kg ⁻¹]	control	72	0.0000	0.0000	0.0000	0.0011	0.0001
Hg [mg·kg ⁻¹]	control	72	0.0000	0.0000	0.0000	0.0010	0.0002
Cd [mg·kg ⁻¹]	sick	81	0.0006	0.0002	0.0000	0.0124	0.0015
Pb [mg·kg ⁻¹]	sick	81	0.0270	0.0107	0.0000	1.2311	0.1356
Hg [mg·kg ⁻¹]	sick	81	0.0010	0.0007	0.0000	0.0064	0.0010

Several statistically significant correlations were found between lead, cadmium and mercury, and elements of an antagonistic nature and with each other. For the control group, correlations were shown: Mn and Pb (R = 0.254; p = 0.222), Cu and Pb (R = 0.316; p = 0.004), Zn and Cd (R = 0.240; p = 0.031), Cd and Cu (R = 0.316; p = 0.004), Fe and Hg (R = 0.323; p = 0.003), Zn and Hg (R = 0.467; p = 0.000).

For the group examined: Pb and Hg (R = 0.467; p = 0.000), Cd and Fe (R = 0.261; p = 0.027) and Cd ad Cu (R = 0.329; p = 0.005); Cd and Zn (R = 0.307; p = 0.009), Pb and Hg (R = 0.467; p = 0.000).

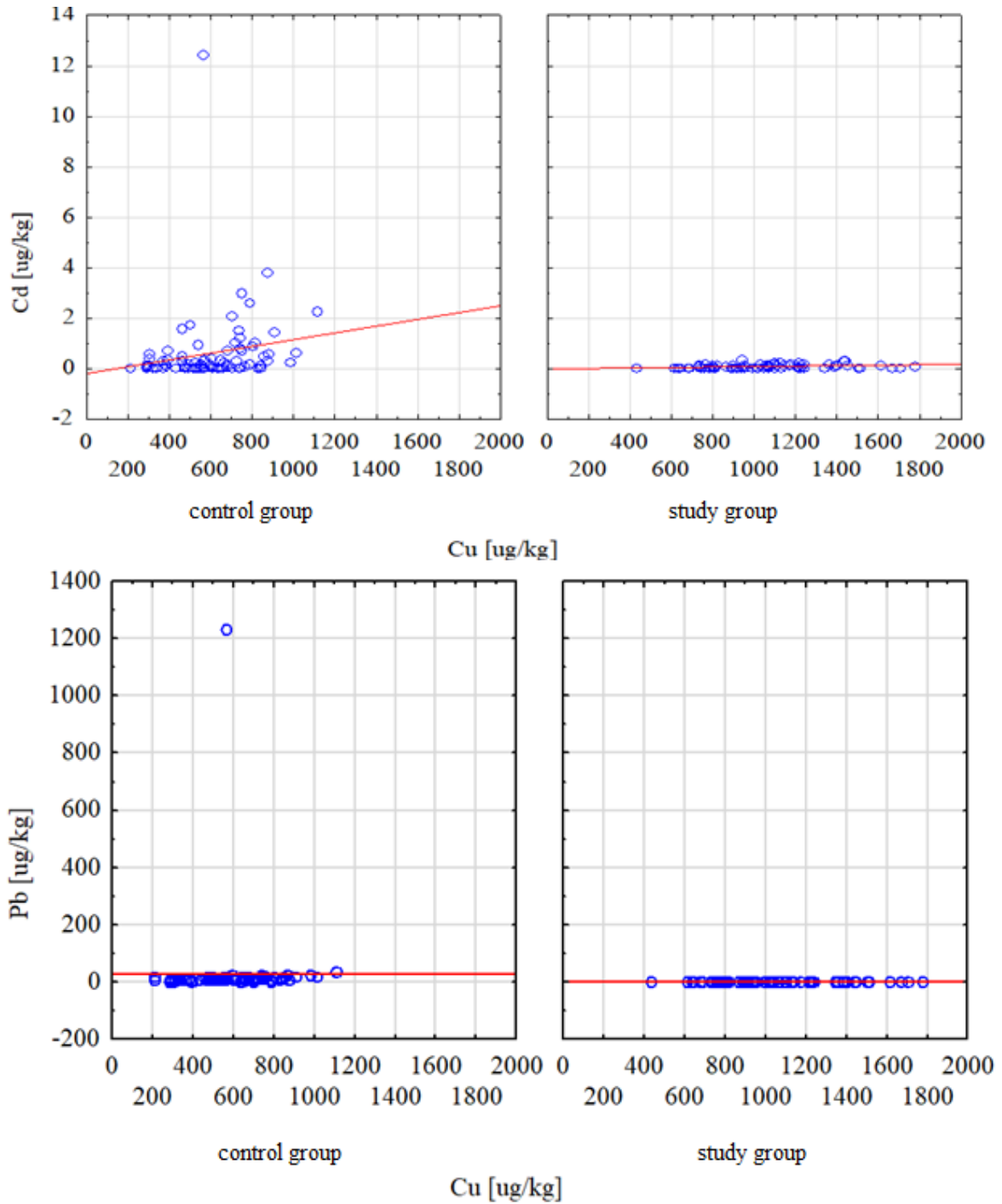


Fig. 7. Results of study. Correlation between Pb-Cu and Cd-Cu in control and study group.

8. DISCUSSION

Cataract is a disease that results from many environmental factors, both internal and external. It is a frequent object of many scientific studies aimed at searching for etiology and new diagnostic methods and medicinal [21, 22]. It was also indicated that heavy metals (in particular cadmium, lead) contribute to damage to the genetic material and indirectly, through inducing oxidative stress in human tissues [21, 23]. The results obtained in the research in this study indicate a higher level of lead concentration in the control group, it may be caused by the physiological adaptation of people suffering from cataracts. There were minimal differences between the cadmium and lead concentrations in comparison to the cataract control group. Statistically significant relationships were obtained in the control group for pairs: Pb-Mn and Pb-Cu. In the group, cataracts only for Pb-Hg. More relationships appeared in the case of cadmium, where a statistically significant relationship was noted for copper and zinc in the control and for iron, copper and zinc in the cataract group [20]. There is a hypothesis that the emergence of a greater number of statistically significant relationships is associated with easier interaction of cadmium with other elements than in the case of lead. The results of this study may become the basis for further analyzes of the problem of the influence of heavy metals on the incidence of cataracts.

9. CONCLUSIONS

- Differences in the concentration of heavy metals in the blood of cataract patients compared with the healthy control group were demonstrated
- There are significant interactions between individual chemical elements that influence the development of cataracts. Correlations of the analyzed chemical elements (Cd, Pb and Hg) are important in the development of cataracts ($p = 0.000$)
- Chemical elements from various groups of physiological influence determine the course of the gradual development of cataracts.

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