SUMMARY

Metalosis is a common condition affecting patients who have been implanted with metal implants. The amount of implant particles released into the synovial fluid correlates with the concentration of metal ions in the blood. It gives the opportunity to assess the degree of implant damage by measuring the concentration of elements that are included in its composition in the blood. Measurements of this type are one of many input data used in the process of improving existing materials used in the production of implants. No less valuable information would be knowledge about the spatial distribution of metal ions released from the used implants. Unfortunately, the methods of spatial determination of metal ions in hard tissues so far require a complicated sample preparation procedure and have a limited field of sample observation, which can significantly affect the possibility of their use to assess the distribution of ions in bone tissue.

This dissertation presents a newly developed method for measuring the spatial distribution of ions of selected heavy metals found in metal alloys commonly used in implantology in bone tissue. The method is based on the laser induced breakdown spectroscopy (LIBS) technique and allows the unambiguous determination of the presence of a given element and its spatial distribution in bone tissue. As part of the conducted research, the method of sample preparation before the measurement was optimized, the measurement data acquisition parameters were determined and the spatial resolution of the method was specified by determining the minimum distance between neighboring measurement points. In addition, a quantitative calibration of the method was carried out using a matrix containing strictly defined amounts of heavy metal salts.

The work also deals with issues concerning the influence of iron, chromium and cobalt salts on selected cell structures and processes. Thermodynamics of diluting biologically relevant salts in the presence of Fe^{2+}, Cr^{3+} and Co^{2+} ions were carried out. It was found that presence of each of tested salts increases enthalpy of dilution of NaCl, KCl, $CaCl_2$ and their mixtures. The obtained results show how heavy metal ions can disrupt physiological fluid homeostasis. In addition, it has been shown that the presence of biologically relevant concentrations of proteins and lipid aggregates does not significantly affect the thermodynamics of the aqueous phase caused by the presence of biologically relevant ions. These studies were carried out on model systems in the form of well-defined lipid aggregates and concentrated globular protein (albumin) solutions. The obtained results indicate the possibility of existence of new, previously undescribed mechanisms of conditions affecting the optimization of energy expenditure in the cell.

In order to explore the possibility of heavy metal ions to affect the cell, the influence of Fe^{2+}, Cr^{3+} and Co^{2+} ions on the lipid bilayer permeability was investigated. Changes in the organization of lipid bilayer due to forced difference of osmotic pressures across the membrane in the presence of heavy metal ions were determined. All of the examined ions caused changes in the organization of the lipid bilayer, especially in the interphase area, thus affecting the diffusion of water. The largest difference in comparison to control measurements was caused by the presence of iron ions. On the basis of obtained experimental data, permeability of the lipid bilayer was determined. All of the studied ions reduce the permeability of bilayer, and the scale of the effect overlaps with the influence of particular ions on the organization of the bilayer.

The results of the research presented in the study allowed to offer a new method for the determination of spatial distribution of heavy metals in bone tissue enabling assessment of the local concentration and, as a consequence, potential toxicity of heavy metal ions from implants. Additionally, it was shown on in vitro models that selected heavy metal ions (Fe^{2+}, Cr^{3+} and Co^{2+}) change the thermodynamics of aqueous solutions and modify the properties of lipid aggregates. These results allow for a better understanding of the molecular basis of homeostasis of aqueous solutions containing proteins and lipids, and of how this homeostasis is altered by metal ions known for their non-specific toxicity.