disease. In addition, under the influence of cadmium, calcium metabolism disorders, the formation of kidney stones and hypercalciuria occur [11]. The International Agency for Research on Cancer classifies cadmium as the first group of carcinogens leading to oncological diseases [12].

The solution to this urgent problem requires the widespread use of modern technologies for the purification of water resources, which include adsorption methods.

In recent years, the possibility of using natural and modified clays as adsorbents for the removal of various toxic heavy metal ions from aqueous solutions has been thoroughly studied. For example, in [13], the sorption activity of natural zeolite and chamotte clay concerning $Pb^{2+}$ ions was studied. As a result, it was determined that the objects of study have a sufficiently high sorption capacity (14 mg/g for zeolite and 11 mg/g for clay), and the process itself is described by the Langmuir model.

In another work, the adsorption of $Cd^{2+}$, $Pb^{2+}$, $Cr^{6+}$ ions from wastewater using natural clay was investigated [14]. This study confirms that clay is a good adsorbent for removing these metals from wastewater. Also, the value of the Langmuir and Freundlich constants indicates a good adsorption capacity.

The high sorption capacity of clays is due to a number of important properties: a large specific surface area, porosity, surface charge, surface functional groups, etc. [15]. Therefore, clays and clay minerals can be used as sorbents for cleaning various toxic contaminants, including heavy metals.

However, since clays are formed as a result of natural transformations and weathering of soils, not all of them have the necessary structure that provides the above properties. And thus, not all natural clays have a high sorption capacity.

It is possible to increase the sorption capacity of clay by modification, as evidenced by many studies [16]. For example, in [17] the adsorption of lead (II), zinc (II) and cadmium (II) in single-element and multi-element systems on untreated, acid-activated and aluminum-coated Tunisian smectite was investigated. The chosen order of adsorption Pb (II)> Zn (II)> Cd (II) showed the importance of the phenomenon of competition in the adsorption of the pores of the clay material.

Thus, there is a need to develop new composite materials with high sorption characteristics. However, many sorbents have a high cost, an insufficient degree of purification of water bodies from various toxic substances. In this regard, the purpose of this study is to obtain an effective composite material based on natural clay from the Kyzylsok deposit. The modification of natural clay was carried out with polyvinylpyrrolidone (PVP).

PVP is an amorphous linear polymer. It is hygroscopic, soluble in water, non-toxic, has an affinity for organic polymers. Its aqueous solutions have a slightly acidic reaction (pH 5). It is reasonable to associate the high sorption capacity of the pyrrolidone fragment with its structure (Fig. 1) [18]:

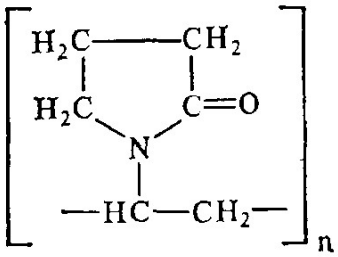

Figure 1 – The structure of PVP

This class of reagents represents compounds with grafted complexing groups that form strong bonds with metal ions dissolved in water [19]. Therefore, a probable sorption mechanism can be considered as complexation associated with the presence in the PVP structure of functional groups with donor nitrogen atoms, which, in turn, can bind metal ions into strong complexes.

## Materials and methods

The following were used in the work: clay from the Kyzylsok deposit (Almaty region, Kazakhstan), polyvinylpyrrolidone (PVP) with a molecular weight of 10,000 g/mol, $Pb(NO_3)_2$, $CdCl_2$. All chemicals were of analytical grade and purchased from Sigma Aldrich (Germany).

*Equipment.* To determine the surface properties of the clay, we used a Quanta 3D 200i Dual system (FEI, USA) scanning electron microscope. Elemental analysis of the natural clay was carried out using energy dispersive spectrometry (EDAX). The initial and residual metal concentrations were determined by a Shimadzu 6200 atomic absorption spectrophotometer. The results were processed using the ORIGIN 9.5.1 software.

*Modification of clay.* Original clay was previously ground and sifted through a sieve to remove mechanical impurities. A 0.1% PVP solution is mixed with the clay in a 1:10 ratio, stirred at 200 rpm for 24 h, filtered and dried at t ≈ 100 ° C for 1 hour, and then in the air for 24 hours. The obtained