peels and pumpkin were used as bioadsorbents. Yellow passion-fruit shell was used as adsorbent for removal of ions of Cr (III) and Pb (II) from water. The highest removal efficiency was observed at pH = 5 both for chromium and lead. The removal efficiency of Cr (III) ions was about 63% and about 20% for Pb (II) [15].

Banana peel was used as adsorbent to remove Cr (VI) ions from industrial wastewater [16]. The sorption process was carried out at the pH range of 1-9. Maximum Cr (VI) removal was observed at pH = 2, the removal degree reaches more than 95 %. Another work has been provided using banana peel as adsorbent for treatment of wastewater collected from Gelox paints, Kaduna state, Nigeria [17].

A lot of research works were performed using orange peel as an adsorbent for heavy metal ions removal [18-20]. Orange peel along with date palm fibers were used to remove copper (II), lead (II) and arsenic (V) ions from aqueous solutions [21].

A lot of researches have been done using peel of pomegranate [22, 23]. Pomegranate peel was used to adsorb copper, cadmium, nickel and zinc ions [24]. Biosorbent shows the highest adsorption capacity of heavy metals at pH 4.5. Adsorption of copper and cadmium ions represents the highest results, followed by ions of zinc and nickel. Adsorption of Cr (VI) is the lowest at pH 4.5. The maximum removal of copper ions was 0.0677 mmol/g at initial 0.787 mmol/l of the solution.

Thus, an analysis of the literature has shown that composite materials based on orange peel and pomegranate peel are of practical interest for use in the process of sorption of heavy metal ions, but they should be modified to increase the sorption activity. For our knowledge, there is no data on the use of polyethylene glycol (PEG) as a modifier for the preparation of composite materials based on orange peel and pomegranate peel in the literature. The previous studies [25] have shown that PEG can be used as an effective modifier of sorbents based on natural materials. The adsorption activity of PEG-modified OP and PP towards copper (II) and zinc (II) ions was studied in the current work.

Materials and methods

Composite materials preparation

Orange (OP) and pomegranate (PP) peels were collected from local markets and juice-producing shops. At first, peels were washed with distilled water, finely cleaned and left to dry at room temperature. Then the dry peels were mechanically ground till fine powder was obtained.

Obtainment of the composite materials based on the peels was carried out according to two-step procedure: first with a solution of sodium hydroxide (NaOH), then with a solution of polyethylene glycol (PEG).

Obtaining the composite material based on orange peel was carried out according to the following procedure. Orange peel powder weighing 5 g is placed in a glass; 100 ml of an aqueous solution containing 0.1 M NaOH is poured into this glass. Next, the resulting solution with the OP is stirred with a glass rod to prevent lumps, and then continued mixing using magnetic stirrer at 100 rpm for 60 min. The resulting gelatinous solution is left over night. On the next day the process of polymer modification begins. First, solution is rinsed with distilled water until a neutral medium is reached (pH of 6-7). Then the solution is filtered. After that the sorbent remaining on the filter paper is dried and subjected to polymer modification. For this purpose, 100 cm^3 of 0.1 % polyethylene glycol is poured into a glass with a sorbent obtained in the previous step. After 60 minutes of stirring on a mixer, composite material is dried in an oven at 100 °C for 2 hours, then left to dry until completely drying at room temperature. The obtained composite material was ground in order to further study of its characteristics.

The composite material based on pomegranate peel was obtained by the same method as in the case of orange peel.

Adsorption experiments

The following solutions containing heavy metal ions of various concentrations are prepared for the experiment:

– solution of the $CuCl_2 \cdot 2H_2O$ salt with a metal concentration of 10-50 μg/ml;

– solution of $ZnCl_2$ salt with a metal concentration of 10-50 μg/ml.

The sorption process was carried out under static conditions with outstirring, at the room temperature equal to T = 298 K.

Sorbent with a mass of 1 g is placed and 100 ml of solution is poured into a measuring cup (flask) with a capacity of 100 cm^3. Furthermore, an aliquot of the solution is taken after a certain period of time and kept at room temperature until equilibrium was established.

Results and discussions

Sorption characteristics of initial and modified composite materials based on orange and pomegranate peels