Recycled Sorbents for Wastewater Treatment

I N Pugacheva¹, S B Zueva², L In Molokanova¹

¹Department of Industrial Ecology, Equipment for Chemical and Petrochemical Production, Voronezh State University of Engineering Technologies, 19, Revolution Avenue, Voronezh, 394043, Russian Federation
²Department of Technology of Organic Compounds, Polymer Processing and Technosphere Safety, Voronezh State University of Engineering Technologies, 19, Revolution Avenue, Voronezh, 394043, Russian Federation
³Department of industrial and information engineering and economics, University of L’ Aquila, Italy

E-mail: eco-inna@yandex.ru

Abstract. The today’s continuous industrial growth of major industrial centers has caused the discharge of heavy metal-polluted wastewaters to skyrocket. Improperly treated wastewater may reach natural water reservoirs, where heavy metals will accumulate in water and bottom sediments, resulting in secondary pollution and thus deteriorating the ecological conditions. Thus, it is imperative to improve the existing wastewater treatment technologies and invent new ones, as well as to find new efficient sorbents. Meanwhile, a variety of enterprises generate waste that could be used for adsorption. For instance, the textile industry generates considerable amounts of pulp-containing waste that could be used to make promising sorbents. The paper presents a method of producing powdered sorbents from pulp-containing waste of textile industry. The team researched how the pH of thus produced sorbents and the mixing time affected the adsorption of heavy metals (nickel). The finding is that the produced powdered sorbents are suitable for tertiary wastewater treatment.

1. Introduction

The Water Strategy of the Russian Federation for Until 2020 notes that only 11% of the total wastewater going to water reservoirs is treated as required by the standards, whereas most of the effluents either remain untreated (17%) or inappropriately treated (72%).

Particularly threatening is the accumulation of heavy metals in water reservoirs; settling on the bottom, they are transformed by benthos microorganisms, which might result in polluting the water with toxic compounds while also contributing to the buildup of metal compounds in hydrobionts. This is why the maximum permissible concentration (MPC) of heavy metals has very low values; however, this also means that treating heavy-metal wastewaters to the standard-required levels is difficult. There is a dire need for a wastewater treatment method that could efficiently extract heavy metals. In this regard, it seems relevant to search for new wastewater treatment solutions that could help comply with the quality standards while being affordable and using upgraded equipment rather than newer units. One well-established wastewater treatment method is referred to as adsorption; it is efficient, produces no secondary pollution, and can be used to extract valuable components from the effluents.
Industries use different sorbents that are classified as either carbon or mineral sorbents. The former group comprises activated coals, peat, and other materials, mainly produced by processing a variety of organics; the latter group comprises silica gels, alumina gels, and zeolites [1-3]. Activated charcoal is a popular product for removing metal ions; however, its production process is energy-intensive and therefore costly; besides, this sorbent needs regeneration. Despite the variety of existing sorbents, many of them fail to meet the extensive set of requirements, which motivates the continuous search for, and development of, next-generation sorbents [4-6]. This effort prioritizes the production of relatively cheap sorbents from industrial waste, as such an approach contributes to recycling [7, 8]. Waste-based sorbents are devoid of the biggest con many sorbents have, namely the prohibitive costs. Pulp-containing waste of textile industry is suitable for making sorbents. Some portion of this industry’s waste is already in use in other industries. Thus, the heavily clogged cotton fibers are used for plugging oil wells when drilling. Some flaps and trims can be used to make asphalt felt and bitumen. Hard-to-recycle lining materials are garnetted and then used as fillers in construction materials or as heat and sound insulation placed under linoleum [9]. However, most of textile waste is either burned or left at landfills. Meanwhile, papers [10-12] propose a promising method to use pulp-containing waste of textile industry as a multifunctional additive to elastomer compositions. Such additives enable more efficient and eco-friendlier production of filled emulsion-polymerized rubbers [13-15].

As of today, researchers and practitioners alike are interested using pulp-containing plant materials to make sorbents to extract heavy metals from aqueous solutions [16-18]. However, such materials tend to have relatively low kinetic properties, are not highly selective, and their adsorption capacity is lackluster. This is why before such a material could be used as a sorbent, it has to be modified [19-21].

**The goal** hereof is to test recycled materials, in particular pulp-containing textile waste, as powdered sorbents for extraction of heavy metals from wastewater.

### 2. Methods and materials

To make a pulp-based powdered sorbent, the research team used cotton fiber-containing textile waste. The cotton fiber was powdered as follows. First, the experimenters crushed the fibers. Then the crushed material was placed in a reactor, stirred, and exposed to a 30 wt.% sulfuric acid solution. The reaction mix was heated to 60–80°C and kept at this temperature for 1.6 to 2 hours; the resulting mush was filtered. Then it was washed with distilled water to pH 1÷7. The resulting powdered sorbent (C) was dried for 1 to 2 hours at 70-80 °C. After dried, the sorbent was crushed to a finer particle size. This produced the following sorbents: C1 (pH=1.5); C2 (pH=3); C3 (pH=5); C4 (pH=7).

### 3. Results

Testing the particle size of these powders returned the following weighted average values: ~0.57 mm for pH 1.5 to 3 sorbents; ~0.14 mm for pH 5 to 7 sorbents. A JSM-6380 scanning electron microscope was used to analyze the elements contained in the particles; this revealed that the pH 1.5 to 3 sorbent contained bonded sulfate groups.

The next step was to test the feasibility of using such sorbents to remove heavy metals (nickel) from wastewater. To that end, the team used a test solution that contained 5 mg/l of nickel ions. Powdered sorbents were dosed to 0.5 wt.% and 1.0 wt.%. Experiment was designed to find how the sorbent type could affect the pH of the standard solution as well as how the mixing time could affect the heavy-metal extraction rate.

Mixing was done in an open desktop shaker (Innova 2000). pH was measured by a HANNAHI 254 auto-calibrated pH meter. The adsorption capacity of the sorbents was measured by an Agilent 5100 ICP-OES unit (an inductively coupled plasma optical emission spectrometer). Data analysis led to a finding that sorbent pH did not significantly affect the test solution pH. The best mixing time that maximized the extraction of nickel ions was 5 to 15 minutes at 1.0 wt.% sorbent dosage, see Figure 1.
pH 3 to 5 sorbents prove to have the highest adsorption capacity. They were able to extract up to 20% of nickel. For better extraction of heavy metals from wastewaters, it will be necessary to either find another method for making sorbents from pulp-containing textile waste, or to modify these sorbents.

4. Conclusions
Thus, this research has produced the following findings:
– recycled pulp-containing textile waste has uses in various industries. It can be used to make multifunctional additives for emulsion-polymerized rubbers, or as a source material for promising powdered sorbents for wastewater treatment against heavy metals;
– the research team-produced powdered sorbents (pH 3 to 5) were able to extract up to 20% of nickel ions from wastewater. This makes them recommendable for tertiary treatment.
– further improvements will necessitate modifying the powdered sorbents.

References
[1] Dudarev V I, Irincinova N V, Filatova E G 2017 Adsorption of nickel (II) ions from aqueous
solutions by carbon sorbents Izv. universities. Chemistry and chemical technology 1 pp 75-80
[2] Obuzdina M V, Rush E A, Shalunts L V 2017 Solving environmental problems of wastewater treatment by creating a sorbent based on zeolite Ecology and industry of Russia 8 pp 20-25
[3] Velichko L N, Rubanovskaya S G 2012 The use of natural materials in the extraction of metal ions LAP LAMBERT Academic Publishing 76 p
[4] Taranovskaya E A, Sobgaida N A, Markina D V 2016 Sorption materials based on chitosan for the treatment of effluents from heavy metal ions Ecology and Industry of Russia 5 pp 34-39
[5] Platonova D S, Gurin A V, Adeeva L N 2016 Modified sapropel sorbents for wastewater treatment Ecology and Industry of Russia 11 pp 20-25
[6] Guo X, Zhang S, Shan X 2008 Adsorption of metal ions on lignin J. Hazard. Matter 151 pp 134-142
[7] Hisham A Essawyb, Magdy F Mohameda, Nabila S Ammarc, Hanan S Ibrahimc 2017 The promise of a specially-designed graft copolymer of acrylic acid onto cellulose as selective sorbent for heavy metal ions International Journal of Biological Macromolecules 103 pp 261-267
[8] Ulyanova V V, Sobgaday N A 2016 Utilization of ceramics and agricultural waste into sorption materials for the treatment of effluents from heavy metal ions Ecology and Industry of Russia 7 pp 4-9
[9] Ilyichev V A, Kolchunov V I, Bakaeva N V, Kobeleva S A 2017 Environmental safety of the use of textile waste in the building materials industry News of higher educational institutions. Technology of the textile industry 1(367) pp 194-198
[10] Pugacheva I, Nikulin S 2017 Composite materials: production, properties and application LAP LAMBERT Academic Publishing 219 p
[11] Nikulin S S, Pugacheva I N 2012 The use of textile waste to obtain powdered fillers Izv. Universities Chemistry and chemical technology vol 55 Issue 5 pp 104-107
[12] Misin V M, Nikulin S S, Pugacheva I N 2016 Cellulose-based textile waste treatment into powder-like fillers for emulsion rubbers. Engineering textiles research methodologies, concepts, and modern applications Apple Academic Press pp 59-77
[13] Pugacheva I N, Nikulin S S 2011 The intensification of the drying process of rubber by the introduction of polymer fillers at the stage of its production International Journal of Applied and Basic Research 10 pp 54-55
[14] Misin V M, Nikulin S S, Pugacheva I N 2016 A study on possibilities for cellulose-based textile waste treatment into powder-like fillers for emulsion rubber. Process advancement in chemistry and chemical engineering research Apple Academic Press Inc. (Canada) pp 37-53
[15] Pugacheva I N, Nikulin S S, Sedykh V A 2014 Styrene-butadiene rubber composite materials containing organic powder additives Materials Technologies. Instruments vol 19 1 pp 64-66
[16] Hubbe M A, Hasan S H, Ducoste J J 2011 Cellulosic substrates for removal of pollutants from aqueous systems: a review Metals, BioResources 6(2) pp 2161-2287
[17] Kozlov V A, Nikiforova T E, Loginova V A, Koifman O I 2015 Mechanism of protodesorption-exchange of heavy metal cations for protons in a heterophase system of H2O-H2SO4-MSO4-cellulosesorbent Journal of Hazardous Materials 299 pp 725–732
[18] Hokkanen S, Bhatnagar A, Sillanpaa M A 2016 review on modification methods to cellulose-based adsorbents to improve adsorption capacity Water Research 91 pp 156-173
[19] Onishchenko D V, Reva V P, Chakov V V 2013 The use of renewable plant materials to form functional materials Ecology and industry of Russia 1 pp 39-43
[20] Abdel-Halim E S 2014 Chemical modification of cellulose extracted from sugarcane bagasse Arabian Journal of Chemistry 7 pp 362-371
[21] Kutsenko M, Ovcharuk V, Solovev D B 2019 Application of Singular Value Decomposition Method for Acoustic Emission Data Analysis 2019 International Science and Technology Conference "EastConf", International Conference on. [Online]. Available: http://dx.doi.org/10.1109/EastConf.2019.8725314