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ANALYSIS OF REMOVAL METHODS OF TOXIC HEAVY METALS USING BIO-ABSORBS

The heavy metals pollution among various types of contaminations is a serious hazard for environment and human health. Different methods of removing heavy metals have different advantages and disadvantages, among them biological techniques of absorption/ adsorption have been considered. The main benefits of biological absorption, compared with the conventional methods, are low cost, high efficiency, reducing chemical and/or environmental sludge, no need for additional nutrients, and the possibility of recycling of metals. The absorption of heavy metals by microbial cells is recognized as a potential alternative to existing technologies of removal of toxic heavy metals using waste from the food industry and agricultural wastes as bio-absorbs. Therefore, the main the goal of this article is evaluate the potential and advisability and effectiveness of using food industry waste and agricultural waste to remove or significantly reduce toxic heavy metals from contaminated food and water. And also to study the mechanisms of using of waste from the food industry and agricultural wastes as bio-absorbs to determine the best option of using, what would improve it. To achieve the goal, the work has been studied and analyzed all attainable sources of agro based low-cost reasonable adsorbents for their feasibility in the removal of heavy metals from food stuff and contaminated water. Since most of the researches have been carried out in pilot form and has not been tested at the industrial level, then it is necessary to improve these methods for their implementation and utilization in the treatment of the industrial contaminated water and also food products. From the analysis it is evident that the most attractive as bio-absorbs are such materials such as potato peel, sawdust, citrus peels, mango peel, corn cob, rice husk, tree fern, wheat bran, grape bagasse, coconut copra meal, orange waste, walnut, hazelnut, almond shell, tea waste. And especially the use of these materials is attractive from the economic point of view as the most affordable and cheap.

Keywords: heavy metals, biodegradable, agricultural waste, microbial biomass.

1. Problem statement. Heavy metals cause major environmental pollution. They accumulate in soil, plants and crops through irrigation with polluted effluents or wastewater (Akbari-adergani et al., 2017). The toxicity of heavy metals such as Lead (Pb), Cadmium (Cd), Mercury (Hg), Arsenic (As) to human beings and animals is the resulted of exposure to long term even in low content of contaminations in our environment, Including in the air we breathe, water, food, and so many other factors of every day in our life (Ziarati et al., 2018a). Some toxic heavy metals, such as lead, cadmium, nickel, cobalt, chromium, and arsenic cause toxic for living organisms. Toxic heavy metals enter various food chains and cause toxic effects on the ecosystem as well as humans and animals (Malik et al., 2016). These toxic ions not only pose potential risks to human health but also cause physical and sometimes life-threatening illness (Abdi and Kazemi, 2015). Heavy metals are considered as hazardous pollutants due to toxicity even at low concentrations (Shekhar and Biswas, 2015). Pollution of heavy metals from agricultural crops using repeated programs of sewage sludge and industrial effluent can have long-term effects on soil microorganisms (Sameera et al., 2011). Various effects of heavy metal toxicity to humans have been reported. Over critical surface of Nickel may be known to cause kidney problems, gastrointestinal tract, pulmonary fibrosis and skin dermatitis, which is a human carcinogenic. Mercury is an element of neurotoxin that can cause damage to the central nervous system. High concentrations of mercury cause lung and kidney function impairment, chest pain, and respiratory obstruction. Exposure to chronic cadmium also leads to kidney dysfunction and at high levels it can lead to death. Also, high levels of lead can cause damage to the central nervous system. Or high levels of lead can also damage the kidney, liver and the cellular reproduction system and brain function and toxic symptoms of anemia and so forth (Fu and Wang, 2011).

Different methods of removing heavy metals have different advantages and disadvantages, among them biological techniques of absorption/adsorption have been considered.

The main benefits of biological absorption, compared with the conventional methods, are low cost, high efficiency, reducing chemical and/or environmental sludge, no need for additional nutrients, and the possibility of recycling of metals. The absorption of heavy metals by microbial cells is recognized as a potential alternative to existing technologies of removal of toxic heavy metals using waste from the food industry and agricultural wastes as bio-absorbs.

Thus, the question arises of the advisability and effectiveness of using food industry waste and

agricultural waste to remove or significantly reduce toxic heavy metals from contaminated food and drinking water.

2. Analysis of the recent researches and publications.

Today, various technologies such as chemical deposition, electrochemical separation, membrane separation, reverse osmosis, exchange of ions and resins, although effective for removal of metals but these methods are still not competitive for industrial application. Such methods involve large amounts of capital or operational costs and are not effective in removing metal ions at levels close to ppm (Gupta et al., 2015). Adsorption as a process gained much more attention recently after the use of low-cost adsorbents became so popular especially bio-sorbents. Sources of different types of conventional and nonconventional adsorbents are illustrated in the flow chart in figure 1 (El-Sayed and El-Sayed, 2014).

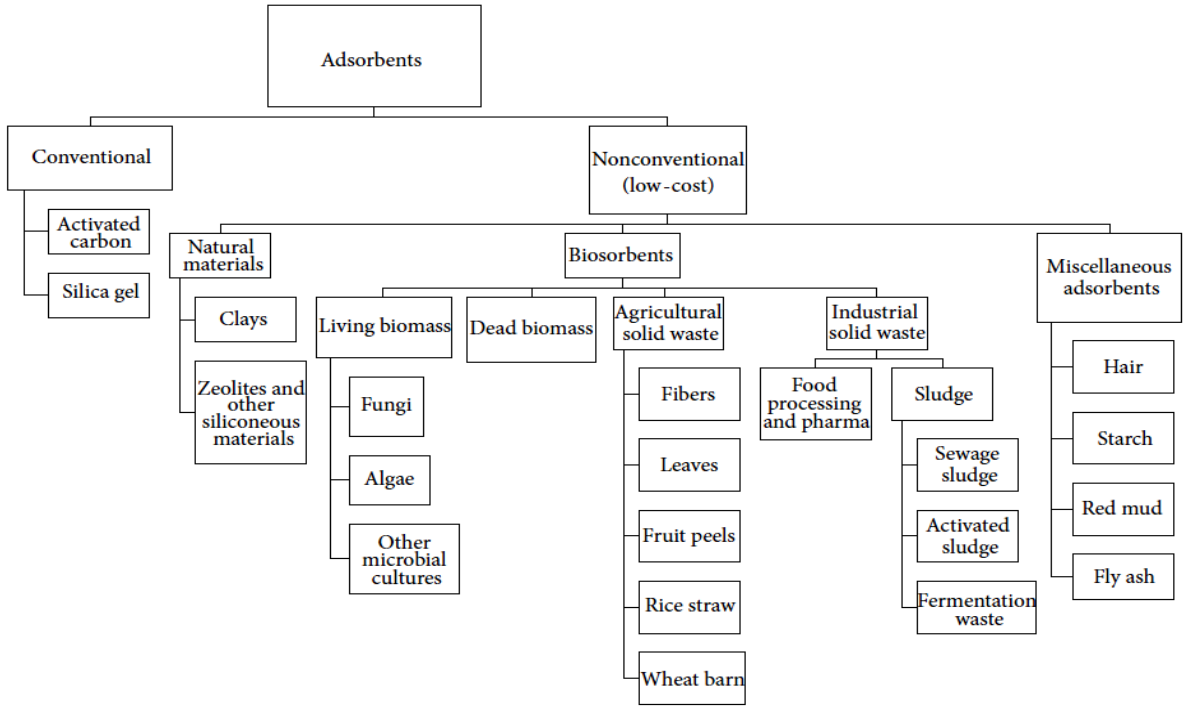

Figure 1 – A schematic flow diagram showing the different types of available adsorbents

The adsorption method is an effective and economical method for the removal of heavy metals. In this method, biodegrades such as biomass microorganisms (bacteria, mold, yeast, algae), active carbon and agricultural waste are used (Dhir and Kumar, 2010; Gupta et al., 2009). Agricultural wastes as bio-absorbents are the most applicable. Advantages of these compounds include low cost, proper efficiency, minimum waste and residual materials and recycling ability (Ahmad Khan et al., 2004; Rao et al., 2010). The biological absorption method consists of things created by inactive and non-living matter of biological origin, and there are water solutions to absorb and collect metal ions. In other words, the interactions between the biomass and metal ions, the independent physical and chemical process and metabolism with the main mechanism of absorption are absorption, exchange of ions, surface complexity and precipitation. In fact, this is an active process depending on the metabolism of living organisms.

Today, the biological absorption technique has been very successful in comparison with conventional techniques for separating metal ions from ppm to ppb in water suspensions (Ziarati et al., 2018b; Gupta et al., 2015). The three main advantages of biological technologies for eliminating pollutants include:

1) The biological processes can be carried out locally at the polluted site;

2) The biological processes is usually environment (no secondary pollution);

3) The biological processes are cost-effective (Abdi and Kazemi, 2015).

In fact, biological absorption is a method of removing metals or non-metals and small particles using any biological molecule (Mathew et al., 2017). Various natural adsorbents such as agricultural Residues including sunflower stalks, maize bran, coconut shell, waste tea, rice straw, peanut and walnut husks have been tested to achieve effective removal of various heavy metals (Dhir and Kumar, 2010).

3. Statement of the problem of removal of heavy metals from food and contaminated water using bio-absorbs and its solution.

In connection with above the authors set the goal of this article evaluate the potential and advisability and effectiveness of using food industry waste and agricultural waste to remove or significantly reduce toxic heavy metals from contaminated food and drinking water. And also to study the mechanisms of using of waste from the food

industry and agricultural wastes as bio-absorbs to determine the best option of using, what would improve it.

3.1. Study and analysis of methods of removal of heavy metals by bioactive adsorbents.

The term bio-sorbent refers to materials derived from microbial biomass, seaweed, or plants that have adsorbent properties. The seed absorption process involves a solid phase (adsorbent: biological material) and the liquid phase (solvent, typically water) containing dissolved species (Shekhar and Biswas, 2015). Living and non-living cell and biomass products can be used for effective absorption, but their cost and effectiveness factors remain questionable. There are various physical, chemical and biological methods for the removal of metal ions using food industry waste and agricultural waste. Many biological agents increase the rate of removal of heavy metals from food, water and waste water in ppm to ppb levels due to reducing their contents. Few types of bioactive adsorbents are attached to heavy metals without any particular priority. Some adsorbents are specially bound to certain types of metals. Bioactive adsorbents, due to the fact that they derive from agricultural and animal waste, have low costs and prices. Therefore, they are more important for the use (Mathew et al., 2017).

A sample of microbial bio-absorbers is presented in table 1.

The cellular structure of a microorganism can trap heavy metal ions and then arrange them on cell wall binding sites. This process is called inactive absorption or inactivation and it is independent of the cycle of metabolism. The amount of metal absorbed depends on the kinetic equilibrium and the metal composition at the cell surface. The mechanism involves several processes, including electrostatic interactions, ion exchange, precipitation, redox regeneration process and surface complexation compounds (figure 2).

Table 1 – Types of biomass that have been used for preparing bio-sorbents

Category	Example
Bacteria	B. laterosporus (Zouboulis et al., 2004) Enterobacter sp. J1 (Lu et al., 2006) Pseudomonas sp. (Ziagova et al., 2007) Bacillus jeotgali (Green-Ruiz et al., 2008) P. jessenii (Rajkumar and Freitas, 2008) Arthrobacter sp.(Hasan and Srivastava, 2009) Pseudomonas fluorescence (Uzel and Ozdemir, 2009) Ecoli (Quintelas et al., 2009) Bacillus cereus (Sinha et al., 2012) Micrococcus luteus (Puyen et al., 2012) Ochrobactrum intermedium, Cupriavidus metallidurans (Fan et al., 2014) Desulfovibrio desulfuricans (Kim et al., 2015) Enterobacter cloacae (Haq et al., 2016) Alcaligenes sp. (Jin et al., 2017)
Algal	Dunaliella sp. (Dönmez and Aksu, 2002) Chlorealla sorokintana (Akhtar et al., 2003) Sargassum wighti (Vijayaraghavan et al., 2005) Lessonia nigrescens (Hansen et al., 2006) Asparagopsis armata and Codium vermilara (Romera et al., 2007) Spirogyra sp. (Gupta and Rastogi, 2008) Sargassummuticum (Freitas et al., 2008) Chlorella miniata (Li and Zhang, 2010) Spirulina platensis (Çelekli et al., 2010) Cladophora sp. (Lee and Chang, 2011) Micrasterias denticulata (Volland et al., 2013) Sargassum muticum (Ungureanu et al., 2015) Chara aculeolata (Sooksawat et al., 2016)
Fungal	Mucar rouxii (Yan and Viraghavan, 2001) Ganoderma lucidum (Muter et al., 2002) Aspergillus niger (Dursun et al., 2003) Saccharomyces cerevisiae (Özer and Özer, 2003) Botrytis cinereal (Akar et al., 2005) Penicilliumsimpliccium (Fan et al., 2008) Pleurotus platypus (Das et al., 2010) Rhizopus oryzae (Yong-Qian, 2012) Penicillium citrinum (Verma et al., 2013) Aspergillus brasiliensis (Pereira et al., 2014) Saccharomyces cerevisiae (Fadel et al., 2017)

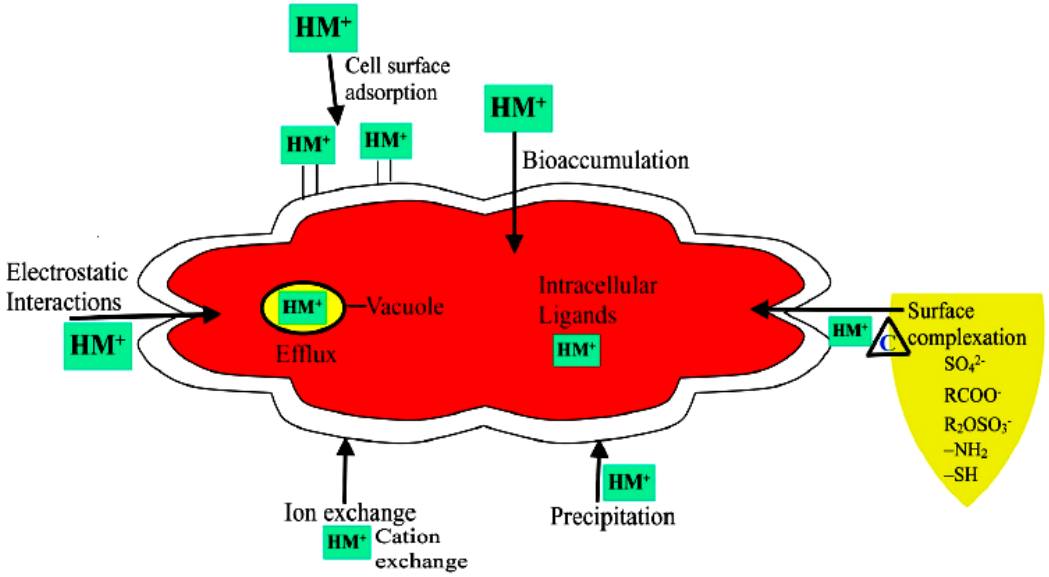

Figure 2 – Mechanisms of heavy metal uptake by microorganisms (Ayangbenro and Babalola, 2017)

Of course, the mechanism that carries microorganisms to metals is relatively uncertain in some cases, but it has been shown that living and non-living biomass may be absorbed in concentrated processes as they often have a significant bearing in comparison with metals and other unfavorable conditions (Gavrilescu, 2004). This process is fast and can be balanced in a few minutes. Typically, Bio-sorption can be carried out by fragments of cells and tissues, or by dead biomass or living cells as passive uptake via surface complexation onto the cell wall and other outer layers.

Another method is a process where heavy metal ions throughout the membrane are going into cytoplasm through the metabolic cycle of the cell known as a bio-storage or active absorption method (Ayangbenro and Babalola, 2017).

Factors that influence the bioavailability are (Fomina and Gadd, 2014):

1) Solution pH;

2) Ionic strength of solution;

3) Initial pollutant concentration;

4) Other pollutant effects including competition for binding sites or other interferences;

5) Bio-sorbent nature and the availability of binding sites;

6) Temperature;

7) Increasing agitation speed in appropriate aqueous systems.

Ziarati et al., in 2018 claimed about factors affecting the bio-adsorption and mentioned that the efficacy of the metal uptake by the microbial biomass is essential for the industrial application of bio-adsorption, as it gives information about the equilibrium of the process which is necessary for the design of the equipment (Ziarati et al., 2018b). Some factors affect the process of bio-adsorption as follows:

– Temperature seems not to influence the bio-adsorption performances in the range of 20…35 °C (Brady et al., 1994; Subhashini and Swamy, 2013);

– pH which is considered as the most important parameter in the bio-adsorptive process: it affects the solution chemistry of the metals, the activity of the functional groups in the biomass and the competition of metallic ions (Brady et al., 1994; Srivastava et al., 2005; Subhashini and Swamy, 2013; Salman et al., 2014);

– Biomass concentration in the solution is one of the concerns of biosorption which integrated removal of sorbate from the solution that may occur over a wide concentration range for a given biomass concentration (Fomina and Gadd, 2014).

– Bio-adsorption technique in condition of presenting more than one type of metal ions is mainly utilized to treat wastewater; the removal or decreasing of one metal ion content probably be affected by the presence of other metal ions.

According to the location where the metal removed from solution is found, bio-adsorption can be classified as:

– extra cellular accumulation/ precipitation;

– cell surface sorption/ precipitation;

– intracellular accumulation (Srivastava et al., 2005; Puranik et al., 2005; Subhashini and Swamy, 2013; Salman et al., 2014).

This analysis shows that the bio-absorption technique is also considered by many researchers as a suitable and new method. The major factors which affecting the absorption process include the initial concentration of ion metal, pH, temperature and the concentration of biomass in the solution.

3.2. Advisability analysis of removal methods of heavy metals by bio-absorbs obtained from wastes food stuff and agricultural wastes.

Sub-products of agricultural products are usually called «agricultural wastes» because they are not the primary product. These wastes are mainly in the form of product residues (remaining stems, straw, leaves, roots, shells, etc.) and animal waste (fertilizer). Agricultural wastes are widely available, renewable and practically free hence they can be an important source for obtaining

heat, steam, charcoal, methanol, ethanol, biofuels as well as raw materials: animal feed, compost, energy, biogas production, etc. (Elly, 2011; Vambol, 2017).

Food waste is produced throughout the life cycle of food. Of the agricultural food losses, up to 42 % of them are produced by households, 38 % occur during food processing and 20 % are distributed throughout the chain. In the food industry, waste products are derived from the processing of raw materials of vegetables and animals for food, which generally involves the extraction or separation of nutritional units from residues with a lower nutritional value or non-edible components (Baiano, 2014; Sagdeeva, 2018). Consequently, the use of such wastes as bio-sorbents is advisable. It is explained by the following:

– Removal or significant reduction of heavy metals in food and contaminated water is provided;

– Wastes are used with advantage and their accumulation in landfills is excluded, which also prevents pollution of the environment (Koloskov, 2018);

– The cost of waste is always significantly lower than the specially created bio-absorbs.

Today, the excessive release of heavy metals into the environment due to industrialization and urbanization has created a major problem around the world (Obi et al., 2016; Balaceanu et al., 2018; Vambol et al., 2017, Kolesnyk et al., 2018). That is why in recent years, agricultural waste has proven to be a low cost alternative for removal or significantly reduce toxic heavy metals from food and contaminated wastewater, if applied as bio-sorbents.

Table 2 lists agricultural wastes, which are used as bio-sorbents for the removal of heavy metals.

Table 2 – Samples and examples of agricultural materials and wastes used to remove heavy metals

Category	Group	For Example
Natural waste	Plant residues, sawdust, tree barks, weeds, etc. (Abbas et al. 2014)	Husk: Rice husks (Nakbanpote et al., 2000), Olive husks, Millet husks, Coconut husks (Reddy and Yang, 2005), Rice Husk (Alidoost-Saharkhiz-Lahiji et al., 2016), Shell: Almond shells, Coconut shells, Hazelnut shells, Peanut shells, Walnut shells Straws: Barley, Legume, Rice, Wheat straw Stalk :Corn stalk, Cotton stalk, Sorghum stalk
Agricultural and industrial waste	Fruit/Vegetable wastes, rice straws, wheat bran, soybean halts, Fermentation wastes, food/beverage wastes, activated sludge, anaerobic sludge (Abbas et al., 2014)	Apricot Pit Shell (Tavakoli-hosseinabady et al., 2018), Banana Peel (Motaghi and Ziarati, 2016), Sour Lemon (Alimardan et al., 2016)

Mostly agricultural and plant wastes were used as bio-adsorbents. There are generally three types based on the sources:

– Non-living biomass such as bark, lignin, shrimp, krill, squid, crab shell, etc.;

– Algal biomass;

– Microbial biomass, e.g., algae, bacteria, fungi and yeast.

Agricultural wastes in the preparation of bio-adsorbents are also promising such as potato peel, sawdust, citrus peels, mango peel, corn cob, rice husk, tree fern, wheat bran, grape bagasse, coconut copra meal, orange waste, walnut, hazelnut, almond shell, tea waste (Malik et al., 2017). The adsorbent preparation, adsorption mechanism and subsequent regeneration and recovery have been illustrated in figure 3.

So, microbial biomass is one of the cheap deoxidants to remove heavy metals. The biological absorption process has many attractive properties including the removal of metal ions in a wide range of pH and temperature. Due to the absorption of metal, the reason for this difference in the microbial biomass (bacteria, fungus, algae, etc.) with macroscopic material (plant products) is because of the nature of the cell wall components and the functional groups involved in metal binding.

3.3. Analysis of the efficiency of the use of agricultural wastes as bio-absorbs to remove heavy metals from contaminated wastewater.

The main subject in the vegetable and fruits supply chain management (V & F_SCM) is the post-harvest loss (PHL), which is described as any loss that takes place after harvest and before using, it occurs in different stages in the supply chain and amounts to about 20 to 60 % of the total cultivation over total the countries. Minimization of the damages or wastages will enhance the availability of the food, reduce the cost of the products and it could be considered as a better choice than increasing the cultivation of the agricultural products (Gardas et al., 2017).

Agricultural wastes, if they contain toxic heavy metals, can have many problems in the treatment and use of effluent in the factories. The waste from the fruit and vegetable processing industry is used as a bio-absorbent material for the removal of toxic heavy materials from sewage and wastewater. The disposal of heavy metals is a matter of waste that is important in the watershed. Traditional methods for the removal of heavy metals from wastewater include reducing deposition, ion exchange, filtering and electrochemical processes, all of which may be ineffective, or may occur when metals are high in concentrations.

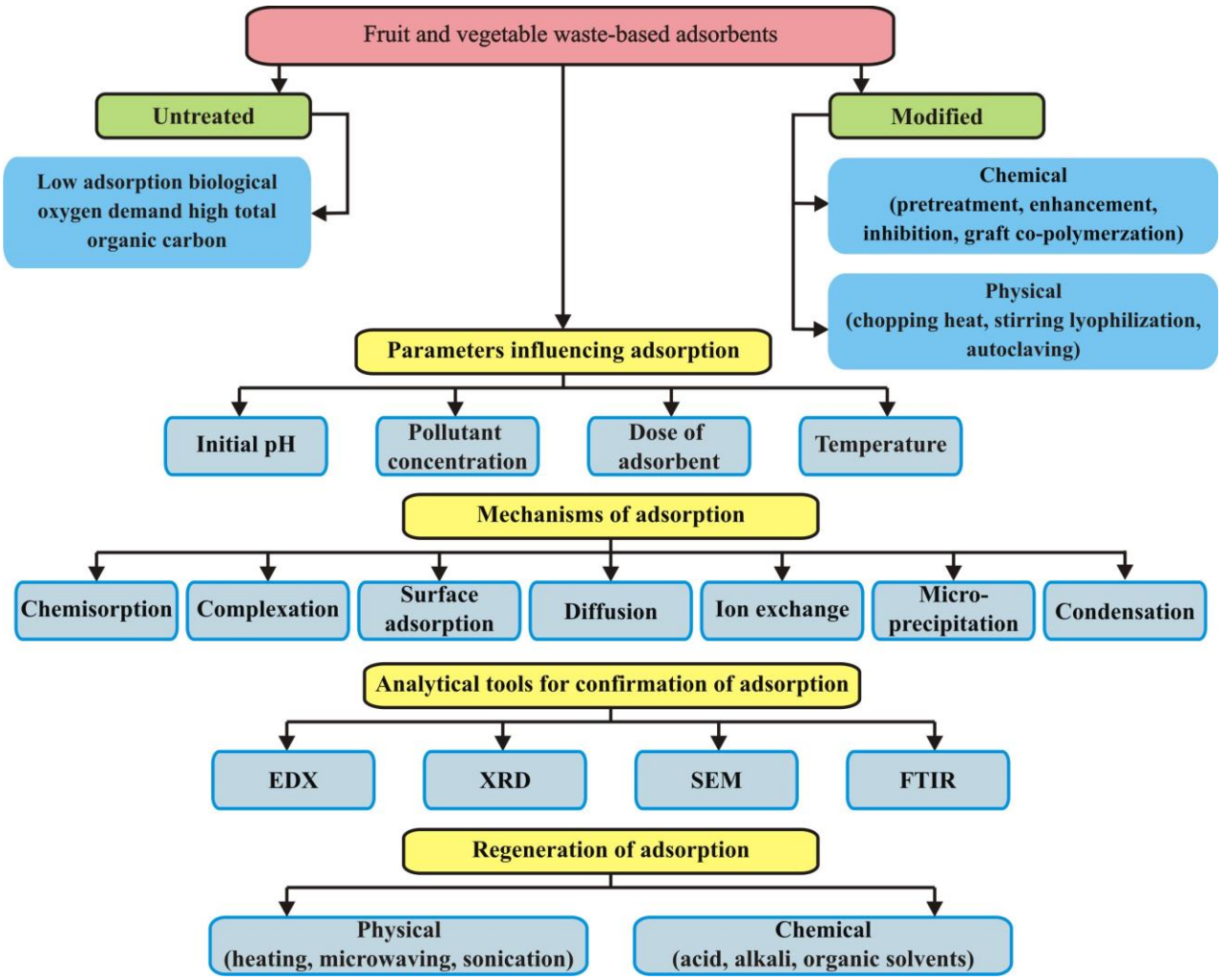

Figure 3 – Schematic diagram depicting the fruit and vegetable waste-based adsorbents, their modifications, adsorption mechanisms, tools for analysis and regeneration (Patel, 2012)

Due to relatively low prices for agricultural waste, them expediency of using as a bio-absorbs which can be used effective removal and recovery of heavy metal ions from drinking water or contaminated wastewater is high (Arvanitoyannis et al., 2008). Even the peels of different types of fruits are considered as fruit waste material that can be used for biosorption of heavy metals in different wastewater. Biological absorbers are based on the goal of achieving an environmental factor using household waste such as banana, orange peel, potato peel, pomegranate peel, kiwi, tomato skin, pumpkin skin, etc. (Fomina and Gadd, 2014), which is low cost, comfortable and very effective. Banana skin absorbent is a good absorbent and highly successful method of water purification because the banana skin contains nitrogen, sulfur and carboxylic acids (Bharat and Manchada, 2017).

Table 3 contains more examples.

Table 3 – Examples of the use of agricultural waste in removing heavy metals from water and wastewater

Researchers	Extractable metals	Applied agricultural waste as a bio-absorbs	The environment from which toxic metals are extracted
Al-Qahtani, 2016	Cd^{+2}, Zn^{+}, Cr^{+3}	Waste fruit cortexes	Water
Ziarati et al., 2015	Ni, Cr(VI), (III)	Modified shell of wild endemic almonds	Contaminated Water
Hegazi, 2013	Fe, Pb, Ni	Rice husk and fly ash	Waste water
Koel Banerjee et al., 2012	Cu	Watermelon shell	Aqueous solutions
Ye et al., 2010	Cd(II)	Natural and modified rice husk	Aqueous solutions
Kumar and Bandyopadhyay, 2006	Cd	Pretreated rice husk	Aqueous solutions
Malkoc and Nuhoglu, 2005	Ni	Tea factory waste	Aqueous solutions
Çay et al., 2004	Cu, Cd	Tea-industry waste	Aqueous solutions
Villaescusa et al., 2004	Cu	Grape stalks wastes	Aqueous solutions

From the analysis, we can say that nowadays, using the various methods available, it is very important to use practical method that has the lowest cost and high profitability.

Agricultural wastes in the preparation of bio-adsorbents are promising such as potato peel, sawdust, citrus peels, mango peel, corn cob, rice husk, tree fern, wheat bran, grape bagasse, coconut copra meal, orange waste, walnut, hazelnut, almond shell, tea waste. And especially the use of these materials is attractive from the economic point of view as the most affordable and cheap. Removal methods of heavy metals that use these substances as a bio-absorbs also have shortcomings, but due to new aspects, cause a lot of interest among researchers, which in their works improve these methods. Most of the researches have been carried out in pilot form and has not been tested at the industrial level. The need for implementation and utilize of these materials in the treatment of the industrial wastewater treatment plant and also edible stuffs such as fruits, cereals and crops.

Conclusions.

1. The bio-absorption technique is also considered by many researchers as a suitable and new method. The major factors which affecting the absorption process include the initial concentration of ion metal, pH, temperature and the concentration of biomass in the solution. The biological absorption process has many attractive properties including the removal of metal ions in a wide range of pH and temperature.

2. Microbial biomass is one of the cheap deoxidants to remove heavy metals. The biological absorption process has many attractive properties including the removal of metal ions in a wide range of pH and temperature. Due to the absorption of metal, the reason for this difference in the microbial biomass (bacteria, fungus, algae, etc.) with macroscopic material (plant products) is because of the nature of the cell wall components and the functional groups involved in metal binding.

3. Nowadays, using the various methods available, it is very important to use practical method that has the lowest cost and high profitability. Since most of the researches have been carried out in pilot form and has not been tested at the industrial level, then it is necessary to improve these methods for their implementation and utilization in the treatment of the industrial wastewater treatment plant and also food products. From the analysis it is evident that the most attractive as bio-absorbs are such materials such as potato peel, sawdust, citrus peels, mango peel, corn cob, rice husk, tree fern, wheat bran, grape bagasse, coconut copra meal, orange waste, walnut, hazelnut, almond shell, tea waste. And especially the use of these materials is attractive from the economic point of view as the most affordable and cheap.

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Conflicts of Interest.

None of the authors have any conflicts of interest associated with this study.

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АНАЛІЗ МЕТОДІВ ВИДАЛЕННЯ ТОКСИЧНИХ ВАЖКИХ МЕТАЛІВ З ВИКОРИСТАННЯМ БІО-АБСОРБЕРІВ

Забруднення важкими металами серед інших видів забруднень є серйозною загрозою для навколишнього природного середовища і здоров'я людини. Різні способи видалення важких металів мають різні переваги й недоліки. Відомі біологічні методи абсорбції / адсорбції. Основними перевагами біологічної абсорбції в порівнянні з традиційними методами є низька вартість, висока ефективність, скорочення хімічного та / або екологічного шламу, відсутність необхідності у додаткових поживних речовинах й є можливість рециркуляції металів. Метод поглинання важких металів мікробними клітинами, заснований на використанні відходів харчової промисловості і сільськогосподарських відходів як біологічних поглинаючих речовин, визнається як потенційна альтернатива існуючим технологіям видалення токсичних важких металів. Тому основною метою цієї статті є оцінка потенціалу, доцільності й ефективності використання відходів харчової промисловості і сільськогосподарських відходів для видалення або значного зниження концентрації токсичних важких металів із забруднених харчових продуктів й води. А також вивчити механізми використання відходів харчової промисловості і сільськогосподарських відходів як біологічних поглиначів для визначення найкращого варіанту з метою його удосконалення. Для досягнення цієї мети в роботі були вивчені і проаналізовані всі доступні джерела дешевих прийнятних адсорбентів у агропромисловому комплексі для їх здійсненності у видаленні важких металів з харчових продуктів і забрудненої води. Оскільки більшість досліджень були проведені в експериментальній формі й не були протестовані на промисловому рівні, необхідно удосконалити ці методи для їх впровадження й використання при обробці промислових забруднених вод, а також харчових продуктів. З аналізу видно, що найбільш привабливими як біологічні поглинаючі речовини є такі матеріали, як кірка картоплі, тирса, цитрусова шкірка, шкірка манго, кукурудзяні качани, рисова лушпиння, деревне папороть, пшеничні висівки, виноградна лоза, апельсинові відходи, горіх, фундук, мигдальна раковина , відходи чаю. До того ж використання цих відходів доцільно з економічної точки зору як найбільш доступна й дешева сировина.

Ключові слова: важкі метали, біорозкладні й сільськогосподарські відходи, мікробна біомаса.

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АНАЛИЗ МЕТОДОВ УДАЛЕНИЯ ТОКСИЧНЫХ ТЯЖЕЛЫХ МЕТАЛЛОВ С ИСПОЛЬЗОВАНИЕМ БИО-АБСОРБЕРОВ

Загрязнение тяжелыми металлами среди других видов загрязнений является серьезной угрозой для окружающей природной среды и здоровья человека. Различные способы удаления тяжелых металлов имеют разные преимущества и недостатки. Известны биологические методы абсорбции / адсорбции. Основными преимуществами биологической абсорбции по сравнению с традиционными методами являются низкая стоимость, высокая эффективность, сокращение химического и / или экологического шлама, отсутствие необходимости в дополнительных питательных веществах и возможность рециркуляции металлов. Метод поглощения тяжелых металлов микробными клетками, основанный на использовании отходов пищевой промышленности и сельскохозяйственных отходов в качестве биопоглощающих веществ, признается как потенциальная альтернатива существующим технологиям удаления токсичных тяжелых металлов. Поэтому основной целью этой статьи является оценка потенциала, целесообразности и эффективности использования отходов пищевой промышленности и сельскохозяйственных отходов для удаления или значительного снижения концентрации токсичных тяжелых металлов из загрязненных пищевых продуктов и воды. А также изучить механизмы использования отходов пищевой промышленности и сельскохозяйственных отходов как биологических поглотителей для определения наилучшего варианта с целью его усовершенствования. Для достижения этой цели в работе были изучены и проанализированы все доступные источники недорогих приемлемых адсорбентов на основе агропромышленного комплекса для их осуществимости в удалении тяжелых металлов из пищевых продуктов и загрязненной воды. Поскольку большинство исследований были проведены в экспериментальной форме и не были протестированы на промышленном уровне, необходимо усовершенствовать эти методы для их внедрения и использования при обработке промышленных загрязненных вод, а также пищевых продуктов. Из анализа видно, что наиболее привлекательными как биопоглощающие вещества являются такие материалы, как корка картофеля, опилки, цитрусовая кожура, кожура манго, кукурузные початки, рисовая шелуха, древесный папоротник, пшеничные отруби, виноградная лоза, апельсиновые отходы, орех, фундук, миндальная раковина, отходы чая. К тому же использование этих отходов целесообразно с экономической точки зрения как наиболее доступное и дешевое сырье.

Ключевые слова: тяжелые металлы, биоразлагаемые и сельскохозяйственные отходы, микробная биомасса.