ENVIRONMENTAL SERVICES

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Activated Carbon Removal of Pharmaceuticals

Introduction on C12

C12 Environmental Services specializes in activated carbon consulting. Specifically, the team excels at developing and assisting with the selection of activated carbons for numerous applications. The team has developed one-of-a-kind carbons for mercury capture, food and beverage, potable water, and a myriad of other applications. The extensive experience provides a foundation to assist with market analyses, feasibility studies, product development, patent preparation, manufacturing design, full-scale plant build out, and assistance with plant commissioning/operation.

Activated Carbon Application in Drug Removal/Deactivation

Adsorption by activated carbon is a multipurpose treatment technique practiced widely for contaminant and chemical removal across various applications worldwide. Activated carbon is ideal for removing small molecular organic compounds like pharmaceutical drugs due to the availability of high surface area, the combination of a well-developed pore structure and surface functional group properties [1,2]. The efficacy of pharmaceuticals removal by activated carbon has been very well studied worldwide [3,4,5,6,7]. The most relevant studies are summarized below for specific drugs.

Activated carbons are widely used clinically to treat accidental or deliberate drug overdoses. Administered in the form of a slurry to prevent drug absorption by the gastrointestinal tract and to enhance the elimination of drugs already absorbed. This treatment is recommended within 0.5–1.0h from the ingestion of a toxic amount of a drug.

Removal/Deactivation of Ibuprofen by Activated Carbon

Ibuprofen is a nonsteroidal anti-inflammatory drug that can be used to treat fever and mild to severe pain. It is a monocarboxylic acid that is a propionic acid in which one of the hydrogens at position 2 is substituted by a phenyl group. The adsorption of ibuprofen onto commercial activated carbons has been studied by various university research groups successfully. One group looked at comparing activated carbon removal of ibuprofen to other minerals and concluded that the highest sorption capacity was found using activated carbon in comparison to montmorillonite, kaolinite and goethite[4]. Another research team out of the University of Florida studied the removal of ibuprofen (in addition

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[6] Snyder, S.A., Adham, S., Redding, A.M., Cannon, F.S., DeCarolis, J., Oppenheimer, J., Wert, E.C. and Yoon, Y., 2007. Role of membranes and activated carbon in the removal of endocrine disruptors and pharmaceuticals. *Desalination*, *202*(1-3), pp.156-181.
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to 6 other pharmaceuticals) in urine using activated carbon and biochar resulting in greater than 90% removal for each of the pharmaceuticals after just 24 hours [8,9,10].

Removal/Deactivation of Acetylsalicylic Acid (Aspirin) by Activated Carbon

Acetylsalicylic acid (common name of Aspirin) is a nonsteroidal anti-inflammatory drug that can be used to reduce pain, fever, or inflammation. It is a member of the class of benzoic acids that is salicylic acid in which the hydrogen that is attached to the phenolic hydroxy group has been replaced by an acetoxy group. The adsorption of acetylsalicylic acid (ASA) onto high-surface-area, commercial activated carbons has been investigated in adsorption isotherms at different pH values, including pH 1.5 to simulate conditions existing in the stomach [11,12,13].

Removal/Deactivation of Lorazepam by Activated Carbon

Lorazepam is an anti-anxiety medication used to calm nerves by releasing inhibitory neurotransmitters in the brain. It is a member of the benzodiazepines drug class where a benzene ring and a diazepine ring are attached.

Several studies have found that Lorazepam can be removed from waste waters by activated carbon adsorption mechanisms [14],[15],[16]. Another group, who made a Lorazepam stock solution, discovered 70% adsorption by activated carbon within the first 8 hours after application and over 99% adsorption after 28 days[17]. The surface characteristics - micropore area, micropore volume, and specific surface area - of activated carbon were considered to be the driving factors.

Removal/Deactivation of Diazepam by Activated Carbon

Diazepam is a medication used for a wide range of conditions including anxiety, seizures, and some withdrawal syndromes. It acts as an anxiolytic which targets chemical messengers in the brain that help decrease abnormal excitability. Diazepam is a member of the benzodiazepines drug class where a benzene ring and a diazepine ring are attached. Removing diazepam from water has been proven to be highly dependent on the type of activated carbon used [18]. In this study, activated carbon showed

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90% removal for several pharmaceuticals including diazepam[19]. Additionally, it was observed that the potential for adsorption is dependent on how soluble diazepam is in certain solutions[20]. Another study observed higher adsorption rate as time passed: 99% over 28 days of exposure. Additionally, only 1.6% of diazepam was observed to leach out of the activated carbon[21].

Removal/Deactivation of Suboxone/Buprenorphine by Activated Carbon

Suboxone (buprenorphine and naloxone) is used to treat narcotic addition. Buprenorphine is an opioid used to treat acute pain, chronic pain, and opioid use disorder. It works by displacing other opioids from brain receptors, then it binds tightly to those same receptors essentially blocking other opioids from occupying those sites. Buprenorphine is a morphinan alkaloid that is 7,8-dihydromorphine 6-O-methyl ether in which positions 6 and 14 are joined by a -CH2CH2- bridge, one of the hydrogens of the N-methyl group is substituted by cyclopropyl, and a hydrogen at position 7 is substituted by a 2-hydroxy-3,3-dimethylbutan-2-yl group. Naloxone binds to opioid receptors potentially blocking the effects of other opioids.

Suboxone – administered orally as a disintegrative film – was found to be successfully adsorbed by granular activated carbon possibly due to its high solubility rate in water (6-7 mins). The increased hydrophobicity of buprenorphine onto the non-polar surface of activated carbon is believed to be the driving mechanism for the 90% deactivation rate [22]. In a study examining sewage treatment effluent, granular activated carbon and ozone treatment together removed 87-95% of 24 pharmaceuticals, buprenorphine being 1 of 24.

Removal/Deactivation of Methadone by Activated Carbon

Methadone is a synthetic opioid with analgesic activity used for chronic pain and opioid maintenance therapy. It fully attaches to opioid receptors in the brain and has actions similar to those of morphine and morphine-like agents. Methadone is a synthetic diphenylpropylamine similar in structure to acetylmethadol and propoxyphene.

Activated carbon systems alone are effective at removing various pollutants but can also be used alongside other treatment options. Methadone removal from wastewater utilizing several treatment options, including a granular activated carbon filter, resulted in a 91% removal outcome. Removal efficacy depends on the water quality and pollutant competition on the activated carbon [23]. Another study resulted in an average of 98.7% removal for 7 pharmaceuticals in dosed water, methadone included[24].

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