Eco. Env. & Cons. 28 (4) : 2022; pp. (2140-2146)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i04.076

A Study Into the Alteration of Physical and Chemical Characteristics of Activated Carbon Surface for Purifying Water

Hanumant Singh Chouhan

Department of Chemistry, S.M.C.C. Govt. College, Abu Road 307 026, India

Received 7 May, 2022; Accepted 1 July, 2022)

ABSTRACT

The most common applications of activated carbon in today's world are process water treatment, commercial and industrial wastewater treatment, and air/odour abatement. When transformed to activated carbons, carbonaceous source materials have the potential to efficiently cleanse and eliminate a wide range of pollutants from water and wastewater streams. With over 1,000 recognized uses, activated carbon's potential is limitless. AC may be tailored to satisfy a wide range of unique purposes, from gold mining to water purification, and food manufacturing. Non-polar adsorbents like activated carbon work well. It may be used with a range of substances to adsorb diverse qualities of wastewater due to its large specific surface area and micropore, high adsorption performance, and recycling. This research aimed to look into the influence of chemical surface features on activated carbons' application in water purification.

Key words : *Activated Carbon (AC), Water purification, Physical and chemical Properties of AC, Types of AC.*

Introduction

Carbon is the 15th most copiouscomponent in the crust of the earth beside the 4th among the most profuse component in the cosmos by mass, after helium, hydrogen, as well as oxygen. Carbon and carbon-containing compounds are employed in a variety of ways by scientists, companies, and consumers, including AC, which may be used to filter water. AC is a kind of carbon that has been made exceedingly porous to provide a great area for chemical reactions. It is a non-graphitic amorphous microcrystalline form of carbon treated to acquire a high core porosity due to a network of interconnected openings. It's possible that individuals at the time relied only on intuition, with little understanding of how the impact worked. The mechanism has been known since the seventeenth century (Zhi and Liu, 2016). Lipscombe developed a carbon compound for cleaning portable water in 1862. This breakthrough cleared the door for the marketable use of AC, first in the potable water industry and later in the wastewater industry.

AC is a class of microporous resources utilized as adsorbents in a wide range of industrial usage, including the elimination of liquid and gaseous contaminants. The term "activated carbon" refers to a group of "carbonaceous adsorbents" having an extremely amorphous construction and a mature inner pore construction. Wood, coal, lignin, and coconut shell are among the carbonaceous-rich materials used to make Activated carbon. The enormous microporous surface area of AC causes the adsorption phenomena. Because of the huge surface area compared to the carbon particle's size, it is simple to eliminate significant quantities of contaminants in a tiny contained region. The adsorptive structure of AC is made up of aromatic planes of arranged carbon atoms. These graphitic planes stack into crystallites, or turbostratic layer stacks similar to graphite. The planes' angular orientations in the Activated carbons, on the other hand, are random, while they are highly organized in graphite (Yao *et al.,* 2016). The presence of heteroatoms like hydrogen, oxygen, sulphur, and nitrogen in the procedure of atoms chemically linked to the construction is generally related to AC. Oxygen is the most plentiful heteroatom in the carbon matrix, appearing as carbonyl, carboxyl, phenols, quinones, lactones, and other functional groups. These functional groups may substantially impact Activated carbon's unique adsorption capabilities. Two principal oxidation techniques, dry and wet, are used to produce the surface oxygen complexes of Activated carbon. At low or reflux temperatures (100 °C), wet oxidation involves responses between AC surfaces and oxidising solutions, including aqueous sulfuric, nitric, ortho-phosphoric acids, and hydrogen peroxide.

Adsorption occurs as a consequence of intermolecular attractions in the tiniest pores. Perhaps by physical attraction or chemical interaction, the pollutants in the water are deposited onto the surface sites of the AC. Chemical adsorption changes the molecular structure of the adsorbate, whereas physical attraction does not. These two processes are also referred to as physisorption and chemisorption (Limousy *et al.,* 2016). The chemicals are adsorbed onto activated charcoal in one of two ways: either it 'detests' water or is drawn into the AC. After adsorbates disperse to the active site, activated carbon adsorption follows three main steps:

- Substances adsorb to the carbon surface outside.
- Substances having the greatest adsorption possible energy migrate into the carbon adsorption pore.
- Matters adsorb to the carbon's inner graphitic platelets.

Because of the differences in beginning basic materials as well as the activation process, each pore size distribution is different. Activated carbons are classified as macroporous, mesoporous, or microporous depending on pore diameter as a measure of pore size. "Bituminous and anthracite coal and coconut shell-based raw materials" are utilized to make the most often used activated carbon in water filtration. Renewable resources include "coconut shell and wood-based raw materials used in an activation". Despite employing billions of coconut shells every year, coconut farms on millions of acres of property endure delivering all of the environmental advantages of green trees by absorbing CO_2. Coconut shell ACis the slightestgrimy has a high microporous content and is ideal for "organic chemical adsorption". When compared to other forms of AC, coconut shell-based carbon has the maximum hardness, making it perfect for water filtration.

Characteristics of Activated Carbon

AC qualities may be studied from both a physical and chemical standpoint.

Physical Properties

The surface area of AC is the essential physical attribute of the material. The surface area accessible for adsorption is determined by the molecular extent of the adsorption as well as the pore width of the AC for certain uses. In general, gas phase adsorbents with a majority of holes 3 mm in diameter or smaller are classified as liquid-phase carbons. Owing to the need of quick liquid diffusion, they require bigger holes. The density of AC and its particular adsorptive ability for a given material may be utilised to estimate the grades of AC needed for a given system (Hu, D. 2021). When pressure drop associated carbon losses are a problem, the mechanical power and resistivity of the particles are critical.

Chemical Properties

Iodine Number

Once the iodine content in the leftover "filtrate is 0.02 normal", the iodine value is represented as the milligrams of iodine absorbed by 1 gram of carbon. The most basic measure used to assess AC performance is the iodine number. It is a unit of measurement for the activity that is often expressed in milligrams per gram (mg/g). It corresponds to a carbon surface area of about 900 m^2 and 1100 m^2 per gram. For liquid phase purposes, it is the industry standard.

Molasses Numbers

Certain carbons are better at adsorbing bigger molecules than others. Molasses number, also known as molasses competence, is a measurement of the AC's mesopore concentration based on molasses adsorption from solution. A high molasses number specifies a lot of large molecule adsorption. The efficiency of molasses is expressed as a percentage (range 40 percent - 185 percent) (Liu *et al.,* 2015). The molasses number in Europe (which ranges from 525 to 1100) is inversely proportional to the molasses number in North America.

Tannin Adsorption

Tannins are made up of a combination of big and medium-sized particles. Carbons adsorb tannins with a mix of micropores and mesopores. Parts per million levels are used to describe a carbon's capacity to adsorb tannin (range 200 ppm -362 ppm).

Apparent Density

Activated carbon with a higher density has a higher volume activity and is usually of a higher grade.

Dechlorination

The "dechlorination half-value length", which evaluates the chlorine elimination effectiveness of Ac, is used to assess certain carbons. "The depth of carbon necessary to lower the chlorine level in a flowing stream from 5 ppm to 3.55 ppm is known as the dechlorination half-value length".

Ash Content

The total effectiveness of Ac is reduced by ash. Metal oxides, particularly iron oxide (Fe_2O_3), may seep from Ac, causing it to discolour. Total ash quantity is less important than acid or water-soluble ash particles.

Rigidity Number

It is a measurement of the AC's capacity to preserve its physical integrity and survive backwashing and other frictional forces. The toughness of AC varies greatly based on the raw material used in its manufacturing and the amount of activity.

Practice Size Distribution

The greater the accessibility to the surface area and the quicker the adsorption kinetics, the finer the particle size of Ac. This must be taken into account in vapour phase systems since pressure loss has an impact on energy costs.

Types of Activated Carbon Alteration Process

The surface of AC may be changed to improve affinity for the anticipatedcontamination according to the desired contaminants' kind and composition. It may attract a range of compounds onto its hydrophobic interior surface since it is an inert porous carrier material with a high detailed surface part. Various techniques of modifying Activated Carbon exist, depending on the requirements, to render the surface available to a range of reactants. The surface treatment of Activated Carbon usually follows the activation stage. Chemical modification, physical modification, as well as biological modification are the three types of alteration. Chemical modifications may be further classified into two categories: acidic and basic surface modifications (Liu *et al.,* 2020). Surface saturation of activated carbon with active metals, including their oxides is the third form of chemical modification. Heat therapy is the most common physical alteration. Biological alteration is a modern strategy in which biological environmental management technologies may be employed for water treatment as well as other purposes. Activated carbon surface modification

- ***Chemical modification***

It is generally recognized that the AC surface may exhibit basic, acidic, or neutral behaviour regarding the occurrence of surface practicalclusters. "Acidic functional groups on carbon surfaces have been investigated for the elimination of heavy metals from water and found to be extremely advantageous because metal ions have a propensity to form metal complexes with the negatively charged acid groups". The primary acidic groups are found on the AC surface. All chemical treatments that use oxidising agents to create acidic functional groups decreasethe detailed surface partof theentire pore capacity, owing to the loss of absorbentconstructions within AC during the oxidation process (Moallemi *et al.,* 2019). As a result, other ways of increasing

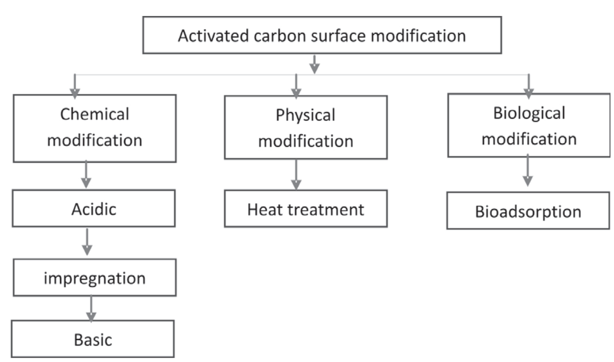

Fig. 1. Methods for modifying activated carbon

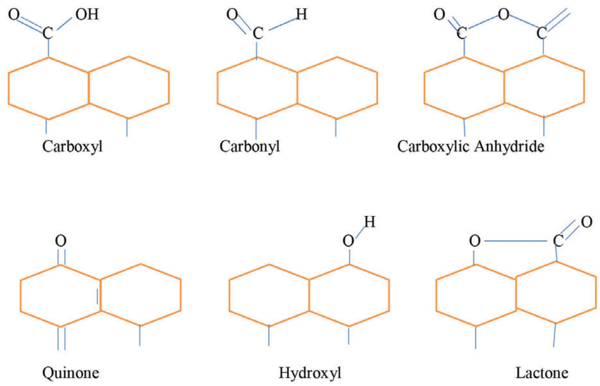

Fig. 2. On Activated Carbon, a diagram illustrating several acidic functional groups

acidic surface groups without causing significant pore damage are being investigated. Treatment of activated carbon with chemicals like "aqueous ammonia" and"sodium hydroxide" results in chemical changes of basic clusters on the surface. OH^- ions are predicted to respondto activated carbon's surface functional groups in alkaline solutions. The alkaline treatment of AC helps to improve the adsorption of organic substances from water.

Among the most significant chemical alterations is surface impregnation. Impregnation is the term used to describe the fine dispersion of chemicals and metal particles inside the pores of AC. The impregnation of AC is advised for the following three aspects.

- To enhance Activated Carbon's built-in catalytic oxidation capacity in order to improve its catalytic qualities.
- To encourage Activated Carbon as well as the impregnating agent to work together.
- To improve Activated Carbon's capability as an inert porous carrier. Due to their much higher sorption volume for particles that the host activated carboncannot bind without the impregnant, the impregnation of Activated Carbonwith metals like copper, silver, nickel, aluminium, as well as iron has recently piqued researchers' attention. In water, Activated Carbon saturated with such change metals showed increased adsorption ability or responsiveness towards cyanide, fluoride, and heavy metals, including arsenic.

Physical alteration

So far, the most common approach for physical alteration has been heated treatment. In nature, AC handled thermally in an inert environment becomes elementary. Every chemical alteration approaches listed above reduce internal surface area and pore volume in general. In most cases, physical change improves physical features. The surface oxygen functional groups may disintegrate at high temperatures, which is a substantial disadvantage of heat treatment. This may lead to a reduction in adsorption process. In this regard, promising modification approaches including such plasma treatment are being further researched to improve chemical features while preserving and improving physical qualities.

Plasma dealing

"Plasma oxidation is a process in which GAC (granular activated carbon) is exposed to plasma under pressure or atmospheric conditions in the presence of controlled air or oxygen". There is virtually little textural change throughout this procedure, though there is a significant shift in the surface chemistry of granular activated carbon. Surface acidity would rise during plasma oxidation due to the "chemical addition of oxygen to carbon surfaces" since oxygen free radicals respond strongly with carbon particles at the marginal surface of the graphitic platelet. Plasmatreated carbons might be used as a source of specialised carbons in the future to remove certain pollutants from the air or water. Research should emphasize how to fully use plasma treatment's potential for eliminating certain pollutants, metals, and microorganisms. The plasma dealingprocedure necessitates a one-time investment in equipment and arrangement and ongoing electrical costs to create plasma. As a result, the method would not be prohibitively costly, even when treating huge amounts of AC (Voliotis *et al.*, 2017). The procedure would also offer carbon the ability to eliminate a wide range of contaminants or chemicals without producing any wastes or reducing carbon's productivity and effectiveness.

Biological modification

Microorganisms in water are a major source of worry across the globe. The adsorption of these organisms on AC has gotten a lot of interest in the past several decades because of:

- AC's adsorptive capabilities, which result in a rise of nutritional and oxygen concentrations as well as the elimination of disinfection chemicals;
- AC particles have a porous shape that provides

microorganisms with a protected habitat;

The availability of a wide range of surface functional groups on AC, improves microbe adherence. Large-size bacteria become caught inside the activated carbon in the granular activated carbon compartment. In the activated carbon chamber, where the temperature, as well as organic nutrients, are optimum for development, the confined bacteria begin to proliferate. If the carbon medium is not updated on a regular basis, this bio-fouling may lead granular activated carbon or carbon chunks to exude a decomposing stench (Voliotis *et al.,* 2017). New bacteriostatic approaches for chemical activation would be beneficial in extending the life of carbon medium, controlling HPC development, and preventing malodors.

NSF Standard 42 provides a test for the carbon chamber's biostatic properties to verify that the filter does not enable bacterial growth. Water exiting the strainer must contain no more than 20% more bacteria than water entering the filter over time. "The geometric mean of the heterotrophic plate counts of the product water samples from each system shall be no greater than that of the influent challenge samples, within a measurement precision of +/- 20%," according to the standard, which must be measured over a six-to-thirteen-week test phase, based on the arrangement's capacity. Dechlorinated tap water with native "HPC, 200-600 ppm TDS, and TOC >/= two ppm" was used as the test water.

Silver impregnation

Antimicrobial silver is often used to safeguard a broad range of items against bacteria, fungi, mould, and other organisms. Colloidal silver ($AgNO_3$) is an excellent bactericide for swimming pool water treatment. The usage of colloidal silver in intake water has also been tried, although with some success. Leach level and cost are two challenges that colloidal silver surface activated carbon modification faces. To address these concerns, various research investigations are being conducted to incorporate nano silver impregnation to reduce leach while lowering costs. Only a few businesses have created a one-of-a-kind nano silver impregnation technique that addresses both difficulties with colloidal silver impregnation. Compared to typical colloidal silver, impregnation of coconut shell-based AC offers various potential benefits, counting non-detectable quantities of silver in the output water. At extremely low (ppb level) concentrations, many approaches are employed to evaluate Ag levels in water samples. With the above-mentioned procedure, it is possible to minimize the silver content, resulting in lower overall costs compared to colloidal silver impregnation AC.

Application of Activated Carbon in Purifying Water

Activated carbon comes in two forms: PAC and granular activated carbon. The latter is utilised to adsorb organic DBP precursors in packed-bed pillars downstream of non- granular activated carbon filtering or membrane procedures. Granular activated carbon packed-bed columns may also offer adsorptive volume for a variety of microconstituents as well as taste and odor-causing chemicals. Because this sort of granular activated carbon column is employed in an adsorptive mode, it must be renewed or changed on a regular basis to maintain the process's adsorptive capability (Khorasgani *et al.,* 2020). Because of the solids loading, granular activated carbon contactors might get considerably fouled. As a result, this section focuses on PAC as a pretreatment that may be used to augment other pretreatment methods.

AC is produced from high-carbon-content trash in the setting. For the manufacture of AC, lignocellulosic as well as coal resources have been employed as raw materials. Physical activation and chemical activation are the two approaches for creating AC that may be employed in water purification operations. AC has a great capability for heavy metal adsorption due to its increased total area, micro - porous abilities, as well as chemical intricacy of its external area."H-type and L-type stimulated active carbon are the two types. When injected into water or handled with strong acids, H-type carbon takes on positive charges and is classified as hydrophobic (Peng *et al.,* 2020). The L-type carbon is a more powerful solid acid than the H-type carbon, which has a negative charge in water and can neutralise strong bases while remaining hydrophilic". Based on its physical appearance, AC is divided into four categories. Powders (PAC), granules (GAC), fibres (ACF), and clothing (ACC). Commercialized activated carbon (CAC) is now widely utilised across the globe.

AC products have a wide range of applications since they are employed in almost every part of lifetime. They are crucial and so cannot be overstated. These are some of the usages:

Application in Analytical Chemistry

In reduced separation technique of carbohydrates using ethanol liquids as the stationary stage, AC in a fifty % w/w mixture with celite is used as the solid stage of development in analytical or preconcentration procedures.

Fuel Storage

The capacity of AC to supplyusual gas and hydrogen gas is currently being investigated. The porous substance acts as a sponge for a variety of gases. The gas is drawn to the carbon material by Van-der Waals forces. Carbons with bonding energies of 5 to 10 kilojoules per mole (kJ/m) have been discovered (Hayashi *et al.,* 2002). The gas may be desorbed and burned or utilised in a hydrogen fuel cell when exposed to high temperatures.

Gas Purification

Filters containing AC are often used to eliminate oil odours, vapours, as well as other hydrocarbons from compressed air and gas. "Radioactive gases from a nuclear boiling water reactor turbine condenser are retained using activated carbon filters. There are residues of radioactive gases in the air sucked from the condenser". These gases adsorb and are retained in the vast charcoal layers, where they quickly degrade into non-radioactive solid substances. Whereas the drinkable air flows through, the solids are retained in the charcoal atoms.

Medical Application

Poisoning, including overeatsproduced by oral feeding,is treated with AC. Thismakes the toxic blind and prevents it from being absorbed by the gastrointestinal system. Medical staff deliver AC on the scene or in a hospital's crisis room in situations of suspected poisoning (Li *et al.,* 2015). Dosing is normally done empirically at 1 gram per kilogram of body weight.

Chemical Purification

AC is widely used to purify solutions that include undesired coloured impurities, like during an organic chemistry recrystallization method.

Water Purification

The most widely acknowledged technique of portable water filtration is the use of activated carbon. Insecticides, herbicides, chlorinated hydrocarbons, and phenols are all removed from the water supply (Sivapragasam *et al.,* 2021). It's also utilised in reaction catalysis, electroplating baths, besides aquarium water filters to remove pollutants.

Mercury Scrubbing

AC, which is commonly coated with iodine or sulphur, is extensively employed at the well head to apprehension mercury releases from "coal-fired power plants, medical incinerators, and natural gas".

Process of Manufacturing Activated Carbon

Steam activation, and chemical activation, besides thermal dealing out processes are the three primary methods used in the industrial synthesis of activated carbons. "Softwood, coconut shell, lignite, hardwood, grain and agro products, bituminous coal, anthracite, and other raw materials or precursors are utilised in the synthesis of activated carbon". Chemical activation is a method of constructing AC from sawdust, wood, or peat that involves the use of chemicals. Phosphoric acid and Zinc Chloride are the most often utilised activating agents in the chemical activation procedure, which involves combining an "inorganic chemical compound with carbonaceous raw materials". Steam activation is a process that employs gases, vapours, or a combination of both to activate coal, coconut shell, and grain-based activated carbons.

Thermal processing is a method for the separation that eliminates undesired components from a carbonaceous precursor by heating it to different temperatures (Kamal Hasani *et al.,* 2021). This procedure is less costly than the other two and fulfils all environmental regulations, but the others need more expensive solutions to obtain the same goals.

Conclusion

AC made from coconut shells has a small internal surface area at first; thus, it must be modified to increase its area and openingconstruction. The monolayer capacity and surface coverage of coconut shell-based AC were increased by devolatilization. Treatment with nitric acid, on the other hand, binds oxygen functional groups to the adsorbent, decreasing the carbon resources' adsorption performance, monolayer capacity, and surface exposure. Agricultural AC, such as coconut shell, enables more effective use of agricultural waste.

The primary aspects of AC are briefly described on this page, and a broad range of surface alteration approaches for water purification. In addition, the benefits and drawbacks of such procedures are examined in relation to eliminating various kinds of water pollutants. Chemical changes, particularly acidic treatment, are the most extensively employed procedures, presumably because the needed aqueous solutions are simple and readily available. The elimination of heavy metals from water has been demonstrated to be more beneficial with oxidative treatments, whilst the elimination of organic contaminants from water has been shown to be more favourable with thermal treatments. As a result, it is clear that the kind of contaminant species in water should be considered while selecting specific AC modification approaches. Chemical treatments to improve surface functions may, on the other hand, have a negative impact on AC's physical characteristics or vice versa. This offers up new possibilities for modifying AC in order to produce both chemical and physical properties at the same time.

Acknowledgements

Author is very much thankful to the Principal and lab boy of S.M.C.C. Govt. College Aburoad (Raj.) who appreciate him for doing such kind of research.

References

Hayashi, J., Horikawa, T., Takeda, I., Muroyama, K. and Nasir Ani, F. 2002. Preparing activated carbon from various nutshells by chemical activation with K2CO3. *Carbon.* 40: 2381–2386.

Hu, D. 2021. Figures of the manuscript of "Physical and chemical properties of black carbon and organic matter from different combustion and photochemical sources using aerodynamic aerosol classification. figshare [Figures], https://doi.org/10.6084/m9.figshare.15172572.v1, 2021.

Kamal Hasani, Sama Hosseini, Heliya Gholizadeh, Abdollah Dargahi and Mehdi Vosoughi, 2021. Enhancing the efficiency of electrochemical, Fenton, and electro-Fenton processes using SS316 and SS316/b-PbO2 anodes to remove oxytetracycline antibiotic from aquatic environments. *Biomass Conversion and Biorefinery*. 49 https://doi.org/10.1007/s13399-021-01967-z

Khorasgani, N.B., Sengul, A.B. and Asmatulu, E. 2020. Briquetting grass and tree leaf biomass for sustainable production of future fuels. *Biomass Conv. Bioref.* 10: 915–924.

Li, Q., Qi, Y. and Gao, C. 2015. Chemical regeneration of spent powdered activated carbon used in decolorization of sodium salicylate for the pharmaceutical industry," *Journal of Cleaner Production*. 86 : 424–431.

Limousy, L., Ghouma, I., Ouederni, A. and Jeguirim, M. 2016. Amoxicillin removal from aqueous solution using activated carbon prepared by chemical activation of olive stone. *Environ. Sci. Pollut. Res.* 1–12.

Liu, D., He, C., Schwarz, J. P. and Wang, X. 2020. Lifecycle of light-absorbing carbonaceous aerosols in the atmosphere. *npj Clim. Atmos. Sci.* 3: 40, https://doi.org/10.1038/s41612-020-00145-8, 2020.

Liu, D., He, C., Schwarz, J. P. and Wang, X. 2020. Lifecycle of light-absorbing carbonaceous aerosols in the atmosphere. *npj Clim. Atmos. Sci.* 3: 40, https://doi.org/10.1038/s41612-020-00145-8, 2020.

Liu, D., Taylor, J. W., Crosier, J., Marsden, N., Bower, K. N., Lloyd, G., Ryder, C. L., Brooke, J. K., Cotton, R., Marenco, F., Blyth, A., Cui, Z., Estelles, V., Gallagher, M., Coe, H. and Choularton, T. W. 2015. Aircraft and ground measurements of dust aerosols over the west African coast in summer 2015 during ICE-D and AER-D, *Atmos. Chem. Phys.* 18: 3817–3838, https://doi.org/10.5194/acp-18-3817-2018, 2018.

Moallemi, A., Kazemimanesh, M., Corbin, J. C., Thomson, K., Smallwood, G., Olfert, J. S. and Lobo, P. 2019. Characterization of black carbon particles generated by a propane-fueled miniature inverted soot generator. *J. Aerosol Sci.* 135: 46–57. https://doi.org/10.1016/j.jaerosci.2019.05.004, 2019.

Peng, L.C., Gao, J., Yao, S., Lan, X.Q., Li, H.P. and Song, H. 2020. Modified ginkgo leaves for adsorption of methyl violet and malachite green dyes in their aqueous system. *Desal. Water Treat.* 206: 358–370.

Sivapragasam, C., Aruna Janani, V., Andappan, A., Archana, B., Vasudevan, M. and Natarajan, N. 2021. Real-time monitoring as an adaptive strategy towards green treatment of textile effluent using biosorbent from Acalypha indica. *Water Supply.* 21 (5) : 2019-2034. https://doi.org/10.2166/ws.2021.033

Voliotis, A., Prokeš, R., Lammel, G. and Samara, C. 2017. New insights on humic-like substances associated with wintertime urban aerosols from central and southern Europe: Size-resolved chemical characterization and optical properties. *Atmos. Environ.* 166: 286–299, https://doi.org/10.1016/j.atmosenv.2017.07.024, 2017.

Yao, S., Zhang, J., Shen, D., Xiao, R., Gu, S., Zhao, M. and Liang, J. 2016. Removal of Pb(II) from water by the activated carbon modified by nitric acid under microwave heating. *J. Colloid Interface Sci.* 463: 118–127.

Zhi, Y. and Liu, J. 2016. Surface modification of activated carbon for enhanced adsorption of perfluoroalkyl acids from aqueous solutions. *Chemosphere*. 144: 1224–1232.