Application of Biochar for wastewater

treatment and recovery of value added products

A

Seminar Report

Submitted in partial fulfillment of the requirements for the award of the degree of

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With specialization in

BIOTECHNOLOGY

Under the supervision

of

Dr. ASHOK NADDA

(Assistant Professor)

by

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

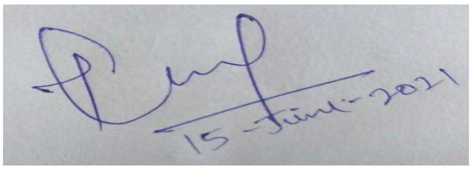
WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

May-2021

STUDENT’S DECLARATION

I hereby declare that the work presented in the Seminar report entitled “**Biochar application for recovery of value added products from wastewater treatment: a review**” submitted for partial fulfillment of the requirements for the degree of Master of Science in Biotechnology at Jaypee University of Information Technology, Waknaghat is an authentic record of my work carried out under the supervision of Dr. ASHOK KUMAR NADDA, Assistant Professor. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my seminar report.



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May-2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled "**Biochar application for recovery of value added products from wastewater treatment : a review** " in partial fulfillment of the requirements for the award of the degree of Master of Science Biotechnology and submitted to the Department of Biotechnology and Bio Informatics, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by Tanvi Kaushal (197811)during a period from January, 2020 to May, 2020 under the supervision of Dr. ASHOK NADDA, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: - ………………………

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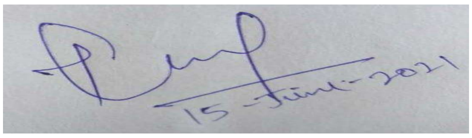

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LIST OF ACRONYMS AND ABBREVIATIONS

MPa	Megapascal Pressure Unit
HTC	Hydrothermal carbonization
TOC	Total Organic Carbon
TSS	Total suspended solids
BPA	Bisphenol A
PCP	Pentachlorophenol
VOC	Volatile organic compounds
ENR	Enrofloxacin
OFC	Ofloxacin
MCB	Magnesium oxide coated corncob biochar
TET	Tetracycline
LVX	Levofloxacin
CIP	Ciprofloxacin
GFX	Gemifloxacin
CTC	Chlortetracycline
SMX	Sulfamethoxazole
BMA-ABS	Biochar-mediated absorption-algal-bacterial system.
CFU	Colony-forming unit
AD	Anaerobic digester
PCP	Pentachlorophenol
ZVI-MBC	Zero valent iron magnetic paper mill sludge biochar

ABSTRACT

Over the previous decades, limitations in water resources has changed the human perspectives of waste water i.e., conversion of waste to value-added resource. Utilization of waste-water will not only mitigate scarcity of water, but can also help in recovering nutrients and energy. Furthermore, scientists have investigated biochar-application for the removal ofvarious contaminants from aqueous wastes. Biochar has numerous advantages in relation to: cost, pollutant adsorption efficiency and nutrient retention endow possibility for valuable resource recovery from biochar, plus being an a new sorbent with a lot of promise, it has shown much more applications such as a variety of sources for the feedstocks, easy to prepare, and a very favorable surface and structural properties. Therefore, studying and considering relationship between resource recoveries from biochar is important to develop the properties of biochar in remediation of environment and the sustainable utilization of waste water. This following reviews provide a schematic overview of the recent advancements in biochar application for recovery of value added products from wastewater treatment, along with different mechanisms of sorption involved Contaminants from wastewater are removed with this method

Keywords: *Biochar, water, energy, resource, sorbent etc.*

1. INTRODUCTION

Water is a crucial resource used for almost all industrial, agricultural, urban, purposes. Moreover, rapid growth of urbanization and industrialization has made proper, safe utilization of water and its conservation is also a huge challenge (Bolisetty et al., 2019). Shortage of pure or useable water is global problem, faced by whole of the biosphere, (Garcia et al., 2015). Hence, alternative sources of water are being investigated for meeting the rising global water demand. Volumes of waste water generated from both industrial and domestic activities are considered as potential resources for reclamation of wastewater. Moreover, the recovery of valuable resources from wastewaters has also gained massive attention because of its environmental and economic benefits. Furthermore, achievement of sustainable waste management includes multiple resources like metals, nutrients, and energy etc. In a recent study DiazElsayed et al., (2019) reposted different waste water technologies integrated with resource recovery processes across various scales So far, no single technology is capable of recovering multiple valuable resources from waste water. Different approaches been applied and trade-off the target resource. For instance, recovery of some resources requires sophisticated, infrastructural and great quantities of energy. On the other hand, many efficient technologies of resource recovery exert detrimental impact on the environment through persistent discharge of contaminants in the same (Holmgren et al., 2015).

Emerging subsets for the biochar application arewastewater treatment. A Strong capture capability for different substances, hydrophobicity, a large surface area, high organic C- content, large pore volumes, abundant and diverse functional groups, results in increasing relevant experiments and researches associated with resource recovery and biochar. Furthermore, because the feedstocks are sourced from nature, biochar is both resourceful and cost-effective.or agricultural biomass, solid waste, and a big part contributes in the reduction of carbon emissions (Ahmad et al., 2014, Lehmann et al., 2011). Biochar is a material with very rich carbon content is a product of thermal decomposition that lacks oxygen (Sohi et al., 2012). Progress in the production process of many forms of biochars has improved their qualities, performance, and applications in a variety of fields in recent years. Biochar experiments are being carried out all around the world., with a very diversepurposes depending upon the feedstock, production processes and the modification methods. (Tan et al., 2015). Number of researches has revealed interests over biochar in increasing crop yield and improving the soil properties (Yu et al., 2019, Agegnehu et al., 2017, Awad et al. 2017, ÖZ et al., 2018). Many researchers have shown that biochar can be easily produced from the green wastes, woodchips, straws, shells, bagasse, and manure are just a few examples. (Ahmad et al., 2014, Thornley et al., 2009, Nanda et al., 2016). Biochar is basically by-product of some thermo chemical transformations like pyrolysis, gasification, hydrothermal carbonization, torrefaction (Meyer et al., 2011). Biochar for the treatment of wastewater has positively shown a number of advantages in terms of agricultural remediation and soil amelioration in terms of physical and chemical nature. The physicochemical features of the material, such as surface area, acid–base behaviour, porosity, surface functional groups, and element composition, are all dependent on the feedstock and pyrolysis temperatures. (Ahmad et al., 2014; Uchimiya et al., 2013, Nachenius et al., 2013, Manariotis et al., 2015). The main aim of this article is:

(a) exploring efficiency and mechanisms of resource recovery by biochar;

(b) brief the methods of resource recovery after proper waste water treatment;

(c) demonstration of practical re-application of the resources to be recovered;

(d) gain interests of for treating waste water by biochar and resource recovery;

(e) enlighting future researches in biochar-based methods for resource recovery.

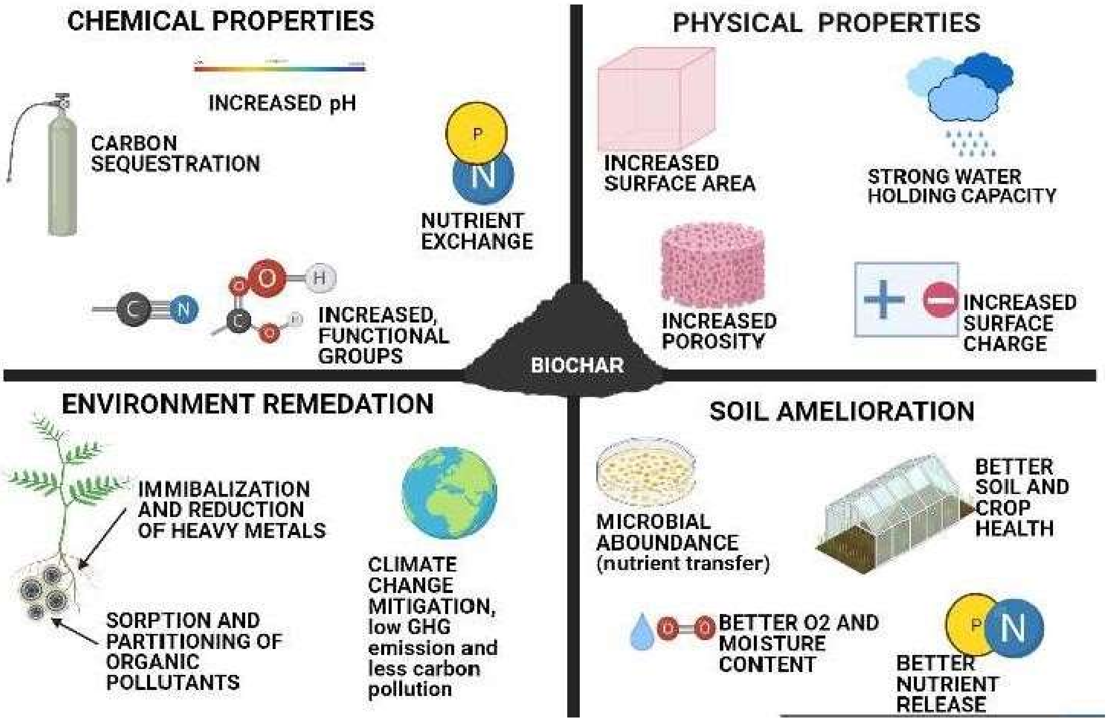

Fig 1. Properties of biochar in terms of physical and chemical nature and environmental applications.

2. BIOCHAR PRODUCTION VIA CONVENTIONAL METHOD:PYROLYSIS

Biochemical techniques are more environmentally friendly, however they are not suited for large or industrial scale production due to lower conversion efficiency, long-length reaction steps, and high production costs. (Mulbry et al., 2005, Ji et al., 2014). The algal biomass is primarily transformed to bio-char by thermochemical processes., like (HTC) hydrothermal carbonization and pyrolysis (Maurya et al., 2016, Yu et al., 2017, Wang et al., 2013). Pyrolysis is a process that turns dry biomass into bio-oil, bio-char, and a proportion of gases in the absence of air or oxygen at temperatures between 400 and 600 degrees Celsius (Chen et al., 2015). Pyrolysis can be either slow or quick depending on operational circumstances such as heating rate, temperature, and residence time.. Fast pyrolysis uses high heating rates up to 600 ºC, less residence time, high transfer of heat and rapidly coolingof the pyrolysis vapor (Azizi et al., 2017). HTC can make bio-char from wet biomass at low temperatures (180-260°C) and moderate pressures (less than2 MPa).

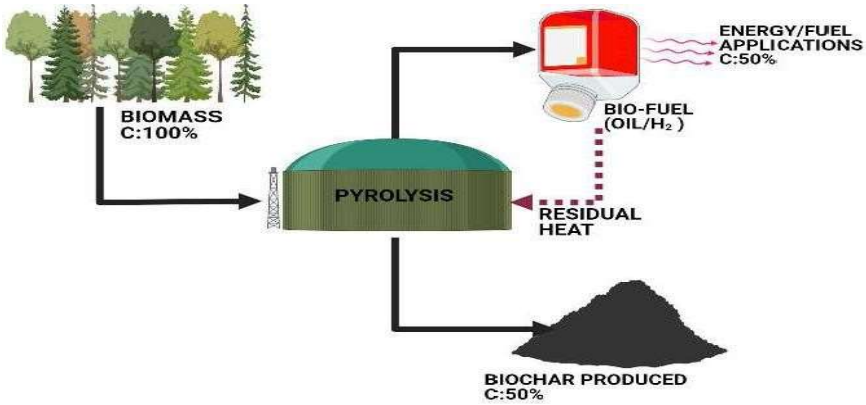

Fig.2 Brief biochar production via: pyrolysis.

3. BIOCHAR and WASTEWATER TREATMENT

Biochar is depicted in Figure 2 being utilised at various stages of the wastewater treatment plant to improve treatment efficiency and byproduct recovery. Biochar's use in wastewater treatment is governed by a number of mechanisms, including microbial cell buffering, adsorption, and immobilisation.. When combined with treated effluents, biochar can effectively absorb nutrients such as phosphate and nitrogen, allowing it to be used as a "nutrient-enriched substance" for soil remediation and crop production. By adsorption of different inhibitors or harmful substances, biochar employed in activated sludge treatment can increase the treatment and settling capability of the contaminant in the sludge. Sand can provide a surface for microbial immobilisation. Adding biochar in biological systems eventually helps in improving the soil-amendment and the properties of bios lid. As the use of biochar for soil grows in popularity, its application in wastewater treatment can boost the value chain and generate additional economic benefits. (Mumme et al.,2014).

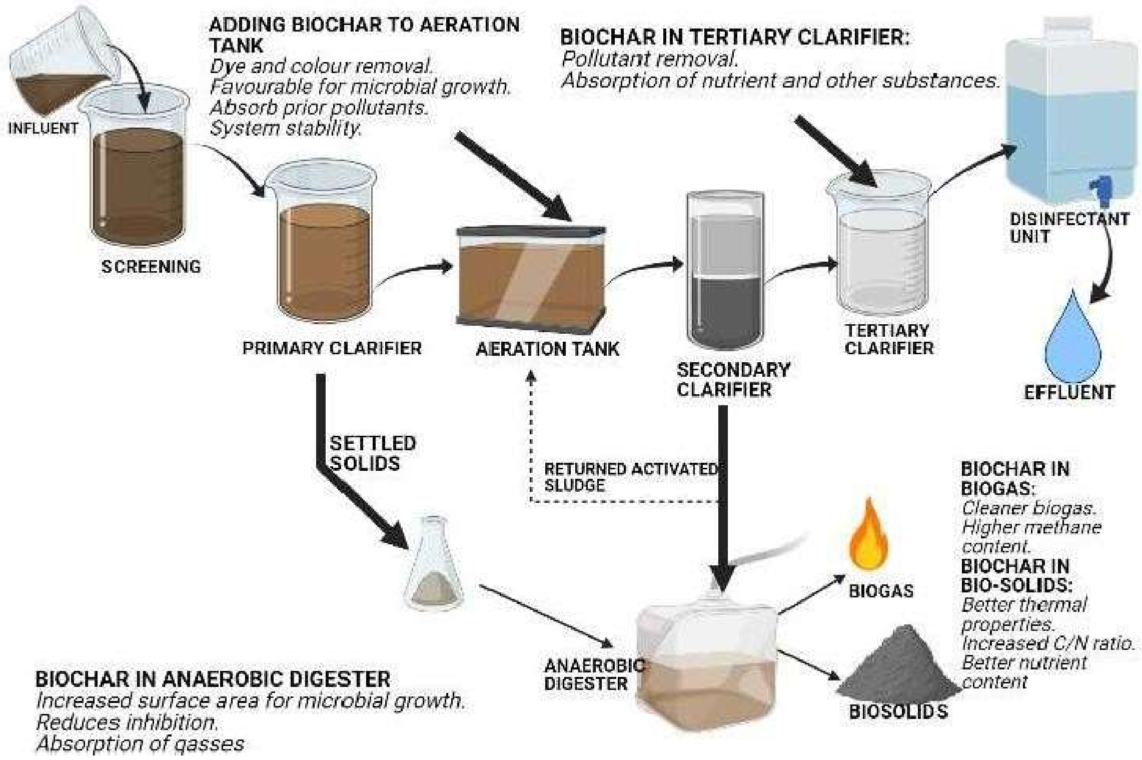

Fig. 3 Schematic removal of pollutants from wastewater by biochar.

4. MECHANISMS FOR ADSORPTION FOR POLLUTANT REMOVAL

In the biochar adsorption process, adsorbate is basically associated with the surface ofadsorbent until its equilibrium is accomplished (Fagbohungbe et al., 2017) steps involved in biochar adsorption procedure include:

SURFACE SORPTION

Also called as physical sorption is basically a physical technique where chemical bonds are formed through metal ion diffusion in the pores of the sorbent. The carbonization temperature affects the pore volumes and surface area of (biochar) sorbent. Kumar et al. investigated the adsorption of uranium onto biochar made from pine wood at pyrolysis temperatures of 300 and 700°C in 2017. The findings indicated that biochar produced at a high temperature When compared to a low-temperature version, this one totally removed uranium. It was also framed that highcarbonization surely enhances the pores volume, surface area of biochar.

CATION/ION EXCHANGE

The primary notion behind this mechanism is that protons and ionised cations, as well as dissolved salts, are exchanged on the surface of biochar particles. The size of the particle to be removed and the functional group present on the surface of the biochar determine the adsorption capabilities of this approach for the removal of pollutants. (Rizwan et al., 2016). In 2017 Ali et al., In his article framed that, higher the exchange of cation, the higher will be adsorption of metals. However, as the pyrolysis temperature rises above 350 °C, the capacity for cation exchange decreases., wheat straw, grape husk, stone, plum, nutshell. authors showed a very high removal of Pb and Cd for iron oxides containing feedstock. Such feedstock enhanced the capability of exchange of cations positively.

PRECEPITATION

One of the most commonly used and main mechanisms for inorganic pollutant removal using biochar. Mineral precipitates are formed into the solution of thesorbing material, specifically for biochar produced from cellulose and hemicelluloses degradation with pyrolysis temperature< 300 °C along with alkaline properties (Cao et al., 2010). Puga et al., (2016) that biochar from sugarcaneand straw dust enhances precipitation of both Cd and Zn. They claimed that surface precipitation efficiency depends on the temperature of pyrolysis.

COMPLEXATION

This mechanism includes multi-atom formation arrangement through interactions between specific metal ligands for the formation of complex. Biochar pyrolyzed at comparatively low temperatures bind with the pollutant and due to the presence of functional groups like phenolic, lactonic and carboxyl, contain oxygen in their structures. Thus, the oxygen content present can increase biochar’s capability of surface oxidation to enhance pollutant complexation process. (Mohan et al., 2007, Liu et al., 2009). Biochar pyrolyzed from vegetal biomass has been shown to have a high efficiency for absorbing contaminants such as Cu, Cd, Ni, and Pb by binding and forming metal complexes with functional groups such as carboxylic and phenolic. The plant-derived biochar was shown to have a significant level of surface complexation.

ELECTROSTATIC INTERACTIONS

One of the most vital mechanisms that involves adsorption of pollutants, mainly ionizable organic components to the positive charge on the surface of biochar by electrostatic interactions. The ability to attractor repels pollutants basically depends upon ionic strength and pH of the aqueous solutions (Ahmad et al., 2014, Zheng et al., 2013). Inyang et al., (2014) Biochar pyrolyzed from bagasse composite with carbon nanotubes was used in the experiment to eliminate methylene-blue. This study tells the increase in ionic strength of sorbate from the value 0.01 to 0.1M. NaCl decreased the adsorption capacity of methylene- blue from the value 4.5 to 3 mg/g. There was an increase in repulsive electrostatic interactions between the sorbent and the sorbate as a result of this.

PARTITIONING

The adsorbate diffuses into the pores of the (non-carbonized part) biochar in this approach. To further accomplish sorption, these pores interact with organic adsorbate. This adsorption is determined by the properties of biochar (crystalline or amorphous carbon) Sun et al., 2011 presented results from Cao et al.,(2009) and Zhang et al., (2013a, b) about biochar made from wood, grass can increase the adsorption of furidone and norfurazon by pre-filling and partitioning.

PORE FILLING

Organic pollutants can be found on the surface of biochar, which has micropores (less than 2 nm) and mesopores (2–50 nm). The polarity of the organic contamination, as well as the nature and kind of biochar, determine the pore filling approach. Biochar pyrolyzed from oak and loblolly, gamma grass for sorbing catechol utilising the micropore filling process is better and dominant mechanisms, according to Kasozi et al., (2010). Biochar should have a little amount of volatile materials and exist at very low contamination concentrations to improve the efficiency of this process.

HYDROPHOBIC INTERACTIONS

Adsorption of the hydrophobic elements and the neutral organic compounds includedin the hydrophobic interaction processes. This interaction requires less energy than the mechanism of partition. Furthermore, organic contaminants adsorb on the graphene structure due to hydrophobic interactions. (Zhu et al., 2005). Chen et al., (2011a, b) showed the perfuoro-octane-sulfonate sorption on maize straw biochar.

5. BIOCHAR APPLICATION FOR RECOVERY OF VARIOUS COMPOUNDS

Biochar can be widely used for water treatment because of its ability to absorb contaminants from liquid solutions (Chen et al., 2011a, b).

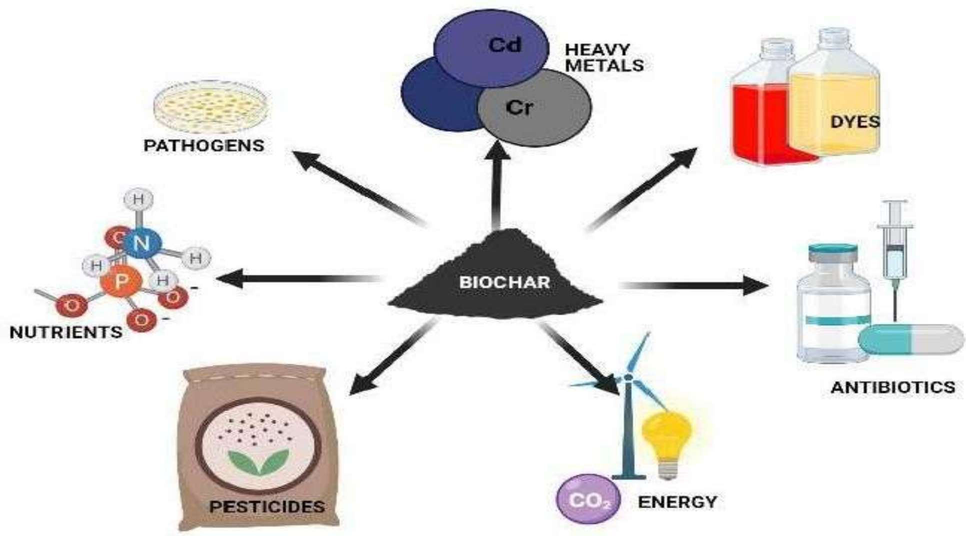

Fig. 4 Different value-added-products removed from wastewater

HEAVY METAL REMOVAL

The majority of heavy metals in water resources arise from anthropogenic activities such as purification, mining, and electronic assembly effluents (Li et al., 2017). Biochar has been proposed as a means of removing heavy metals from wastewater. At varying pH levels, the elimination process is dependent on the valence state of the goal metal (Li et al., 2017).Precipitation, ion exchange, complexation, electrostatic interactions (chemisorptions), and physical sorption are some of the systems that could be used to recover heavy metals from wastewater using biochar. Because of their surface heterogeneity, biochars, like activated carbon, have a high sorption capacity for heavy metal contaminants. (Kasozi et al., 2010). Furthermore, a substantial surface area with a sufficient pore network, including micropores, has been demonstrated in many biochars (less than 2 nm), macropores (more than 50 nm), and mesopores (2- 50 nm) (Mukherjee et al., 2011). Biochars with a large surface area and pore volume have a high affinity for metals because metallic particles are physically sorbed onto the char surface and trapped inside the pores. (Kumar et al., 2011). Numerous biochars have surfaces with negative charge and can sorbpositively charged metals via specific ligands, electrostatic attractions and specific functional group present on biochars communicate with different metals for the formation of complex particles (Dong et al., 2011, Wang et al., 2014, Cao et al., 2009, Inyang et al., 2012a, Inyang et al., 2011a).

INTERACTION MECHANISM BETWEEN BIOCHAR AND HEAVY METALS:

There are a variety of strategies that can help regulate heavy metal ejection from aqueous solutions. Biochar can be employed in a variety of ways, including precipitation, complexation, ion exchange, electrostatic cooperation (chemisorptions), and physical sorption. Biochar generally have a very large pore volume, surface area and have more affinity for metals since metallic particles can be actually sorbed on biochar surface and can be held inside the pores (kumar et al., 2011). Many biochars contain negatively charged surfaces that can bind to positively charged metals, known as ligands, via electrostatic attraction. Specificity and other beneficial groups found on biochars can also work together to create complexity with certain heavy metals. (Dang et al., 2011, Wang et al., 2014, Inyang et al., 2012). In Contrast with the activated carbon, biochar gives off an impression of being a novel Adsorbent with the potential to be low-cost and effective. The synthesis of activated carbon necessitates a higher temperature and an additional activation procedure. Biochar, on the other hand, is less expensive to produce and requires less energy. (Cao et al., 2009). Zheng et al., 2010, Keiluweit et al., 2009). Heavy metals are ejected via physical sorption, which involves the diffusional growth of metal particles into sorbent pores without the formation of chemical interactions. The rise in carbonization temperature (=3000C) will support high surface area and pore volumes in plant and animal biochars. Heavy metal sorption on biochar surfaces via the exchange of ionizable cations/protons with broken up metal species has also been documented (Mukharjee et al., 2011). Another approach for heavy metal immobilisation is electrostatic collaboration between surface charged biochars and metal particles.. System of biochar relies on biochar-metal sorption measure which depends on pH arrangement and point of zero charge (PZC) of biochar (Mukharjee et al., 2011). Carbonization at high temperatures (>4000C) promotes the production of grapheme structures in burns, which support electrostatic sorption systems (Kim et al., 2013). During the assimilation test, Precipitation is defined as the formation of solid(s) in a solution or on a surface. Precipitation is a common term used to describe a crucial technique for immobilising heavy metals using charcoal sorbents. Because of the improvement in adsorption measurement, the most important boundaries are the pH of the arrangement. It has an effect on the adsorbent's surface area, charge, ionisation level, and speciation. Biochar is made up of various functional groups (principally oxygen containing groups, for example hydroxyl, AOH and carboxylate, ACOOH ;). The increase in the pH arrangement is influenced by changes in these functional groups.. The functional groups on the biochar are positively charged at low pH. (Jadia et al., 2008). The underlying, morphological, natural, and properties of biochars are all said to be affected by pyrolytic temperature (Kolodyn et al., 2012, Zang et al., 2013).

Table no. 1 pyrolysis biochars made from a variety of feedstocks for heavy metal removal

HEAVY METAL	**PYROLYSIS TEMPERATURE °C.**	**SOURCE OF BIOCHAR**	**TIME (hours)**	**RECOVERY**	**REFERENCE**
Pb(II), Cd(II) Co(II)	500	Camel bones	1	344.8 322.6 294.1	Alquadami et al., 2018
Re(VII)	500	Bamboo shoot shell		10.2	Hu et al., 2019
Mo	300, 450, 750	Microalgae+ iron	1	78.8	Johansson et al., 2015
Pb	600	branches of fruit trees (Pruned)	4	17.7–19.2	Park et al., 2015
Hg(II)	450	Bagasse/pecan skin	2	13	Zhang et al., 2015
As(II)	400	sludge	2	3.08–6.04	Zhang et al., 2015
Cd(II)	450	Water hyacinth	1	70.3	Tytlak et al., 2015
Cr(VI)	350–650	Wheat straw	-	23.6	Zhao et al., 2013
Pb^{2+}	600	Bamboo,hickory, bagasse,wood	1	14.3	Manariotis et al., 2015
Hg(II)	300–900	Malt spent rootlets	1	130	Liu et al., 2014
Ni(II)	300,350,	Lotus stalks		61.7	

NUTRIENTS

Biochars absorb cations by the process of cation exchange due to high surface- charge -density ,porosity, high surface area, availability of both polar and non polar sites on biochar surfaces that enables it to absorb the nutrients (Hale et al., 2013). Some nutrients, such as nitrogen, phosphorus, and humic acid, can be recovered from wastewater using biochar, as shown below.

NITROGEN and PHOSPHORUS

Nitrogen production as a fertilizer is a bit energy intensive process and Phosphorus is non-renewable resource, and the discharge of such nutrients after wastewater treatment causes eutrophication of environment. Therefore, recovery of such nutrients from wastewater has attracted lots of attention. In addition, bio-char has the potential to help manage eutrophication and pollution. Biochar has significant absorbent abilities for both organic and inorganic pollutants, as well as a high potential for carbon sequestration from the atmosphere (Cao et al., 2010, Arun et al., 2018, Lehmann et al., 2006, Mohan et al., 2014;).Ammonia and nitrate both these forms of (N) nitrogen are present in waste water . Ammonia is an aerobic pollutant that leads to eutrophication of water. Although nitrogenous fertilizers play a major role in increasing the yield and improvising the quality of soil as well as agricultural products. Therefore, recycle the nitrogen content from wastewaters resolves the problem of both water pollution and shortage of resource. Activated carbon along with other carbons- materials have a good efficiency for the recovery of nitrogen, hence, biochar can be considered a potential component for the recovery of nitrogen (Huggins et al., 2016). R ammonium has a wide occurrence so it has become a challenge to remove it . pH is the initial factor that is considered while going through the ammonium- nitrogen removal process, Because ammonium in alkaline wastewater converts to ammonia-gas, the component to be recycled dissipates, resulting in a primary stage -air pollution. (Trinh et al., 2017, Xu et al., 2018). Biochar-mediated absorption-algal-bacterial system (BMA-ABS) was investigated by Yu et al.,2020 for recovering nutrients from swine wastewater with high ammonium concentration. As a result of the combined effects of algal-bacterial and biochar, nutrient concentrations were reduced, and N and P recovery efficiencies were above the 95th percentile (Yu et al., 2020). Biochar basically possess a nice recovery capability as in comparison to the traditional technologies. In limited studies, biochar has proved absorption of NH4 −, NO3 −, and PO4 3− despite of the fact that these carry different charges and properties (Yao et al., 2011). In 2011 Chen et al., in his study used PO4 ions were adsorbed at the binding sites that were contained in the nano-sized MgO particles on the surface of digested sugar-beet biochar pyrolyzed at 600°C. According to Zhu et al., 2012, pyrolysis of orange peel into biochar at temperatures ranging from 250 to 700°C eliminated between 8 and 83 percent of phosphate from the waste solution.

Table no. 2 pyrolysis biochars made from a variety of feedstocks for heavy nutrient removal.

FEEDSTOCK FOR BIOMASS	**PYROLYSIS TEMPERATURE ^{o}C**	**TIME (h)**	**NUTRIENT**	**RECOVERY mg/g**	**REFERENCES**
Grapevine canes	400,500	1	N	16.9,25.9, 32.0,375	Marshal et al., 2017
Wood cutting rice husk	600	10	N	446+_0.602, 39.8+_0.54	Kizito et al., 2015
Wood, corn cobs, rice husk, sawdust	600	10	P	7.67,643,573,54 1	Kizito et al., 2015
Lodgepole, pinewood	1000	1	N, P	1.0, 3.6	Huggins et al., 2016
Cacao shell, corn cob	350	3.5	N, P	3990+_138mg/kg 697+_23mg/kg	Hale et al., 2013
10% (bay laurel, mixed hard wood and softwood) 60%	180-395	6	Fexalindicators and nutrients		Afrooz et al., 2017

pine, 20% eucalyptus					
Rice husk	450	2	N, P, HA	58.20, 125.36, 34.57	Zing et al., 2019
Sugarcane crop harvest residue	550	1	N, P, HA	22 ,398 ,247	Li et al., 2017
sawdust and dolomit e	400, 550, 750, and 900	1	P, HA	07, 469	Le et al., 2018
Corn straw	550	1	N, P	3.16 ±0.52 , 3.22 ± 0.34	Yu et al., 2020
Powdere dstraw	600, 700, 800	2	P	3.16 ± 0.52 3.22 ± 0.34 total P	Li et al., 2019

HUMIC ACID

Humic acid (HA) also known as humate is an organic- macromolecular material existing both widely, naturally and fraction of(DOM) dissolved-organic-matter in eutrophic water bodies. Humate can supposibly increase plant growth, however it is quiet good to recycle it from the waste and reusing it for the soil and crops (Jing et al., 2019; Li et al., 2018).Absorption capability and biochar for humic acid/ humate depends on the surface charge, therefore pH here becomes a very important condition. A proper study done by Li et al., in 2018, showed that biomass,co-pyrolysed with natural dolomite powder showed π - π interactions between HA and biochar (carbon matrix) and this is the desirable procedure for recovery of humate/HA (Li et al., 2018).

DYES

With rapid growing textile industry, dye-wastewater accounts for industrial wastewater in large proportion. the biochar sorption method is specifically favored for treating dye- wastewater. Biochar under extreme conditions work as an adsorbent. Concentrations of the temperature, dye/biochar, pH play major roles in determining biochar efficiency (Park et al., 2019, Zhang et al., 2020) . modification done by Nickel in the biochar helped in adsorbing dye-methylene blue with adsorption capacity 479.49 mg/g and temperature 20 °C from the wastewater (Yao et al., 2020). Two of the most commonly used dyes in dyeing wool carpets, Lanasyn Gray and Lanasyn Orange, could sorb on the nano- porous biochar generated from bamboo cane feedstock, according to Pradhananga et al., (2017).. The sorbing capability of both dyes was 2.6 103 mg g1, and pore-filling was believed to be the major sorption process. This high sorption capability was attributed to the used biochar's high specific surface area (2,130 m2 g 1) and pore volume (2.7 cm3 g 1).. In 2018, Zazycki et al. created pecan-nutshell biochar to remove Reactive Red 141 dye from effluent water. The above biochar was inexpensive and helpful to the environment., and it could be used to replace all other existing conventional adsorbent. Aromatic cationic dyes like methyl-violet and methyl-blue sorption was higher in biochar with more O- and H-functional groups (400°C), although the process was very pH dependent (Adeel et al., 2017, Teixido et al., 2011). The process of extracting colours from waste waters using biochar entails a number of intricate interactions (both physisorption and chemisorption) between the dye (adsorbate) and the biochar (adsorbent). The current literature concludes that the adsorption process necessitates numerous mechanisms that all act together, with some of them dominating and others depend on system conditions. Mechanisms such as van der Waals interaction, pore-filling effect, chemical action, electrostatic contact, ion exchange, - contacts, surface complexation, and cation- interactions all play essential roles in adsorption processes, depending on biochar, dyes, and the solvent.

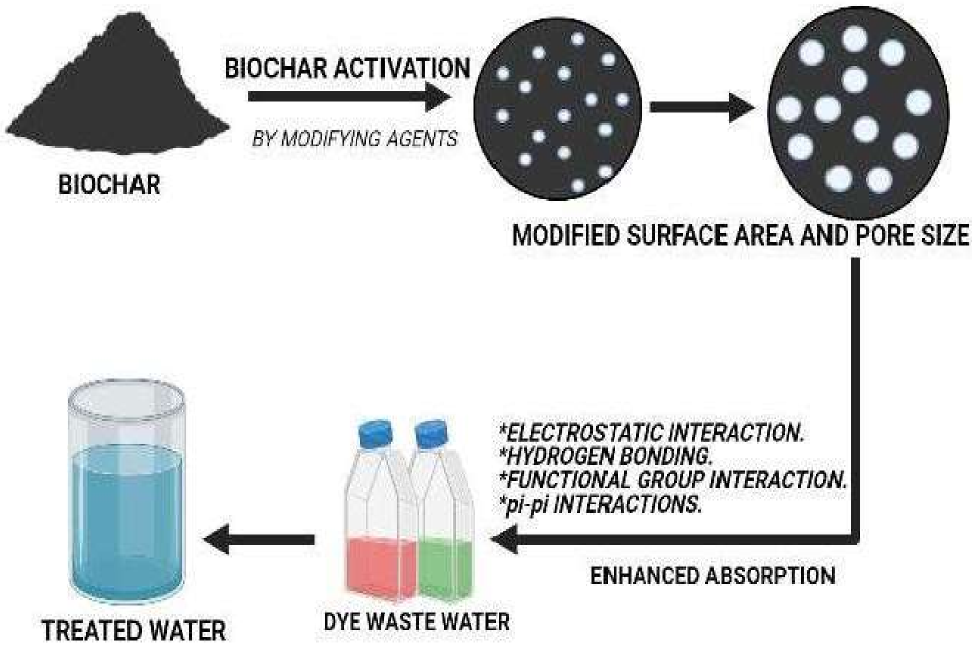

Fig. 5 schematic route of adsorption of dye from wastewater by biochar

Table no. 3 pyrolysis biochars made from a variety of feedstocks for dye removal

BIOMASS	**DYE RECOVERED**	**TEMPERATURE °C**	**pH**	**TIME**	**RECOVERY**	**REFERENCE**
Date palm petiole	Crystal Violet	30	7	15m	209 mg/g	Chahinez et al., 2020
Activated wakame	Rhodamine B	20	2-12	-	533.77 mg/g	Yao et al., 2020
Chitosan Beads(surfactantmodified	Tartrazine	50	3	120m	30.03 mg/g	Pal et al., 2019
Crab Shell (calcium rich)	Congo red	25	4	2m	20317 mg/g	Dai et al., 2018

Lotus stones	Basic Yellow 28	20	8	180	424 mg/g	Boudechiche et al 2019
Opuntia ficusindica	Malachite Green	30	6	120	1341.38 mg/g	Choudhary et al 2020

Pesticides

Pesticides have been demonstrated to be hazardous to both the environment and human life in several studies (Rasheed et al., 2019). Chronic exposure to pesticides like atrazine (1- chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine), which limits photosynthesis in sensitive plants, can cause problems like retinal degeneration and cardiovascular dysfunction. Pesticides can be beneficial to agricultural production and the economy, but excessive use of pesticides can be hazardous to soil organisms and upset ecological equilibrium, as well as human health (Zhong et al., 2018). Biochar can be utilised as a distinct-remediation approach in wastewater treatment to recover pesticides (Dai et al., 2019) Suliman et al. (2016) found that pyrolyzing rice-husk, soybean-derived biochar at 600–700°C can remove non-polar trichloromethylene (VOC) and carbofuran (pesticide) from polluted water.. Due to interactions between pollutant functional groups present on the surface of biochar, pyrimethanil and diesopropylatrazine (fungicide/pesticide) were efficiently removed with red-gum wood-chips and broiler litter biochar pyrolyzed at temperatures less than 700°C, and same biochar at pyrolysis temperature 300°C .(Suo et al., 2019). Suo et al., (2019b) used pre-modified biochar for enhanced adsorption of "triazine," with pore filling, hydrogen bonding, van der Waals' forces, and electrostatic interactions as part of the adsorption mechanism. Zhao et al (2013) proposed that -interactions, electrostatic interactions, and van der Waals forces were the key adsorption processes for trapping "atrazine" by maize straw-biochar. Zhao et al. revealed in 2018 that electrostatic interactions between biochar and waste water Animida Cloprid caused Animida Cloprid to be adsorbed onto biochar is then going to be made from the available peanut shells..

ANTIBIOTICS

Sulfonamides were first developed in the 1930s, and since then, antibiotics have been widely utilised to treat infectious diseases in both medical and agricultural settings (Lucas et al., 2016a), with global consumption ranging from 1 lakh to 2,00,000 tonnes per year. Antibiotic residues have been detected at large quantities in wastewater treatment facilities and effluent receiving waters due to the widespread use of antibiotics on a global scale (Lin et al., 2009). Factors that contribute are that 30-90 percent of antibiotics eaten are not metabolised in the human body, according to surveys, analyses, and research., and are surely excreted out into wastewater systems, (Watkinson et al., 2007), and over 50% of people have disposed off unused prescriptions improperly (Rosenblatt et al., 2009); however these issues are exacerbated by present culture of misusing antibiotics and improper over prescription (Ackerman et al., 2012). Experiments and research have demonstrated that WWTFs are effective in passively eliminating antibiotic residues from 20 to 90% (Watkinson et al., 2007) by sludge adsorption (Perini et al., 2018), natural breakdown of some antibiotics, such as penicillins (Becker et al., 2016). Cephalosporins, for example, are another type of antibiotic (Guo et al., 2015) Fluoroquinolones and tetracyclines are more resistant to natural degradation and are more likely to survive in the environment (Becker et al.,2016). As a result, for the removal of degradation-resistant, antibiotic-residues from wastewater systems and wastewater-biosolids, a more efficient, non-toxic treatment is required.. Biochar is the most promising aspect for removing antibiotics because it exhibits many sorption interactions, including hydrogen bonding, electrostatic, p-p interactions, covalent, and p-p interactions (Peng et al., 2016), as well as having a high aromaticity and hydrophobicity, allowing it to sorbaromatic, hydrophobic antibiotics (Ahmed et al., 2017). Taheran et al., in 2016 illustrated that biochar made up frompinewood waste has the capability to absorb against CTC and SMX. Shimabuku et al., in 2016 recorded eucalyptus-based biochar has a good absorbing capacity against SMS. Wang et al., in 2015 recorded his research on bamboo-based biochar that absorbed against enrofloxacin (ENR) and OFC. Oladipo and Ifebajo put their magnetic chicken bone biochar (MCB) to the test against TET in 2018.This biochar contained ferric andferrous sulfates for increasing its magnetic properties and this resulted in the removal of 98.89mg TET/g MCB after just 180 minutes.

Table no.4 Pyrolysis chars made from a variety of feedstocks for antibiotics removal

Source of Biochar	**Specific Surface Area (m2 / g)**	**Pyrolysis Temp. (^oC)**	**Antibiotics c Tested**	**Maximum Adsorptionn (mg/ g)**	**Adsorption Conditions**	**Reference**
bamboo	665.3	500	ENR, OFC	45.88+_0. 90	96 Hours, 25 o C,170 rpm pH 3-10,	Wang et al., 2015
Pinewood	852.95	525	CTC	434.8	72Hours,29 8K,150 rpm pH 1	Teheran et al., 2016
Rice husk	168	600	LVX	5	30 o C, 24 Hours, pH 8	Yi et al 2016
pinewood	312	600	LVX	7.8	30 o C, pH 6.5, 24 Hours,	Yi et al 2016
Rice husk MeOH	65.97	438.85+_ 439.85	TET	-95	298 K, 350 Hours, pH 2	Jing et al., 2014
sludge	110.0	500	GFX	19.80+_0. 40	25 o C, 96 Hours,170 rpm, pH 8.13	Yao et al., 2013
Chicken bone	328	500	TET	98.89	26 o C, 180 Mins ,pH 8.0, 150 rpm	Oladipo et al., 2018
milkvetch	203.70	700	CIP	68.9+_3.2 3	25 o C, 12 Hours, 160 rpm, pH 6	Kong et al., 2017
Coconut shell	365	500	TET	94..2	25 o C, 48 Hours,170 rpm, pH 6,	Shan et al., 2016

PATHOGENS (MICROORGANISMS)

Biochar for the elimination of microorganisms and pathogens from urban runoff, which is expected to include a large number of micro-contaminants and flows into usable surface water such as streams and lakes. This water can be used for both agricultural and domestic purposes. Irrigating crops with such contaminated water runoff lead to a serious microbial- contamination of the fruit and vegetable crops. Therefore, Biochar filters for removing unwanted microbial pollutants are being made. Perez-Mercado et al., (2019) tested and demonstrated that using a biocharfilter, >1 log10 CFU Saccharomyces cerevisiae could be recovered efficiently and successfully from diluted wastewater under situations such as on-farm irrigation. Biochar particle size is an important element in microbial recovery and elimination. Biochar particles of the smallest size (d10 = 1.4 mm) can eliminate 1 log10 CFU of bacteria. Rice-husk biochar filtration was identified by Kaetzl et al., 2019. Rice husk that has not been pyrolyzed or processed serves as a low-cost filter. Rice husk or san filters functioned and performed similarly to charcoal filters.. After that, the treated or filtered wastewater was used in a pot test for lettuce irrigation. The contamination caused by the faecal indicator bacteria was >2.5 log units, while the total recovered microbial contaminant was >2.5 log units.

ENERGY

Transfer of volatile solids/ mixes into sludge and further to biogas is the most efficient method to recover energy through the method of anaerobic digestion (AD).Moreover, Biochar enhances performance, stability and efficiency of the digestion process, and couples the thermo chemical and biological conversions in AD system. Biochar performs a number of roles like enhancing the performance of digestion process, improvising efficiency of digestion.

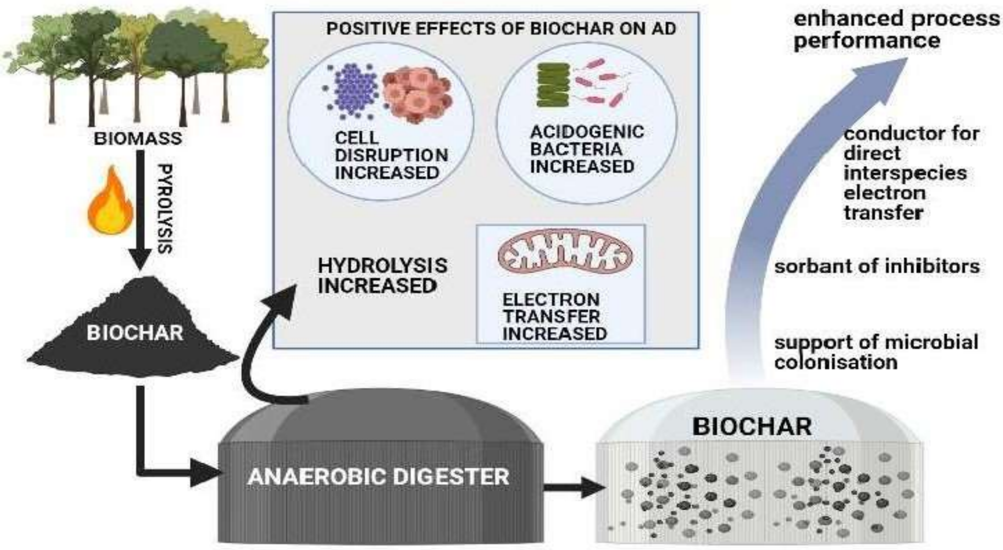

Fig. 6 energy absorption via: anaerobic digester using biochar.

Baek et al. in 2018 and Chen et .al in 2014 both these researchers provided the information that biochar is responsible for increasing electron transfer between same species and volatile, fatty acid-oxidizing bacteria as well as the hydrogenotrophic- methanogens (crucial for methane production) (Baek et al., 2018). AD goes through three phases:

1. Hydrolysis
2. Acidogenesis and Acetogenesis,
3. Methanogenesis.

The production of methane would be the final process, yet every process produces the most energy. Biochar enhanced production of methane in AD has stimulated growth of correlative microorganisms and also activated activity of the enzymes (Qui et. al 2019). Duan et al., 2019 showed that biochar has the ability to destroy cell walls of matter that is insoluble so that availability of the digested sludge can be increased. Biocharhas showed wonderful impacts in hydrolysis phase, activation and enhancement of required enzyme activity VFAs (Volatile fatty acids) is a major product of the second phase i.e acidogenesis and acetogenesis. Further it is a major precursor for the production of methane. Biochar results in high VFAs production so that the final methane concentration can be increased. The third phase, also known as the methanogenic phase, is a slow-moving phase for the entire anaerobic digestion system. Many scientists have turned their focus to modified biochar production and energy recovery after Luo et al. (2015) observed that biochar addition has shortened the length of the entire methanogenic stage while also increasing the rate of maximal methane generation.

6. PARAMETERS THAT AFFECTS ABSORPTION OF CONTAMINANTS ON BIOCHAR:

STRUCTURAL CHARACTERSTICS

The adsorbent's accessible volume of micropores limits the different sorption mechanisms of an adsorbate (Zabaniotou et al., 2008, Lowell et al., 2004). Adsorbents have holes of various sizes that are classified as micropores, mesopores, or macropores based on the width of the opening (Mosher et al., 2011). The most numerous components in biochar structure are micropores, which are also responsible for the biochar's vast surface area and high adsorptive capacity. In 2008, Zabaniotou et al. discovered that biochar pyrolyzed at high temperatures has a greater micropore volume, ranging from 50 percent to 78 percent of total pores. As a result, the size of the adsorbate is a crucial parameter for managing biochar sorption.. However, the larger the adsorbate, the greater the likelihood of obstruction at the sorption sites, the smaller the particle, the lower the mass transfer, and the higher the van der Waal forces for the adsorbate to penetrate into the adsorbent (Daifullah 1998). Adsorption rate is also influenced by the levels and types of surface functional groups present (Qambrani et al., 2017). Distribution of the functional groups on the is obtained by the composition(chemical) of feedstock, temperature and method of carbonization (Ahmed et al., 2012).

Qambrani et al.,.in 2017studied that, because of pyrolytic conditions, the - CH_2, O-H, CC=, CO=, -CH_3 surface functional groups in the biochar were altered, which promoted hydrophobic interactions. Abundance of the O and N-containing surface functional groups on biochar shows its hydrophobic nature, lower the O and N-containing surface functional groups, more will be the hydrophobic nature of biochar (Moreno et al., 2004).

TEMPERATURE

The temperature of the media in which biochar is applied has an impact on adsorption capacity. Many investigations have found that an increase in adsorption effectiveness is caused by a rise in temperature, indicating that the absorption mechanism is endothermic. Enaime et al., in 2017, reported that sorption of indigo-carmine on activated biochar made from potassium hydroxide, increases with temperature raise because of endothermic nature of sorption mechanism. Temperature increase, produces an increment in mobility of the dye and increase porosity of the char. another study done by Kizito et al., in 2015 showed the increased temperature from15 $^{\circ}$C to 45°C for adsorption of NH4 $^{+}$-N was allowed to increase adsorption efficiency. the researchers although claimed that, increasing temperature from 30 $^{\circ}$C to 45 $^{\circ}$C is good pollutant removal efficiency.

pH

Solution pH is a major factor for controlling adsorption mechanisms, by influencing, surface charge of adsorbent, speciation, ionization degree of adsorbate (Kilic et al., 2013). If solution pH gets greater than point of zero charge, deprotonation of carboxylic and phenolic along with negative charge both are present on the surface of adsorbent. At comparatively low pH, the surface functional groups like the amine possess positive charge and gets protonated, which promotes adsorption of the anions. Hu et al. in 2020 and Kizito et al. in 2015 published studies on the effect of pH on adsorption efficiency and capacity for (NH4 +-N) ammonium. The researchers discovered that lower pH (e.g., pH = 3 or 4) resulted in decreased NH4 +-N adsorption on charcoal. similarly with the original solution, increasing the pH between 4 and 8, When the pH was raised above 9, the adsorption capacity of NH4 +-N rose and then dropped (Kizito et al., 2015).

DOSAGE OF ABSORBANT

Adsorbent dosage has a major influence on adsorption system and its sorbent-sorbate equilibrium. Increased dosage of adsorbent leads to increased removal efficiency due to more availability sorption sites (Tsai et al., 2013, Chen et al., 2011). Adsorbent dosage should be optimized so that it can reach to the properties like proper removal efficiency, cost-effective process. Reduction in adsorption capacity, can be observed when the rate of dosage is in large amount, overlapping of layers of absorption could be seen, which can moreover shield the active sites on the surface of absorbent (Linville et al., 2017)

7. BIOCHAR TECHNOLOGY IN DIFFERENT WASTE WATERS.

Discussions above have shown that biochars are very much effective for the removing contaminants because of specific properties of biochars like having a large and abundant surface area and functional groups. So, biochars are increasingly becoming important for remediating pollutants in sectors like industrial and agricultural for improvement of environmental quality (Dai et al., 2017a).

INDRUSTRIAL WASTE WATER TREATMENT

The various sources that generate industrial waste water include mining, battery manufacturing industries, smelting, chemical industries, leather manufacturing, dyes, and others. This waste water mainly contains heavy metals, organic pollutants for which biochars can easily be useful. After crosslinking, the biochar and chitosan combination was cast into beads, membranes, and solutions. Furthermore, it can be used as an adsorbent to remove heavy metals from industrial wastes. The ratio of biochar to chitosan appears to impact the adsorption of certain chemicals such as arsenic, copper, lead, cadmium and heavy metals that ore can be found in industrial wastewaters (Hussain et al.,2017). Biochar prepared from bagasse, adsorbed lead from effluent generated from battery-manufacturing industry . Maximum adsorption capability reached 343 12.7 mg/g (Poonam et al., 2018). Wathukarage prepared biochar for removing crystal violet (CV) from wastewater taken from industries' that were dye-based. The CV sorption was governed by some parameters like surface area, pH value, pore volume of the biochar (Wathukarage et al., 2017). Thus, from most experiments on biochar and its application for removing pollutants from different industrial wastewaters conducted within the lab-setting, biochar can also be further utilized for future research and also for the implementation in real-world.

AGRICULTURAL WASTE WATER TREATMENT

Contamination in Agriculture is increasingly becoming serious because of the rapid development in agricultural-based industries. Day to day large amount pesticides and also toxic heavy metals are directly or indirectly discharged in the farms (Wei et al., 2018). Many scientists have utilized biochar and simultaneously modified it for the treating agricultural contamination. The pentachlorophenol (PCP) pentachlorophenol was removed from agricultural effluent using zero valent iron magnetic paper mill sludge biochar (ZVI-MBC). The ZVI-MBC adsorbs, dechlorinate PCP from PCP must be totally removed from the effluent (Devi et al., 2014). Biochars produced from rice straw and phosphoric acid have a high adsorption capacity for atrazine and imidacloprid in agricultural effluent (Mandal et al., 2017). Electrostatic interactions, surface complexation, and other adsorption processes for heavy metals in agricultural wastewater are common. ion exchange, 398 intermolecular interaction, cation-π bonding, and π-π interactions (Wei et al., 2018).

MUNICIPAL WASTEWATER TREATMENT

Biochar directly or indirectly can be used with other technologies, like biochar filters for treating municipal wastewater, which can result in recovering good amounts nitrogen and phosphorus and other nutrients (Cole et al., 2017). The combination of biochar and aluminium oxyhydroxides was used to recycle and reuse phosphorus-treated wastewater. Electrostatic attraction was used as the adsorption mechanism in this case. Phosphorus was adsorbed on the modified or engineered biochar and further can be used as fertilizer for crops (Zheng et al., 2019a). Biochar pyrolysed from waste sludge acted as a catalyst for ozonating refinery-wastewater and show comparatively a high removal rate. As biochar has surface functional carbon groups, metallic oxides and Si/O structures and also promote oxidation hydroxyl radicals and petroleum contaminants are formed (Chen et al., 2019). Biochar can be made from municipal biowaste at biofiltration and used to remediate municipal wastewater. Biochar's porous structure allows it to operate as a biofilter (Manyuchi et al., 2018). Adding biochar also increases removal rate of both hydrophilic and polar components.

STORMWATER TREATMENT

Due to advancement in urbanization, stormwater overflow has been generally concerned due to its impact on water quality (Mohanty et al., 2014). Stormwater overflow can essentially add to the debasement of regular water quality and needs treatment before release, which is essentially due to expanded convergences of metals, natural matter and organic poisons (Gray et al., 2016, Tian et al., 2016). Biofiltration and Bioretention are the processes used for treating stormwater, but purification of removed contaminants is not ideal by these systems (Lau et al., 2016, Ulrich et al., 2017). A recent experiment showed aluminum-impregnated biochar that effectively removed $As5^{+}$ and other pollutants such as Pb^{2+}, Cu^{2+}, Zn^{2+}, and $PO4^{3-}$ etc. (Liu et al., 2019a). Biochars integrated as biofilters for the removal of (BPA) bisphenol A by treating stormwater stormwater. Biochar pyrolysed from wood dust shown a comparatively high adsorption capability of BPA attribute because of high surface areas, pore volume of the biochar, also promotes the growth of Phragmites Pustralis, and also increases the removal rated of nitrogen, E. coli, phosphorus, TOC, TSS, (Ashoori et al., 2019). Generally, biochar has effectively utilized as filter media for the treatment of stormwater. Pollutant removal capacities here depends depend on the properties of biochar, characteristics pollutant, and the wastewater's aqueous chemistry (Mohanty et al., 2018).

8. FUTURE DIRECTIONS AND ENVIRONMENTAL CONCERNS

Biochar's benefit for reusing resources necessitates specific inputs or initials and produces specific outputs or finals. In resource recovery, the foundation and distribution of recommendations are critical. Consistency and assistance in resource recovery will be obtained without difficulty. For example, biochar production strategies and sources. Biochar-based recyclables, as well as resource recovery and reapplication, should be described in legal systems. Public investment and collaboration in resource recovery legislation will increase public confidence and acknowledgement of recovered objects. Biochar, in its whole, demonstrates the potential for resource recovery and reuse. With the progress of water quality monitoring, there are more opportunities for further research into wastewater-based resource recovery systems. Biochar can produce a more significant and successful implementation of the exhibition and full-scale projects with a minimal financial and ecological impact.. The long-term impact of biochar after its use, as a rising substance commonly used in water, needs more powerful and reliable data. Furthermore, biochar should be seen as an innovation as part of the recycling process rather than a substance used in resource recovery in order to achieve consistent..

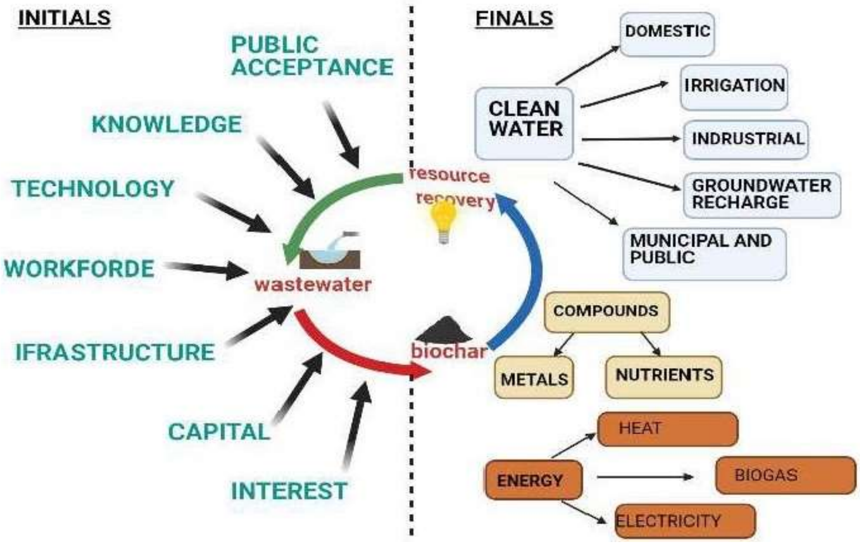

Fig. 7 Schematic view of future resource recovery with biochar and involvement of inputs.

9. OUTLOOK AND CONCLUSION

The review depicts that; biochar is a very interesting adsorbent having high stability, efficiency and has a very broad prospect for removing typical pollutants that are present in wastewater. As a cluster of investigations on biochar sorption behaviour, the sorption mechanisms are manifested. Biochar changes have also received a lot of attention based on the mechanics. Meanwhile, environmental concerns in contrast to biochar and its applications are on the basis of cost, stability, performance, sustainability and co-contaminant. Moreover, future researches are being put forward to facilitate biochar and its practical applications. Biochar also helps in decreasing bioavailability, mobility and toxicity of pollutants and isreported quite beneficial for removing the pollutants with high concentrations

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