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RECLAMATION OF PESTICIDES CONTAMINATED SOIL AND WATER USING BIOCHAR: A REVIEW ON ADSORPTION POTENTIAL OF BIOCHAR

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Review Article

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ABSTRACT

The application of agrochemicals into the environmental matrix has sluggishly degraded the quality of their original form. Pesticide consumption in the agricultural sector has been used for the quantity production of crops however, now considered as a culprit for the quality crops. Lands that once provided ample crops of good quality are now facing a case of severe damage impacting their crop quality. The prime need is to reclaim these contaminated matrices. For the same, an eco-friendly approach should be adopted. One such approach is the application of biochar for pesticide sorption. Biochar is a carbon-rich, stabilized product acquired when biomass undergoes pyrolysis at 200-650˚C. It is known for sequestration ability and mitigation of environmental contaminants. Its properties (surface area, pore size, ash contents, and functional groups) determine the potential for sorption. Biochar when modified is most effective for the sorption mechanism. For instance, rice straw biochar when treated with phosphoric acid (T-RSBC) showed stronger adsorption capacity for sorption in waste water effluent. Corn straw when doped with phosphorus functional groups was highly effective for adsorption of triazine pesticide from water. Other biochar that could remove pesticides are corn cob and corn starch. Activated coconut shell biochar showed the highest adsorption capacity for diazinon removal from water than other modified coconut shell biochar. Plant biochar (pine needle, oak wood, corn stover) having a high content of lignin have better properties such as large surface areas (112-642 m^2g^{-1}) and macropores (0.06-1.90 cm^3g^{-1}) that increase the sorption capacity of pesticides in soils than animal and cellulose-based biochar. This review paper aims to evaluate the role of biochar in the sorption of pesticides from soil and water.

Keywords: Biochar, Sorption potential, Pesticides, Reclamation.

INTRODUCTION

The demand for food is never going to be stabilized. It has been established that this demand is accelerating at an unprecedented rate. Recently, we have witnessed how development can turn into an uncontrollable disaster, which made us to change our lifestyle. However, one of the sectors that remained functioning was the agricultural sector. The production of food never stopped and stock of harvested crops saved our lives even in a pandemic. Pesticide managed to flourish as it offers beneficial attributes to the agricultural sector though it comes along with harmful impacts as well. Of all the pesticides available, organochlorines pose potential threat to human and ecosystem for their ability to persist, bioaccumulate, and bio-magnify in the environment (Juraske et al. 2007). The residue of pesticides in India is very high even though it consumes a lesser rate of pesticides (600g/hectare) than other developed countries (3000g/hectare) (Kumar et al. 2013). The exclusion of pesticide application from agricultural production practices will incur 50% loss of crops (Yavari et al. 2015). On the other hand, incorrect or excessive utilization will lead to substantial hazards. Pesticide contamination in soil and water happens due to surface runoff, leaching to groundwater, and air drifting (Meftaul et al. 2019). South-Asian countries like India, Pakistan, Srilanka, Nepal, & Bangladesh reported high levels of OCPs in the environmental matrix. In India, among

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different environmental matrices, water and soil reported most of the OCPs contamination (Ashesh et al. 2022). India marks 90000 tons of pesticide production and consumes 50000 MT. More than 98% of water resources in India are contaminated with DDT & HCH (even after the imposed ban) (Ashesh et al. 2022).

Fig. 1: Comparative diagram showing pesticide adsorption on soil amended with biochar (right) and unamended soil (left).

It is very necessary for the world to adopt strategies that are efficient in protecting the environment from pesticide's side effects (Yavari et al. 2014). Nowadays, biochar has fetched global attention as it has been reducing the bioavailability of pesticides, hence, hindering the process of bioaccumulat-ion (Yang et al. 2017). Therefore, the waste material can make all the difference. The old saying, "Lotus blooms in mud" can never go untrue. Biochar refers to carbon-rich material that is produced from pyrolysis of waste biomass (Suo et al., 2019) that can be utilized for its adsorbing properties. India generated 370 Mt of agricultural wastes per year (Ponnam et al. 2020). However, according to recent reports, it generates 500 Mt of residues annualy (Krishnaveni & Dayana 2021). Its low cost, and ability to reduce pollution makes it an efficient strategy to reduce pesticide pollution. The aim of this review is to indicate scope of the sorption potential of biochar for reclamation of pesticide contaminated soil and water.

Use of Biochar for pesticide adsorption

Burning of biomass through pyrolysis in the low/no oxygen supply in a closed system produces a by-product known as biochar. Their characteristics such as surface area, and pore volume depend upon the conditions applied during the process of pyrolysis like temperature and duration of exposure (Taha et al. 2014). Biochar is chosen for removal of pesticides because of its large surface area. Adsorption capacity of biochar is directly proportional to its surface area (Bahrum et al. 2020). However, Mondal et al. showed that biochar with lesser surface area and pore volume showed greater adsorption capacity (Mondal et al. 2017). They even treated the Rice stalk biochar (RSBC) with phosphoric acid (T-RSBC) which further reduced the surface area and pore volume resulting in increase in adsorption efficiency of atrazine and imidacloprid. Biochar possesses some of the unique properties like aromaticity, and highly carbonaceous nature. These properties together make them >2000 times effective in pesticide adsorption than soil (Kookana 2010). Biochar, when incorporated into the soil, stopped the microbial degradation of pesticides and other organic compounds. With this, it also reduces the availability to, and uptake of pesticides by plant species. Biochar prepared from agricultural wastes such as rice stalk (Liu et al. 2015; Mondal et al. 2017), corn stalk (Taha et al. 2014; Mondal et al. 2017; Suo et al. 2019), coconut shell (Baharum et al. 2020), neem waste (Ponnam et al. 2019), apricot kernel and orange peel (Abelhameed et al. 2020), wood derivatives, such as bamboo chips (Mandal et al. 2017), manures of poultry, pig, and cattle (Liu et al., 2015) have been tested for pesticide removal from water matrix in the recent past. Similarly, more examples of removal of pesticides from soil and water matrix is given in table 1.

Table 1: Adsorption percentage of biochar for pesticides.

Biochar	Pesticides	Adsorption %	Matrix	References
Coconut shell modified biochar	Diazinon	98.96	Aqueous solution of pesticides	Baharum et al. 2020
Rice straw biochar (T-RSBC)	Atrazine	58.9-89.8	Waste water	Mandal et al. 2021
	Imidacloprid	58.2-89.5		
Neem waste (Azadira-chta indica)	Bentazone	55.20	Aqueous solution of pesticides	Ponnam et al. 2019
Corn stalk biochar	Triazine	96	Polluted water	Suo et al., 2019
Wheat straw biochar	Atrazine	48	Aqueous solution of pesticides	Yang et al. 2017

Eucalyptus spp. wood chips biochar	Chlorpyrifos, Carbofuran	86-88	Soil	Yu et al. 2009
Green waste biochar (Maple, elm, oak, wood chips and barks)	Atrazine	54	Aqueous solution of pesticides	Zheng et al. 2010
Rice husk & corn stalk biochar	Phosmet	98	Water	Taha et al. 2014
	Carbaryl	90		
	Melathion	88		
Orange peel and apricot kernel biochar	Prothiofus	91.7	Water	Abelhameed et al. 2020
Pinus roxburghii/				
Fe_3O_4/ $BiVO_4$	Methylparaben	86.93	Soil	Kumar et al. 2017
Aged biochar*	Imazamox	80		Gamiz et al. 2019
	Terbuthylazine	96	Aqueous solution of pesticides	
	Picloram	83.5		

*Aged biochar- Freshly prepared biochar was kept in a mesh bag and buried in silt loam soil for 6 months prior to the experiment.

Addition of biochar in soil tend to increase the number of bacterial groups such as Alphaproteobacteria, Betaproteobacteria, Deltaproteobacteria, Gammaproteobacteria, and Rubrobacteridae (Abujabhah et al. 2016). Increase in the number of microbial communities is associated to the increase in nutrient content, organic matter, and water retention ability of the soil after ammendments (Ma et al. 2019). The microbial community present in the soil is responsible for the degradation of pesticides. The soil amended with biochar result in increased mineralization of pesticides as compared to the unamended soil (Qiu et al. 2009). Biochar addition in the soil increases the hydrolytic activity of flurorescein diacetate (FDA). The activity of FDA indicates the presence of microbial activity in soil (Chan et al. 2008). The experiment in which removal of pesticides are studied with the help biochar addition carried out in a few general steps:

- Preparation of biochar through pyrolysis.
- Examination of prepared biochar's characteristics through scanning electron microscope (SEM), BET surface area analysis, and energy dispersive X-ray.
- Examination of pesticide adsorption on biochar through batch technique.

Adsorption mechanism

Soil-pesticide adsorption occurs due to the soil organic carbon (SOC). SOC consists of soft gel like and hard parts. Soft part of the SOC is amorphous, rubber like matrix while the latter that is hard parts are condensed glass like matrix. Pesticides adsorb differently into these two matrices of SOC. The extent to which pesticides can adsorb to soil depends upon its aromaticity. Therefore, the high aromatic nature of biochar makes them stronger than soils (Figure 1) (Kookana 2010). Generally, the sorption process includes three phases. The first one is an instantaneous adsorption phase, followed by slow adsorption phase, which is then followed by the last phase known as equilibrium phase (Liu et al. 2015). In the second phase, the adsorption capacity decreases due to blocking of mesopores and micropores (Figure 2). Now, after the sorption of pesticides, it has to be desorbed to be able to attack on target pests. The further investigation on sorption-desorption of pesticides from biochar has poor evidence (Kookana 2010).

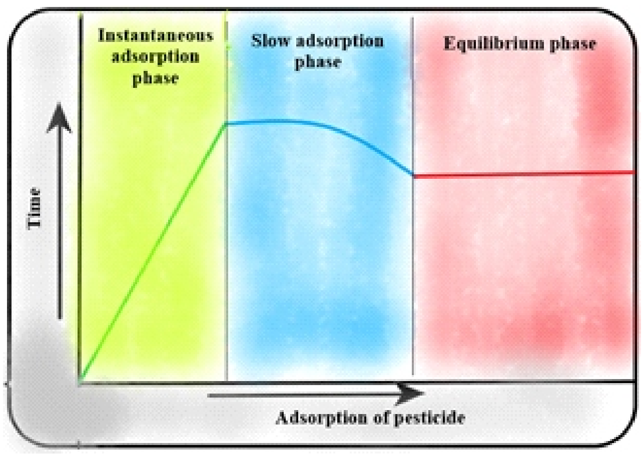

Figure 2. Graph showing phases of adsorption of pesticides on biochar surface.

Factors affecting sorption process

The process of sorption of pesticide to biochar is defined as a physico-chemical shift by which the pesticides can be shifted across solid and the aqueous phase (Yavari et al. 2015). Adsorption of pesticide to biochar is affected by factors such as biochar properties. For example, surface area, CEC, pores diameter, and attached functional groups. The other factors that affect the sorption process are pesticides' properties such as, molecular structure and their size, acidic and alkaline nature, solubility, hydrophobicity, polarity, and environmental conditions such as, moisture, pH, temperature, wind, and light (Yavari et al. 2015). Some of the chemical domains that influence sorption capacity of biochar are H-bonding, covalent bonding, and cation bridging (Gamiz et al. 2019). Apart from this, a few other factors such as aromaticity (Mandal et al. 2017), aging of biochar (Gamiz et al. 2019), sorbent dosage, and presence of other pesticides (Mandal et al. 2021). Some of the factors that affect sorption potential of biochar are:

A. **Temperature:** Adsorption of pesticide onto biochar is favorable at higher temperatures. The process of adsorption is endothermic. Increase in temperature increases the active sites and collision frequency on biochar's surface (Srivastava et al. 2011).

B. **pH:** Low pH favors the adsorption kinetics (Zheng et al. 2010). Biochar which are acidic in nature would have the higher ability to adsorb pesticides. The sorption coefficients of pesticides reduce with an increase in the value of pH. The acidic properties of media would increase the interaction between pesticides (cations) and biochar (anionic surface) through electrostatic interaction that would in turn enhance the sorption capacity of biochar for pesticides.

C. **Surface area, pore volume, and number:** In general, a large number of pores (Yang et al. 2017), larger surface areas, and higher volumes of pores (Taha et al. 2014) are evident to increase the sorption potential of biochar.

CONCLUSIONS

This review highlights the role of biochar in adsorption of pesticides from soil and water. The findings from the review shows that only little research has been conducted in the adsorption of pesticides from water and a very few were researched on soil. By altering the soil and water environment with the addition of biochar, the menace of pesticide pollution can be solved. In comparison to unamended soil, amended soil with biochar has higher potential to reduce the pesticide availability for plant uptake and prevent its bioaccumulation and toxicity in further trophic levels. Biochar application in the soil increases the diversity and number of microbial community present in the soil. The presence of microbial community felicitates biodegradation of pesticides present in soil. Many areas still have dearth of understanding and information which require more research. For instance,

1. Various types of persistent organic pollutants such as OCPs are not researched for its reduction from soil and water.
2. There is limited data available for the matrices such as water and soil.
3. Majority of the research is carried out as experiments in the confined laboratories but the data are not available for field research and still need extensive study.
4. This review indicates that most of the research were carried out for biochar prepared from corn and rice. Other biochar that can be prepared from number of agricultural wastes are needed to be explore for its potential to remove pesticides.

REFERENCES

1. **Abdelhameed, R. M., Abdel-Gawad, H., & Hegazi, B.** (2020). Effective adsorption of prothiofos (O-2, 4-dichlorophenyl O-ethyl S-propyl phosphorodithioate) from water using activated agricultural waste microstructure. *Journal of Environmental Chemical Engineering*, *8*(3), 103768.
2. **Ashesh, A., Singh, S., Devi, N.L., & Yadav, I.C.** (2022). Organochlorine pesticides in multi-environmental matrices of India: A comprehensive review on characteristics, occurrence, and analytical methods. Microchemical Journal, 177.
3. **Baharum, N. A., Nasir, H. M., Ishak, M. Y., Isa, N. M., Hassan, M. A., & Aris, A. Z.** (2020). Highly efficient removal of diazinon pesticide from aqueous solutions by using coconut shell-modified biochar. *Arabian Journal of Chemistry*, *13*(7), 6106-6121.
4. **Gámiz, B., Velarde, P., Spokas, K. A., Celis, R., & Cox, L.** (2019). Changes in sorption and bioavailability of herbicides in soil amended with fresh and aged biochar. *Geoderma*, *337*, 341-349.
5. **Juraske, R., Antón, A., Castells, F., & Huijbregts, M. A.** (2007). PestScreen: A screening approach for scoring and ranking pesticides by their environmental and toxicological concern. *Environment International*, *33*(7), 886-893.
6. **Kookana, R. S.** (2010). The role of biochar in modifying the environmental fate, bioavailability, and efficacy of pesticides in soils: a review. *Soil Research*, *48*(7), 627-637.

7. **Krishnaveni, A. S. & Dayana K.** (2021). Crop Residue Management- A Review. Int. J. Curr. Microbiol. App. Sci. 10(03): 28-33.

8. **Kumar, A., Sharma, G., Naushad, M., Kumar, A., Kalia, S., Guo, C., & Mola, G. T.** (2017). Facile hetero-assembly of superparamagnetic Fe3O4/BiVO4 stacked on biochar for solar photo-degradation of methyl paraben and pesticide removal from soil. *Journal of Photochemistry and Photobiology A: Chemistry, 337*, 118-131.

9. **Kumar, S., Sharma, A. K., Rawat, S. S., Jain, D. K., & Ghosh, S.** (2013). Use of pesticides in agriculture and livestock animals and its impact on environment of India. *Asian Journal of Environmental Science*, *8*(1), 51-57.

10. **Liu, N., Charrua, A. B., Weng, C. H., Yuan, X., & Ding, F.** (2015). Characterization of biochars derived from agriculture wastes and their adsorptive removal of atrazine from aqueous solution: A comparative study. *Bioresource technology*, *198*, 55-62.

11. **Mandal, A., Kumar, A., & Singh, N.** (2021). Sorption mechanisms of pesticides removal from effluent matrix using biochar: Conclusions from molecular modelling studies validated by single-, binary and ternary solute experiments. *Journal of Environmental Management*, *295*, 113104.

12. **Mandal, A., Singh, N., & Purakayastha, T. J.** (2017). Characterization of pesticide sorption behaviour of slow pyrolysis biochars as low cost adsorbent for atrazine and imidacloprid removal. *Science of the Total Environment*, *577*, 376-385.

13. **Meftaul, I. M., Venkateswarlu, K., Dharmarajan, R., Annamalai, P., & Megharaj, M.** (2020). Pesticides in the urban environment: A potential threat that knocks at the door. *Science of the Total Environment*, *711*, 134612.

14. **Ponnam, V., Katari, N. K., Mandapati, R. N., Nannapaneni, S., Tondepu, S., & Jonnalagadda, S. B.** (2020). Efficacy of biochar in removal of organic pesticide, Bentazone from watershed systems. *Journal of Environmental Science and Health, Part B*, *55*(4), 396-405.

15. **Srivastava, V., Weng, C. H., Singh, V. K., & Sharma, Y. C.** (2011). Adsorption of nickel ions from aqueous solutions by nano alumina: kinetic, mass transfer, and equilibrium studies. *Journal of Chemical & Engineering Data*, *56*(4), 1414-1422.

16. **Suo, F., You, X., Ma, Y., & Li, Y.** (2019). Rapid removal of triazine pesticides by P doped biochar and the adsorption mechanism. *Chemosphere*, *235*, 918-925.

17. **Taha, S. M., Amer, M. E., Elmarsafy, A. E., & Elkady, M. Y.** (2014). Adsorption of 15 different pesticides on untreated and phosphoric acid treated biochar and charcoal from water. *Journal of Environmental Chemical Engineering*, *2*(4), 2013-2025.

18. **Yang, F., Sun, L., Xie, W., Jiang, Q., Gao, Y., Zhang, W., & Zhang, Y.** (2017). Nitrogen-functionalization biochars derived from wheat straws via molten salt synthesis: An efficient adsorbent for atrazine removal. *Science of the Total Environment*, *607*, 1391-1399.

19. **Yang, F., Sun, L., Xie, W., Jiang, Q., Gao, Y., Zhang, W., & Zhang, Y.** (2017). Nitrogen-functionalization biochars derived from wheat straws via molten salt synthesis: An efficient adsorbent for atrazine removal. *Science of the Total Environment*, *607*, 1391-1399.

20. **Yavari, S., Malakahmad, A., & Sapari, N. B.** (2015). Biochar efficiency in pesticides sorption as a function of production variables—a review. *Environmental Science and Pollution Research*, *22*(18), 13824-13841.

21. **Yu, X. Y., Ying, G. G., & Kookana, R. S.** (2009). Reduced plant uptake of pesticides with biochar additions to soil. *Chemosphere*, *76*(5), 665-671.

22. **Zheng, W., Guo, M., Chow, T., Bennett, D. N., & Rajagopalan, N.** (2010). Sorption properties of greenwaste biochar for two triazine pesticides. *Journal of hazardous materials*, *181*(1-3), 121-126.

23. **Chan, Y.K., Van, Z. L., Meszaros, I., Downie, A., & Joseph, S.** (2008). Using poultry litter biochars as soil amendments. *Aust J Soil Res* 46:437–444

24. **Abujabhah, I.S., Bound, S.A., Doyle, R., Bowman, J.P.** (2016). Effects of biochar and compost amendments on soil physico-chemical properties and the total community within a temperate agricultural soil. *Appl Soil Ecol* 98:243–253.

25. **Ma, H., Egamberdieva, D., Wirth, S., Li, Q., Omari, R. A., Hou, M., & Bellingrath-Kimura, S. D.** (2019). Effect of biochar and irrigation on the interrelationships among soybean growth, root nodulation, plant P uptake, and soil nutrients in a sandy feld. Sustainability 11(23):6542.

26. **Qiu, Y., Pang, H., Zhou, Z., Zhang, P., Feng, & Sheng, D.G.** (2009). Competitive biodegrada-tion of dichlobenil and atrazine coexisting in soil amended with a char and citrate. *Environ Pollut* 157:2964–2969.