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Environmental Significance of Humic Substances

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SUMMARY

The bold label of humic substances (HS) encircles recalcitrant autochthonous as well as terrestrial organic matter prevalent in soil and aquatic ecosystem, accounting for about 50 to 80% of the organic carbon of soil, natural water and bottom sediments. HS are recognized in modulating plant physiological responses, improving soil structure in hand with soil fertility by promptinguptake of nutrients as well as root architecture. Interactions of HS with environmental chemicals reflect an enhancement in biotic and abiotic degradation of pesticides, phenols and polyaromatic hydrocarbons (PAH) in terrestrial and aquatic ecosystems. The characteristics of humic substances encircling high adsorption capacity, remarkable ion exchange capacity in addition to environmental compatibility offer their feasibility in industry, agriculture, environmental and biomedicine applicability.

INTRODUCTION

Humic substances (HS) are complex mixtures of naturally occurring, high-molecular organic compounds that are created when plant and animal remains decompose in the presence of microorganisms and abiotic environmental factors. The commonly accepted categorization of HS into humin—non-recoverable residue, insoluble in either alkalis or acids; humic acids—HS fraction, soluble in alkalis but insoluble in acids (at pH 2); and fulvic acids—HS fraction, soluble in both alkalis and acids.The term "humic substances" encases both humic and fulvic acids. Humic acids are the most reactive and mobile part of HS, and they incur a substantial part in biochemical and chemical ecosystem processes.The carboxyl, phenolic, alcoholic, carbonyl, amino, and sulfhydryl groups are the most significant functional groups in HS; the dominance of the carboxyl groups contributes to the acidic nature of HS. The biomolecules sugars, fatty acids, polypeptides, and amino acids all have structures that are influenced by the functional groups of HS that have been acknowledged.

Humic substances are known to offer an instrumental part in aquatic and ecosystems. Humic substances have an impact on the transport and degradation of xenobiotics and organic chemicals with natural origins as well as the chemistry, cycling, and bioavailability of chemical elements in both terrestrial and aquatic systems.The mineralization of soil organic matter and discharge of carbon against humification processes could have a significant impact on carbon capture and stabilisation, and as a result, the global climate change. Humic substances exhibit the potential to influence the uptake of contaminants by plants and/or their leaching into groundwater.Humic substances are a significant source of organic carbon in aqueous systems, where they have a long-term impact on the physical and chemical characteristics of waters and can serve as the most significant natural neutralising agents there, for example by promoting the biotransformation of xenobiotics.On the short term basis, the possess the ability to control the bio-concentration and toxicity of heavy metals and xenobiotics as well as serve as a source of organic nutrients.

Environmental issues addressed by humic substances (HS)

The two primary complementary effects of HS on aquatic systems have been identified as the cause of its positive environmental effects: (1) the HS imprints that are a result of their prioractivities on the characteristics of aqueous solutions. These effects connote to the indirect effects and chiefly arise from the knack of HS to create stable natural chelates in hand with themetal complexes in soil and (2) the HS imprints that arise from the direct interaction of HS with the cell membranes of living organisms. These effects connote tothe direct effects and perturb the growth of living organisms viaintricateweb of signaling pathways controlled bychief plant hormones and effectors encompassing auxin,cytokinin, ethylene, abscisic acid, nitric oxide and reactive oxygen species.The discussion of the indirect effects of HS in ecosystems has mainly centred on the indirect effects of HS on organisms, such as the control of nutrients and heavy metals, as well as the modulation of the toxicity of pesticides and other xenobiotics.

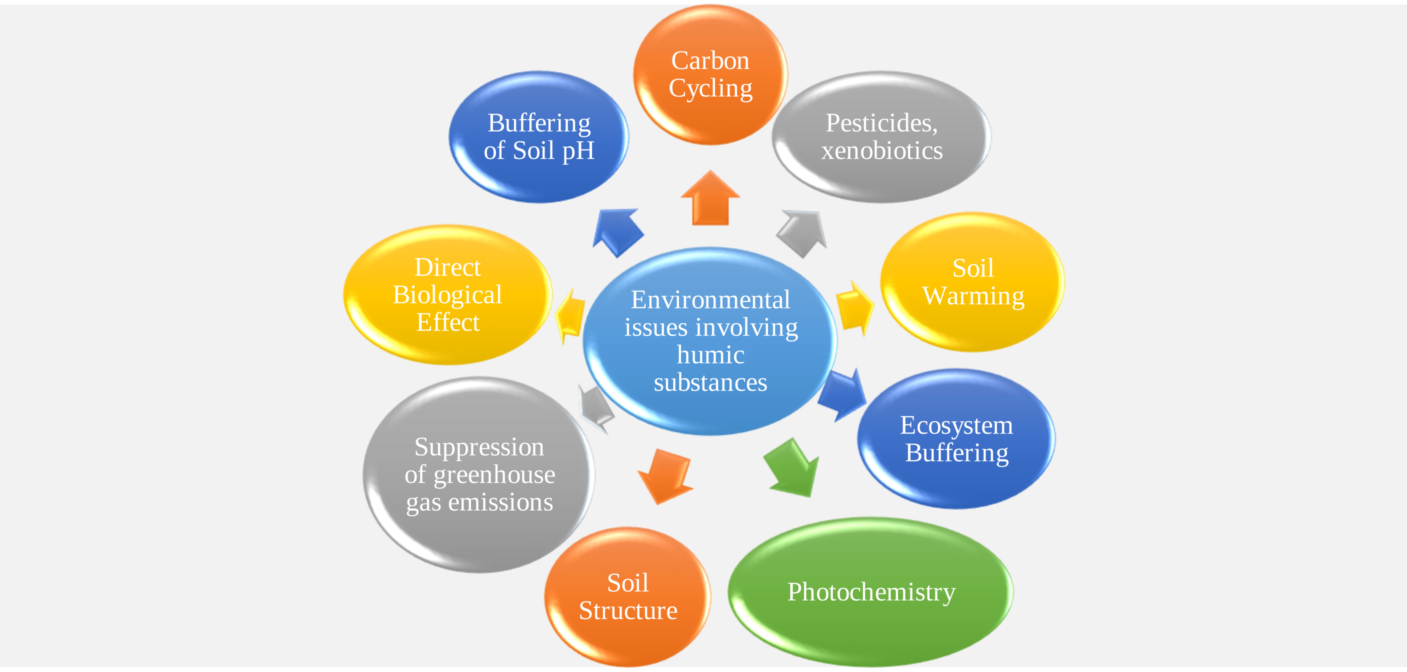

Figure 1: Environmental significance of humic substances

Carbon Cycling

Photochemical degradation of dissolved organic matter crafts an influential part in carbon cycling with regard to natural water, whether directly through photochemical assembly of volatile carbon species or indirectly via the CO_2production as a result of sequential photochemical or biological oxidation etc**.**the alteration in their molecular structure and causing the mineralization of organic carbon to CO_2, humic substances' photochemical reactivity paysto the global carbon cycle and has an impact on the toxicity, mobility, and bioavailability of contaminants.

Pesticides, xenobiotics

Humic substances act as a mediator in the degradation or inactivation of toxic substances.Toxic substances like aflatoxins, nicotine, antibiotics, shallots, and the majority of organic pesticides are either stabilised by soil humic substances or are helped to degrade by them.Not all of the carbon in these toxins is released as CO_2 during the microbial degradation process. The intricate polymers of humic substances stabilise and integrate a part of the aforesaid toxic molecules, predominantly the aromatic ring compounds.Pesticides and other toxic substances are lingered to and rendered inactive by electrically charged sites found on the surfaces of humic substances.Clinging to water-soluble, low-molecular weight humic substances upsurges the mobility of organic pollutants in soil and causes them to leach, binding to high-molecular weight humic substances results in non-extractable residues.Water-soluble pollutants that are present in the leachate can be slowly released from their soil-bound form to create free water-soluble conversion products by low-molecular weight humic material.

Ecosystem Buffering

The leaching of trace minerals into the soil is reduced by electrostatic attraction. Humic substances have electrically charged sites that help them dissolve and bind trace minerals.These organic acids cause the dissolution of primary as well as secondary minerals in the soil by forming organometallic claws, eventually enhancing their accessibility to plant roots. Chelation reduces the toxicity of plant nutrients like iron (Fe), copper (Cu), zinc (Zn), magnesium (Mg), manganese (Mn), and calcium (Ca) as cations, prevents leaching, and speeds up plant root uptake.The root surface is replenished with depleted nutrients owing to the chelates' carrier mechanism. The mass flow pertaining to micronutrient mineral elements to plant roots is also perked up by the chelation process. The availability of harmful heavy metals for plant uptake, such as mercury (Hg), lead (Pb), and cadmium (Cd), decreases as they are chelated.When the soils lack enough humic substances for buffering, direct applications of metallic salts, such as iron sulphate, copper sulphate, and zinc sulphate, to correct trace element deficiencies can result in serious issues. Applying trace minerals in organic chelates is recommended, ideally using humic acids (HAs) and fulvic additions (FAs).

Soil Warming

Humic substances aid in the stabilization of soil temperature and water evaporation rate. Specifically, during times of rapid climatic changes, such as cold spells or heat waves, the insulating qualities of humic substances contribute to the maintenance of a more constant soil temperature.Humic substances stabilise temperature fluctuations and bind water, making it less likely for soil moisture to escape into the atmosphere.

Buffering of Soil pH

Humic substances are recognized in buffering soil pH and liberation of carbon dioxide. Humic compounds have the ability to reduce the pH (hydrogen ion) content of soil.Both acidic and alkaline soils can be neutralised, and once the soil has been neutralised, many trace elements that were previously bound in the soil and inaccessible to plant roots due to acidic or alkaline conditions can now be accessed by the roots of plants.Additionally, humic substances allow soil-based calcium carbonates to release carbon dioxide (CO_2). The plant may absorb the released CO2 or it may create carbonic acids. When carbonic acids interact with soil minerals, plant nutrients are released.

Direct biological effect

Humic substances aid in the stabilization and inactivation of soil enzymes through covalent bonding. Following stabilization, these enzymes are rendered less susceptible to microbial degradation. The enzyme activity is drastically reduced or completely eliminated after it has been stabilised and bound to the humic substances.The processes used to stabilise enzymes aid in limiting potential plant pathogen activity. The pathogens' enzymes bind to humic substances as the potential plant pathogen releases enzymes intended to weaken the plant's defences. Consequently,the potential host plants cannot be invaded by the pathogens.

Suppression of greenhouse gas emissions

The role of HS in suppression of methanogenesis owes to the anaerobic microbial transformation of halogenated organic pollutants towards CO_2 production over CH_4 generation this conversion is accredited to two mechanisms encircling the higher thermodynamic viability of oxidation regarding organic compounds coupled to quinones reduction in contrast to methanogenesis while on the other hand,Some methanogenic archaea have the ability to change their metabolic pathway from methanogenesis to quinone reduction.Additionally, by supporting the oxidation of sulphide (HS), the final byproduct of sulphate (SO_4^{2-}) reducing processes, HS can also increase the CO_2:CH_4 ratio in ecosystems by promoting the recycling of essential elements like sulphur (S) (SR). The recycling of various partially oxidised forms of sulphur, sulfate-reducing bacteria (SRB) would continue to function and outcompete methanogenesis.

Soil Structure

Humic substances comprise the principle components of a friable soil structure. The main ingredients in soil aggregation are myriad of humic substances that contain carbon. To create soil aggregates, humic substances and complex carbohydrates made by bacteria are combined with clay and silt.Colloidal complexes of humus-clay and humus silt aggregates are created as the humic substances become closely linked to the soil's mineral component. Electrical processes that elevate the cohesive forces direct to the attraction between very fine soil particles and clay components which aftermaths results in the formation of these aggregates.The tilth and number of porous openings in soils with a good crumb structure have improved in debt of enhanced aggregate formation as well as stability. These pores enable greater water infiltration as well as gas exchange with the atmosphere.

Photochemistry

The presence of HS in natural waters can have a variety of effects on the photolysis of aquatic organic contaminants. Most solar energy is absorbed by humic substances between 300 and 500 nm.In this region, the absorption of radiation can start a variety of photochemical reactions that result in the production of peroxy and hydroxyl radicals, hydrated electrons, hydrogen peroxide, singlet oxygen, and superoxide.These chemical types encourage redox processes. HS function as sensitizers of singlet oxygen (O_2). Other reactive species, such as hydroxyl radicals, HO, reactive triplet states, superoxide radical anions, O_2, hydrated electrons, and hydrogen peroxide, are also produced as a result of the photolysis of HS. In addition, the formation of SO_4, CO_3, Cl/Cl_2, and H_2PO_4/HPO_4/PO_4 radicals, respectively, results from the scavenging of HO by the ions of sulphate, carbonate, chloride, and phosphate that are also present in natural waters. The majority of these species start chemical reactions that target and ultimately eliminate organic components, giving the water sources a way to self-cleanse.

Table 1: Significance of humic substances in relation to environmental issues

Issue	Role of Humic Substances
Carbon cycling	Major C pool, transformations, transport and accumulation
Light penetration into waters	Absorption and attenuation of light by humic chromophores
Soil warming	Absorption of solar radiation by soil humic matter
Soil and water acidification	Binding of protons, aluminium and base cations in soils and water
Nutrient source	Reservoir of carbon, nitrogen, phosphorous, sulphur and chlorine
Nutrient control	Binding of iron and phosphate
Microbial metabolism	Substrate for microbes
Weathering	Enhancement of mineral dissolution rate
Soil formation (podzolisation)	Translocation of dissolved humic substances and associated metals (Al, Fe)
Properties of fine sediments	Adsorption at surfaces and alteration of colloidal properties
Soil structure	Aggregation effect on soil minerals solids
Photochemistry	Mediation of light-driven reactions
Heavy metals	Binding, transport, influence on bioavailability, redox reactions
Pesticides, xenobiotics	Binding, transport, influence on bioavailability
Radioactive waste disposal	Binding and transport of radionuclide ions in groundwaters
Ecosystem buffering	Control of proton and metal ions concentrations, persistence
Direct biological effect	Uptake and direct interaction with living organisms

CONCLUSION

Humic substances exhibit a wide array of agro-environmental applications owing to their constructive part in up surging the soil fertility, tempering plant physiological responses and regulating the pollutant accessibility across different environment ecosystems.The significance of humic substances as the ideal eco-friendly natural product for ecological intensification of terrestrial environments is perked up by these positive roles as well as the current global challenges oriented for meeting safe food demand maximization in a sustainable manner.However, the investigations at finer scale to assess the molecular boxes and signal trajectories entangled in the intersection of humic substances and different tropic levels demand an accomplishment in the upcoming epoch.

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