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Water Hyacinth: AResource for Sustainable Products

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***Abstract*:*Eichhornia crassipes* (water hyacinth) is a vegetation that grows anywhere in standing water such as rivers, lakes etc., and found all over the world. It is often regarded as a dangerous weed due to its quick reproduction, reduction of nutrients and oxygen in water bodies, and significant disruption of the growth of flora and animals. Cleaning up water bodies that have water hyacinth infestations can frequently be challenging due to the plant's high rates of regeneration, survival, and growth. These qualities of water hyacinth can be seen favorably, nevertheless. Hyacinth has been studied for its potential as a heavy metal, water pollution, and other contaminant absorber. Even though water hyacinth stems and leaves have been used as absorbents in numerous research, the plant also has some novel and unusual uses. Water hyacinth is valuable in the development of supercapacitors, the manufacturing of ethanol, and the enhancement of plant and animal immunological resistance. This paper gives a review on several water hyacinth products that can be obtained, highlighting how this invasive species can be used to produce sustainable materials.**

***Keywords*:Water hyacinth, Invasive, Renewable resource, Bio-products**

I. Introduction

The monocotyledon Water hyacinth belongs to the family Pontederiaceae. Native to the Amazon Basin of South America, it is a perennial herbaceous aquatic plant that floats freely. A German naturalist C. Von Martius discovered it in 1823 while researching the Brazilian flora. The plant has grown globally since the late 1800s. This invasive plant originated in the Amazon and has since rapidly colonized other both tropics and subtropics countries in Latin America, Africa, The Caribbean, The Pacific, and Southeast Asia. This invasive weed has affected substantial freshwater bodies, wetland and marshlands regions in Middle East and Africa, claimed by Navarro and Phiri (2000). Large populations of water hyacinths are currently found in more than 50 tropical and subtropical nations. This plant species poses a significant concern to the environment and people due to its capacity to establish dense mats with more than two million plants per hectare (Rakotoarisoa et al., 2016; Rakotoarisoa, T. F. 2017).Millions of riparian populations rely on water bodies for their livelihoods, and water hyacinth causes significant environmental and economic problems for them. It has also become another barrier to growth. This is a result of the weed's effects on hydropower production, access to water supply, transportation,irrigation, fishing, water level, and the quick reproduction of pathogens (Dersseh et al., 2019).

To control the water hyacinth, a variety of approaches (manual, mechanical, chemical, and biological) are utilized worldwide. Controls, on the other hand, would need time and energy, as well as being costly and environmentally unfriendly. These practices may have detrimental effects on both the environment and people. The economical usage of the plant thus represents an alternate form of control. This facility is currently used in the production of handicrafts, biogas, fertilizers, fodder, furniture, paper and briquettes as well as the phytoremediation of industrial wastewater. However, the application of water hyacinth is restricted in underdeveloped and remote areas of developing nations because a lack of electricity and technology as well as generally poor infrastructure (Rakotoarisoa et al., 2016).

Fig.1: Bloom of water hyacinth

Understanding the possible use of water hyacinth as a different bio-products and dispelling the myth that it is a weed would be made easier by showing how it can be used in a range of ways. The objective of this analysis is to give a summary of the many uses for water hyacinth that will help realize its distinctive qualities and potential.

Causes of Rapid Water Hyacinth Expansion

The water hyacinth can survive in a range of habitats, including tropical, subtropical, warm temperate, and rainforest climates. The environment and the water body are the two key factors that influence how quickly the water hyacinth reproduces. The primary determinants of water hyacinth growth include temperature, sun shadow, salinity, eutrophication, disturbance, pH, and reproductive systems. The ideal conditions include shallow, quiet water, sediment that has been deposited over the top of the bed that is rich in organic matter, and the presence of crucial nutrients like phosphorus and nitrogen. The ideal temperature range for the growth of water hyacinths, according to Gaikwad and Gavande (2017), is between 28°C and 30°C. Because the invasive weed's root system is unable to absorb enough nutrients for general growth, sunlight is essential for photosynthesis. 2% salt in the water is the ideal salinity level for water hyacinth. Because of their potential to flush away weed downstream, flooding, waves, and currents are the key factors that upset the stability of the weed. The most common nutrients in water bodies that help this invasive weed grow faster are nitrates, phosphates, and sulphates. These nutrients may have been introduced to the environment through nutrient-polluted water from nearby residential areas, industrial regions, and agricultural fields. Growth of the plant is also influenced by its reproductive system. Water hyacinth can quickly regenerate from just the stem fragments. Before germination occurs after six months, the seeds can survive in the soil for more than 15 years. (Dersseh et al., 2019; Rakotoarisoa, 2017).

Environmental Impacts of Water Hyacinth

The effects of water hyacinth on the economy, environment, and public health are detrimental. Inability to acquire pure water, a rise in the frequency of diseases caused by water contamination, movement within the community and interpersonal dispute, and challenges in discovering water sources are some of the social repercussions. A deterioration in fish production and quality, reduction in transportation of water, obstruction of turbines and tunnels, a reduction in generation of hydropower, obstruction of irrigation channels, and a downturn in tourism are only a few of economic repercussions of water hyacinth. The most significant environmental effects include a drop in water quality, enhanced evapotranspiration causes a water loss, flooding, siltation, and a decrease in aquatic species. The weed reduces water flow via irrigation channels by 40% to 95%. The weed harms hydropower plant generators and water coolers, it has been reported to cause a loss of electrical output of up to 15 MW (Mbula, 2016). Some repercussions of this bothersome plant on fisheries comprise the development of invasive weed, decreasing biodiversity, destroying fish habitats, disrupting food chains, and contaminating the food chain. Destruction of fish habitat is a result of deoxygenation, turbidity, sedimentation, eutrophication, and the development of aquatic weeds. The quality of the water is significantly impacted by water hyacinth. Water hyacinths decrease water clarity as well as heavy metals, dissolved oxygen, phosphorus, nitrogen, and other pollutants. In comparison to areas without an infestation, water bodies with a water hyacinth infestation exhibit higher turbidity, more chlorophyll-a, more COD, less dissolved oxygen, fewer nitrates, and low pH. Due to its huge surface area, it increases evapotranspiration rates, which alters the hydrologic equilibrium of bodies of water (Dersseh et al., 2019).

The Necessity of using Water Hyacinth as a Sustainable Product

Mostly water hyacinth aquatic plant removal procedures, including mechanical, artificial, chemical, and biological are merely temporary fixes. However, the reality is this water hyacinth issue cannot be completely resolved. Because all these techniques were only utilized to remove the plants at specific times, the daughter plants eventually formed a group and effectively covered the water bodies. Therefore, the only way to utilize these plants is in other ways. Because of their increased productivity and biodegradable qualities, all researchers are currently focusing on this natural aquatic plant. In addition, researchers are currently working on their projects and aiming to finish their research on the water hyacinth plant all over the world. These plants are mostly utilized in the production of biofuels, biogas, mushrooms, natural fibre composites, particularly biocomposites, bio-fertilizers, raw materials for handicrafts, and many other products (Ajithram et al., 2021).

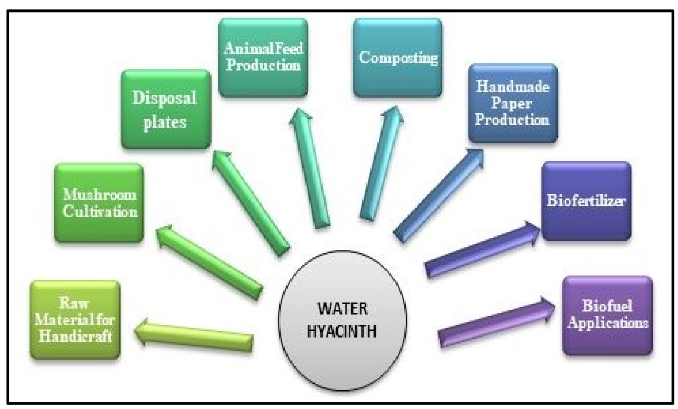

Fig. 2: Sustainable bio-products of Water hyacinth

Raw Material for Handicrafts

A variety of handicrafts, including large and tiny caps, shopping bags, wallets, sandals, and mats, can be made from dried water hyacinth stems. According to a 2016 study by Rakotoarisoa et al., water hyacinth handicrafts in Madagascar might be sold for three times as much as the market price of local papyrus handicrafts while taking up one-third less time to produce. Government assistance is needed to improve managerial and marketing skills, access to funding, and market research to support this effort.

Fig 3: Handicrafts made from *Eicchornia*

Mushroom Cultivation

An effective method of producing oyster mushrooms has been tested by Mukhopadhyay (2020), using invasive aquatic weed water hyacinth as a base in various ratios with rice straw (RS) (1:1, 1:2, and 2:1). With a 1:1 combination (RS + WH 1:1), mushroom production rises significantly, especially after the first flushing. The nutritional composition of rice straw-grown oyster mushrooms or rice straw that has been boosted with water hyacinth (1:1) did not vary significantly. Toxic substances (Pb, Cd, As) and minerals (Fe, Cu, Zn) did not assemble at a toxic level despite passing from the RS + WH (1:1) substrate to the mushrooms. The findings of this study suggested that mixer of water hyacinth weed biomass and rice straw could be used as a replacement substrate for *Pleurotus species* cultivation to lower the cost of producing protein-rich oyster mushrooms and to environmentally friendly reuse the massive amount of water hyacinth. (Mukhopadhyay et al., 2020).

Chen et al. (2010), examined the success of growing*Pleurotusgeesteranus* on substrates with various amounts of water hyacinth that had been crushed before being dipped in biogas from a pig farm and dried. For making the mushroom-growing medium, water hyacinth material was used in place of sawdust. We evaluated the yield, heavy metal, and amino acid content of mushroom fruiting bodies. When the ratios of water hyacinth and sawdust in the medium were equivalent, the mushrooms across the eight treatment groups produced the highest yield and most amino acids. According to the restrictions outlined by China's food hygiene and safety legislation for edible mushrooms, most of the mushroom samples did not include levels of heavy metals that were higher than the maximum allowable levels of Hg, Pb, and Cd. The suggested water hyacinth waste utilization may be advantageous to the environment in several ways, including forest protection by lowering the need for natural wood for mushroom cultivation.

Disposal Plates

To create strong, biodegradable plates and bowls, water hyacinth leaves can be compressed together in a compression molding machine using the right mold model. By employing this technique, hyacinth weeds can be transformed into bio plates (Ajithram et al., 2021). Consequently, these eco-friendly plates can be used in place of plastic ones.

Fig 4: Disposable Plates

Animal Feed Production

Chang et al. (2016) discovered that after receiving various treatments, prawns fed water hyacinth shown a noticeably enhanced immune response and sickness resistance. Because, it contains necessary amino acids like methionine and lysine as well as 4.7% fat and a crude protein content of up to 12.4%, water hyacinth was the palatable plant for animal diet. After 4 months, compared to the control, prawns fed hyacinth had a survival rate that was up to 77.7% higher. Additionally, several non-immuno-specific reactions had grown dramatically, including total hemoglobin, various hemoglobin counts, phenol oxidase activity, etc. Hyacinths are said to be good for usage as prawn feed due to their straightforward treatment process, improved immunological resistance, and ability to survive (Chang et al., 2016).

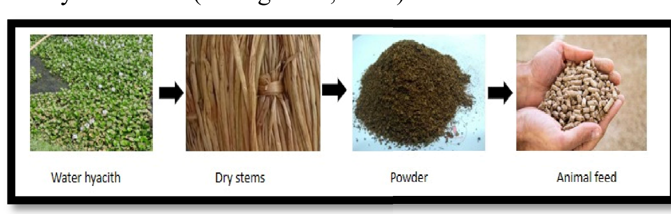

Fig. 5: Animal feed production

Raw Materials for Handmade Paper Production

Islam et al. 2021, explored the viability of using water hyacinth as a raw material to produce handmade paper and compost in Bangladesh. Water hyacinth was potash pulped using potassium hydroxide with varied alkali concentrations (8-12%) and liquid to solid ratio of 7:1 for two hours at 145 °C. Hydrogen peroxide (H2O2) was used to bleach the pulp, and the brightness, tear, and tensile index of bleached and unbleached pulps were compared using the appropriate TAPPI criteria. Compost was created by combining the produced black liquor with water hyacinth and kitchen biodegradable garbage. Indicating a considerable impact of bleaching on the quality of WH paper, the brightness, tear index, and tensile index of bleached hand sheets were found to be 37.2%, 6.79 m. Nm^2/g and 49.2 N m/g, respectively. The potassium and nitrogen content of the compost were dramatically raised by the addition of black liquor. As a result, water hyacinth can be used as a raw material for making handmade paper, and a byproduct of the manufacturing process can be added to compost to increase its nutritional value(Islam et al., 2021; Guna et al, 2017).

Biofertilizer

Rakotoarisoa et al. conducted research on water hyacinth composting in 2016, gathering fresh plants along Lake Alaotra's coast. Water hyacinth generally stores heavy metals in its roots, which were afterwards removed. To hasten the decomposition process for the compost, fresh weed was cut into pieces (approx. 2cm). The compost was created in three distinct ways: (i) aerobically (after adding branches to the base of the pile), (ii) anaerobically (by covering the pile with plastic sheets), and (iii) in a trench dug into the earth. To create the compost, three layers were used: soil and chopped water hyacinth (20 cm), cow dung (5 cm), and mango (*Mangifera indica* L.) leaves (5 cm), which increased the amount of compost overall.

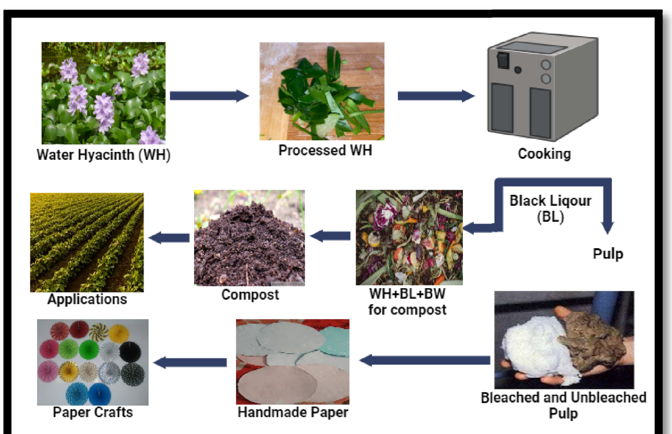

Fig. 6: Production of compost and paper

The stacked pile was then watered, and stacking carried on until the mound was 1.5 meters high. When composting had reduced the substrates to a crumbly, black mess after a month, composts were then watered every two days and moved onto fresh bases every two weeks. The best water hyacinth fertilizer for encouraging plant development was determined through a growth experiment utilizing Chinese cabbage. According to their research, Chinese cabbage treated with composts made from water hyacinth gained more biomass than Chinese cabbage treated with NPK and cow manure. Ash and water hyacinth green manure both performed poorly. Compost ensures higher agricultural yields while lowering the expense of chemical fertilizer purchases. Using water hyacinth as a composting material can increase soil fertility over time while minimizing negative environmental effects.

Water Hyacinth-based Heavy Metal Sorbent

One of the applications of water hyacinth that has been the subject of the most research is its use as an absorber for heavy metals in contaminated water. Both separately and together, the sorption of heavy metals in the leaves, roots, and stems has been studied. Mohanty et al. (2006) investigated the ability for the water hyacinth stems and roots to absorb Cr (VI) from the solution. The roots and stems of water hyacinth were dried and processed into a powder on a 52 mesh screen. Batch absorption experiments took place in a conical flask (250ml) for 450 minutes at 25 °C. At varied absorption circumstances, the kinetics of adsorption and absorption isotherms were studied. At 10 ppm, linear absorption grew up to about 60 minutes before beginning to saturate. Increasing the dose of the sorbent led to a comparable rise, but when the pH was increased from 1 to 5, its removal efficacy decreased from 95 to around 15%. The capacity to remove up to 96% of the metal was deemed suitable for practical applications in this investigation. Another study investigated the capacity of water hyacinth-produced biochar to absorb Cu, Cd, Zn, and Pb from aqueous solutions. As potential materials for the treatment of soil and contaminated waters, the sorption and desorption of heavy metals (Cu, Cd, Zn, and Pb) in biochars derived from water hyacinth, eucalyptus forest residues, green coconut pericarp, castor meal and sugarcane bagasse were evaluated. As a result, the examined biochars' high capacity for sorption and low reversibility for sorption show that they are suitable as materials for the treatment of heavy metal-contaminated water. (Doumer et al., 2016; Guna et al, 2017).

Biofuel applications

For use as a renewable fuel source, water hyacinth has been recognized as having potential. In addition to being used as fuel directly, the plant has been investigated as a potential resource of biodiesel and bioethanol. The three standard steps to produce ethanol from water hyacinth were said to include pretreatment, saccharification, and fermentation. For creating bioethanol at competitive prices, it was believed that xylanase production needed to be done effectively. Also considered to be a potent biohydrogen generator is the water hyacinth. In order to produce hydrogen, hyacinth stems were hydrolyzed. In total, 126.7 mmol H_2/L of hydrogen were produced. In order to aid in solubilization, water hyacinth was also thermally processed for the formation of methane in hot air ovens, microwaves, autoclaves, and hot water baths, which produced the maximum solubilization of 55%. The hyacinth produced 3039 ml/g of volatile methane solids after being heated to 90 °C for an hour as contrasted to the untreated hyacinth's 2396 ml/g.(Pattra et al., 2015; Barua et al,2017).

Reinforcement for composites

A variety of materials have been made from Water hyacinth and used as reinforcement. To develop a biocomposite, TiO2 nanoparticles, water hyacinth cellulose, and chitosan solution were mixed. In order to promote polydispersity and hydrophilicity, the nanoparticles were designed to act as chelating agents and create a network. It looked at how effectively reactive colours were removed from textile effluent by the biocomposite. The biocomposite's surface area was 173 m^2/g, which was much greater than the 133 m^2/g surface area of the untreated samples. The micropore volume had increased in a similar manner, going from 0.0774 cm^3/g to 0.0913 cm^3/g. Because there are protonated amine active sites at low pHs, the dye's sulfonate groups may interact with them more strongly, allowing for the absorption of a significantly higher dye concentration (up to 95%). The biocomposite's ability to adsorb the dye in a monolayer with a capacity of 0.606 mg/g was more in line with the Langmuir isotherm than anything else. Despite achieving high dye clearance, the biocomposite's capacity to desorb the dye was not investigated. Additionally, substantial nanoparticle modification could raise the cost of the absorbent and decrease its biodegradability (El-Zawahry et al., 2016; Tan et al., 2016).

II. CONCLUSION

Globally, the need for sustainable products and materials is growing. Finding renewable, sustainable, and affordable materials is important due to the growing population, the depletion of natural resources, and health issues caused by the usage and disposal of products made of synthetic polymers. Most biomasses are non-thermoplastic, difficult to dissolve, and contain a mixture of cellulose, hemicellulose, and lignin, which makes them challenging to process. A distinctive biomass, water hyacinth has been utilized to study and create a wide range of goods. Hyacinth is particularly appealing as a raw material due to its quick growth, possible low cost, and renewable nature. Although the viability of using Water hyacinth for a variety of uses has been established. Most investigations have been conducted out of academic curiosity, and there are currently no hyacinth-based goods or technology on the market. Up until now, research on water hyacinth has mostly focused on its potential as a fuel source, sorbent for metals and dyes, composite material, and other uses. It is critical to avoid thinking of water hyacinth as a weed. To further understand the composition, processability studies, and novel application potential, research is required. Water hyacinth appears to be the most promising source of renewable, affordable, and sustainable bio-products among the numerous bio-masses now on the market.

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