WATER HYACINTH (*EICCHORNIA* SPP.): INTERVENTION OF TECHNOLOGY HAS TRANSFORMED THIS NUISANCE AQUATIC WEED INTO A POTENTIAL BIORESOURCE.

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Abstract: Water hyacinth, an Aquatic weed, is one of the important source of water pollution and is a primary reason for degradation and loss of water bodies on earth. Their excessive growth causes oxygen depletion and formation of dense mats on the water surface which blocks sunlight from penetrating the water surface thus harming aquatic flora and fauna. They also harbour disease vectors (mosquitoes), blocking water flow for navigation/ irrigation and disrupting ecosystems. However, the intervention of technology has changed its fortune from an obnoxious weed into a potential bioresource. Scientists and Researchers world over have explored the immense benefits of *E. crassipes* for its usage as raw material in small scale industries and factories. By optimising the pre-treatment methods, the raw material can be used in Handicrafts, Textiles & Paper-pulp industry, Biofuel production (Biogas, Bioethanol, Briquettes etc.), water purification & wastewater treatment etc. Hence, application of innovative methods and green technology can transform this biowaste into a bio-wealth.

Key words: Water hyacinth, aquatic weed, water pollution, technology, bioresource, bio-wealth

INTRODUCTION

Aquatic weeds are hydrophytes which grow rapidly in water having adverse effect on the ecosystem by impeding water flow and depleting oxygen levels. They are primarily invasive species (non-native aquatic plants) which have proliferated on introduction, dominating the environments into which they have been introduced (Hussner, 2012). Amongst one such species is Water hyacinth (*Eicchornia* spp.) which is invasive in many tropical and sub-tropical countries of the world. It originated in the Amazon basin of South America and from there spread to the tropical and sub-tropical regions of the world (Julien, 2001). Its growth has been reported in countries across all the continents (Tellez et al., 2008). The International Union for Conservation of Nature has recognised it as one of the 100 most aggressive invasive species and one of the 10 severest weed plants in the world (Zhang et al., 2010; Patel, 2012). In India, it is believed that Water hyacinth was introduced during the British rule in the 18th Century, as an ornamental plant owing to its beautiful purple-pink flowers. Within few years, it became a problematic invasive hydrophyte, as it spread rapidly, suffocating freshwater bodies and posing serious ecological threats (Sharma *et al*., 2016). In India, commonly known as "Bengal Terror", its control has become a massive challenge throughout the Country.

There are about seven species of Water hyacinth. A monocotyledon (within the group of lilies), it belongs to the genus *Eicchornia*. The seven species of this hydrophyte are: *E. natans*, *E. heterosperma*, *E. crassipes*, *E. azurea*, *E. diversifolia*, *E. paniculata* and *E. paradoxa* . Amongst all the seven species, E. crassipes is most prolific in its growth. Under suitable conditions of temperature and humidity, E. crassipes blooms throughout the year and increases its population in 12 to 14 days (Omnofunmi et al., 2018). It reaches its climax between the months of June and September, the maximum growth being in the month of July (Akinyemiju and Bewaji, 2007). Morphologically, the plant can be divided into 3 major portions- a brown fibrous submerged root, green tender stalk and plump green, lustrous, ovoid photosynthetic leaves (Ndimele, 2010). The leaves of the plant can grow above the top of the water surface upto 1 metre. An upright stem bears the inflorescence having 8-15 distinct lavender flowers, each with 06 petals. The fully grown plant comprises long pendant roots, rhizomes, stolons, leaves, inflorescence and fruit. *E. crassipes* during its growth forms thick grass mats (upto 2m thick) covering the vast area of its aquatic habitat. The plant can adapt to a wide range of ecological condition, having strong tolerance to pH, nutrient variations and temperature conditions. Its growth is easily stimulated in the presence of nitrate and phosphate rich nutrients. This results in change in water chemistry and disruption of aquatic biota, resulting in high rate of evapotranspiration. Slowly, the ponds, lakes and rivers are drying up, which is a grave concern for the environment.

The threat this obnoxious weed has posed to biodiversity has been described as alarming and hence attention is being given now to explore its potential as a bioresource (Hossain et al., 2015). Several scientists, researchers and entrepreneurial initiatives across the globe are working on the potential of this weed to transform it into a useful resource with economic, environmental and industrial value. Over the last few decades, technology has helped to convert Water hyacinth into a valuable raw material. Various industries, researchers, and startups have developed innovative uses for this plant.

MAJOR TECHNOLOGICAL INTERVENTIONS:

2.1 Handicrafts and Textiles & Paper and Pulp Industry

Technology has enabled the drying, weaving, and processing of Water hyacinth stems into durable materials (Nasrudin et al., 2020). The various products made from processed Water hyacinth includes Baskets and bags, Mats and carpets, Furniture (chairs, tables), Wall hangings, Coasters and trays, Home décor items, textiles etc.

The properties of *Eichhornia spp*. which has augmented its use for making handicrafts and textiles are: (a) The stalks become strong and flexible when dried. (b) Machines can now strip, twist, and braid the fibers efficiently. (c) Eco-friendly and biodegradable products are in demand globally. This has also created employment opportunities for rural artisans, especially women.

Similarly, in the Paper & Pulp Industry, technology now allows converting Water hyacinth fibers into high-quality paper. The major steps involved in the process are: harvesting of Water hyacinth plants, chopping and drying the stalks, pulp formation using mechanical and chemical methods, blending with other plant fibres and finally paper sheet formation. The product can then be used in making notebooks, handmade paper, packaging material, Stationery and craft items. Thus, this offers an eco-friendly alternative to tree-based paper.

2.2 Biofuel Production

Advanced biotechnology has enabled scientists to convert Water hyacinth into different forms of biofuel. Biofuels are any energy enriched chemicals that are produced *via* biological means or derived from chemically converted biomass of once living organisms (Rodionova et al., 2017). The low lignin content present in Water hyacinth makes the plant a great choice for biomass that can be exploited in the biofuel industry. It has only 10% lignin content compared to general land plants which have high lignin content of around 15-30%. Lignin composed of phenylpropanoid groups acts as a polymer around the hemicellulose microfibrils, binding the cellulose molecules together and protecting them against chemical degradation (Vidya Sagar and Aruna Kumari, 2013). Lignin cannot be converted into sugars and therefore is not practical for biofuel production. Scientists have undertaken various studies to evaluate the production of biofuels (hydrogen, methane, ethanol) from Water hyacinth using various treatment methods like Dark fermentation, Dark fermentation + photo- fermentation and Batch fermentation (Cheng et al., 2010, 2015, Varanasi et al., 2018, Kaur et al., 2019, Varanasi and Das, 2020).These studies have indicated that chemical pretreatment and enzymatic hydrolysis must be well controlled to ensure more than 60% of lignin reduction. Thus, the Water hyacinth has to undergo several pre-treatment processes like feed stock processing, treatment with acids and alkalis and finally sugar estimation to convert the large quantity of cellulose into bio-ethanol (Awasthi et al., 2013).

2.3 Biogas

Biogas is the product of fermentation of organic materials in the absence of oxygen using micro- organisms (Ayanda et al., 2020). It is a clean and low- cost fuel. Water hyacinth can be used as an effective biomass for biogas production (Adegunloye et al., 2013; Bhattacharya and Kumar, 2010; Vidya Sagar and Kumari., 2013). The plant contains high cellulose content. Anaerobic digesters are being used to convert it into methane-rich gas which is a renewable source of cooking and heating fuel. Fadairo and Fagbenle, 2014 reported production of three litres of biogas from 2.5 kg of dried biomass of Water hyacinth mixed with cow dung and poultry droppings in the ratio of 2:2:1 alongwith 62% and 34% of methane and carbon dioxide respectively. Njogu et al., 2015 have reported biogas yield between 70%-75%, which is high enough to power internal combustion engines coupled with an electricity generator. Yadvika et al., 2004 have worked upon the methods to increase the biogas production rate in biogas technology. In rural areas, the feed required for biogas is available in plenty. The production rate of biogas is very low in winter. Hence, it is imperative to improve the process of anaerobic digestion by optimizing several operational parameters and using biological and chemical additives. The researches have led to setup of biogas plants that use *Eicchornia* spp. as a key feedstock often mixed with other organic waste like cow dung. These plants convert the Water hyacinth into biogas for energy, while the remaining serves as a valuable fertilizer, offering a sustainable solution for waste management and renewable energy. Realizing the potential of this aquatic weed as a resource for Biogas, studies are focusing on improving the percentage of biogas production by introducing certain pre-treatment methods. Pre-treatment of Water hyacinth with pure culture isolates of *Citrobacter werkmanii* VKVVG4 produced biogas three times more than untreated Water hyacinth (Barua et al., 2018). It has been reported that the gas generated from Water hyacinth is of high methane content and enough to power a gas generator. So, studies have proved that the option of biogas production as a way of green energy exploration using Water hyacinth may not only sustain the energy availability but also improve environmental sustainability *via* social, economic and physical well being of the environment.

2.4 Bioethanol

Bioethanol is an exhaustible source of energy. Its reserves are depleting and it is a matter of concern. Hence, the production of bioethanol from aquatic weeds which contains hemicelluloses content proves beneficial. The biomass can be converted into fuel ethanol though the three processes, i.e., hydrolysis, fermentation and distillation. Since ethanol is the feasible alternative to petroleum based fuels, its use is increasing day by day. The feedstock required for the production of ethanol is plant or agricultural residues which require huge capital investment. Water hyacinth biomass is considered to be more suitable because of its favourable properties (48% hemicellulose, 18% cellulose, 3.5% lignin). Water hyacinth biomass is available in plenty and hence it provides the feedstock required for the production of ethanol. Aswathy et al., (2010) recorded that it is possible to g*et al*most 71% efficiency in the saccharification of Water hyacinth biomass with very crude and cost effective methods of pre-treatment and onsite enzyme production.

2.5 Briquettes

Water hyacinth can be turned into briquettes, a sustainable biomass fuel, offering a way to manage the invasive weed and create cheap energy for cooking and heating in rural areas. The process involves preparing the plant (drying, shredding), carbonizing it (heating in low O2), grinding, mixing with a binder and pressing into a solid fuel. These briquettes burn slowly and produce less smoke. Hence, it reduces dependence on wood, LPG, and fossil fuels. Several studies have been carried out in this regard to explore the potential of Water hyacinth biomass for the preparation of briquettes. Carnaje et al., 2018 have proved in their studies that the developed briquette from Water hyacinth biomass could be used as a fuel in rural areas, and its production could help intervene and alleviate the environmental problems caused by this highly invasive weed in water bodies. Moki et al., 2020 explored in their studies the potential of Water hyacinth briquettes as alternative to the local wood fuels through mercerization process to enhance the qualities of a biomass briquette and encourage its use as fuel (as a source of renewable energy).

2.6 Water Purification & Wastewater Treatment

One of the biggest technological breakthroughs is using Water hyacinth in phytoremediation—the natural process of plants cleaning water. The plant absorbs heavy metals like lead, mercury, and cadmium (Adewumi and Ogbiye, 2009, Pramanik et al., 2015). The leaves, roots and the bulb tissues of the plant exhibit hyperaccumulation abilities for heavy metals (Thapa et al., 2016). Based on the property that it removes toxins, nitrates, phosphates, and organic pollutants, it is being advocated for use in wastewater treatment plants and polluted lakes. Water hyacinth has shown its ability to reduce the concentration of heavy metals, dyestuffs and even water physico-chemical parameters (Priya & Selvan, 2017). The weed has been reported to bioremediate soil contaminated with crude oil and Total Petroleum Hydrocarbons (THC) (Udeh et al., 2013). In the Sukinda chromite mines (SCM) in India, the removal of toxic hexavalent chromium from wastewater was experimented using Water hyacinth. Upto 99.5% of chromium removal was achieved with about 100 L of wastewater in 15 days (Saha et al., 2017). In the same study, water parameters like total dissolved solids and biochemical oxygen demand were greatly reduced in toxic water. It was further reported that Water hyacinth was also able to remediate cyanide from blast furnace water as much as 95% in three days. Wenwei et al., 2016, reported the ability of Water hyacinth to actively remove nitrate in agricultural eutrophic wastewater. The plant has the capacity to store excess nitrate in its root and shoot system. Water hyacinth is a very good plant for rhizo-filtration process, a technology that is being explored as a means of controlling pollution (Ayanda et al., 2020).

There are multiple benefits associated with Water hyacinth in water purification and wastewater treatment. It includes, Low-cost water purification, Improved water quality without chemicals and Restoration of damaged ecosystems. This technology is being used in several countries, including India, China, and Thailand.

2.7 Organic Fertilizer and Compost

Modern composting systems have transformed Water hyacinth into nutrient-rich manure. The plant contains nitrogen, potassium, and phosphorus. This makes it an appropriate raw material for inorganic fertilizers and compost manufacture. Compost made from Water hyacinth alone has been shown to make better quality compost than compost made from a combination of Water hyacinth and manure which suggests that composted Water hyacinth could be used as an alternative to peat in substrates for nurseries (Yan et al., 2015). Mixtures of Water hyacinth manufactured into agricultural fertilizers from several forms of animal wastes, plant wastes, house-hold and domestic wastes etc. are utilized to improve water retention in soils in land -locked areas (Selvaraju, 2012).

Water hyacinth has also been found to be a very good raw material for vermicomposting. Vermicomposting using Water hyacinth mixed with cow dung significantly improved the growth of *Arachis hypogea* planted in the field (Snehlata and Rao, 2018). Water hyacinth vermi-composted with *Lactobacillus sporogenes* led to an increase in nutrient composition of the vermicompost after 60 days, suggesting that the weed could be a good biofertilizer (Sakthika and Sornalakshmi, 2019)

Composting machines can be used to accelerate decomposition. Organic manure improves soil texture and moisture retention and reduces the use of chemical fertilizers and supports sustainable farming.

2.8 Animal Feed (in limited quantities)

When properly treated and dried, Water hyacinth can be used as a supplementary feed for Cattle, Goats, Pigs, Fish (in aquaculture). Advanced processing removes harmful elements and increases digestibility.

ECONOMIC AND SOCIAL IMPACT ON SOCIETY

From the reports published in magazines and daily newspaper, it has been found that technological use of Water hyacinth has created multiple benefits for the Society:

3.1 Generated Employment Opportunities

Several Rural women's cooperatives and self-help group's (SHG's) are making handicrafts and contributing to one's economy. Small-scale industries producing paper or briquettes have been set up.

3.2 Eco-Friendly Industries

The small-scale industries are using eco-friendly products for production. As a result, it creates less pollution than other industries. The eco-friendly products obtained from Water hyacinth provides a sustainable alternative to plastic and other chemicals.

3.3 Income Generation

Communities that once struggled with clogged waterways are now earning money by harvesting and selling Water hyacinth.

3.4 Restoration of Water Bodies

Water hyacinth has helped in restoration of water bodies primarily through phytoremediation resulting in clean lakes and ponds. The biomass harvested subsequently can become a valuable compost, biogas or bioproduct. It can revive fisheries industry and improve local biodiversity.

CONCLUSION

Water hyacinth, once one of the world's worst invasive aquatic weeds, has been successfully transformed into a valuable resource due to technological innovations. Instead of viewing it as a menace, countries now recognize its potential in handicrafts, fuel production, water purification, biofertilizers, and more. This shift demonstrates how science, creativity, and technology can turn an ecological problem into an economic opportunity. By managing Water hyacinth sustainably, we can protect ecosystems while supporting green industries and local communities.

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