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An Overview of Water Hyacinth (*Eichhornia Crassipes*) Proliferation and its Environmental Consequences on the Deltas of Nigeria

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ABSTRACT

The macrophyte water hyacinth (E*ichhornia crassipes*) was first reported on the Nigerian coastal waters in 1982. Since then, it spread rapidly and by 1985, it had colonized much of the creeks and lagoons. A coast-wide survey was carried out to determine the environmental factors influencing proliferation of water hyacinth. In addition to its impacts on the ecological, social and economic aspects of the environment and the effective use of the prevailing methods of control. The study area was divided into six zones from which field investigations were conducted. The study made use of both primary and secondary data. Primary data included direct personal observation and oral interview. While the secondary data included published and unpublished materials, it was discovered that the nutrient-rich environment contributed significantly to the rapid proliferation of the weeds. Its infestation impaired fishing, breeding and nursery grounds for microbes and parasites, impaired marine transport, human health and water quality among others. Efforts aimed at controlling it were taken, manual and mechanical extraction of the weeds seen to be the most adopted strategy at certain locations along the coastal fringe. But infestation in creek and lagoon environment remained untackled despite consernted efforts. The adoption of an integrated management approach where other methods failed, water hyacinth can be converted to usable materials such as paper production, rope and mat making, production of fish feeds, water purification and biogas production among others. This will go a long way at eradicating the weed as most of them will be used for beneficial purposes rather than constituting a problem to the environment.

Introduction

Water hyacinth (*Eichhornia crassipes*) is a flowering, floating, freshwater plant and native to South America (Eborge, 1984; Bos, 1996). It has beautiful, large, pale-blue flowers with purple and yellow spots on the petals and shiny round green leaves. The flower is bought in the local markets within the West African and South American countries (Grodowitz, 1998), where it is a source of income for women. Water hyacinth is an aquatic plant which can live and reproduce floating freely on the surface of freshwaters and can also be anchored in mud (Akpofure, 2009). The plant size ranges from a few inches to a metre in height. The plant is a perennial aquatic herb, which belongs to the family pontedericeae, closely related to the liliaceae (lily family). The plant originated in the Amazon Basin and was introduced into many part of the world as an ornamental garden pond plant due to its beauty.

Water hyacinth is a very productive photosynthetic plant (Frick *et al*., 1999). The plant reproduces by means of vegetative propagation and by seeds. Every piece of water hyacinth that breaks off is capable of developing into a new plant. The parent plant develops side shorts and these break off and develop into new daughter plants (Gopal, 1987; Bos, 1996; Harley *et al*., 1997). Water hyacinth grows over a wide variety of wetland types like lakes, streams, ponds, waterways and ditches. The plant obtains its nutrients directly from the water and grows extensively in nutrient-enriched water. New plant populations resulting from each parent stock are distributed by wind movements and water current. As in other biological processes, the growth rate of water hyacinth is dependent on temperature and pH of the surrounding environment (Linsey and Hirt, 2000). The optimum water temperature for water hyacinth growth is 21^0C – 30^0C. In a flowing stream, the plant may tolerate as low as 0^0C for a short period of time. Water hyacinth is sensitive to pH, preferring a pH range of 7.5 – 8.0. The plant is also very sensitive to wind and may be distributed by being blown by wind. The growth and spread of the plant is also affected by the degree of salinity. This probably explains the absence of the plant in some coastal creeks in Africa where the degree of salinity of between 15-36 persists especially during the dry season (Jones and Greenfield, 1991).

Statement of the Problem of the study

Water hyacinth (*Eichhornia crassipes*) as an alien, floating water weed has spread throughout vital freshwater bodies and wetlands of Africa (International DC, 2000) since the late 1800s. The aquatic plant poses serious socio-economic and environmental problems for millions of people in the riverine communities and is, therefore, an added constraint on development. Since 1900s more than 12000 ha of this weed have infested the lakes, rivers and creeks of the delta areas in Nigeria, affecting the livelihood of, more than 40 million people in Nigeria. The rampant growth of this weed is attributed to agro-

allied chemicals entering the waterways and the presence of pollutants in the water from towns, petroleum related industries within and outside the creeks of the delta areas and minerals from soil erosion. Water hyacinth thrives in water bodies surrounded by habitats experiencing excessive use of agricultural fertilizers and excessive deforestation. The large number of water hyacinth along most fresh water systems of the Nigeria's coastal belt is attributed to high level of discharges into these water systems, which increases the nutrient availability in the waters. These nutrients are freely absorbed and metabolized by the free-floating water hyacinth for continuous growth and proliferation. This continuous growth and proliferation of water hyacinth within the delta areas of Nigeria enables the plant weed to obstruct electricity generation, irrigation, navigation and fishing, increases water loss resulting from evapotranspiration; and facilitates proliferation of such diseases as bilharzias. It is against this background that this study intends to examine the proliferation of water hyacinth and its environmental consequences on the delta areas of Nigeria.

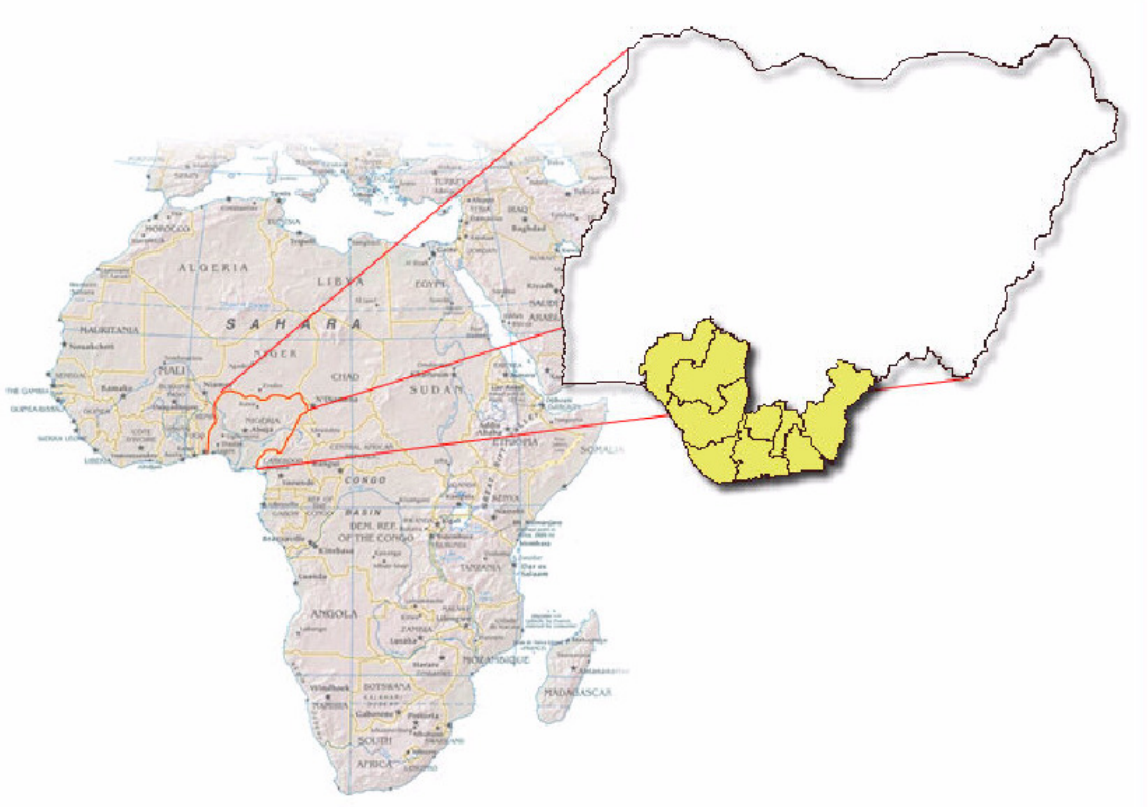

Figure 1: The Map of Nigeria showing the delta areas
Source: Udonwa *et al*., (2004)

Materials and Method

The study area was divided into six (6) zones within which field investigations were conducted. The process of data collection involved both direct personal observation and oral interview. The study was based on the examination of the problems posed by water hyacinth proliferation on the environment, so as to define an integrated management approach as a solution to arrest the issues for sustainable development. The study also made use of secondary data. Therefore, the variables determined were the growth characteristics of water hyacinth, their effects on the environment and the effectiveness of the prevailing methods of control. Also, diagrams were used to give visual impression of the integrated management approach hierarchy to the world most troublesome aquatic weed on the coastal environment.

Results and Discussion

Growth Characteristics Of Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is a non-native, free-floating aquatic macrophyte. It is to the Amazon region of South America. It spreads gradually for many decades. There were increased reports of water hyacinth in the delta region of Nigeria during the 1970s, and by 1981, water hyacinth has covered 1,000 acres of the delta, and 150 of the 70 miles of water ways (US Army Corps of Engineers, 1985). Water hyacinth is characterised by lavender flowers and thick, highly glossy leaves up to ten inches across. These features have made water hyacinth a favourite in ornamental ponds and it can be readily purchased as aquatic nurseries. The plant grows from 1½ to 4 feet in height, and the floating portion of a single plant can grow to more than four feet in diameter. As much as 50 percent of a single water hyacinth's biomass can be roots, which extend to a depth of up to two feet in the water (Batcher, 2000). Water hyacinth often forms monospecific mats across sloughs and other waterways (Cohen and Carlton, 1995). The mats are dispersed by winds and currents. In the delta, water hyacinth is found in sloughs, connecting waterways, and tributary rivers. The growing season for water hyacinth in the deltas of Nigeria is typically from March to early December. Plant die back or reduce growth during the dry season months. However, the majority of plants do not die, and carry-over plants begins to grow in spring during rainy season. Plants can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, extremes of nutrient availability, pH, temperature, and toxic substances (Gopal, 1987). Water hyacinth reproduces both vegetatively and sexually. Seeds often sprout along the muddy shorelines, and drop into the water with high tides. In vegetative reproduction, short runner stems radiate from the base of the plant to form daughter plants (Batcher, 2000). Nursery areas include slow moving waterways, temporarily isolated oxbow lakes, tule stands along channel margins, and stagnant, dead-end sloughs. Small colonies of plants separate and form floating mats that drift downstream,

infesting new areas. When water hyacinth extends into faster channels, or when higher flows occur, plants are torn away from their mats and moved by currents and wind until they encounter obstructions such as marinas, irrigation pumps or backwater areas (US Army Corps of Engineers, 1985).

The Problems Associated with Water Hyacinth

Water hyacinth creates serious problems in the deltas of Nigeria. This world's most troublesome aquatic weed is becoming a very serious problem in many Nigeria creeks. A high level of water hyacinth infestation has been observed in several water bodies of Nigeria (Akinyemiji, 1987; Mitchell, 1985). Problems created by these aquatic weed falls into five general categories: (i) transport and recreation; (ii) agriculture and fishing; (iii) human health; (iv) hydropower and water supply; and (v) ecosystems. This paper analyses each of these problem areas.

It's Impact on Marine Transport

In Nigeria, infestations of water hyacinth in the Badagry creek, bordering Benin, were first reported in local newspapers in 1982, and in 1985 the alarm of the invasion of Nigeria coastal creeks and lagoons was raised by one of the national newspapers. Since 1985, water hyacinth has spread throughout most of the inland coastal waters, rivers and creeks of the delta area in Nigeria (Farri and Chizea, 1995; Kusemiju, 1995). In the 1970s and early 1980s, there were a growing number of complaints about water hyacinth by private boat drivers and maritime operators in the delta area of Nigeria. The Nigerian Federal Inland Waterways has lost an estimated $4 million from 1981 to 2010 due to unusable ships and launch ramps, reduced sales, increased rental boat repairs, labour and equipment to deal with the aquatic weed problems (Adekoya *et al*., 1993; Bailey and Litterick, 1993; Aoi and Hayashi, 1996; Arora and Mehra, 2003). Water hyacinth clogs waterways and impedes navigation, presents a safety hazard to boating and water-skiing, and leads to hull damage when boats collide with obstructions hidden under water hyacinth. Access to harbours and landing jetties are seriously hindered by mats of water hyacinth. Canals and freshwater rivers have become impassable as they clog up with densely intertwined carpets of the plant (Dribble *et al*., 1996; Bicudo *et al*., 2007 and Coetzee *et al*., 2007). It is also becoming a serious hazard to river transport as large floating mass of water hyacinth hinder the movement of marine vessels. Many delta boat harbours and marinetimers have been forced to restrict operations because the aquatic weed block facilities and damaged boats. Boats are unable to launch due to closed ramps and boat motors are damaged by overheating when water cooling systems become plugged with plant material. The houseboat rentals and other marinetime businesses have reported reductions in the use of their facilities due to water hyacinth (Cossu *et al*., 2001).

It's Impact on Agriculture and Fishing

The presence of water hyacinth in the delta areas of Nigeria has been cited

as far back as 1989 (Moorhouse *et al*., 2001). By early 1990s, the adverse effects arising from water hyacinth mats were alarming (Twongo and Balirwa, 1995). Concern over the threat by water hyacinth to the thriving fisheries of Nigeria's delta areas has intensified. The creeks and rivers in Nigeria supply on the average 938,000 tons of fish per year (Harley, 1990). The sub-sector contributes $133 million to GDP and $56 million to export earnings. Furthermore, the subsector contributes to food insecurity, income generation and employment opportunities to the local and poorer members of the riparian communities. Water hyacinth concentrations affect fishing by blocking fish landing sites, swamping fish breeding areas and impeding fishing activities which are reflected in reduced level of production, a reduction in species diversity of the catch, poor quality of fish, rising costs of operation, lower incomes to the fishermen/women and higher prices to consumers. The invasion of the creeks by the weed has caused fish to migrate to open waters (de Marco *et al*., 2001) particularly in the creeks and rivers of Niger Delta areas of Nigeria and has thus reduced the potential of fishing, spawning and nursing. The cover of the landing sites is already causing fishermen to take longer time to land and motorised canoes to consume more fuel per catch of fish (Mangas-Remirez and Elias-Gutierrez, 2004; Martinez and Gomez, 2007).

Water hyacinth mats invade fishing grounds and blocked waterways. For the individual fishermen interviewed within the riverine communities, the aquatic weed mats reduced their catch by covering fishing grounds, delaying access to markets due to loss of output, increasing fishing costs due to the time and effort spent clearing waterways, forcing translocation, and causing loss of nets. Mailu's (2001) report cited declines of 14 percent, 37 percent, and 59 percent in the catches of *oreochromis* (a large genus of tilapia), *clarias* (a genus of catfish), and *mormyrus* (a genus of bottom-feeding breams), respectively. Twongo (1998) noted that the weed mats sealed off breeding, nursery, feeding and fishing grounds for various inshore fish species. It is not necessary to reiterate the noxious effects caused by the floating weed, water hyacinth (*Eichhornia crassipes*). There are already many papers giving valuable information about the effects of water hyacinth on agriculture (Achmad, 1971; Desougi and Obeid, 1978; Gopal 1987; Holm *et al*., 1991). In the Niger Delta creeks in particular, water hyacinth affects the normal activities of fishermen and transporters of goods. When fish landing are severely infested, boats are sometimes trailed to the shore. On certain occasions when fishermen have to wait for awhile in order to get going to the shore, they risk finding the entire catch rotten. Normally transporters of goods and fishermen consume two to three times more fuel when water hyacinth infestation is high and the fish catch is reduced by 50–75%. In some riverine communities in the Niger Delta where fishing is the basic source of income generation, water hyacinth

present a serious socio-economic problems (Giraldo and Garzon, 2002; Hellmann *et al*., 2008). Dense mats of floating water hyacinth form an almost impenetrable barrier to canoes. Water hyacinth covers fishing areas near the shore and necessitates long or time consuming journeys to reach open water. All types of nets are difficult to place where water hyacinth is present. There is insufficient clear water for the use of cast nets and seine nets. Clear patches in the weed must be cut for placement of gill nets. Long lines and nets left in the water are swept away by the weed, reducing catches and causing losses of fishing gear. Fewer fish, by number and weight are found in water hyacinth area. The diversity of species is also smaller in the presence of the weed and sometimes catches are poor that fishermen abandon the area. At Ogrienghagbene community in Delta State, fishermen take five hours to reach fishing grounds on the far side of the creek where they stay for up to two weeks before returning. Also, at Odimodi community in Delta State, fishing was abandoned at one time in 1991 because of the aquatic weed.

It's Impact on Human Health

Water hyacinth (*Eichhornia crassipes*), the world's most troublesome aquatic weed, was spread by man out of its original habitat in South America, it has left a trace of misery in tropical areas around the world (Pieterse, 1978; Gopal, 1987; Pieterse and Murphy, 1990). In the absence of its natural enemies the reproductive potential of this scourge is enormous. In addition, the water hyacinth's free-floating habit makes it a very effective colonizer of newly invaded fresh water bodies. It rapidly out compete other plant species and forms dense floating mats, which may completely cover the water surface. Consequently, the often multi-functional use of infested canals, rivers and lakes becomes seriously hampered. In addition to direct harmful effect such as impeding transport of irrigation and drainage water, hindering navigation, interfering with hydroelectric schemes, it also brings about indirect negative effects. These include increased health hazards by the formation of habitats which are favourable for the development of vectors of human diseases such as malaria and schistosomiasis. The plant tragedy is closely connected with its exotic, hyacinth-like flowers. This plant block light penetration and impedes photosynthetic actions thereby breaking down life cycles and food web systems in the water (Center *et al*., 1999). The diseases associated with the presence of water hyacinth especially in tropical developing countries like Nigeria are among those that cause the major public health problems; some species of mosquito larvae that thrive on the environment is created by the presence of the plant (Akpofure, 2009).

The weed has also been reported to impact negatively on the health of the people of the riverine communities in the Niger Delta area of Nigeria. It provides habitats for vectors of malaria and bilharzias, and it harbours poisonous snakes. It has been suspected by different scholars to be the major transmitter of amoeba, dysentery and typhoid and the

second leading cause to severe skin rashes in the delta areas of Nigeria and West Africa as a whole. Its roots turn water muddy and dirty, making the water supply unsuitable for drinking and for other domestic uses. This impact poses additional burden on the limited health services and facilities available to the poor rural communities.

Its Impact on Hydropower and Water Supplies

Many large hydropower schemes within and outside Africa are suffering from the effects of water hyacinth. Recently, there have been reports of its invasion in Lake Kainji (Farri and Chizea, 1995; Kusemiju, 1995) and the river Niger upstream from this artificial lake. The slow waterfall at Lake Kaniji is a victim of the weed's rapid reproduction rate. In Lake Kaniji, infestation is still relatively average, however, in certain parts of the lake a shore vegetation of water hyacinth has developed up to 19 metres wide. Heavy mats of floating water hyacinth are already pressing on the dam at Kaniji Power Station. The turbines of the power station at the dam are often shut down in order to clean the intake-screens of the turbines and plugged filters of the cooling system. Increasing amount of time and money has been invested in clearing the plants to prevent it entering the turbine, causing damage and power interruptions.

The main water supply intake at the riverine communities in the Niger Delta areas has been threatened by water hyacinth infestation. The riverine communities had to hire labour to keep the intake clear in early 2002. This exacerbated the already erratic water supply of the riverine communities, where water in the form sachet water is sold to consumers at exorbitant prices. Local communities depending on the streams and rivers for domestic purposes have complained of the poor water quality. Gastro-intestinal illnesses caused by drinking the river water have been reported from informal interviews. Access to livestock watering points has been hampered by the presence of stationary dense mats of water hyacinth.

Its Impact on Evapotranspiration

Various studies have been carried out to ascertain the relationship between water hyacinth and the rate of evapotranspiration compared with evaporation from an open-surfaced water body. The rate of water loss due to evapotranspiration can be as much as 1.8 times that of evaporation from the same surface but free of plants (Akpofure, 2009). This has great implications where water is already scarce. It is estimated that the flow of water into the creeks and rivers of Niger Delta is reduced by up to one-tenth due to increased losses from water hyacinth. The massive cover by the weed has increased the rate of evapotranspiration resulting into the problems of water balance. The physical reduction of water bodies in some of the creeks and rivers in delta areas of Nigeria may be gradually taking place due to the decomposition and sedimentation of rotten weeds and other organisms. Eutrophication in some of the creeks also reduce water quality due to the fermentation of dead organisms.

It's Impact on Water Quality

The decomposition of the plant and associated bacterial growth causes very high biochemical oxygen demand (BOD). BOD significantly decreases water quality of the river body which in most cases in the Niger Delta area of Nigeria is the source of drinking water for the rural people (Akpofure, 2009). Prior research on water hyacinth's effects on water quality has focused mainly on the consequences of the dense mats formed by the interlocking of individual plants. The most commonly documented effects are lower phytoplankton productivity and dissolved oxygen concentrations beneath mats (Rommens *et al*., 2003; Mangas-Ramirez and Elias-Guttierrez, 2004; Perna and Burrows, 2005). Other water quality effects include higher sedimentation rates within the plant's complex root structure and higher evapotranspiration rates from water hyacinth leaves when compared to evaporation rate from open water (Gopal, 1987). Water hyacinth also has been found to stabilize pH levels and temperature in experimental lagoons, thereby preventing stratification and increasing mixing within the water column (Giraldo and Garzon, 2002). Photosynthesis is limited beneath water hyacinth mats, and the plant itself does not release oxygen into the water as do phytoplankton and submerged vegetation (Meerhoff *et al*., 2003), resulting in decreased dissolved oxygen concentration. The extent of dissolved oxygen reduction is dependent on the capacity of the water hyacinth mat to prevent light infiltration into the water column. This is the case and experience of the delta areas of Nigeria and some other Africa countries at large.

It's Impact on the Ecosystem

The delta ecosystem of Nigeria is critically an important part of Niger Delta's natural environment and the ecological hub of the surrounding environment. In addition, it is probably the third most invaded ecosystem worldwide, with over 95 invasive non-native species (Cohen and Carlton, 1995). Different scholars have found out that non-native species accounted for 60 – 100 percent of common species at many sites. Water hyacinth is part of a nationwide invasion of non-native species. It is labelled as an invasive modifier. It provides a structurally complex canopy – roots in the water column and leaves above water provide habitat for both native and non-native species. These aquatic weed are extremely dangerous because of their ability to displace native plant species, harm fish and wildlife, reduce food web productivity, or interfere with water conveyance and flood control systems (Toft *et al*., 2003). Similarly, the US Fish and Wildlife Service notes that excessive water hyacinth growth outcompetes native vegetation clogs waterways, impeding and impairing aquatic life. Water hyacinth increases sedimentation and accretion of organic matter, inhibits gaseous interchange with the air, reduces water flow, and depletes oxygen, all of which harm other aquatic organisms. In the delta areas of Nigeria, water hyacinth is prolific, other aquatic plants have

difficulty surviving (Akpofure, 2009). This causes an imbalance in the aquatic microsystem and hence, various range of fauna that relies on the diversity of plant life for its existence has gone extinction.

Integrated Water Hyacinth Management Approaches to Effective Control Measures

The integrated water hyacinth management strategies are as shown in fig 1, which are discussed in turn.

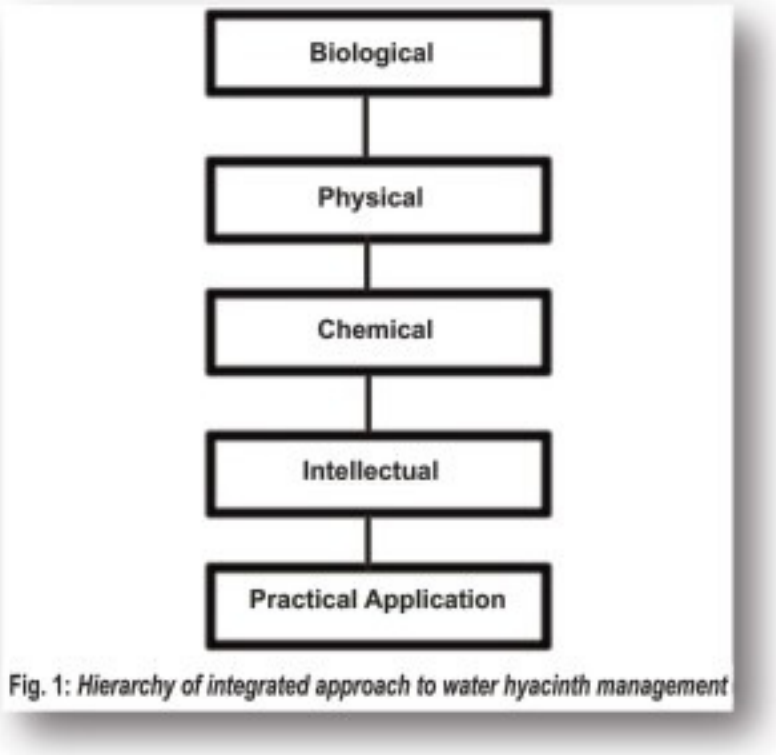

Fig. 1: *Hierarchy of integrated approach to water hyacinth management*

The Biological Method of Control

Biological control is an attractive alternative to mechanical and chemical control programmes because it avoids the introduction of toxic chemicals, it is not labor or equipment intensive, and it has the potential to be self-sustaining if the introduced biological agent can reproduce successfully in the new environment without causing further ecological effects (Seagrave, 1988). Biological control is the most widely favoured long-term control method.. Biological control is the use of host specific natural enemies to reduce the population density of a pest. Several insects and fungi have been identified as control agents for water hyacinth. These include a variety of weevils, moths and fungi. It is said to be environmentally benign as the control agents tend to be self-regulating. Control programmes are usually inexpensive due to the fact that the control agents are known and only a

small numbers of staff are required to run such programmes. Much of the cost of biological control programmes is on the front end, mainly related to research and development. Biological controls are often viewed as a long-term, sustainable solution to water hyacinth control. Host specificity is critical to any successful biological control programme.

One major drawback is that it can take a long time to initiate such projects because it can take several years for the insect population to reach a population density sufficient enough to tackle the pest problem. In tropical systems, biological control is thought to take 3-5 years to become effective (Harley, 1990); therefore its use has been limited to tropical and sub-tropical regions. Ideally, the introduced agent will have a narrow range of requirements to keep the effects focused on the target plant but broad enough to maintain a viable population when the host plant is in low densities. Common biological control options for water hyacinth include various insect species and introduced plant pathogens (Coetzee *et al*., 2007). *Neochetina eichhorniae* and *N. bruchi* are two commonly used weevil species from the plant's native range (Sosa *et al.,* 2007).

In general, the water quality impacts of biological control methods appear quite similar to other removal techniques. The insect reduces water hyacinth buouyancy, causing plants to sink to the bottom and decompose (Wilson *et al*., 2007). While this process may not drastically affect water quality in deep areas or where large mats of water hyacinth do not sink at once, shallow areas are more vulnerable to the negative effects associated with the decomposition of plants. One of the advantages of this method is the potential for it to become a self-sustaining aspect of ecosystem function. However, it is still a non-native component introduced to the ecosystem, and it has the potential to affect other aspects of the ecosystem (Simberloff and Stiling, 1996).

Physical control Method

Mechanical removal of water hyacinth is seen as the best short-term solution to the proliferation of the plant. This option includes harvesting plants and in-site cutting. There are several advantages and disadvantages to implementing a mechanical control strategy depending on the option chosen. In general, there is no water-use restrictions associated with method and it does not require much technical expertise. Mechanical control immediately opens physical space (habitat) for fish, boat traffic, fishing, and recreation. It is, however, costly, using either land-based clamshell bucket cranes, draglines or booms or, alternatively, water based machinery such as mower, dredges, barges or specially designed aquatic weed harvesters. In-situ cutting, where plants are left to die and decompose in the water can decrease dissolved oxygen and alter trophic structure as result of changes in nutrient and carbon balances (Scheffer *et al*., 1993; Greenfield *et al*., 2007). Moreover, low dissolved oxygen catalyzes the releases of phosphorous

from the sediment and an increase in phosphorus often leads to a subsequent increase in water hyacinth or algae blooms (Perna and Burrows, 2005; Bicudo *et al*., 2007). While this is an obvious downfall of in-situ cutting, harvesting the plant can be costly and logistically difficult. Water hyacinth is comprised of approximately 90% water, making it very heavy to transport (Gopal, 1987). It also acts as a sink for heavy metals and other pollutants, therefore the issue of disposal and storage of decaying water hyacinth becomes an important health and ecological consideration once the plant is out of the water. Mechanical control may not be cost effective for extensive areas when large cutting or dredging equipment is required. Physical removal of water hyacinth may require establishment of an offsite disposal area, which can be more expensive than the removal process itself (Thayer & Ramey, 1986).

Chemical Control

Chemical control plans have been introduced in several locations worldwide; Glyphosate (Roundup), Diquat, and 2, 4-D amine are common herbicides used on water hyacinth (Seagrave, 1988; Gutierrez *et al*., 1994; Lugo *et al*., 1998). Chemical control plans are considered less labor -intensive and less expensive than mechanical control, especially at large scales. Although chemical control plans can cover large areas in short time periods, herbicides can become expensive if management requires repeated applications. The cost of the chemical plan will depend heavily on the equipment used to administer the herbicide (e.g. backpack sprayer, helicopter, or airboat). Spraying large areas within a short time span can cause dangerous deoxygenation of water (Lugo *et al*., 1998). Herbicides are less selective than mechanical or manual approaches and can kill non-target algae and macrophytes (Seagrave, 1988), resulting in far reaching ecological impacts (Richards *et al*., 1985; Arora and Mehra, 2003; Rocha-Ramirez *et al*., 2007). The herbicide should be sprayed directly onto the leaves of water hyacinth to avoid killing algae in the water column (Seagrave, 1988). In a research carried out by Olaleye *et al* (1993), chemical control programme in a Nigerian creek produced a significant increase in fish abundance 14 days after treatment. The increase was assumed to be a result of the removal of plant barriers to fish movement. However, not all fish species experienced a significant population increase following treatment, suggesting other factors driving fish distribution. A final consideration with the implementation of a chemical control plan is the water use restrictions that may be required by law following herbicide spraying. The implementation of a chemical control plan can have significant socio-economic impacts if beneficial or designated uses of the water body are affected.

Intellectual Approach

Besides the aforementioned three control mechanisms of water hyacinth proliferation, the following intellectual approach can eradicate the world most troublesome aquatic weed.

Avoid the Discharge of Industrial Effluent into Water Bodies

Industrial effluent that is discharged in a water body is a source of nutrient for the plant growth. It can be argued that a reduction in nutrients in the water body will result in a reduction in the proliferation of water hyacinth. In recent decades there has been a significant increase in the level of nutrients dumped into waterways from industrial and domestic sources as well as from land where fertilizers are used or where clearance has caused an increase in runoff.

Educational Awareness

As a matter of policy, government should embark on an effective and aggressive educational campaign to elicit support from the local communities to continually clear water hyacinth along their shorelines. Posters showing the harmful effects of water hyacinth should be displayed in the communities. An environmental campaign programme will promote public awareness and responses. It will also create public commitment and enlighten the people on the dangers of water hyacinth proliferation and appropriate attitudes to them will be stimulated and thereby minimize the spread of the plant.

Research Development

Research institutions should develop economically attractive uses for water hyacinth. Water hyacinth application in the purification of industrial waste water and in the bioremediation of crude oil contaminated soil is a welcome development

Practical Application of Water Hyacinth

Ninety five percent of water hyacinth is water; it has a fibrous tissue, a high energy and protein content that can be used for a variety of applications. These applications include:

Fibre Board Production

Another application of water hyacinth is in the production of fibre boards for a variety of end uses. For example, the House and building research institute in Dinka have successfully used fibre board made from water hyacinth to carry out indoor partitioning of walls and ceiling.

Fertilizers

Water hyacinth can be used on the land either as a green manure or as compost. As a green manure it can be either ploughed into the ground or used as mulch. The plant is ideal for composting. After removing the plant from the water it can be left to dry for a few days before being mixed with ash, soil and some animal manure. Microbial decomposition breaks down the fats, lipids, proteins, sugar and starches of the plant. The mixture is left to compost. The compost increase soil fertility and crop yield and generally improves the quality of the soil.

Rope Production

The fibre from the stems of the water hyacinth plant can be used to make rope. The stalk from the plant is shredded lengthways to expose the fibres and then left to dry for several days. The finished rope is treated with sodium metabisulphite to prevent it from rotting. In Bangladesh, the rope is used by a

local furniture manufacturer who winds the rope around cane frame to produce an elegant finished product.

Paper Production

Water hyacinth can be used in paper production. Although, water hyacinth fibre alone does not make a particular good paper, when the fibre is blended with paper or jute, the result is good. The Mennonite central committee of Bangladesh has been producing paper from water hyacinth for some years now.

Animal Fodder

Studies have shown that the nutrients in water hyacinth are available to ruminants. In China, pig farmers boil chopped water hyacinth with vegetable waste, rice bran, copra cake and salt to make a suitable feed. In South-east Asia some non-ruminant animals are fed rations containing water hyacinth.

Basket and Mate Making

Water hyacinth can be used, when properly dried, to make baskets and matting for domestic use. In India, water hyacinth is used to produce good-looking baskets and woven articles for the tourist industry.

Water Purification

Water hyacinth can be used to aid the process of water purification either for drinking water or for liquid effluent from sewage systems. In a drinking water treatment plant, water hyacinths have been used as part of the pre-treatment purification step. Clean healthy plants have been incorporated into water clarifiers and help with the removal of small flocs that remain after initial coagulation and floc removal of flocs and also slight reduction in organic matter in the crater. The major characteristics of water hyacinth that make it attractive for waste water purification are their extensive root system and rapid growth rate. The root system is an excellent medium for the filtration/adsorption of suspended solids. Pilot-scale tests on the application of water hyacinth to treat effluent from existing lagoons at Exxon Refinery and Petrochemical Complex in Baytown has been carried out. Substantial reductions in total suspended solids (TSS), biochemical oxygen demand (BOD), nitrogen, phosphorus, and heavy metals (Zn, Fe, Pb, Cr and Cd) were achieved. A Process flow diagram for hyacinth system designed to produce secondary effluent is shown in fig. 2.

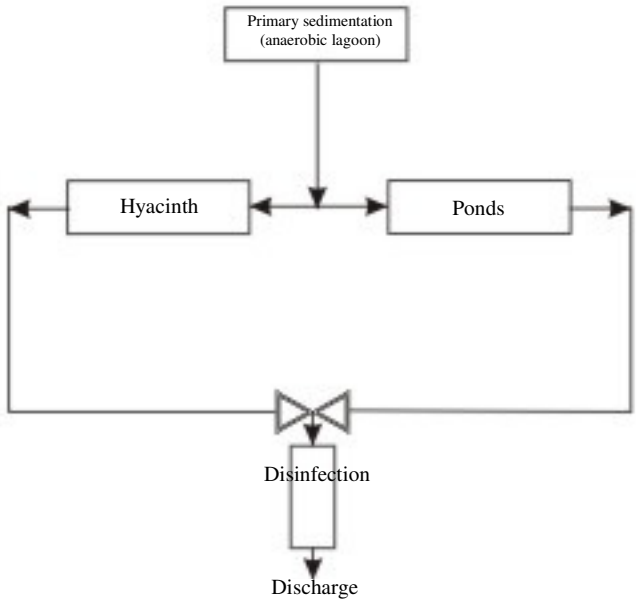

Fig. 3: *Process- flow diagram for water hyacinth designed to produce secondary effluent* (Corbitt, 1998)

Fish Feed

Water hyacinth can be used as feed to fish directly. Species of fish such as Chinese grass carp, tilapia, silver carp and silver dollar eat water hyacinth. Water hyacinth has been added to the diet of channel cat fish fingerlings to increase their growth. The decay of water hyacinth also releases nutrients which promote the growth of phytoplankton with subsequent increases in fish yield.

Charcoal Briquetting

Water hyacinth can be pyrolyzed for briquetting of charcoal dust. However, for a plant to produce 40 tons per day of briquettes an area of 12 hectares would be required for drying the water hyacinth, 1,300 tons of wet hyacinths would be required for daily and the climate would need to be one of low humidity and relatively high temperature.

Biogas Production

Water hyacinth can be treated to produce biogas (methane). The process is one of the anaerobic digestion which takes place in a reactor or digestion and the usable product is methane gas which can be used as a fuel for cooking, lighting or for powering an engine to provide shaft power. The residue from the digestion process provides fertilizer rich in nutrients.

Remediation of Crude Oil Contaminated Soil

Water hyacinth can be used to remediate crude oil contaminated soil. This is based on the fact that it can make soil more fertile and has the potential to regenerate degraded soil. When crude oil contaminated soil was treated with slurry of water hyacinth, the population of total

heterotrophic and hydrocarbon utilizing bacteria increased tremendously, causing a 53 percent reduction of total petroleum hydrocarbon in the contaminated soil.

Conclusion

Proliferation of aquatic weeds especially water hyacinth is a major problem of our coastal areas in recent times. This is partly due to the rich nutrient base that fosters plant growths. This has impaired fishing, marine transportation, increase water loss through evapotranspiration, impaired on hydropower and water quality and also caused imbalance in the aquatic ecosystem. Measures adopted at managing the spread of the weed, manual and mechanical extraction leaves much to be desired. As both stationary and mobile mats of water hyacinth in creeks and lagoons is still a common feature in our coastal environment. Hence, an integrated management approach, if adopted by converting the weeds to beneficial use such as rope production, mate making, water purification among other, instead of the present nuisance they cause to our coastal environment will go along way to making the weed human and environmentally friendly.

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