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Water hyacinth paper. Contributions to a sustainable future

The water hyacinth is an aggressive plant, which has been a terrible nuisance on almost all continents for more than 100 years. The problem has now grown to such proportions that governments are at their wits end. There isn't one method of control that offers solace in the long term, except perhaps an integrated approach. Within this a modest role has been set aside for the production of hand-made paper from the biomass of the water hyacinth. A development organization in Bangladesh originally came up with the idea to try out the water hyacinth. In fact, the water hyacinth contains too much water and many impurities, which are difficult to remove, but eventually it has become possible to produce a paper of reasonable quality.

The water hyacinth was first recorded as a separate species by the explorer of tropical South America. C.E.P. von Martius in 1824. It was the botanist, C.S. Kunth, in 1842 who named the plant after the then Prussian minister of education, culture and medicine. John Albert Friedich Eichhorn. From that moment on the botanical name for the water hyacinth has been Eichhornia crassipes (Mart.) Sols. The very first mention by Sir Patrick Browne, based on a plant collection from Jamaica, dates back to 1756. It's clear that the water hyacinth was wide-spread in the northern part of South America in the 19th century. Furthermore, the water plant displayed great diversity in its natural habitat, flower colour and other characteristics. At present we have distinguished at least eight species of water hyacinth, which occur in almost every part of the world.

Spreads with lightning speed

Over a period spanning one and a half centuries, the water hyacinth has spread with lightning speed over large parts of the world. Not surprisingly, it’s a very fast growing plant. The biomass doubles its surface area within 14 days, sometimes even in 6 days. Water hyacinths float on the surface and set roots in the shallows. They propagate by sending out runners on which young plantlets develop. These divide away from the parent plant very easily. Moreover, they can produce an enormous number of seeds (surviving for up to 15 years in the river bottom) equally as well. The consequences of

this rampant growth are immense, both for man and nature. By way of illustration: at present 80% of the Ugandan shoreline of Lake Victoria is covered in it,
and the Kenyan port of Kisumu is cut off from the rest of lake Victoria by large islands of water hyacinth, which together measure more than 2000 hectares. Ships take 5 hours to berth and local fishermen don't stand an earthly chance of wrestling their way through this biomass. To the south of Kisumu, in Kusa Bay, the plant has destroyed the livelihood of a fishing community of 2000 people. Their 52 fishing boats lie idle on the beach.

Prolific growth
It's not only the local economy that has been stagnated by the prolific growth of the water plant, its dense coverage prevents sunlight from penetrating the water, causing indigenous plants to die and rot. The weed removes oxygen from the water, resulting in the death of many fish. In addition, the luxuriant mats of vegetation provide an ideal breeding ground for micro-organisms, which in turn cause malaria, bilharziasis, river blindness and other infectious tropical diseases. The infrastructure also suffers considerable damage. Inlets of hydro-electric plants are damaged, pumps for (drinking) water supplies are fouled, turbine motors of power plants overheat and drainage canals are blocked just to name a few of the problems connected with social amenities. One analysis has estimated the damage around Lake Victoria at 150 million dollars per year. There are corresponding problems in other regions, sometimes less extreme than Lake Victoria's case, but nonetheless alarming. And there doesn't seem to be an end in sight. Not only does the water hyacinth know no natural enemies, but man has also indirectly contributed to the further spread of the water hyacinth. Effluence from factories and sewers form a perfect growing medium for the weed.

Control and application

Over the last few decades, a lot of experience has been acquired about various methods of control, such as mechanical removal, chemical herbicides and the introduction of natural predators. Ultimately, it seems that only a combination of all three methods, coupled with a clear understanding of the local situation, will be the answer. Although even this method of integrated pest management probably won't achieve the definitive and total eradication of the water hyacinth. Part of an integrated programme could be the search for a useful application for the plant in question. Some think that this runs counter to the main aim of control - namely total eradication - and that you would be creating a market for the very product that you are controlling. The problem of the pervasive growth of the water hyacinth is, however, so extensive that its regulated use could certainly make a positive contribution to the management of the problem. This is why useful applications are now being sought for the water hyacinth. Already many possibilities have been investigated. In various cultures the plant is used as a food source for both people and animals. This is not as strange as it sounds because the protein levels in the plant are relatively high. Some species of fish feed on the roots and during their meal are caught in nets made from the same material. In Taiwan, Java and the Philippines, the inhabitants sometimes eat the young leaves. The Chinese in Malaysia cook the leaves and stems into a mash and feed it to their pigs.

Fertilizer
The plant is better known as a fertilizer. Bengali people and some other Asian peoples use it to fertilize their land. The application methods differ from region to region. The one uses it as compost, the other sprays it as liquid manure onto the land, while others use it as a top dressing on agricultural land. The water hyacinth is also eminently suited for use in a biogas installation. Here again the high water content is an advantage. One hectare of water hyacinth produces 70,000 m^3 gas, in other words 1 kilo of dried plant material produces 370 litres of gas. In southern South America the water hyacinth has even been employed in the purification of sewage. Research has shown that the water plant has the capability to absorb all kinds of organic and inorganic elements. This means that the plant can be employed specifically to clean polluted waterways: it even absorbs heavy metals and radioactive materials.

Fibre as raw material
The fibres of water hyacinths can also be utilized. In Cambodia they plait ropes from the fibres and even sacks are produced from the water hyacinth. In Thailand, the dried plant material is soaked in glycerin to make the fibres more pliable and more receptive to dyes for making hard-wearing sandals.
Napkin-rings, chair seats and placemats have in the meantime appeared on the market. Most of the products come from non-governmental organizations (NGOs) in Kenya, Bangladesh. Thailand and the Philippines.

Paper made from water plants

The last is the best, you could try and make paper from the water hyacinth. There are two ingredients that are indispensable to making paper: water and fibre. Without water there is no paper. We can beat fibres till we're blue in the face, but until they are suspended freely in water, it's impossible to form paper from them. Fibre is present in all parts of the plant kingdom. Chemically the plant fibres consist of cellulose, which forms the main constituent of the cell walls. The fibres are present in different parts of the plant: the stem, the leaf and the fruit. In order to make the plant fibres suitable for the manufacture of paper the fibre has to be rendered soluble: the recovery or extraction process. This entails removing as much of the noncellulose material as possible from the plant fibres. These days, this is done with chemicals. Not every plant is suitable for paper

production. In the first instance, it depends on the quantity of fibrous tissue in the plant; this can vary quite markedly from plant to plant. In addition the quality is very important: how strong and long the fibre is, for example. Lastly, an aspect particularly important to economic viability: how easy it is to recover the fibre from the plant.
Sometimes a plant does indeed have high fibre content but it is particularly difficult to break it down sufficiently to make it soluble.

Papyrus and reed
In the past, fibre from water plants was almost never regarded as a potential raw material for paper. Papyrus, which was used as a writing material in ancient times, is not considered to be paper because the thin strips of papyrus plant (Cyperus papyrus) have been joined together by means of beating. In literature from the beginning of the previous century, there are suggestions that paper could be made from the water hyacinth, but the experiments were very discouraging. That's why nothing came of it. A notable exception was the Rumanian paper-mill in Braila which, in 1956, used the Common Cat's-tail (Phragmites communis) from the Danube delta as a raw material. More than 60% of this enormous delta is covered in reeds, 125,000 metric ton of which was used for paper production per year. With the emergence of a more artistic approach to papermaking some 50 years ago, just about everything has now been tried in the hollander beater. Although, of course, never on a huge scale.

Paper from the water hyacinth
In Bangladesh, in 1980, there was an attempt to produce paper from water hyacinth. The first results fell very short of expectations. It appeared to be no easy task to make paper from a water plant such as this. The paper wouldn't dry, was very weak and not a pleasant colour. First and foremost, there is the high water content of a water hyacinth: 90 to 95%. The plant can lose or absorb a great deal of water in a short space of time, depending on changes to the temperature. Not for nothing is the Hindi name for water hyacinth *samudra sokh* which means they who can absorb an ocean.

Drying
Lowering the water content in the biomass was therefore the first priority. In developing countries, you would assume that drying in the sun would be the solution, but because of the often high humidity the material became moldy within two days.
It's precisely because of the high water content that the plant can't dry sufficiently in those two days Once the plant mass has become moldy it's useless. Artificial drying is an option, but uses relatively high amounts of fuel, which is not only very expensive in most developing countries but also unavailable. Perhaps the solution lays in the pressing of the raw material before the cooking. Tests revealed that it was advisable to cut the water hyacinth into small pieces about two centimetres to begin with. This eased the progress

of the process. However, a disadvantage of pressing is that in the process the fibre mass becomes rather stringy. This makes it difficult to separate the fibre bundles from the pith in the later stages. The solution that has now been found is to feed the small pieces of plant through a double rolling mill for crushing. In this way, some of the water trapped in the plant is already released and in turn some of the nonfibrous materials, such as the pith, are released with it. An alternative to this is to feed the plant mass into an edge runner mill or kollergang. These mills separate the fibres from the pith much more efficiently, resulting in a homogenous plant mass. In this way, together with the intermediary phases, we can reduce the water content quite drastically. Now that so much water has been removed from the plant, it can be easily dried within a couple of hours on the premises without going moldy. The advantage of drying the plant is that, among other things, it can be stored for a long time and be used as required.

Cooking

As we saw earlier, the water hyacinth absorbs a lot of water. This means that we need relatively more chemicals for cooking than normal, on average 2.5 to 3 times as much. Chemical materials in developing countries are always extremely expensive and most have to be imported. An additional problem is compliance with the Commodities Act (if there is one) that often leaves a lot to be desired. Therefore, you don't know if you've actually purchased what's on the label, that's if the product has a label. The storage, handling and adherence to the safety regulations as far as the chemicals used on the project are concerned also leaves a lot to be desired. This usually occurs because of ignorance. Therefore cooking the fibres involves a lot more than just choosing the correct chemicals. Fortunately, the cooking time for the water hyacinth is short so this saves on expensive fuels. There are different ways of chemically recovering the cellulose. In practice we have learned that it's best to cook water hyacinth in sodium sulphite (Na_2S0_3). In this way you achieve the highest fibre yield with the best possible quality of paper. The worst results were achieved with the more regularly used and more environmentally friendly sodium hydroxide (NaOH). It is best to do the cooking in a sealed vat. This means we can achieve high temperatures and subsequently reduce the cooking time. Because of the pressure created during the cooking, the vat must of course be able to meet certain specific requirements. Needless to say this entails significant costs. Not surprisingly, it is not always possible to purchase such an expensive high-pressure boiler. Sometimes it's possible to reach higher temperatures by changing the type of fuel: each type of fuel has its own net heating value.

Beating

The fibres of the water hyacinth are reasonably long and comparable with that of straw, sugar cane and jute. Nonetheless, water hyacinth will never produce an incredibly strong paper. The weak and rigid cell wall means that the fibre is extremely fragile and breaks

easily. This means that beating with the hollander would cause a great deal of damage. Therefore, we cannot chop and mix the fibres in the usual way. Beating is necessary in order to break down the fibre bundles into individual fibres so that they are suspended in the water and form a layer when scooped onto the mould.
A large part of the function of the hollander has already been taken over by the edge runner mill,
and also by the initial segmentation of the plant and of course the crushing process. However, the hollander also provides a good homogenous mass. Therefore, just a few minutes in the hollander is recommended, but then with the clearance between the roll and bedplate set as wide as possible to prevent the fibres being crushed or chopped any further.

Dehydration
The chemical composition of the water hyacinth varies a great deal with the local conditions, the time of the harvest and the development of the plant. The pure fibre content is worth mentioning, around 50%. However, water hyacinth also contains considerable quantities of other materials, such as lignin, pectin, fat and resin. Almost all of them are the building materials, which cement the cells together; they are known collectively as hemi cellulose. It is namely the inherent characteristics of the hemi cellulose, which confound us when making paper from the water hyacinth. There are certain elements in the plant that we can never remove during the cooking process. This prevents the fibre from being completely dissolved and property distributed in the water in the forming vat, which means the pulp has an extremely low freeness. When it has been prepared in the correct way, water hyacinth pulp has, according to Canadian Standard Freeness standards, a freeness of 40 - 80 ml whereas wood pulp, for example, has a freeness of 700 - 750 ml. Therefore, if we are not careful it wilt take an incredibly tong time before the newly formed sheet of paper actually dries. This is one of the reasons why we mustn't beat the pulp in the hollander for too long. This would make the pulp mass even finer and therefore more difficult to dehydrate. Unfortunately, this problem has not yet been completely resolved. Although shortly we expect, with external help, to be able to produce an acceptable type of paper from the water hyacinth.

Paper and cardboard
Will the production of hand-made paper be the solution to the water hyacinth: an ecological disaster of worldwide proportion? Of course not. Nobody would be so naive as to defend such a hypothesis. A drop in the ocean then? At the moment, certainly, but that could change. If governments set up more small-scale paper production units using the water hyacinth as a basic raw material, they will be able to make a positive, modest to be sure, contribution to the solution of a complex problem. In the meantime, a Kenyan NGO involved with Lake Victoria has already adopted the idea. In addition, the production of cardboard

from water plants could also be an option. Plans have been developed in Senegal to produce cardboard on a moderate scale from Reed Mace (Typha latifolia), a less problematic relative of the water hyacinth. Perhaps this will soon be the case with the water hyacinth too. In Bangladesh, hand-made paper made from the water hyacinth is already providing a modest source of income to the poor. It is gratifying to see that 100 families in Bangladesh have been able to build up a decent existence by making paper from water hyacinth.

The lightning advance of the water hyacinth

Man himself is responsible for the lightning speed with which the water hyacinth has spread. Even before it had been properly described, it had reached botanical gardens in Europe. Prized for its beautiful flowers, the water hyacinth was propagated as an ornamental plant by the botanical gardens. Today, this weed is to be found everywhere in the tropics and sub-tropics, between the latitudes 38° N and 38° S, in 53 countries. It grows in ponds, pools, water tanks, ditches, lakes, irrigation channels, fish farms, paddy fields, streams and rivers. In short, wherever there is some moisture and warmth. Only Europe has escaped its strangle-hold.

Asia

The Japanese introduced the plant into their island kingdom during the Meiji period (1868-1912). In 1894 this ornamental plant found its way from Europe to Bogor, the Dutch East Indies' Botanical Gardens on Java. The plant grew so rampantly that lorry-loads of it were thrown into the Tji Liwung, a river that flows through gardens. In this way the weed was able to begin its conquest of Java. Not long after, it overmastered the rest of Asia. This ornamental, imported as a botanical treasure, developed into a real curse on humanity. Even in 1902, the French in Vietnam were worried about its uncontrollable growth. In Burma, the weed led to legal action being taken in 1917. In 1914, four years after the introduction of the plant in 1890, the ornamental found its way to Bengal. When it appeared that the weed was blocking the water traffic on the rivers, it was decided in 1914 to take serious measures to curb this unruly growth. It took until 1936 before these were actually laid down in law. In spite of the early verification of the problem, the plant was still introduced into Papua New Guinea in 1962.

North America

Undoubtedly, the farmer who planted out this 'beautiful water plant' in Palatka in 1880, couldn't have known what disastrous consequences would follow on from his deed. Cowboys provided an even more rapid spread of the plant by placing it on the menu for their cattle. The ever-intensifying shipping trade did the rest. By the end of the eighties, non-indigenous plants like the water hyacinth (which is the worst culprit) have afflicted most of the 450 lakes in the American state of Florida. Apart from the ecological problems caused by the weed in Florida, it has caused considerable damage to bridges, flood barriers and lock gates.

Africa

Eichhornia crassipes has now grown into one of the worst ecological problems in developing countries and is considered to be one of the most aggressive species on earth. In Africa, it has ruined the ecology of Lake Victoria, the second largest freshwater lake in the world. In 1989, large thickly matted rafts of it drifted down the Zaire and Kagera rivers in Rwanda and couldn't be checked. At that time, the weed covered 10.000 ha of the lake's surface. The first 15 to 30 metres out from the shoreline are choked with water hyacinth, sometimes to a depth of two metres. Five hundred metric tons of it grows in the lake every day. In some places you can walk over the green mat from island to island. It's no wonder the shoreline is literally choking to death because of it. In 1999, the Lake Environmental Management Project was set up with a great deal of money from the World Bank, the Netherlands and Japan with the task of ridding the lake of the water hyacinth. The aim is for Tanzania. Uganda and Kenya to cooperate and work together on investigating mechanical, biological and chemical control methods. The Dutch Royal Institute for the Tropics, among others, is also involved in this project. Unfortunately, until now it hasn't provided the desired results. The problem has made the water hyacinth infamous worldwide. The era of 'the ornamental water hyacinth' is definitely belongs in the past. Fortunately!

Controlling the water hyacinth

There has been much experimentation in the last 30 years to combat the water hyacinth. Some methods have had disastrous consequences, others have been to no purpose and yet others only exacerbate the situation. It's also not easy to control a plant that grows almost everywhere. It has been found at an altitude of 1.600 metres and at temperatures from 1 C° to 40 C°. When frozen the leaves die, but not the plant. To be brief: the plant has the ability to adapt itself to every physio-chemical and climatic condition. The fight can be carried out from different fronts: a chemical, biological and mechanical approach. The most modern and also the most expensive method is Integrated Pest Management.

Chemical control

One of the ways of controlling the water hyacinth is with the help of chemicals, such as herbicides. However, this brings with it one great danger, certainly with large-scale or incompetent use. In which case the cure can often be worse than the complaint. This is how the extensive use of the defoliation chemical 'Agent Orange' (2.4-dichlorophenoxyacetate acid) in the Sudan - the consequences of which are well-known from the Vietnam War - led to serious illness amongst local fishermen. In Zimbabwe they were confronted with the death of fish on a massive scale because of excessive use. It is the organisms at the lower end of the food chain in particular that ultimately suffer from the use of chemical herbicides: they store up the non-biodegradable herbicides in their bodies year in year out. Currently, the call for chemical herbicides has again increased because the alternatives are not effective enough. Present research is concentrating especially on the easily biodegradable herbicides. Agents like glyphosate and yet again 'Agent Orange' are being tested. The side effects of the former would be limited. It sounds pretty desperate, but even ecologists consider chemical control to be necessary. Another great disadvantage with chemical control is that the plant is not eradicated but only checked: the water hyacinth sprouts again from the dead remains of the plant after spraying.

Biological control

The fact that the water hyacinth is in most cases a foreign interloper means it has no natural enemies. But of course they do exist. Therefore scientists have been diligently searching for such creatures. The search yielded 90 South American species of weevil, as well as an Argentinean and American moth, and a fungus. The weevil Neochetina in particular has been mobilized into battle. Both the adult beetles and the larvae affect the plant. In 1972, the weevil was introduced for the first time in Florida. After it proved to be successful it was introduced in other parts of the world. A just as successful relative followed two years later. In 1993 two species of weevil were introduced in Lake Kyoga in Uganda and later in Lake Victoria. The weevil established itself well in the first take, but in Lake Victoria it hasn't yet spread out enough from the original release point. The weevil doesn't seem to be working completely effectively: it is a long-term process and the question is whether the introduction of the beetle into large areas overrun by the water hyacinth will be effective enough. In India, Indonesia, Thailand, Florida and Zambia the weevil has been able to control smaller affected areas. The Argentinean water hyacinth moth (Sameodes atbiguttalis) has had some success in southern North America. Although the immediate effect appears to be limited the moth does slow down the development of large mats in the early stage of growth. In Australia, the Sudan and South Africa the moth has also achieved some success. An indigenous moth (Bellura densa) was introduced into the control programme in the eighties in the southern states of America. Unfortunately, the insect doesn't appear to have hit the mark yet. At the moment the effectiveness of a vehement pathogenic fungus from Florida (Cercospora rodmanii) is under investigation. Scientists are also looking for other predators in the original territory of the water hyacinth: the Amazon. Currently, biological control is enjoying more recognition than chemical control. Nonetheless, the question remains whether you should fight exotics with exotics. History has taught us that this can make matters worse.

Mechanical control
'Weeding' the weed mechanically is also an option. At least there are no immediate adverse affects attached to this method. However, this form of control doesn't seem to be as simple as it at first appears. It is namely the sheer volume of the water plant that complicates the issue, often involving many metric tons per day. Besides which, the weight of the mats mustn't be underestimated. The plant itself consists of 90-96% water and the mats themselves also hold great quantities of water. Nevertheless, in different areas the fight is entered into with great fortitude. In 1997, the Kenyan fishermen in Kusa Bay tried for three days a week to clear the water hyacinth by hand in order to force a way through for their boats. But to no avail so they stopped. Moreover, it's also dangerous: the plant mass harbours snakes, snails carrying bilharzias, mosquitoes, hippopotami and crocodiles. In addition, it contains sewage deposits, which could harbour cholera bacteria. Already from one village alone, five people have fallen victim to crocodiles and three to hippos. In Uganda, machines have been set to work. The first specialty constructed water bulldozers came from England. During the very first encounter they proved to be no match for the weed and sank to the bottom. Machines built in the Netherlands did work and are in service at Jinga keeping the outlets of the hydro-electric plant clear. With the help of powerful motors, the four boats clear a path daily through the green mass. A fencelike structure on their stems sweeps the green debris to a spot on the shore where a conveyor belt has been erected. This scoops the harvest out of the water into waiting trucks, which then drive to a dumping site a couple of 100 metres away. A similar system is employed in India and Hungary. The effect of mechanical removal is now under discussion. Not only is the harvest sometimes dangerous, but storage is also a problem. Due to the great quantity of water the plant contains, it takes months before the dumped biomass has rotted away. Some experts maintain that removal in fact makes space for even more water hyacinth. Ultimately, it seems that the benefits of mechanical control are, as far as large areas are concerned, very small and often require additional funding.

Integrated Pest Management
All three methods work to a greater or lesser degree. In practice the introduction of weevils perhaps provides the most benefit because they deal with the problem on a large scale. But no single method offers universal salvation: certainly not in the long term. As is the case with other problems, the insidious spread of the water hyacinth cannot be attributed to one cause alone. Logically speaking then, the answer doesn't lie with just one method of control. Modern science established this long ago. Our world is so complex that nothing can be explained monocausally (be caused by one thing). We wish it could but the fact is it isn't. In addition, the influence of man on his environment has been underestimated for many years. If we want to change what's happening to the environment then we have to also change the behaviour of man in his environment. This line of reasoning has now led to the setting up of programmes for an integrated control of f plagues, Integrated Pest Management. This programme unravels the complex web of inter-relationships between man, nature and problem in order to see where and at what point adversaries can be put into action. At the same time, the consequences of the suggested measures can be calculated.

The search for new types of fibre

The search for different sorts of fibres for paper production is not confined to recent times. The need for alternative raw materials to rags has already provided various 18th century scientists with many headaches. However, it wasn't until the beginning of the previous century with the invention of the paper machine and moreover a crisis in the European rag trade that the need for an alternative to rags really became urgent. The colonies were scoured in search of new fibre materials. The invention of the chemical recovery process of wood for paper production initially brought solace. Nevertheless, the search for non-European alternatives continued: they could be cheaper after all. The only alternative fibre dating from this period still in use is 'esparto' (Stipa tenacissima), a grass species that occurs mainly in North Africa and Spain. Other products resulting from the extensive research into fibres are rope from Manilla hemp (abaca), sisal and ramie ('China grass'), and mats from coconut fibre. In the latter half of this century, new types of fibres were introduced on a commercial basis, namely for non-European paper mills. After the Second World War especially mills for making paper from bamboo and bagasse (a fibrous residue from sugar cane) were built on various continents. These days every production process must be sustainable: paper and wood production too. This makes nonwood fibres an interesting option for the industry once more, especially for the paper industry in developing countries. The demand for raw materials has clearly changed because of this. Originally the materials had to have a high and, above all, recoverable fibre content, today it is durability factors that play the leading role. Other social forces, such as the international conservation movement and non-governmental organizations (NGOs) control and stimulate the trend towards sustainable paper production. Seen in this context the modest role that the water hyacinth now plays as a raw material for paper could in the future increase significantly.

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