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Potential Uses of Some Aquatic Weeds as Paper Pulp

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ABSTRACT

Potential use of waterhyacinth, torpedo grass and giant bulrush as pulp material was investigated by studying their fiber morphology, the appropriate procedure of paper pulp making and quality of the pulp produced. Waterhyacinth has the longest fiber but the lowest Runkel number, and ash content of waterhyacinth is the highest of the three species. However, the total cellulose and lignin contents of waterhyacinth are lowest. Evaluation of the pulp quality showed that the ratio of raw material to pulp production is over 0.4, which is a moderate value. The permanganate number of waterhyacinth is high, indicating that the bleaching of the materials requires a high amount of chlorine and hypochlorite. In the bleaching process, the fine fiber will be

washed out, so that the yield of the bleached pulps is relatively lower than the unbleached ones. The physical properties of waterhyacinth paper pulp are good as characterized by tearing and folding resistance, etc. Processing of this plant material is rather difficult because of the character of fiber suspension. In general, the three aquatic weed species can produce a moderate quality of paper pulp, although the economic aspects still have to be further studied.

INTRODUCTION

In Indonesia, the first aquatic plant inventory was in 1928 when a German limnological expedition recorded eighty aquatic weed species (4). The list included waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) which was introduced into Indonesia in 1894 as an ornamental plant, found the environment suitable, and has grown into a massive population. The problem was only realized in the 1920's when it became a serious problem in Rawa Pening, a lake in Central Java. Later it became serious in other lakes in East Java (Wlingi and Jabung lakes) and Sumatra (Kerinci lake, etc.). In Kalimantan, of 8 million hectares of open water, 60% is covered by waterhyacinth (1). Waterhyacinth, torpedo grass (*Panicum repens* L.), and giant bulrush (*Scirpus grossus* L.f.) are 3 of the 10 important aquatic weeds in Indonesia and in Southeast Asia (3). These 3 aquatic weeds are especially important in Rawa Pening lake. Waterhyacinth floats on the surface, while torpedo grass and giant bulrush grow in the ditches of the lake and on floating islands. Based on their abundance, distribution and importance in Rawa Pening, waterhyacinth is first, torpedo grass second, and giant bulrush sixth on the list of 30 important weed species (of 215) found in the lake (5).

There is an increasing awareness of the problems of aquatic weed infestation due to the increasing efforts in the proper management of water resources in Indonesia. Multipurpose projects have been carried out by the Ministry of Public Works to build dams thus creating man made lakes, to improve and develop irrigation canals, to regulate water level for flood control, to produce hydro electricity and to increase fish production. The degree of harmful effects of aquatic weeds depends very much on the purpose and need of a body of water and it is difficult to calculate in monetary terms. In any case, the harmful effects are mostly related to the population density of the respective species. Aquatic weeds, especially waterhyacinth, have a very rapid growth rate under tropical conditions. There have been no proper analyses to evaluate the hazard of aquatic weeds to the ecosystem. One of the most important factors in securing the optimization of water resources is the success of aquatic weed management.

In most newly built man made lakes, preventive measures to control new infestations of aquatic weeds have been widely and effectively practiced. These include eradication of noxious aquatic weed species found in the inundated lake sites, regular monitoring systems and traps. However, in most situations, especially referring to the already established irrigation and drainage systems, rivers and lakes, manual control efforts are only implemented when the weed reaches an overpopulated situation and the problem becomes intolerable. Manual control methods are very expensive although it provides employment for farmers and villagers. It is obvious that control measures have to be properly planned and consistently applied. It is particularly important since manual control gives no residual effect, on the contrary, it often reduces the crowding effect on the population so that the actual regrowth rate is stimulated.

The most recent approach is to integrate most of the efforts, particularly to follow up manual weeding with proper utilization of the harvested aquatic weeds. Waterhyacinth and hydrilla (*Hydrilla verticillata* L.f. Royle) is commonly used as cattle feed and soil additives (mulched or composted). Waterhyacinth is also used as a bedding material for mushroom culture (*Volvariella volvacea* (Ball. ex Fr Singer). This paper reports the possible utilization of waterhyacinth, torpedo grass and giant bulrush as supplements in paper pulp production.

MATERIALS AND METHODS

Waterhyacinth, torpedo grass and giant bulrush were collected from Krawang area and were sundried. Morphological study of the fiber and chemical analysis of these aquatic weeds were done with TAPPI standard (Technical Association of the Pulp and Paper Industry).

Since these plants contain high levels of parenchymatous cells they need to be depithed before pulp processing. Depithing was carried out by grinding the cut samples of the aquatic weeds in the wet state through a disk refiner with a wide opening between the plates, then screening them on a wire screen in the dry state.

Pulp processing was done with soda process in an autoclave with a 4 liter capacity and rotated in hot air. Sodium hydroxide was used at 12-14% concentration based on oven dried raw materials. Cooking conditions were; maximum temperature 135 C, period to maximum temperature 90 minutes, period at maximum temperature 45 minutes, ratio of solution and materials 5:1.

The pulp obtained was then bleached by a four stage (CEHH) bleaching process consisting of a chlorination stage (C), an alkali extraction stage (E), a first hypochlorite stage (H) and a second hypochlorite stage (H).

Unbleached as well as bleached pulps were evaluated by beating in a laboratory Niagara beater, then made into test sheets and tested for physical properties in a constant temperature and humidity room. TAPPI standard methods were used throughout the experiments. During the beating experiments, pulp samples were taken at 10 minute intervals, their freeness measured and then made into test sheets.

RESULTS AND DISCUSSION

A study of the fiber morphology and chemical composition of the weed species is necessary in order to have a better understanding of their characteristics and behavior during pulping. Results of these are presented in Table 1 and Table 2.

TABLE 1. FIBER MORPHOLOGY OF SOME AQUATIC WEEDS, CONSIDERED AS POSSIBLE UTILIZATION IN PAPER PULP PRODUCTION.

Parameters	Water-hyacinth	Torpedo grass	Giant bulrush
Fiber length L, mm	2.12	0.91	1.59
Outer diameter d, micron	13.93	10.27	5.32
Luman diameter 1, micron	9.22	4.62	2.06
Fiber wall thickness W, micron	2.36	2.83	1.63
Runkel number $\frac{2W}{l}$	0.51	1.23	1.58
Length diameter ratio $\frac{L}{d}$	152	89	298

Torpedo grass has the shortest fibers with a relatively thick fiber wall and a Runkel number exceeding one. Waterhyacinth on the other hand, has rather long fibers and a Runkel number of 0.51. A Runkel number less than one and rather long fibers are favorable features of papermaking, since by mechanical treatment, through beating of fibers, paper strength development could be obtained.

TABLE 2. CHEMICAL COMPOSITION OF SOME AQUATIC WEEDS BASED ON OVEN DRIED SAMPLES.

Constituents	Waterhyacinth		Torpedo grass	Giant bulrush
	stems	leaves		
Ash	22.29	15.41	7.39	11.45
Silica	1.41	0.67	4.10	8.27
Cold water solubles	29.81	28.00	13.40	10.13
Hot water solubles	24.71	28.56	15.83	14.43
1% NaOH solubles	56.59	63.77	51.97	49.67
Alcohol benzene solubles	13.65	13.43	8.30	6.89
Pentosans	15.83	14.60	24.06	21.21
Lignin	8.67	23.54	21.48	26.12
Total cellulose	57.66	48.57	62.25	61.78
Cross & Bevan cellulose	—	—	53.88	52.14

TABLE 3. SODA PULPING OF SOME AQUATIC WEEDS.

Species	NaOH (%)	Yield (%) Total	Yield (%) Screened	Permanganate number
Waterhyacinth	12	42.1	39.5	20.0
Torpedo grass	12	44.8	42.8	12.8
Torpedo grass	14	44.3	42.8	9.8
Torpedo grass[a]	14	37.0	35.1	10.6
Giant bulrush	12	45.5	43.4	14.4
Giant bulrush	14	39.9	37.2	12.2

[a]The sample did not undergo any pretreatment (depithing).

In general, the weeds all have a high ash content, and in giant bulrush and torpedo grass this consists mostly of silica (Table 2). Hot and cold water solubles, as well as 1% NaOH solubles are also high, especially those of waterhyacinth. The chemical composition of parts of waterhyacinth are quite different as indicated in the analysis of its stems and leaves. Problems were encountered during Cross and Bevan cellulose determinations so that it is not presented in Table 2.

Results of the depithing process where part of parenchymatous cells were removed, provided yields for waterhyacinth of 83.2%, torpedo grass 93.9%, and bulrush 85.6%.

Giant bulrush and torpedo grass pulp behaved normally during washing and screening. The waterhyacinth pulp was difficult to wash due to a very slow drainage caused by the presence of slimy material.

The characteristics of pulps prepared from a certain raw material would depend on the physical elements present

TABLE 4. STRENGTH DEVELOPMENT OF PULP SHEETS.

Pulp	Beating time minutes	Freeness °SR	Tear factor	Burst factor	Breaking length meter	Folding endurance
Waterhyacinth (unbleached)	0	35	38	30	3,800	31
	10	54	32	43	6,200	96
	20	62	19	42	6,300	51
	30	72	16	43	5,900	103
Waterhyacinth (bleached	0	29	55	40	5,900	134
	10	49	32	63	8,000	2,754
	20	64	34	67	8,100	3,600
	30	73	31	67	6,800	598
Torpedo grass (unbleached)	0	34	50	25	3,900	14
	10	55	28	33	5,300	37
	20	75	12	32	4,600	20
Torpedo grass (bleached)	0	29	65	34	3,800	484
	10	50	43	38	5,300	70
	20	61	41	40	5,700	74
	30	72	34	44	5,300	65
Giant bulrush (unbleached)	0	18	133	32	2,300	29
	10	29	86	54	3,600	28
	20	50	52	60	4,500	25
	30	66	47	54	4,400	23
Giant bulrush (bleached)	0	17	64	17	3,200	30
	10	28	39	27	6,400	609
	20	40	35	31	6,700	819
	30	56	17	26	7,600	1,057

in the pulp, their dimensions and chemical composition, as well as the chemical treatments to which the material is subjected during digestion, bleaching, beating, etc.

Of the three weed species, torpedo grass has the shortest fibers with a relatively thick fiber wall. Even if these features are not that favourable from the paper-making point of view, when strength is considered, but the lower lignin content would make it easier to pulp which is also shown in the low permanganate number obtained (Table 3). Compared with waterhyacinth, giant bulrush has not as long fibers. The length to diameter ratio, however, is almost twice as high, which probably account for the initial high tear factor of the unbleached pulp (Table 4). The favourable features in fiber dimensions, shown in a high fiber length and low Runkel number of waterhyacinth could be seen in the strength development of the unbleached as well as bleached pulps of waterhyacinth (Table 4). High burst factors, breaking lengths and folding endurance were less favourable compared with the other two weed species, resulting in a pulp with a high permanganate number. In this respect more chemicals are required for cooking and bleaching. At similar cooking conditions, using 12% NaOH, waterhyacinth gave the lowest yield and the highest permanganate number.

On bleaching towards a brightness of 80% Hunter, an increase in breaking strength and folding endurance is observed on all three species. The bursting strength of waterhyacinth is also noticeably increased.

These preliminary investigations showed that positive as well as negative features are observed in each species when pulped, which could probably be corrected or balanced out by mixing them or even mixing any one of them with the conventional materials for pulpmaking such as straw, wood, or used papers in recycling or reuse processes. Further work is needed to collect more data and apply methods to improve results.

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Waterhyacinth as A Potential Plant in A Paper Factory

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ABSTRACT

Under laboratory conditions, waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) absorbed sodium, silica, chlorine and sulfur from the waste water of a paper factory. The optimum absorption was obtained approximately after 72 hours. Further investigation showed that waterhyacinth is also a potential material for paper pulp. Petioles of waterhyacinth with 100 cm length, yielded 52 to 83% pulp. Waterhyacinth can therefore provide a paper factory with double functions, i.e. as absorbant of pollutants and be harvested and used to supplement paper pulp material. The pulp has 20.8 G.E. brightness, 12.3 permanganate number, 8.79% ash content and 2.0 mm fiber length.

INTRODUCTION

The fact that vascular plant can absorb, translocate and metabolize or concentrate various chemicals has been known since 1936 (12). The capability of vascular aquatic plants to assimilate nutrients and remove excess nitrates, phosphate and heavy metals from sewage effluents has been recognized for several years (4, 10, 11, 12).

In Indonesia, paper plant factories usually discharge their waste water into irrigation systems. With the current capacity of the paper factories, their waste water will not create any serious problem to rice fields. The potential pollutants of a paper factory to be discussed in this paper are chlorine (Cl), sulfur (S), sodium (Na) and silica (SiO_2). The reason these pollutants are of concern is because chlorine will decrease the pH of soil, which may reduce the uptake of minor elements by plants (3). Sulfur will impact characteristic taste and odour in the water and high content of sulfate in drinking water can cause diarrhea. Silica must be removed from steam boiler water, to prevent hard scale formation in the boiler (8), while sodium in substantial amounts will disturb soil permeability (3).

In using waterhyacinth to absorb pollutants, regular harvesting is needed to renew the absorbing capacity of the plants and to reduce the plant population. In order not to create another waste problem caused by the harvested