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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 waterhyacinth, utilization of waterhyacinth in the respective paper factory as a raw material will be very beneficial. According to Monsod (6), the average cellulose content of waterhyacinth is about 84.8% and J. Decker of Boise Cascade of New York (6) found the quality of hyacinth pulp very encouraging. The pulp responded to bleaching, had low permanganate number, high bursting and folding strength, and the shrinkage was minimal. The United Nations (6) predicted a world wide shortage of wood fiber. Considering that waterhyacinth is a good potential source of long fiber pulp, the wood fiber insufficiency as raw material can ostensibly be augmented by blending the hyacinth's fiber with short fiber pulp from wood bagase in order to obtain reasonable quality pulp and paper.

MATERIALS AND METHODS

Experiment 1

Waterhyacinth plants were selected based from the same SGR (Summed Growth Ratio) which have 5 to 6 leaves; 12 to 16 cm in height and 33 to 43 g in weight. These plants were cultured for 3 days in demineralized water. Waste water was collected from the Padalarang paper factory, which was a mixture of wastes from cooking, bleaching and finishing departments of the factory. The experiments were conducted in the glass house without special arrangement for light, temperature or humidity. The temperature ranged between 25 and 30 C, while the relative humidity was between 80 and 90%. The treatments were: waste water without dilution (A), twice diluted waste water (B) and 20% Hoagland solution (C) as a control. The removal periods were 1, 3 and 5 days. Two waterhyacinth were grown in each pot which was filled with 7 liters of solution. Each series consisted of 9 pots, 4 elements, 3 replications, plus 1 pot for the control solution without waterhyacinth. With 3 kinds of solution and 3 removal periods, the total number of pots was 81. The waste waters were analysed for chlorine content by the Mohr method (1,5) in which silver chloride is precipitated quantitatively before red silver chromate is formed. The sulfur content was determined by emulsifying the precipitated $BaSO_4$ with glycerol then determining its absorbance with a spectrophotometer (7, 8). Silica content was determined using a spectrophotometric method (7), and sodium content was determined using a flamephotometer at 589 nm wavelength (1, 5).

Experiment 2

Waterhyacinth plants from three locations in Java (Krawang, West Java; Rawa Pening, Central Java; and Curug Lake, West Java) were selected on the basis of size of 25 ± 5 cm, 50 ± 5 cm and 100 ± 5 cm in height. Materials used were complete plants or complete leaves and petiole alone. The soda process used in these experiments were as follows. Fifty grams of dry waterhyacinth was chopped and digested with NaOH concentrations of up to 15% based on its dry weight and with a composition solution of 7:1. The maximum temperature was 98 to 100 C reached in 75 minutes. The pulp was filtered and washed until the waste water was neutral, then pressed to remove excess water. The final water content in the pulp was determined. Similar digestion procedures were done with 20 and 25% NaOH per dry weight of waterhyacinth.

Parameters of the pulp quality was measured following standards of TAPPI (9). These were the brightness, permanganate number, fiber length and ash content.

RESULTS AND DISCUSSION

Experiment 1

The initial concentration of elements in the growth solution are presented in Table 1 (A = waste water; B = twice diluted waste water; C = Hoagland solution).

The amount of minerals absorbed in this study and extrapolated values to the amount of minerals absorbed by 1 ha waterhyacinth is presented in Table 2 and 3. From

TABLE 1. INITIAL CONCENTRATION OF ELEMENTS IN THE EXPERIMENTAL SOLUTIONS.

Element	Solution A (ppm)	Solution B (ppm)	Solution C (ppm)
Na	104.78	50.94	4.06
SiO_2	33.34	15.18	3.70
Cl	66.67	36.85	9.10
S	6.80	3.02	4.53

TABLE 2. PERCENT REMOVAL OF 4 POLLUTANTS FROM STATIC WATER TESTS BY WATERHYACINTH AFTER 1, 3 AND 5 DAYS OF GROWTH. THE GROWTH MEDIA A WAS UNDILUTED PAPER PLANT EFFLUENT, B WAS TWICE DILUTED PAPER PLANT EFFLUENT AND C WAS 20% HOAGLAND SOLUTION.[1]

Days after growth initiated	Sodium			Silica			Sulfur			Chlorine		
	A	B	C	A	B	C	A	B	C	A	B	C
1	7	5	15	32	18	41	24	14	13	13	12	28
3	16	9	35	56	49	63	42	23	20	27	24	38
5	14	7	28	58	55	45	35	21	15	28	22	26

[1]Each value was the mean of two replications. Regression equations were. Sodium: (A) $y = -9.83x + 1.53x^2 + 98.52$, (B) $y = -5.54x + 0.84x^2 + 100.22$, (C) $y = -25.07x + 3.65x^2 + 106.36$; Silica: (A) $y = -24.18x + 2.91x^2 + 89.51$. (B) $y = -18.03x + 1.85x^2 + 89.34$, (C) $y = -31.95x + 5.27x^2 + 85.75$. Sulfur: (A) $y = -21.72x + 3.12x^2 + 94.90$, (B) $y = -11.25x + 1.55x^2 + 96.45$, (C) $y = -10.66x + 1.75x^2 + 96.19$. Chlorine: (A) $y = -14.88x + 1.83x^2 + 101.64$, (B) $y = -11.52x + 1.47x^2 + 98.01$, (C) $y = -18.17x + 2.38x^2 + 95.51$.

TABLE 3. THEORETICAL ABSORPTION OF Na, SiO_2, Cl AND S BY 1 HA WATERHYACINTH.[1]

Minerals	Solutions (Table 1)	Minerals absorbed (g/ha) after 1 day	3 days	5 days
Na	A	6,316	7,850	6,613
	B	1,018	2,260	1,617
		696	852	501
SiO_2	A	7,914	8,503	8,727
	B	3,224	3,278	3,570
	C	1,130	1,826	242
Cl	A	2,318	11,079	5,605
	B	1,670	5,284	2,693
	C	1,052	2,065	1,013
S	A	984	1,563	867
	B	321	380	229
	C	433	506	584

[1]Based on 48,7 tons/ha of fresh weight of waterhyacinth grown in a pond at Bogor and 5% dry weight.

this experiment it can be concluded that waterhyacinth could absorb sodium, silica, chlorine and sulfur from waste water of a paper factory. During 5 day observations, the optimum absorption occurred on the third day. This is because the absorption of minerals in plant tissue is limited. According to Epstein (2) it is like a continuously rotating belt conveyor. The more densely loaded the conveyor, the more materials transported in a time unit, but the conveyor is limited, so there is a certain limit that cannot be exceeded. Comparing the culture solutions, it is obvious that the higher concentration of minerals in the solution, the higher amount of minerals that can be absorbed.

Experiment 2

Results of experiment 2 is presented in Figures 1, 2, 3 and 4. The increase % of NaOH slightly decreases pulp yield, increases degree of brightness, reduced the fiber length and ash content of pulp. Based on the samples of

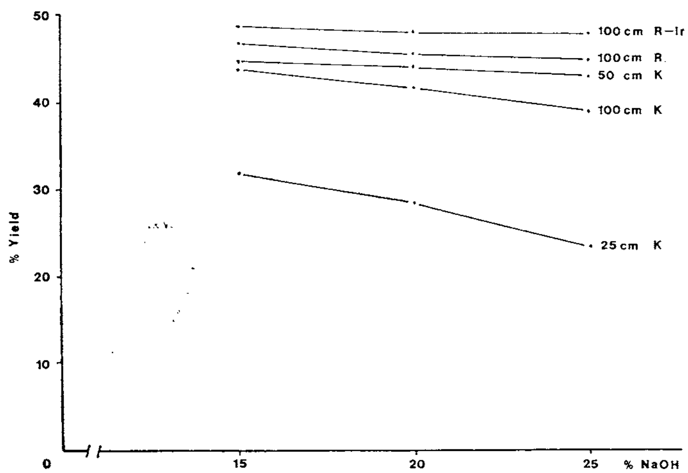

Figure 1. Percent yield of pulp from different materials treated with different percentage of NaOH based on dry weight of waterhyacinth. (K = Karawang, R = Rawa Pening and R–Ir = Rawa Pening without leaves and roots).

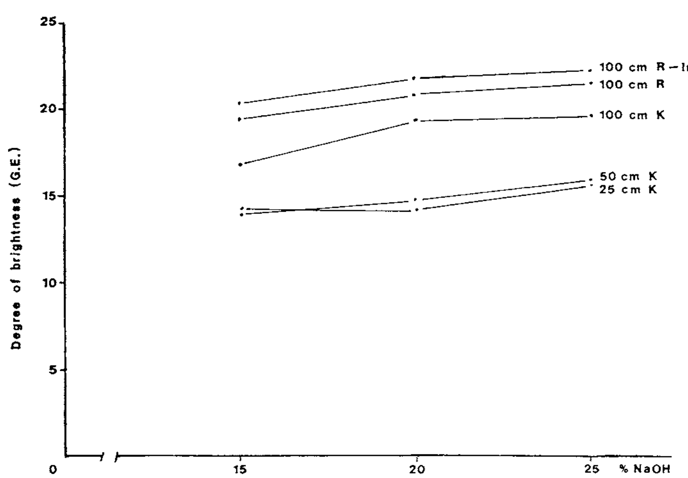

Figure 2. Degree of brightness of pulp from different materials treated with different percentage of NaOH based on dry weight. (See figure 1 for figure legends).

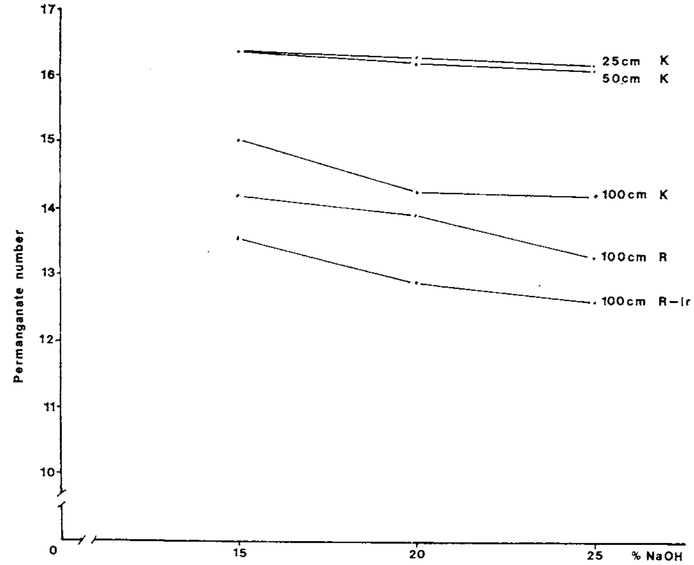

Figure 3. Permanganate number of pulp from different materials treated with different percentage of NaOH based on dry weight. (See figure 1 for figure legends).

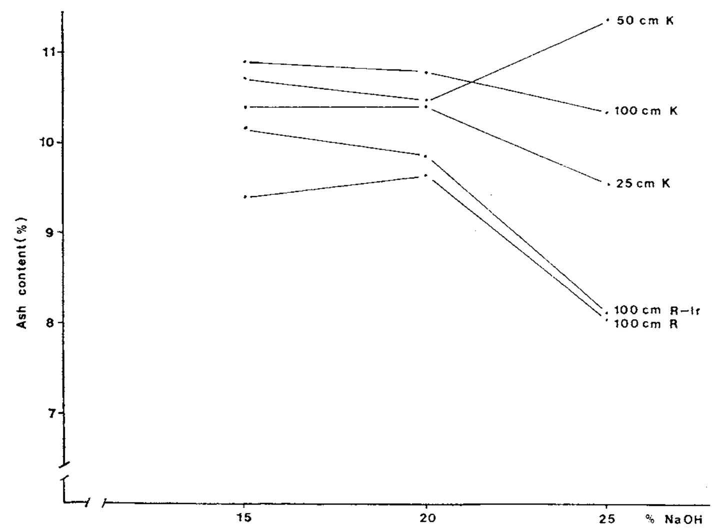

Figure 4. Ash content of pulp from different materials treated with different percentage of NaOH based on dry weight. (See figure 1 for figure legends).

waterhyacinth plants collected from Krawang, and Rawa Pening Lake with different length of plants it can be concluded that the longer the petiole, i.e., 50 ± 5 cm or over, the higher the pulp yield and better pulp quality. Comparisons with rice straw digested with 15% NaOH is presented in Table 4.

TABLE 4. COMPARISON OF PULP QUALITY BETWEEN RICE STRAW AND WATERHYACINTH.

Materials	Yield (%)	Permanganate number	Degree of brightness (G.E.)	Fibre length (mm)
Rice straw	54.28	8.1	53.5	1.2
Waterhyacinth	52.83	12.3	20.8	2.0

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