Utilization of water-plants to upgrade the quality of kraft pulp mill waste water (Grade III effluent)

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SUMMARY:

Laboratory and Pilot scale experiments were conducted to evaluate the feasibility of water-plants viz water hyacinth, Pistia and Nympea, to treat pulp mill waste water. Experiments were conducted with anaerobically treated grade III effluent. Nymphea, did not survive in the effluent whereas water-hyacinth and Pistia grow well. Approximately 30% BOD and 20% COD reductions were obtained in 5 days using both the plants in laboratory scale. In Pilot scale 20% BOD and 15% COD reductions were obtained in 5 days detention with water-hyacinth Ambient temperature and depth of the water play an important role during treatment. At higher temperature i. e. in summer, BOD and COD reductions were more than in winter and both the plants grow in shallow water and die in deep effluent. Thus it is seen that these plants can be used in treatment of the effluents from Bamboo Mill.

During the process of biological degradation bacteria needs Oxygen, when this oxygen is derived from tne organic or inorganic compounds present in the waste itself the system is known as "Anaerobic" when the required oxygen is supplied externally the system is known as "Aerobic". Biological treatment involves the transformation of minerals and non-viable organics into biomass in specialized habitates supporting distinctive, yet complex, communities of living organisms.

Biological degradation and subsequent assimilation of impurities present in raw waste waters by groups of primitive organisms, strongly dominated by bacteria, constitute the preliminary phase in the purification process.

Water-plants found in natural lakes and ponds act as oxygen suppliers. Green plants in presence of sunlight produce oxygen (the well known phenomenon of photosynthesis) and this oxygen is utilised by bacteria for the stabilization of complex organic matter present in the waste water.

Lot of work has been done at university of Philadelphialon utilization of water hyacinth for treating municipal waste. Penfound and Earle[2] conducted a life history study of water-hyacinths and Holn etal[3] made a literature review documenting the spread of water hyacinth throughout the warm region of the world. Cornwell etal[4] recently summerized past studies pertaining to the use of hyacinths for reducing nutrient levels in waste water treatment plant effluent.

Wolverton and Mcdonald[5] conducted a study on the use of hyacinth to improve effluent quality of stabilization pond. Ray Dinges[6] used a controlled culture of water-hyacinth for upgrading stabilization pond effluent. Neuse[7] have conducted several experiments on the utilization of water hyacinth for removal of algae from stabilization pond effluent. In all the above studies water hyacinth was found successful.

In view of the above, experiments were planned to explore the feasibility of (i) water hyacinth (ii) Pistia stratiotes and (iii) Nympea for treating pulp mill waste water (grade III effluent) to reduce BOD/COD and upgrade the effluent quality to meet ISI[9] specifications No. 2490.

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MATERIALS :

For this study the above plants were collected from natural ponds of surrounding area and they are described below :

Water Hyacinth (Eichornia Crassipes)—are large floating aquatic plants. There are chiefly tropical and subtropical plants but introduced into other part of the world as a ornamental plant. Water hyacinth plants of exquisite beauty, with their broad glossy green leaves and light levender flowers aplotched with canary yellow, are found in barrow ditches, and other back waters. They are resistant to insects and disease, but are sensitive to high salinity and low temperature. In India this species is available in abundance as India is a tropical country.

Pistia Stratiotes :

A floating gregarious, stemless, stolonifarous herbs[10], found in tropical countries, distributed throughout India and Ceylon, in still sweet water, having roots of tufted simple white fibres clothed with fibrillac. Leaves 1.25-4 in long in India forms, apex rounded, undulate, Pubescent above and beneath, nerves raised beneath, flabelliform, converging within the margin. Spathe white, obliquely companulate, 0.5 in long, tomeotose externally, gibbous and closed below, contracted about the middle, dilated and nearly circular above.

Nymphea (water Lily)

Large aquatic herbs, root stock, creaping, leaves and floating flowers, having green leaves of 6 in-12 in dia and white or pink flowers. Flowering takes place during the rainy season, found in warmer parts of India, extending to Africa, Java and Philippines, it also occurs in Mungary in the neighbourhood of hot springs.

Effluent

The waste water coming out from different sections of the mills have been segregated into three grade according to their characteristics.

Grade I

Comprises of condensates and cooling waters, it is practically uncontaminated water, hence collected and recycled in the process at suitable points.

Grade II

Consist of white water from paper machine, chlorination and hypochlorite washing from bleach plant and wash water from chipper house. This effluent meets I.S.I. Specifications after treatment. Part of this waste water is recycled in the mill after clarification.

Grade III

This effluent comprises of digester house leakages, pulp washing, caustic extraction effluent from bleach plant and waste water from chemical recovery section. This is the most contaminated water coming out from the mill. It is dark brown in colour and highly alkaline (PH-10-10.5). Its volume is about 3.5 million gallons per day, BOD is 300-350 ppm, COD 1300-1500 ppm and S.S. 300-350 ppm respectively.

Grade III effluent is highly alkaline, hence before biological treatment its PH is adjusted to 8.0 by mixing about 1 million gallons of chlorination effluent, thus total volume of grade III effluent become 4.5 MGD. The present system of treatment for grade III effluent is combination of presettling pond, anaerobic lagoon, aeration tanks and polishing pond and after treatment the quality of the effluent is as under PH-7.5-8.0, BOD-70-80 ppm, COD-600-750 ppm and S.S. 50-60 ppm.

Experimental

In the first stage of this study, laboratory experiments were conducted to see whether these water plants can survive in anaerobically treated grade III effluent and the effect of effluent on the growth and reproduction of plants. Anaerobically treated effluent was selected for the study since it already contains bacteria and has a PH-7.7-8.2, whereas PH of raw grade III is 10.0-10.5 three types of treatments were given to each plant.

i) with 100% grade III effluent.

ii) with 50% grade III effluent, i.e. 1 volume of grade III effluent mixed with 1 volume of plain water.

iii) Control i.e. with plain water, to know how the plants behave with grade III effluent.

Above treatments were given in drums of about 100 litres capacity, with open surface and having an arrangement for water outlet about 7 c.m. above from the bottom of the drum, so that water could be drained without disturbing the bottom sludge bed. Surface area of each drum was 0.24 Sq. meter and height of each drum was 42 cm.

To start with, 5 c m. bottom of each drum was filled with sludge, as the sludge acts as bacterial seed. Experiments conducted with 100% grade III & 50% grade III effluent were seeded with anaerobic lagoon sludge, while the sets with plain water were seeded with the mud from a natural pond. Nutrient nitrogen and phosphorus

added in each drum at the rate 70 ppm N_2 & 50 ppm P_2O_5. As it was thought that this dose will be sufficient to sustain the plants. The three drums were filled with 60 litres of anaerobically treated grade III effluent, three with 60 litres of plain water and remaining three drums with 30 litres of grade III effluent + 30 litres of plain water. Height of the water in each drum was 36 c.m. Three sets were made, Ist set of three drums (one with 100% grade III effluent, 2nd with 50% grade III and 3rd with plain water) for "Water-Hyacinth", second set for "Pistia" and third set for ''Nympea'' and plants were put into each drum in such a way that they covered half the surface area of each drums. All the drums were kept in open so that plants develop under natural conditions. Identical conditions of experiments i. e. equal volume of seed (Sludge), equal volume of waste water or water and equal number of plants into each treatment were maintained. Daily observations were made to see the effect of effluent on plants. Findings are recorded in table—1.

Water hyacinth

It was observed that after three days the leaves of the plant in 100% effluent start turning yellowish and after 7 days completely turns to yellow and start decaying, but meanwhile new leaves start coming out. After 10 days plants came up with all new leaves but of smaller size than the original one. After 10 days growth and reproduction of the plants started but the rate of growth was slow as compared to the rate of growth in plain water. Water hyacinth plants in plain water drum takes 15-16 days to cover the complete surface, whereas 35-37 days was required with 100% grade III effluent.

With 50% grade III rate of reproduction of water hyacinth was found as good as in plain water. After two days a few leaves started turning yellow, but soon they regained original form and after 18 days covered the complete surface. Physical appearance of the plants were even better than plain water. These experiments were conducted in the month of July when the ambient temperature was 30-39°C.

2. **Pistia linn**—Effect of grade III effluent on pistia was similar to that of water hyacinth, but complete defalliation and yellowing of leaves was not observed in this case. Rate of reproduction of pistia was found higher than that of water-hyacinth, but since pistia is a small plant it takes 40 days with 100% grade III and 22 days with 50% grade III effluent to cover the complete surface as compared to 20 days with plain water.

3. **Nymphea**—This plant did not survive even in 50% grade III effluent. All the plants put in 100% grade III or 50% grade III effluent, died within 7 days. Hence further experiments on BOD reduction of grade III effluent were not carried out.

To study the effect of the plants on BOD/COD reduction of grade III effluent, three drums of above mentioned specifications were taken and filled with 60 litres of anaerobically treatad grade III effluent and seeded with anaerobic sludge. Then water hyacinth plants which were already aclamatised with grade III effluent were put in 1st drum in such a way that they cover 3/4 surface of the effluent. Similarly pistia was put in IInd drum and third drum was kept as control. Effluent samples (300 ml) were collected from each drum on 1st day, after 5 days, 7 days, 10 days and 12 days and analyasd in the laboratory for PH, BOD and COD as per "Standard methods for the examination of wate and waste water"[11] to evaluate BOD and COD reduction at different detention period. Practically no plant decay was observed in summer but during extreme winter in the month of Jauuary very few plant started decaying and they were removed. To find out the effect of ambient temperature, above experiments were repeated in winter season as well as in summer. The results are presented in table 2 & 3. Ambient temperature record of Amlai region is given in table—5.

As third stage of this study pilot scale experiments were conducted in a 3 meter × 3 MXI meter pond with 100% grade III effluent using water hyacinth only, to study its effect on BOD/COD reduction. Analysis results with different detention period and flow rate are given in table—4. Pilot scale experiments with pistia were not dong due to non-availability of required quantity of pistia plant. Meanwhile some plants were put in the anaerobic lagoon having water depth 20-30 feet and it was observed that only few plants which comes to the shore of the lagoon due to wind survive and rest of the plants which remained in the middle, died after few days.

RESULTS AND DISCUSSION

Results presented in table—1 reveals that both water hyacinth and pistia survive in anaeronically treated grade III effluent, whereas nymphea die even in 50% grade III effluent. Pistia is less sensitive to grade III than water hyacinth. In case of water hyacinth almost all original leaves died in 7 to 10 days, whereas in case of pistia partial defalliation and incomplete yellowing of leaves were observed. After the plants become aclamatised with grade III effluent growth and reproduction started in both the plants, though the rate of reproduction was less as compared to plain water. In the case of 50% grade III effluent growth rate of

TABLE—1 EFFECT OF GRADE III EFFLUENT ON WATER-PLANTS

Total depth of each drum	— 42 cm
Depth of sludge (seed) in each drum	— 5 cm
Depth of water or waste water in each drum	— 37 cm
Surface area of each drum	— 0.24 Sq. meter
Surface area covered by the plants Ist day	— 0.12 sq. meter i.e. half the surface area of each drum.

Water/ plants	100% Grade III Effluent	50% Grade III Effluent	Plain water (control)
1. Water hyacinth	a) Survive	Survive	Survive
	b) Yellewishness of leaves started after 3 days	Non-significant change	—
	c) Complete leaves turns to yellow and start decaying after 7 days	Only few leaves turn to yellow but no leaves die	All the leaves were found green
	d) All original leaves die and new leaves comes on the plant after 10 days.	Plant start reproducicng only after 3-5 days and growth rate is equal to plain water.	
	d) Plants cover the complete surface after 35 days.	Plants cover complete surface in 18 days.	Plants cover complete surface in 16 days.
2. Pistia	a) Survive	Survive	Survive
	b) Yellowing of leaves started after 2 days.	No significant change.	
	c) Plants started recovering growth and reproduction of new plants started afted 4-5 days.	Plants started reproducing after 4 days and growth was as good as in plain water.	Plant flourish nicely.
	d) plants cover the complete surface after 40 days.	Plants cover the complete surface after 22 days.	Covers the complete surface in 20 days.
3. Nymphea	Plants die within 5 days.	Plants die within 7-8 days.	Plants survive nicely.

TABLE—2 ANALYSIS OF EFFLUENT BEFORE AND AFTER TREATMENT WITH WATER-PLANTS

Parameters/ detention time.	Without plants			With water-hyacinth			With Pistia		
	PH	BOD PPM	COD PPM	PH	BOD PPM	COD PPM	PH	BOD PPM	COD PPM
Ist Set									
Ist day	7.8	196	980	7.9	196	980	7.9	196	980
	8.0	185	900	8.0	185	900	8.0	185	900
After 5	7.9	158	820	7.9	130	725	7.8	128	720
days	8.05	150	750	7.9	124	666	7.9	125	660
After 7	8.0	150	790	7.9	116	680	7.9	114	675
days	8.0	140	725	8.0	112	630	8.1	110	625
After 10	8.0	140	768	8.0	105	655	7.9	106	650
days	8.1	135	705	8.0	100	606	8.0	100	600
After 12	7.9	130	740	8.0	98	640	8.0	98	630
days	8.05	128	686	7.95	94	590	8.05	90	585
IInd Set									
Ist day	8.0	215	1050	8.0	215	1050	8.0	215	1050
	8.2	230	1120	8.2	230	1120	8.2	230	1120
After 5	8.1	180	880	8.1	158	785	8.0	156	780
days	8.4	190	934	8.3	170	840	8.2	170	830
After 7	8.1	172	855	8.2	145	760	7.9	142	750
days	8.3	178	905	8.2	154	810	8 15	155	800
After 10	8.0	164	825	8.05	134	742	8.05	132	740
days	8.3	170	875	8.1	140	790	8.2	138	790
After 12	8.1	158	810	8.1	122	730	8.0	120	725
days	8.25	166	865	8.15	128	780	8.15	126	770
IIIrd Set									
Ist day	7.8	240	1100	7.8	240	1100	7.8	240	1100
	8.2	238	1120	8.2	238	1120	8.2	238	1120
After 5	7.9	196	885	7.8	170	860	7.9	170	865
days	8.2	196	898	8.1	166	874	8.15	166	870
After 7	7.9	184	860	7.9	155	820	7.7	152	830
days	8.3	182	870	8.15	148	826	8.2	146	830
After 10	8.0	176	830	8.0	140	770	7.9	136	774
days	8.3	172	845	8.2	132	780	8.25	132	782
After 12	8.0	170	820	8.0	126	740	7.95	124	735
days	8.25	167	830	8.1	122	750	8.2	120	740

NOTE : Ist set of experiments were conducted in the month of August-September, IInd set in the month of December-January and IIIrd set in the month of February, March.

TABLE—3

REDUCTION IN BOD & COD AFTER TREATING THE GRADE III EFFLUENT WITH WATER PLANTS

Ist set	% Reduction					
	Without plant		With water hyacinth		With Pistia	
Days	BOD	COD	BOD	COD	BOD	COD
Ist day						
5th day	19	16	33	26	34	26
7th day	24	20	40	32	41	30
10th day	28	21.6	46	33	46	34
12th day	32	24	50	35	50	35
IInd Set						
5th day	16	16	26	16	26	26
7th day	21	19	33	27	33	28
10th day	24	22	43	29	39	28.5
17th day	27	23	44	30	45	31
IIIrd Set						
5th day	18	19	30	22	30	22
7th day	19	22	37	26	37	25
10th day	27	25	43	30	40	30
12th day	29	26	48	33	49	34

TABLE—4

ANALYSIS OF GRADE III EFFLUENT SAMPLES COLLECTED FROM INLET AND OUTLET OF PILOT PLANT (CONTAINING WATER HYACINTH).

	Influent			Effluent after 5 days			% Reduction	
Para-meters	PH	BOD PPM	COD PPM	PH	BOD PPM	COD PPM	BOD	COD
1.	7.8	230	1050	7.9	180	900	22	14
2.	8.3	242	1140	8.2	196	965	19	15
3.	8.0	250	1128	8.0	200	956	20	15
4.	8.1	242	1135	8.15	200	963	17	15
Ave.	8.05	241	1113	8.06	194	946	19.5	15
	Influent			Effluent after 7 days				
1.	8.0	240	1200	8.05	182	984	24	18
2.	8.2	254	1180	8.1	190	970	25	18
3.	7.9	248	1180	8.0	188	962	24	18
4.	8.1	242	1172	8.1	180	964	25	17
Ave.	8.05	246	1183	8.06	185	970	24.5	18
	Influent			Effluent after 10 days				
1.	7.8	235	1174	7.9	166	884	29	24
2.	7.8	240	1200	8.0	170	900	29	25
3.	8.0	230	1150	7.95	160	870	31	24
4.	8.2	222	1120	8.2	160	840	28	25
Ave.	8.0	232	1161	8.0	164	874	29	24.5

NOTE : Grade III flow in the expe. pond was 7 litres/hr. at 5 days detention period, 54 litres/hr.at 7 days and 37.5 litres/hr at 10 days detention period.

TABLE—5

TEMPERATURE RECORD OF ORIENT PAPER MILLS, AMLAI FROM APRIL 1980 TO MARCH 1981

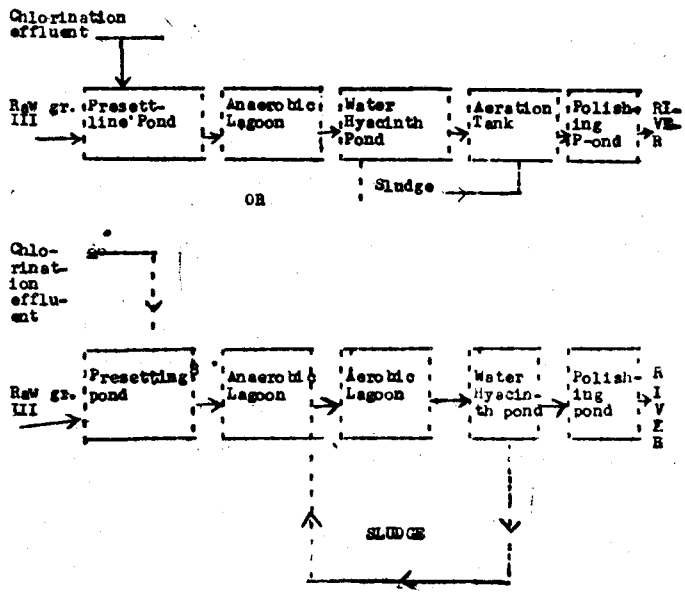
Months	Maximum Temp.		Minimum temp.	
	Min	Max	Min	Max
April' 1980	37.0	45.0	19.5	26.0
May 1980	42.0	47.5	23.0	29.5
June 1980	32.5	46.0	23.0	30.0
July 1980	31.0	39.0	22.5	25 0
August 1980	31.0	37.0	21.5	25.0
Sept 1980	27.0	36.0	17.0	24.5
October 1980	24.0	37.0	14.0	20.0
November 1980	29.5	34.5	8.5	16.0
December 1980	20.0	31.5	5.0	12.0
January' 81	19.0	30.5	3.5	11.0
February' 81	25.5	37.0	6.5	15.0
March' 81	31.5	38.0	10.5	21.0

of 1 meter depth for 5 days, 7 days and 10 days respectively. Here again the reductions obtained were partially due to water hyacinth and partially due to natural oxidation. These experiments were conducted in the month of February and March i.e. in the moderate ambient temperature (25-32°C). In winter season reduction in BOD/COD may be less than the present figures. While in summer it may be more. During winter some plants die and decay, which create extra organic sludge in the system. This organic sludge may be circulated in aeration tank since it contains lot of useful bacterial and other biomass.

water depth in the pond play an important role on the efficiency of these plants for treating waste water. These plants grow better in shallow water and die in deep water. It is because long root of the plants takes nutrient from the soil. Water depth of 3-4 feet was found suitable for water-hyacinth.

Conclusion :

Above experiments indicate that water hyacinth or pistia may be used to upgrade the quality of grade III effluent in combination with other biological treatment system. On the basis of the finding of above experiments a four stage biological system is suggested to treat grade III effluent from pulp mill.



Polishing pond is necessary to settles out the degraded organic matter and any other biomass before the effluent is discharged. The excess sludge produced in the water hyacinth pond may be recirculated in the aeration tank, chlorination effluent is mixed in presettling pond to adjust the

both the plants were found as good as in plain water.

Results presented in table 2 & 3 (Fig. 1, 2) shows that BOD reduction of grade III effluent after treatment with water plants for 5 days were found 26-33% and after 12 days 44 to 50%, similarly COD reduction was 16-26% after 5 days and 30-35% after 12 days in the winter season when the ambient temperature was low (20-28°C in day time) the reduction in BOD and COD was less. As at lower temperature growth and reproduction of the plants stopped. During winter the minimum ambient temperature comes down to 5°C or even below and at such lower temperature the plants died.

BOD reduction of grade III effluent in the experiments conducted without water plants were found 16-19% after 5 days and 27-32% after 12 days. Corresponding COD reduction was 16 to 19% after 5 days 23-26 percent after 12 days. This reduction in BOD and COD were obtained due to natural oxidation. So if the BOD and COD reduction due to natural oxidation was subtracted, we found that BOD reduction due to water hyacinth was only 10-14% in 5 days and 17-19% in 12 days. similarly COD reduction was only 0-10% in 5 days and 7-11% in 12 days. Low reduction in COD/BOD observed may be due to the decay of water hyacinth plants.

Identical results were obtained with pistia (Fig-3). This plant was also affected with low temperature, but the effects were not so pronounced as in the case of water hyacinth.

As presented in table—4 BOD reduction of 19.5%, 24.5% and 29% and COD reduction of 15%, 18% and 24.5% were recorded when grade III effluent was treated with water hyacinth in a pond

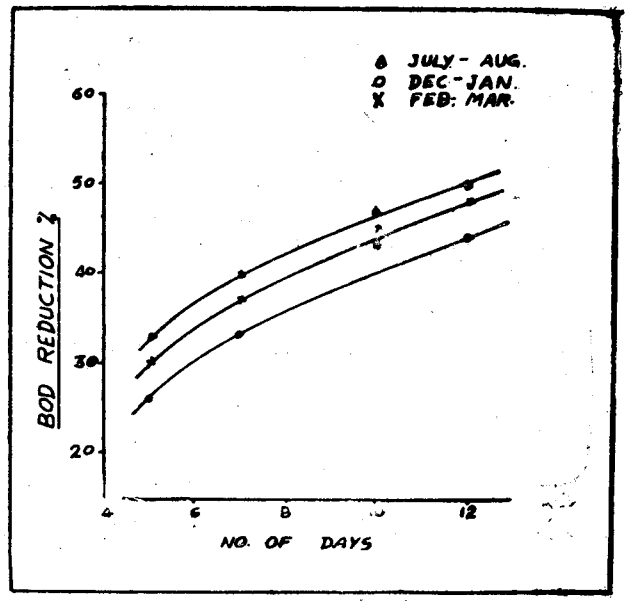


FIG-2:- EFFECT OF WATER HYACINTH ON BOD OF GR-III AT DIFFERENT MONTHS

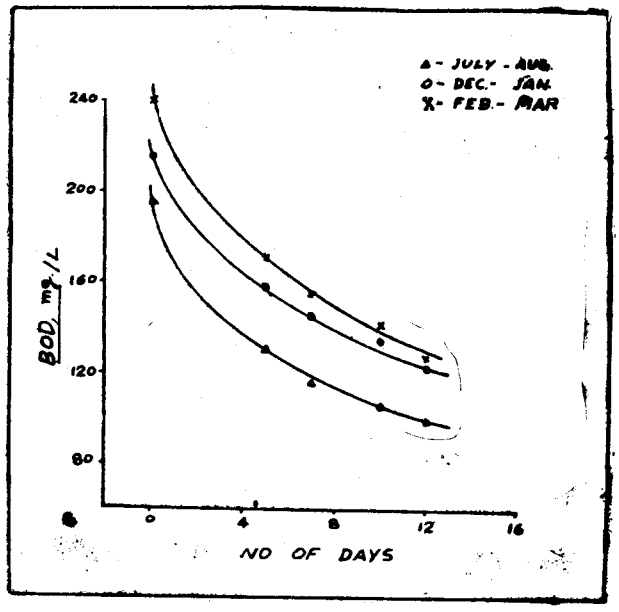


FIG-1 EFFECT OF WATER HYACINTH ON BOD OF GR-III AT DIFFERENT MONTHS

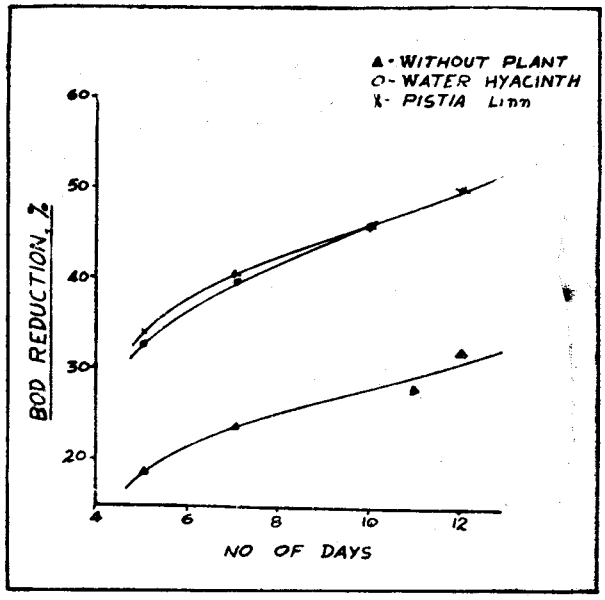


FIG-3:- BOD REDUCTION OF GR-III WITH AND WITH OUT WATER PLANTS

PH (about-8). But water hyacinth may be used as a treatment device, only where sufficient land is available as depth of water hyacinth pond is restricted upto 3 feet only. For 4 million gallons per day of effluent, 25 acre of land will be required to process the effluent for 5 days.

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