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Presented at the 19th Annual Industrial Waste Conference,
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The modified froth flotation process previously reported (1) as promising economic harvesting of algae has been further developed. In addition to bringing a practicable algal harvesting system nearer, the new work indicates that the method may also be useful in the treatment of sewage. The fact that laboratory-grown cultures of algae frothed without the addition flotants indicates that a frothing agent was produced by the cultures themselves. A high-temperature strain of Chlorella pyrenoidosa was initially selected for use in the studies because its adaptability to the conditions of laboratory culture and its relatively high reproductive rate make it desirable for mass culturing as a food source or for gas exchange in closed systems. Following acid pH adjustment of the feed culture, it was placed in a glass cylinder equipped with a porous diffusion plate at the bottom. Air was forced through the plate, creating fine bubbles in the liquid above. A stable foam, highly concentrated in algae, formed at the liquid surface and rose up the column; the foam was collected at a discharge orifice. The feed solution was virtually clarified by this process which harvested almost all of the suspended cells.

Hydrochloric acid was used to lower the pH of the harvest feed cultures and sodium hydroxide for subsequent neutralization. It was found that aeration rate and pH level influenced the degree of concentration obtained.

Subsequent work has considered the desirability of harvesting only a portion of the algae and recycling the remaining culture in a continuous growth system. Successful operation of such a system requires that the algae remain viable despite exposure to the low pH condition in the harvester. Investigations were directed toward determination of viability of cells repeatedly exposed to

harvesting conditions; and their subsequent growth in fresh media, supplemented, unsupplemented, and diluted harvest liquor.

In order to determine the viability of cells which were continuously recycled, and resuspended in fresh medium, the following determinations were made.

Seven hundred ml of urea medium* were inoculated with C. pyrenoidosa and cultured for ten days; 300 ml of the culture were adjusted to pH 3.0 with 0.1 N HCl and harvested. The harvested cells were adjusted to pH 6.0 with 0.1 N NaOH, brought up to 100 ml with deionized-distilled water, and divided into two equal portions. One 50 ml portion was reconstituted to 700 ml with fresh urea medium, and the other 50 ml portion was used in the study on growth in harvest liquor. The portion reconstituted with fresh medium was grown for a period of time after which 300 ml were harvested. The harvested cells were adjusted in pH and resuspended to 700 ml in fresh urea medium.

The harvest-growth cycle was repeated five times during the experiment with the only variable being the length of the culturing period. Fresh comparison cultures were inoculated at the beginning of each growth period. Packed cell volume (pcv) was recorded as ml packed cells/ml total suspension at the start of each growth period and again when the culture was harvested.

The pcv and percentage relationship of the harvested culture and the comparison culture are presented in Table 1. On the average, harvested cells achieved essentially the same growth as the comparison cultures. Furthermore, it is obvious that the recycling through five harvest-growth periods did not result in the loss of viability of harvested cells resuspended in fresh medium.

The extent to which fresh algal cells are supported by liquor that has been used repeatedly for growth-harvest cycles was also determined. A 500 ml aliquot of urea medium was inoculated with C. pyrenoidosa, cultured for four days, and harvested. The liquor obtained from the harvest was adjusted from pH 3.0 to pH 6.8 by the addition of 0.1 N NaOH and inoculated with a known concentration of fresh algal cells. This cycle was repeated for six harvest-growth periods with the only variation being the length of the individual growth periods. No fresh

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*Composition in mg/l deionized-distilled water: $MgSO_4 \cdot 7H_2O$, 1000; KH_2PO_4, 250; Urea, 1000; iron sequestrine, 35; manganese sequestrine, 3; and sequestrines of copper, zinc and cobalt, 1.

Table 1

VIABILITY OF CELLS HARVESTED FROM UREA MEDIUM AND RESUSPENDED IN FRESH UREA MEDIUM

Harvested Culture				Comparison Culture*			Net PCV of Harvested Culture in Relation to Comparison Culture (Percent)
Growth Period (Days)	PCV Inoculum	PCV Harvest	Net PCV Growth	PCV Inoculum	PCV Harvest	Net PCV Growth	
4	.0005	.0030	.0025	.0010	.0040	.0030	83
5	.0005	.0050	.0045	.0005	.0050	.0045	100
4	.0013	.0045	.0030	.0015	.0035	.0020	150
5	.0007	.0050	.0043	.0007	.0045	.0038	112
6	.0005	.0020	.0015	.0005	.0025	.0020	75
Average	.0008	.0037	.0031	.0008	.0037	.0030	103

*Fresh, unharvested cells.

nutrients, liquor, or deionized-distilled water were added to the original liquor. For comparison, at the beginning of each growth period fresh urea medium was inoculated with fresh agal cells to the same concentration as introduced into the liquor culture. The comparison cultures were grown and harvested under normal conditions.

It was found that the liquor does support growth of the algae, but not so well as the fresh medium. Whether the smaller amount of growth in the liquor cultures results from a depletion of nutrients or a build-up of autoinhibitory metabolic products was further investigated.

To determine the limit to which the harvest liquor, diluted by addition of deionized-distilled water with no supplemental medium added can support growth, the following experiments were conducted.

Fifty ml of cells were introduced into a medium composed of 250 ml of clarified liquor and brought up to 700 ml volume with 400 ml of deionized-distilled water. The cultures were grown for various periods, and 300 ml were harvested each time. The harvested cells were adjusted in pH, and resuspended in a liquor-deionized-distilled water medium. The harvest-growth cycle was repeated five times throughout the experiment in progressively diluted liquor media with the length of the culturing period and level of dilution as variables.

During the five sequential growth periods in diluted liquor, dilution factors increased from 2.8 to 172.3 Growth was not inversely proportional: a 61.5-fold dilution (172.3/2.8) resulted in only a three-fold diminution of growth. This dilution does not take into consideration the nutrients removed from the liquor by previous growth. The response demonstrated that the nutrients were not completely depleted during the total 24-day period.

The following experiment was conducted to determine the viability and general condition of C. pyrenoidosa cultures held for a period of 24 hours at pH 3.0.

Two 400 ml Chlorella cultures, one supplemented with urea and the other with KNO_3, were cultured for five days. When KNO_3 was used in the medium, it was added in a concentration of 3.4 g/l, and when urea was used as the nitrogen source instead of KNO_3, it was added in a concentration of 1.0 g/l so that nitrogen concentrations would be equal in the two media. At the end of the five-day growth period, each culture was split into 200 ml portions. One portion of the urea culture was adjusted to pH 3.0 with 0.6 ml of 1 N HCl, and one portion of the KNO_3 culture was adjusted to pH 3.0 with 4.0 ml of 1 N HCl. The other portion of each

culture was retained at its normal pH, 6.4 for the urea and 9.5 for the KNO_3, and was used as a control culture. The experiment was conducted at room temperature (22°C). Visual observations and photomicrographs of all cultures were made every two hours for the 24-hour period. Packed cell volumes and percentage relationship are presented in Table 2.

Table 2

VIABILITY OF CELLS CULTURED IN UREA AND KNO_3 MEDIUM SUBSEQUENT TO MAINTENANCE AT pH 3.0 FOR 24 HOURS AS COMPARED TO NORMALLY MAINTAINED CONTROLS

Culture	PCV Inoculum	PCV 5 Days	Net PCV Growth	Percent PCV Compared to: Urea	KNO_3
Urea Control pH 6.4	.0010	.0060	.0050	100.0	91.0 ~~76.9~~
KNO_3 Control pH 9.5	.0025	.0080	.0055 ~~.0065~~	110.0 ~~130.0~~	100.0
Urea pH 3.0	.0010	.0050	.0040	80.0	72.7 ~~61.5~~
KNO_3 pH 3.0	.0015	.0060	.0045	90.0	81.7 ~~69.2~~

The data in Table 2 suggest that some impairment of the viability of a Chlorella culture occurs when it is maintained at pH 3.0 over a 24-hour period. This was further confirmed by the visual observation in which some cell lysis and cellular debris were noted. However, the data also demonstrate that catastrophic losses did not occur in the experimental cultures. The urea experimental culture achieved 80.0% and, the KNO_3 experimental culture achieved 69.2% net growth with respect to their controls. This loss would very likely be greatly attenuated in pH 3.0 exposure periods approximating those required for harvesting operations.

Studies were made to determine the most economical use of air during the flotation harvesting process. Three acrylic harvest columns were prepared with sintered glass spargers attached to the bottom. Air lines were connected to each sparger-column assembly and in-line air-flow meters were calibrated to deliver air at rates of 40, 90, and 155 std cc/min at 15 psi.

The Standard Methods (2) Jackson candle determination of turbidity was explored as a means of determining cell concentrations in the harvest feed suspension. It was necessary to determine if a direct relationship between cell concentration of sample and turbidity value existed. A series of cell dilutions was prepared. Comparisons between turbidity readings and pcv's were made, and a direct relationship was found. The Jackson candle method was found to be a reliable, rapid method of determining the density of algae in harvest feed suspensions.

The pcv's of the feed cultures, grown in one-gallon jugs for five to seven days, ranged from 0.0026 to 0.0034 ml/ml. Jackson candle determinations were made on the feed cultures prior to acidification. After pH adjustment to 3.0, the feed suspensions were subjected to aeration periods of 1, 3, and 15 min. at each of the three aeration rates. After each independent harvest trial, the turbidity of the harvest feed liquor was determined, and the amount of harvest calculated.

The percent harvest at each aeration rate in relation to length of the aeration period and volume of air is shown in Table 3. At all aeration rates, the cumulative percentage of each culture harvested increased with time. Little additional harvest occurred after three min. of aeration at 90 and 155 cc/min, but an appreciable harvest was obtained by continuing harvesting beyond three min. at 40 cc/min. The cumulative harvest data indicate that the aeration rate of 40 cc/min. is the most inefficient in terms of exposure time. It is also evident from cumulative harvest data that the most efficient harvesting occurs at the highest aeration rate, 155 cc/min.

The amount of harvest relative to unit volume of air expended during the three periods of aeration is important to the overall economy of the system. This relationship is also shown in Table 3. Percent harvest per volume of air expended was greatest when the harvest feed was aerated at 40 cc/min, for all equal aeration periods compared. In fact, the amount of harvest per unit of air expended at 40 cc/min was at least twice that for each of the two higher aeration rates when equal aeration periods are compared. Percentage harvest per unit of

Table 3

PERCENT HARVEST AS A FUNCTION OF DURATION OF AERATION AND AERATION RATE

Duration of Aeration, (min)	Percent Harvest at Indicated Aeration Rate*					
	40 cc/min.		90 cc/min.		155 cc/min.	
	Cumulative	Per cc Air	Cumulative	Per cc Air	Cumulative	Per cc Air
1	56.7	1.42	68.7	0.76	88.8	0.57
3	68.4	0.57	87.9	0.33	97.2	0.21
15	92.4	0.15	88.6	0.07	98.5	0.04

*Average of 3 replications.

air decreased as the aeration rate was increased. This is in agreement with a previous report(1) which stated that harvest concentration increased sharply as the aeration rate was decreased. These data also show that for all aeration rates, the rate of harvest declines rapidly after feed suspensions are aerated for more than 3 min. Therefore, on the basis of air expenditure for desired percent clarification, the most economical harvesting of algae occurred when cultures of the densities considered here were aerated at 40 cc/min for three min. Additional work should explore the 15 min harvesting interval by finer increments to determine the optimum period of aeration more closely. Furthermore, the evaluation of the optimum aeration rate and aeration period for harvesting on the basis of percentage harvest (Table 3) has value only where comparable feed densities are considered.

The minimum and maximum culture densities that could be economically harvested were investigated. An experiment was designed so that daily harvest determinations could be made on cultures grown in one-gallon jugs for one to five days, and initiated at pcv's of 0.0005, 0.0010, 0.0020, and 0.0040 ml/ml. Harvest efficiency and economy could be evaluated from the standpoint of initial culture density and culture age at time of harvest. The cultures were incubated at $37 \pm 2^{\circ}C$ under approximately 2000 ft-c illumination, and aerated with a mixture of approximately three percent CO_2-in-air. On the basis of results described above, all feed cultures were flotation harvested for three min at an aeration rate of 40 cc/min. Harvests were determined indirectly by Jackson candle method.

Cell removal was greatest between about 3.5 and 4.5 days of growth for the cultures initiated at 0.0005 and 0.0010 ml/ml. For cultures initiated at a pcv of 0.0020 ml/ml, maximum harvest was obtained between two to three days of growth. A very dense harvest was obtained for cultures initiated at a pcv of 0.0041 ml/ml after two days of growth. As initial pcv was increased from 0.0010 to 0.0041 ml/ml, the growth interval for maximum harvest decreased. These results indicated interactions among culture density, absolute amount of harvest, and harvesting efficiency. Harvesting efficiency data alone would provide no information on the actual amounts of cells removed from these suspensions. Harvest efficiency, as well as cell removal, did fall dramatically with time for pcv 0.0041 cultures after four days of growth, indicating that, after this age, the ability of the harvesting process did not increase in proportion to growth of the cultures.

For the range of culture densities used in these studies, it was found that the culture density producing maximum harvest lies at a value somewhere between 0.0063 and 0.0105 ml/ml. In other words, a maximum harvest accrued from cultures initiated at a pcv of 0.0041 ml/ml and grown for a period of about two days under conditions described above.

No lower limit of density for efficient harvesting and for total harvest was encountered, although it seems certain to exist. The amount of harvest observed for cultures initiated at a pcv of 0.0005 ml/ml was not appreciably different from that of cultures initiated at a pcv of 0.0010 ml/ml, regardless of age of culture at harvesting.

In the above investigation, samples of each culture were acidified to a pH of 3.0 immediately preceding froth-harvesting operations. The culture pH and amount of 1N HCl required to adjust the 450 ml samples to pH 3.0 were recorded. Regardless of culture inoculum level, acid requirements increased with the age of culture. This phenomenon might be due to the build-up of culture metabolites having high acid-buffering capacity. It was also found that, regardless of age of culture at time of harvest, cultures initiated at pcv's of 0.0010 and 0.0020 ml/ml required more acid than those initiated at the higher and lower culture densities. Acid requirements for cultures initiated at a pcv of 0.0005 ml/ml were about twice those for cultures initiated at 0.0041 ml/ml. However, when acid requirements, on the basis of fresh weight of algae harvested were computed, acid economy was greatest at the highest culture density. Here, too, acid requirements for the two intermediate inoculum levels were greater, regardless of age of culture, than for the higher and the lower inoculum levels.

The present state of the art does not permit accurate determination of cost of harvesting algae by froth flotation, but estimates are possible on the basis of costs of certain important steps in the operation. Capital cost estimates were not made; engineering design effort and pilot plant studies are necessary before such costs can be obtained.

The cost of adjusting a dilute culture and a relatively dense culture was calculated on the basis of acid requirements for a relatively dense culture and a dilute culture. Requirements of base for neutralization were not determined, so estimates of the cost of NaOH were based upon a ratio calculated from acid and costs estimated by Levin et al (1). They estimated the acid and base costs at approximately 40 and 11 dollars, respectively. Based upon current prices of 20°Be' HCl and solid NaOH (76%) the cost of acid and base per ton of dry algae harvested from the dilute culture would be about 42 and 12 dollars, respectively. The cost of acid and base per ton of dry algae harvested from the dense culture would be about 21 and six dollars, respectively.

Air costs were estimated, based on a cost of 0.005 dollars per 1,000 ft^3 at 7.25 psi for aeration of municipal sewage (3). The air cost for harvesting the dilute culture would be $.19 and that for the dense culture would be $.03 per ton of dry algae. This is a reduction of approximately four dollars per ton over air costs perviously reported(1). This is because of the shorter aeration period and lower aeration rate.

Gotaas and Golueke (4) estimated the cost of commercial drying of algae at 20 dollars per dry ton. Total costs for processing one ton of dry algae would therefore be approximately 75 dollars for dilute cultures and approximately 47 dollars for relatively dense cultures. The value of dried algae was estimated to be 80 to 100 dollars per ton, and on this basis, a figure of merit of 35 to 40 dollars for economically harvesting a ton of dry algae was presented in 1957 (5). If these estimates are updated to compensate for increases in the Consumer Price Index since 1957, the current figure of merit would be 38.2 to 43.5 dollars. On the basis cost analysis made here, the figure of merit for producing a ton of dry algae has been virtually attained.

Harvesting of the mixed algal culture in two sewage lagoons, both at Hazleton Laboratories, Inc., Falls Church, Virginia, was investigated. Approximately 300 workers and 2000 dogs and primates are served by the ponds which also receive chemical laboratory wastes. It was observed that the unadjusted sample, pH 9.3, foamed readily with some clarification of the sewage. This foaming was

thought to be due to detergent present. When the sample was adjusted to pH 3.0 with 1 N hydrochloric acid, both the algae and the detritus were removed from the feed suspension. The harvested material was a sticky gelatinous mass and clung to the upper walls of the harvest column. When the detergent was first removed by pre-aeration at the ambient pH, and the sample was acidified to pH 3.0, the algae could be harvested clear of the column. Thus, pH control made it possible to "foam fractionate" the sewage.

One lagoon (273 ft. x 273 ft. x 28 in) was two months old at the initiation of the investigation. The pH of this lagoon ranged between 7.5 and 9.5 with a mean average value of 8.5. Unadjusted samples from this lagoon exhibited little, if any foaming tendency. This was attributed to low "detergent" concentration. The parameters of aeration rate (40, 90, 155, and 220 cc/min) and pH levels (3.0, 3.5, and 12.0) were explored. It appeared that the higher aeration rates yielded greater amounts of harvest, regardless of pH; however, at the higher rates, more waste was carried over into the receiving container and the harvest was diluted. Although it appeared that all of the detritus and algae were removed in most cases, when the feed suspension was adjusted to pH 12.0 and the aeration rate to 155 cc/min., the greatest concentration of harvest was obtained.

In subsequent tests, turbidity values determined by the Jackson candle method were standardized against suspended solids determinations. For the samples tested, a linear relationship was demonstrated between weight of suspended solids and turbidity. The Jackson candle method, therefore, was found to be sufficiently reliable for determining the amount of solids suspended in sewage lagoon samples.

These studies led to a questioning of the generally accepted use of percentage clarification to describe algal harvesting or sewage treatment efficiency. For example, a process which removes a high percentage of suspended algae or sewage particulates from a dilute suspension may not be very efficient in terms of process objectives. On the other hand, the removal of only a small percentage of a dense suspension may be more relavent to the objectives and, hence, more efficient. The best way to characterize clarification processes would seem to be in terms of absolute accomplishment; i. e., amount of material removed per unit of effort, materials or time. The selection of the most suitable process or range of operation would then be made on the basis of the specific need.

Harvesting columns described in the studies with algal cultures were also used in the sewage investigations. Four hundred and fifty ml portions of sewage lagoon feed suspensions were adjusted to pH 3.0, 3.5, and 12.0. The feed suspensions were aerated at approximately 40, 90, and 155 cc of air/min, and harvested at each pH value. Initially, the time which a first burst of harvest occurred was recorded. After the first three min of aeration, relatively little additional clarification was observed. The results are presented in Table 4.

From the data, it is apparent that the clarifications achieved at pH 3.0 and 12.0 are approximately equal. The choice of pH, then, is a matter of economics. On the basis of costs, pH 3.0 is the level of choice since, from experimental data, pH 3.0 is achieved at a cost of $28.40 per million gallons of lagooned sewage versus $278.00 per million gallons adjusted to pH 12.0.

Over a period of several weeks, many harvesting experiments with lagooned sewage were performed. From these experiments, which were independent trials due to the destructive nature of the procedure, a compendium of all data at pH 3.0 has been prepared (Table 5). Turbidity values were converted to weight of suspended solids by use of a standard curve developed for sewage.

These data show impressive removals, even for short aeration periods at low aeration rates. The results are more impressive when it is recalled that the starting material was lagoon sewage which had already been settled for a mean period of more than six weeks. It would be interesting to study the effect of the harvesting process on fresh sewage and sewage lagooned for several days.

From the standpoint of sewage treatment, removal of bacteria from the lagooned sewage effluent would be an important bonus. The distribution of coliform organisms and total bacteria in the feed suspension, in the feed after pH adjustments, in the harvest, and in the clarified effluent, was investigated. The presence of members of the coliform group was determined by the membrane filter technique (6) and total bacteria determinations were made by the standard plate count method (7). A study of the bactericidal effect of the high hydrogen ion concentration was also made.

As shown in Table 6, a reduction in total bacteria population of greater than 90% was observed upon acidification of the feed suspension to pH 3.0; the coliform population was also greatly reduced. The acidification of the feed suspension is thus a significant step toward the production of an inocuous effluent from a sewage lagoon. However, it is also shown in Table 6 that, when

Table 4

THE EFFECT OF pH ON THE FROTH FLOTATION CLARIFICATION OF LAGOONED SEWAGE

pH 3.0

Aeration Rate (cc/min)	40		90		155	
Time of Sampling Feed	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)
Initial Feed	170	0	170	0	170	0
First Burst	120	52	105	22	128	17
Mid-point	108	90	86	90	90	90
Clearing	76	180	73	180	67	180

pH 3.5

Aeration Rate (cc/min)	40		90		155	
Time of Sampling Feed	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)
Initial Feed	190	0	190	0	190	0
First Burst	188	47	182	32	188	44
Mid-point	155	90	180	90	150	90
Clearing	101	180	93	180	100	180

pH 12.0

Aeration Rate (cc/min)	40		90		155	
Time of Sampling Feed	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)	Turbidity Units	Time (sec)
Initial Feed	170	0	170	0	170	0
First Burst	95	68	105	80	115	24
Mid-point	100	90	90	90	90	90
Clearing	76	180	84	180	66	180

Table 5

EFFECT OF AERATION RATE AND PERIOD OF CLARIFICATION OF LAGOONED SEWAGE BY FROTH FLOTATION

(Sewage Adjusted to pH 3.0)

Aeration Period (sec)	Aeration Rate (cc/min)	Volume Air (sec)	Suspended Solids (mg/l)		Solids Removed	
			Feed	Effluent	mg/l	mg/cc Air
52	40	34.6	Trial 1	76	27	0.780
90	40	60.0		69	34	0.566
180	40	120.0		52	51	0.425
22	90	33.1		68	35	1.06
90	90	135.0	103	58	45	0.334
180	90	270.0		50	53	0.196
17	155	43.9		80	23	0.525
90	155	232.5		60	43	0.183
180	155	465.0		47	56	0.120
20	90	30.0	Trial 2	55	59	1.97
40	90	60.0	114	54	60	1.00
180	90	270.0		52	62	0.230
1200	90	1800.0		30	84	0.047
20	90	30.0	Trial 3	65	31	1.03
40	90	60.0		55	41	0.683
60	90	90.0		57	39	0.434
90	90	135.0	96	53	43	0.318
180	90	270.0		50	46	0.171
360	90	540.0		42	54	0.100
900	90	1350.0		42	54	0.040
20	90	30.0	Trial 4	90	5	0.167
60	90	90.0		53	42	0.466
90	90	135.0		54	41	0.304
180	90	270.0		47	48	0.177
480	90	720.0		39	56	0.078
900	90	1350.0		41	54	0.040
1200	90	1800.0		31	64	0.036
90	40	60.0		52	43	0.715
480	40	320.0		35	60	0.188
900	40	600.0	95	38	57	0.095
1200	40	800.0		24	71	0.089
20	155	51.7		63	32	0.619
60	155	155.0		57	38	0.245
90	155	232.5		55	40	0.172
180	155	465.0		44	51	0.110
480	155	1240.0		45	50	0.040
900	155	2325.0		28	67	0.029
20	40	13.3		62	33	2.48
60	40	40.0		59	36	0.900
180	40	120.0		49	46	0.384

the acidified feed suspension was harvested, coliform organisms were completely absent from the clarified waste. The total bacteria were also materially reduced. The fact that the disinfectant action of the high hydrogen ion concentration continued during the clarification process may account for the loss of viable coliform organisms in the harvest and for the relatively small increase in the total bacterial count in that fraction. Apparently, the low pH was more damaging to the coliform organisms than to the total bacterial population. These data indicate that the clarification process can produce a relatively inocuous effluent from a sewage lagoon.

Table 6

THE EFFECT OF pH 3.0 AND THE FROTH FLOTATION PROCESS ON THE DISTRIBUTION OF COLIFORM ORGANISMS AND TOTAL BACTERIA IN SEWAGE LAGOON SAMPLES

Sample	Sample One		Sample Two	
	Coliform x 10^{-3}/ 100 ml	Total Bacteria x 10^{-3}/100 ml	Coliform x 10^{-3}/ 100 ml	Total Bacteria x 10^{-3}/100 ml
Unadjusted Feed	106	28,400	16	17,700
Adjusted Feed	2	2,300	8	2,500
Harvest	0	2,800	2	6,800
Clarified Feed	0	300	0	200

The principal conclusions to be drawn from these investigations are: (a) the froth flotation process approaches a level for the economical harvesting of algae for any purpose: mass production for food or fodder, use in spacecraft or other closed ecological system, clarification of algae from oxidation pond effluent, and reclamation of algae in oxidation ponds for economic use; and (b) the froth flotation method may have use as a new sewage treatment process or as an adjunct to conventional processes.

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