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THE USE OF LAGOONS TO TREAT PRESSURIZED WASTEWATER

When wastewater is pressurized @ 40 psi for 24 to 48 hours certain biological and chemical changes take place which alter the wastewater's degradation rates when discharged into a stabilization pond or lagoon. There appears to be a change in the microorganisms population after pressurized which stimulates the biochemical breakdown and oxidation of the components present in wastewater. There is an increase in the decomposition and nitrification rates of wastewater which can allow greater loading into existing lagoons or the use of smaller lagoons. Pressurization of wastewater prior to discharge can now be a viable treatment method.

1. INTRODUCTION

The need for more efficient wastewater treatment reduction is becoming increasingly important as input loadings are constantly increasing and legislation is placing more constraints and limitations on treated wastewater being discharged into the environment. Process alteration on existing conventional primary and secondary wastewater facilities can only improve efficiencies marginally. What is needed are more efficient methods of tertiary treatment to achieve the reductions to wastewater discharges that are so important. One aspect of tertiary treatment, discharge into stabilization lagoons, can be modified so as to improve the efficiency by accepting a greater load, or using a smaller facility to treat existing waste loading. A pilot plant study was performed in which secondary treatment effluent was pressurized prior to discharge into a simulated lagoon. The result was that the waste degraded faster, nitrification occurred sooner, there was a coliform kill as would be expected from chlorination, and the lagoon was enhanced with dissolved oxygen. It was the intent of this research to investigate the mechanism accounting for this change.

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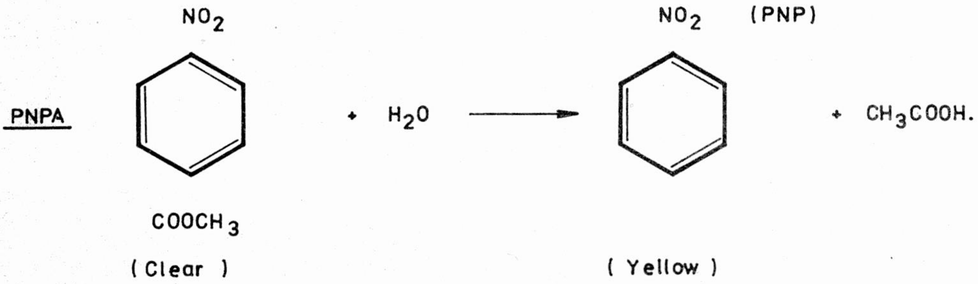
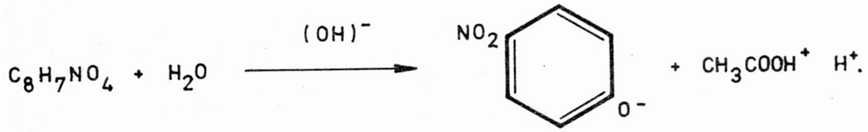
2. BACKGROUND

In a previous study conducted at the New Jersey Institute of Technology (NJIT) it was found that pressure had the effect of increasing the hydrolysis rate of para-nitro-phenyl acetate, $C_8H_7O_4N$ (PNPA), to para-nitro-phenol, $C_6H_5O_3N$ (PNP), as shown



PNPA is a slightly yellow powder which, when dissolved in water, is colourless which then undergoes hydrolysis to produce the intensely yellow PNP whose absorbance can be measured spectrophotometrically and the concentration can be monitored as it is being produced. The reaction is acid or base catalyzed; thus it would have to be performed in a buffer solution, as the product, acetic acid, would lower the pH as it is being formed.

In the basic buffer solution the following reaction takes place:



The para-nitro-phenoxy form produced has a maximum absorbance at 400 nm and this was the species monitored. Pressurized and non-pressurized samples at pH 7.5 and 7.7 were run and aliquots taken off intermittently for up to 160 hours. The results of these trials are shown in fig. 1 and 2. The pressurized sample did show an increase in the rate of hydrolysis at both pH's. For the non-pressurized samples plateaus were reached which signalled the end of the reaction.

3. EQUIPMENT

The research was conducted with a pressure vessel previously constructed by a researcher at NJIT. This device was constructed from one-quarter inch thick lucite plastic formed into a tubular shape one foot in diameter and three feet tall. The equipment is shown in fig. 3.

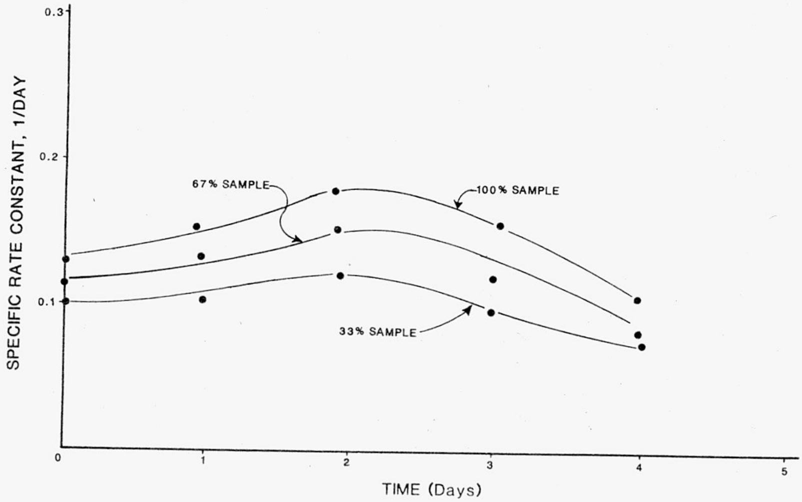


Fig. 1. The effects of pressure on para-nitro phenyl acetate as compared to an aerated sample conducted at pH = 7.5

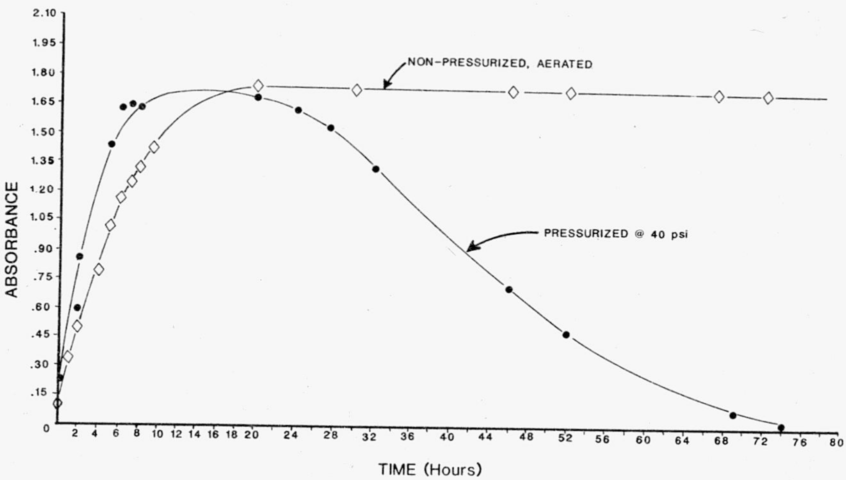


Fig. 2. The effects of pressure on para-nitro phenyl acetate as compared to an aerated sample conducted at pH = 7.7

Air was supplied by a compressor and delivered through porous stones placed on the bottom of the vessel. The device was rated to handle 50 pounds per square inch (psi) as a maximum. During preceding trials it was seen that 40 psi gave the optimum performance. The air pressure maintained in the vessel was set by a pressure regulator and a pressure gauge installed. A relief valve was placed on the upper plate so that a continuous flow of air was always maintained.

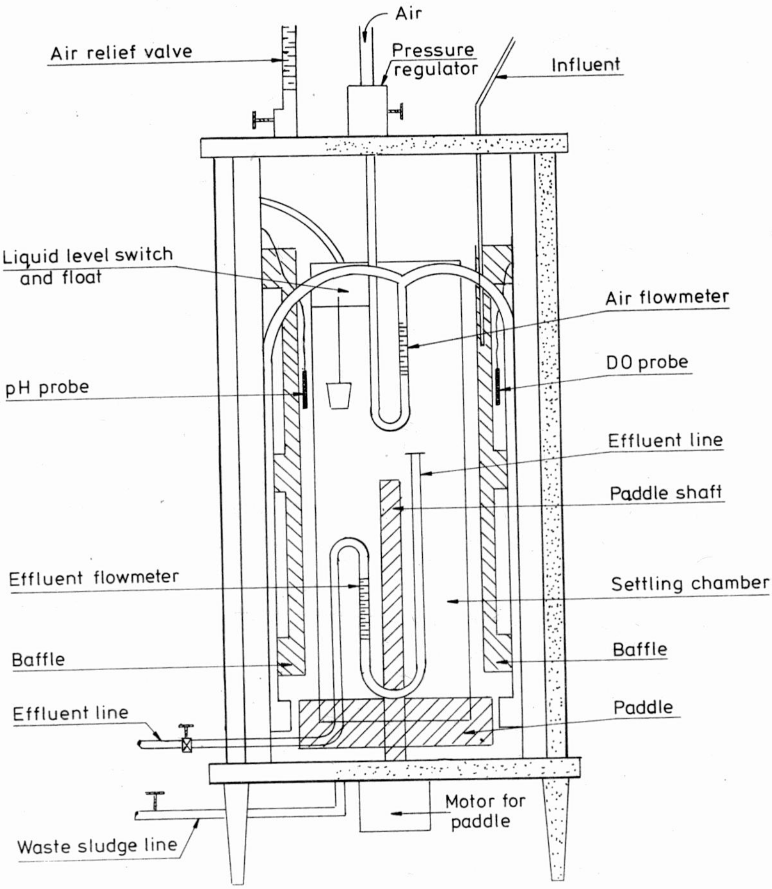


Fig. 3. Pressure vessel used for all pressurization studies

4. PREVIOUS STUDIES

It was decided to apply the findings of previous investigations to examine the effect on wastewater that had been subject to pressurization. Wastewater contains high concentrations of large molecular weight carbohydrates, amino acids, and fats which under non-pressurized conditions are slowly hydrolyzed to sugars, proteins, and fatty acids. In their simpler, smaller molecular weight forms these compounds are more easily oxidized to their stable end products. When biochemical oxygen demand (BOD) determinations were performed it was also found that nitrification occurred sooner in the pressurized sample. This would indicate that pressure increases the rate of ammonification of protein and amino acids. Nitrification takes place only if sufficient ammonia is present as well as the proper concentration of nitrifying organisms relative to carbon oxidizing organisms. Pressurized wastewater experienced a very high kill of single cell coliforms but nitrifying organisms were seen to resist any negative effects due to pressure.

The results of the pressurization process indicated that significant chemical and biological changes took place which altered the biodegradability of the pressurized wastewater. With all of these biological and chemical changes taking place the question of how this could be applied to conventional wastewater treatment was to be considered. Pressurization at 40 psi for a time period of 24 to 48 hours had the following effects:

1) increases in the rate of hydrolysis of carbohydrates to sugars, proteins to amino acids, and fats to fatty acids,
2) increase in the rate of ammonification of protein and amino acids,
3) effect of a microorganism (coliform) kill of 99.4%,
4) receiving water saturation with dissolved oxygen.

5. AFTERGROWTH

The BOD reaction is catalyzed by aerobic microorganisms which derive their energy from the breakdown of organic compounds. The extent by which they can function depends on their nature, temperature, pH, predator-prey relationship, and their position on the growth curve. Environmental stress, such as dilution and/or disinfection, can lower the microbial population to such a degree that single cell bacteria can then experience a population explosion far greater than can normally be expected. The causes responsible for this phenomenon are 1) reduced predator population whose reproduction rate is much less than for the bacteria, 2) a higher food to microorganism, F/M, ratio which results in unlimited exponential growth for the microorganisms. In this flurry of activity the microorganisms would degrade the organics at a faster rate, resulting in a more rapid oxygen demand. As conditions normalize, this increased rate would then revert to the equilibrium conditions that existed before the environmental stress was applied.

6. AREA OF RESEARCH

The research was divided into two parts; the first was to examine the biochemical oxygen demand and microorganism population for non-pressurized wastewater samples, diluted, and allowed to stand, as would be the case in an actual lagoon receiving wastewater effluent. The second part involved pressurizing wastewater samples at 40 psi for 24 hours, diluting, and allowing to stand for up to 5 days. Again, the samples will be analyzed for microorganism population and BOD. Parameters would be evaluated for each situation and compared to determine the effect of pressurization.

7. RESULTS

The first part of the experiment involved wastewater samples being diluted by 2/3rds and 1/3rd and their BOD's and microorganism populations determined. The BOD curves are shown in figs. 4–6. The sample was allowed to stand for up to 4 days

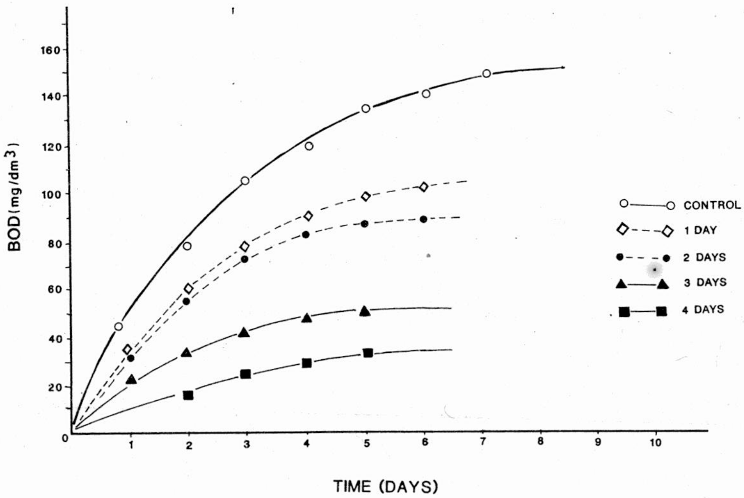


Fig. 4. Undiluted non-pressurized sample allowed to stand for 4 days

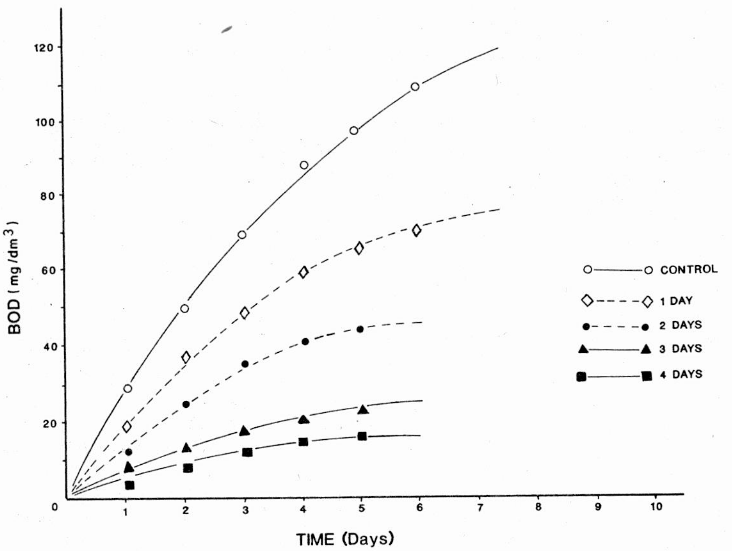


Fig. 5. 67% dilution non-pressurized sample allowed to stand for 4 days

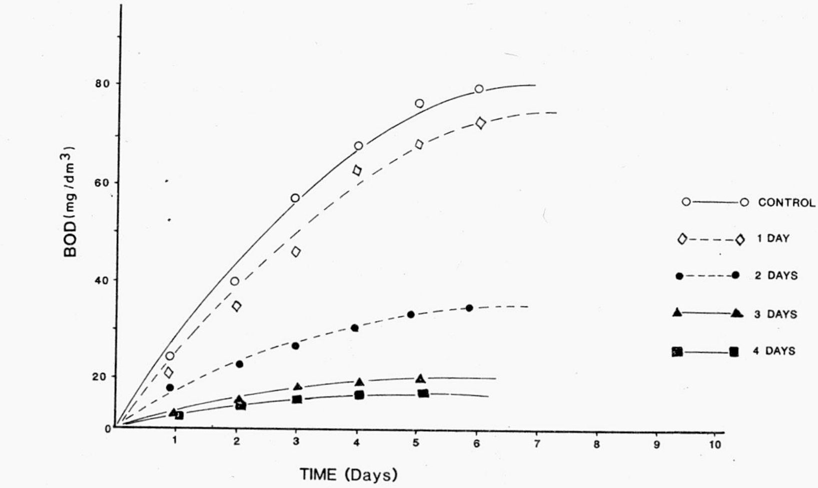


Fig. 6. 33% diluted non-pressurized sample allowed to stand for 4 days

and the daily differences in BOD, the plateaus, are the result of natural decomposition taking place in the vessel. Specific rate constants were determined for all three dilutions and the variations are shown in fig. 7. The specific rate constants were determined daily and these were plotted. There was a slight increase for up to day three indicating a slight increase for up to day three indicating a slight increase in the rate of decomposition before the eventual die-off of the microorganisms.

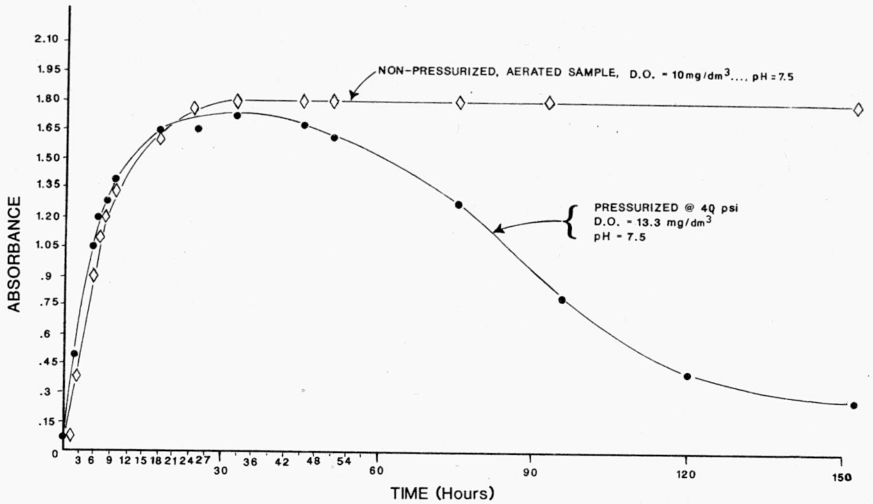


Fig. 7. Variation of the specific rate constant for sewage and diluted samples after being allowed to stand

Coliforms were selected as the indicator of choice and determined using the millipore filter method. The samples were measured daily for coliforms and the results are shown in figs. 8 and 9. The coliforms were plotted in arithmetic and log values. The slope of the graph of the log plot gives the value of the growth rate constant.

For the pressurized samples the BOD and coliforms were monitored for comparison to the non-pressurized sample. The BOD curves for the pressurized

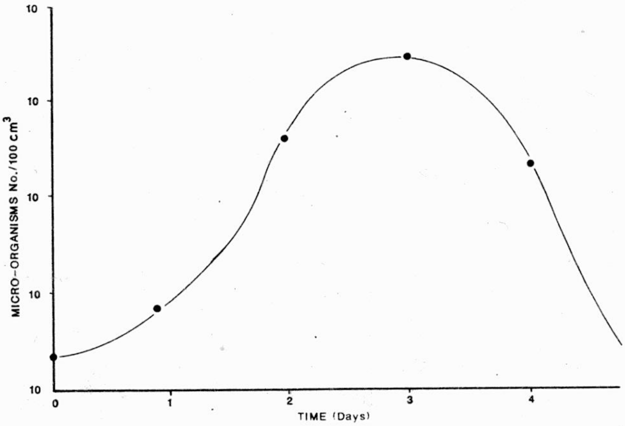


Fig. 8. Micro-organisms present in simulated lagoon samples

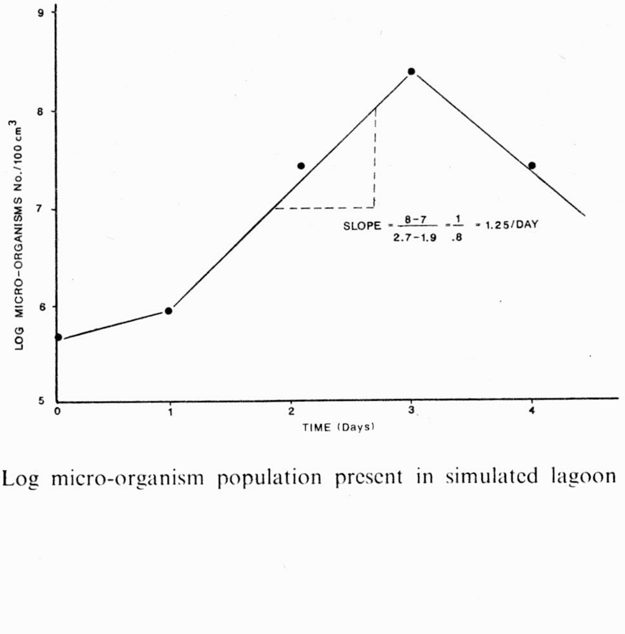


Fig. 9. Log micro-organism population present in simulated lagoon samples

sample show significant difference in the rate at which oxidation takes place. There was a drop-off in the rate of oxidation after 1 day but then the rate accelerated for days 2 and 3. After the third day there was a microorganism die-off and the rate decreased dramatically. Microorganism populations were determined and these are shown in figs. 10–12. The growth rate constant for the pressurized sample also increased indicating the microorganisms were metabolizing the waste at a much faster rate then occurred without pressurization.

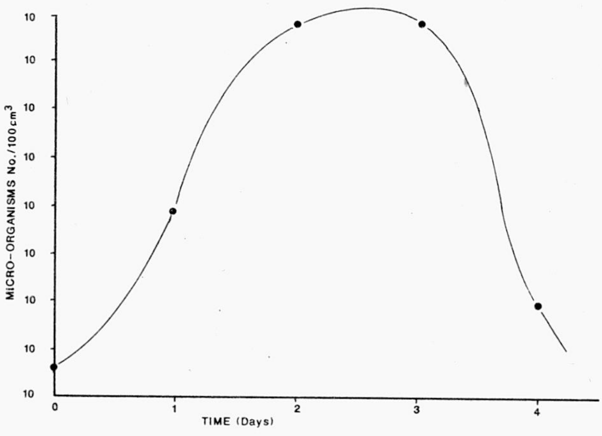


Fig. 10. Micro-organisms present after pressurization in simulated lagoon samples

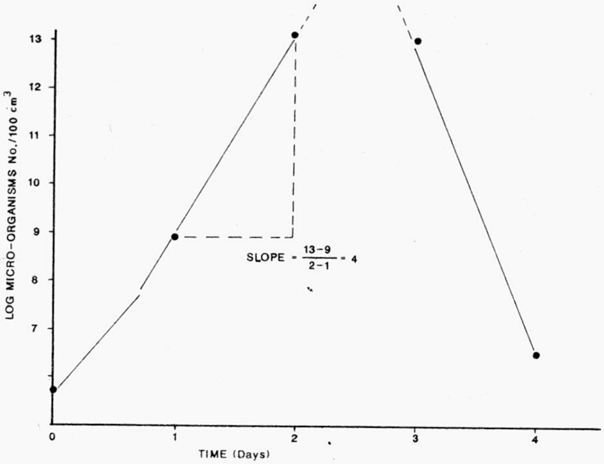


Fig. 11. Log micro-organisms present after pressurization in simulated lagoon

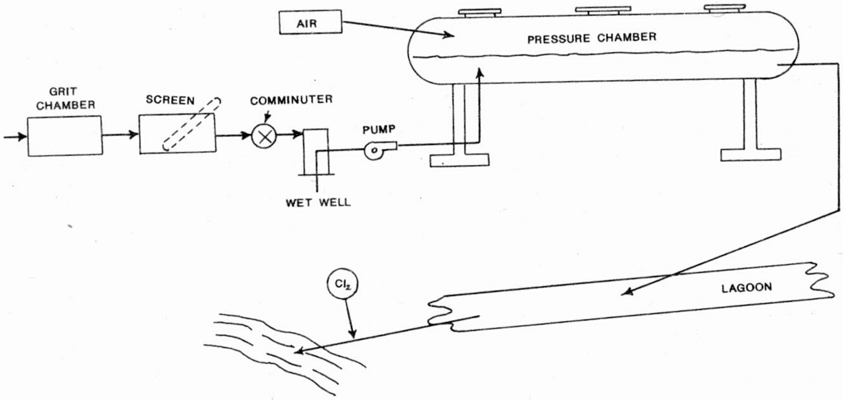


Fig. 12. A sewage treatment plant eliminating secondary treatment by discharging pressurized waste directly into a lagoon

8. CONCLUSIONS

The results obtained indicate that pressurization plays a major role in changing the biodegradation of the wastes during detention times in a lagoon. Wastes are degraded faster which would allow a more rapid turnover time for waste handling. If the process were to be employed existing lagoons could then accommodate greater waste loadings to allow for the primary and secondary plant expansion.

The pressurized waste effluent is saturated in DO which would enhance the water quality of the lagoon even further. Coliforms are killed nearly to extinction during pressurization but the organisms that survive are able to grow faster because the predator population has also been diminished and the existing food is far in excess of the microorganisms needs. The growth is limited only by the ability of the microorganisms to consume the available food. As the growth accelerates and the food supply diminishes, the population increase now leads to more competition for the available food supply and growth is retarded. Predators are beginning to assert themselves and the system slowly reaches the end of the life cycle.

9. APPLICATIONS

An interesting approach using pressure would be as a means to eliminate conventional secondary treatment (trickling filters, activated sludge, etc.) by pumping pressurized effluent to lagoons. The pressurized effluent's characteristics are that it is oversaturated in DO, the microorganism population reduced to a point where it can experience an accelerated growth if given the opportunity, and high in hydrolyzed fractions plus increased concentrations of ammonia hydrolyzed from proteins, amino acids, and other nitrogen compounds. When released into a lagoon the microorganism dynamics take over causing a rapid oxidation of organics, and a rise in microorganism population. The specific rate constant increased to a maximum after three days detention time and then decreased signalling a drop in the F/M ratio causing a decline in microorganism growth reflected by a lower specific rate constant.

With an increase in the ammonia concentration resulting from hydrolysis nitrifying organisms could be placed into the lagoon to effect nitrification. Studies on rivers have shown that immediate nitrification can occur if the river water contains a sufficient nitrifier population and if the effluent is rich in ammonia. The classic two stage BOD profile which occurs in extended laboratory bottle tests is not applicable to an in-vito situation and both nitrification and oxidation can occur simultaneously. The lagoon could accept pressurized pre-treated primary effluent or pressurized waste directly without secondary treatment. A possible treatment scheme is shown in fig. 1.

WYKORZYSTANIE LAGUN W OCZYSZCZANIU ŚCIEKÓW PRZETRZYMYWANYCH POD CIŚNIENIEM

W ściekach przetrzymywanych pod ciśnieniem 40 psi przez 24–28 h zachodzą określone procesy biologiczne i chemiczne, które zmieniają szybkość ich degradacji w lagunach i stawach stabilizacyjnych. Wydaje się, że populacje mikroorganizmów podlegają zmianom podczas pozostawania pod podwyższonym ciśnieniem, które stymuluje rozkład biologiczny i utlenienie składników ścieków. Zaobserwowano przyspieszoną degradację i nitryfikację ścieków, co pozwala na większe obciążenie istniejących lagun lub wykorzystanie lagun o mniejszej objętości. Trzymanie ścieków pod ciśnieniem przed ich zrzutem może stać się istotną metodą ich oczyszczania.

ИСПОЛЬЗОВАНИЕ ЛАГУН В ОЧИСТКЕ СТОЧНЫХ ВОД, ПЕРЕДЕРЖИВАЕМЫХ ПОД ВЛИЯНИЕМ ДАВЛЕНИЯ

В сточных водах, передерживаемых под влиянием давления 40 psi в течение 24–48 часов, происходят определенные биологические и химические процессы, которые меняют быстроту их деградации в лагунах и стабилизационных прудах. Кажется, что популяции микроорганизмов подвергаются изменениям во время, когда они остаются под влиянием повышенного давления, которое стимулирует биологическое разложение и окисление составных элементов сточных вод. Наблюдалась их ускоренная деградация и нитрификация, что способствует большей нагрузке существующих лагун или использованию лагун меньшего объема. Передерживание сточных вод под влиянием давления перед их выпуском может стать существенным методом их очистки.