The ClearCycle™ Treatment of Potato Dehydration Process Waste

Report to: Idaho Supreme Potatoes, Nonpareil, and Pillsbury

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In early November, 1996 Cyclus EnviroSystems set up it's ClearCycle™ waste treatment pilot plant at the Idaho Supreme Potatoes processing facility in Firth, Idaho. The pilot plant was moved from it's previous location at the J.R. Simplot manufacturing plant in Caldwell, Idaho where french-fry potato waste was treated from April, 1996 through September, 1996. The pilot plant was moved to Firth, Idaho to demonstrate the treatment of waste from potato dehydration processing for a group of processing firms consisting of Idaho Supreme Potatoes, Nonpareil, and Pillsbury.

The pilot plant was essentially the same pilot plant used to treat french-fry potato waste at the Simplot plant in Caldwell, Idaho. Certain improvements were made to the mixing system and controls to assist in the 24 hour operation. The biomass used in the earlier pilot operation was maintained in the digesters and used for rapid start-up. Although the biomass had remained dormant for several months, no adverse impact was observed during start-up. Prior to beginning operations, 55 gallons of biomass was wasted to provide more room in the solids holding digester.

OPERATION FROM NOVEMBER 14, 1996 TO FEBRUARY 19, 1997

The pilot plant was started up during the first two weeks of November, 1996. On November 14, documented operation began. The pilot plant was operated over a 14 week period. During that period, the pilot plant was operated for 11.5 weeks. The pilot plant was *not* operated for several days before Thanksgiving, and for the two week holiday period from December 22, 1996 to January 6, 1997. The pilot plant operation simulated real world conditions. It was operated 24 hours per day, six days per week. Since the processing facility was not operated on Sunday, the pilot plant was inactive.

The purpose of the pilot plant operation was to determine the optimum operating conditions and performance of the ClearCycle™ process under actual field conditions. The pilot plant received representative, but concentrated waste from the processing plant. The influent waste characteristics varied as they would during full scale operation.

During the pilot operation, the control variables were the influent temperature, pH, and flow. The operating parameters were changed on a weekly basis. There were 11 operating periods, each with a unique set of operating conditions.

Waste Characteristics

The pilot plant treated concentrated waste from the Idaho Supreme Potatoes' processing facility in Firth, Idaho. All waste produced by the potato dehydration processing facility is treated in a primary clarifier for removal of particulate matter. The concentrated high temperature waste stream adversely effects the clarifier's operation. The concentrated waste streams represent 80% of the waste load in 25% of the total flow. Removal of the concentrated waste streams would greatly improve the performance of the existing clarifier. The waste delivered to the ClearCycle™ pilot plant was only the high temperature and concentrated waste from the production facility. The waste was screened to remove large particles prior to being pumped to the pilot facility. All particles of potato waste greater than 1/32 inch were removed from the pilot plant influent.

INFLUENT TEMPERATURE

Some characteristic of the influent waste were modified during the operation. Normally the temperature of the waste exceeded 110°F. Prior to entering the pilot plant, the waste was cooled through a cooling coil in a water bath. The extent of cooling varied throughout the pilot period. The influent waste had a temperature which varied from 75° F to 105°F. The average influent temperature throughout the entire period was 92.8°F. The average temperature during the low and high temperature operating periods were 89° F and 97.4° F respectively. During week 11 the average influent temperature was 102°F.

INFLUENT PH

The pH of the influent varied to a minor extent. The average influent pH throughout the operating period was 5.95. During the initial weeks (Week 1to 5) of operation, no buffering agent was added to the influent waste. During that period, the average influent pH was 5.6. Influent pH values of 4.8 to 5.3 were common. During weeks 8 to 14, a small quantity of sodium hydroxide was added to the influent to raise the pH to an average value of 6.2.

INFLUENT FLOW

The only other parameter that was controlled during the operation was the influent flow. The influent flow averaged 0.41 gpm (gallons per minute) for a total daily flow of 590 gpd (gallons per day). The highest flow rate was 0.8 gpm during week 2, while the lowest flow rate of 0.22 gpm occurred during the final operating period (weeks 13-14).

The influent waste was monitored for total solids, and total COD on a daily basis. Volatile solids, total TKN, ammonia, total phosphorus, and ortho-phosphorus were also monitored during selected periods of operation.

The waste was a typical organic waste. The total solids were only 74% volatile. The COD /VS ratio was 1.49, a relatively normal value. The total nitrogen (TKN) content was 0.1 g N / g VS (~ 10%). The total phosphorus content was 0.017 g P/ g VS (~1.7%).

PHYSICAL AND CHEMICAL CHARACTERISTICS

Table 1 below presents the influent waste characteristics during the eleven operating periods.

TABLE 1. INFLUENT WASTE CHARTACTERISTICS

Operating Period	Temperature (°F)	pH (units)	Total Solids (mg/L)	Total COD (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Total P (mg/L)
Week 1	92	5.8		11780			
Week 2	97	5.6	10775	10476			
Week 3	82	5.5	13100	12038			
Week 4	92	5.5		12537			
Week 5	86	5.9	11090	13670			
Week 8	85	6.3	12117	13489			
Week 9	92	6.1	11800	13036		67	
Week 10	100	6.4	9640	12350		89	
Week 11	102	6.2		12704	897	63	100
Week 12	101	6.3		11683	670	72	146
Week 13 & 14	92	6.0		9563	825	124	148
Average	**92.8**	**5.95**	**11420**	**12121**	**797**	**83**	**131**

The above described waste was treated in the ClearCycle™ pilot plant. The ClearCycle™ process is described below, while a detailed description of the pilot plant is presented in the section following.

THE CLEARCYCLE™ PROCESS

THE PROCESS IS AN INNOVATIVE TECHNOLOGY WHICH INCREASES THE PERFORMANCE OF ANAEROBIC DIGESTERS.

The ClearCycle™ process is a high rate anaerobic process. High rate aerobic processes, such as the "activated sludge process", have the advantage of conserving bacteria through settling and recycle. A concentrated biomass makes it possible to achieve high treatment efficiencies in tanks with a short Hydraulic Retention Time (HRT). Typically an aerobic biological process will require a 2 hour primary clarification period, 8 hour aeration period, and 2 hour final clarification period, for a total HRT of 12 hours. Stabilization of the resulting waste activated sludge will require substantially larger tank volumes (HRT).

The "anaerobic activated sludge" process for the anaerobic treatment of waste containing suspended solids or oil and grease, such as sewage, sewage sludge, food processing waste, or other organic slurries, has not been practiced since anaerobic bacteria naturally tend to float, due to attached methane gas bubbles, and cannot be effectively concentrated through settling. As a result, conventional anaerobic systems for the treatment of particulate waste, or waste containing oil and grease, require large heated reactors (typically 15 to 20 day HRT) which are expensive to construct, mix, and operate. Providing a method to retain anaerobic biomass within the system will substantially reduce reactor size while improving performance.

THE PROCESSES IS CAPABLE OF TREATING WASTE CONTAINING SUSPENDED SOLIDS AND OIL & GREASE.

The ClearCycle™ process is an innovative technology which increases the performance of anaerobic digesters by recovering biomass from the digester discharge through methane gas flotation. Biogas obtained from the digester is used to float and concentrate the bacteria. As a result, a large biomass population is maintained within the digester. The effluent is a clear liquid with low suspended solids and COD. Dissolved phosphate, and a portion of the ammonia nitrogen, can be recovered, if desired.

The ClearCycle™ processes is capable of treating waste containing suspended solids, and oil and grease, within small reactors, while producing a very clean effluent. The pollutants are converted to gas for energy recovery and soluble inorganic constituents which may be recovered.

SOLIDS ACCUMULATION WILL LIMIT THE EFFICIENCY AND ECONOMICS OF ANY RECYCLE PROCESS.

All separation and recycle processes are limited by the accumulation of inorganic silts and precipitates, as well as the accumulation of slowly degrading organic constituents within the digester. The accumulation of inorganic materials, and slowly degrading organic materials, will severely limit the performance of anaerobic retained biomass systems. Solids accumulation will limit digester mixing and economics of any separation process. The economical separation of biomass requires relatively dilute solutions. To counteract the accumulation of solids, wasting is normally increased. Increased solids wasting lowers the solids retention time (SRT) and reduces the efficiency of the process.

The patented Clear Cycle™ process minimizes the inherent limitations of retained biomass systems. Two smaller anaerobic reactors are used. The process incorporates a device that removes inorganic particulate material (> 50 μ), if present while retaining the organic constituents. Dissolved inorganic solids which may inhibit the process are elutriated from the system. One of the anaerobic reactors provides prolonged hydrolysis of slowly degrading materials with highly concentrated biomass. As a result, the solids retention time is substantially increased while carrying out the biomass separation under relatively dilute conditions. Dilute conditions significantly reduce the cost and energy required for separation.

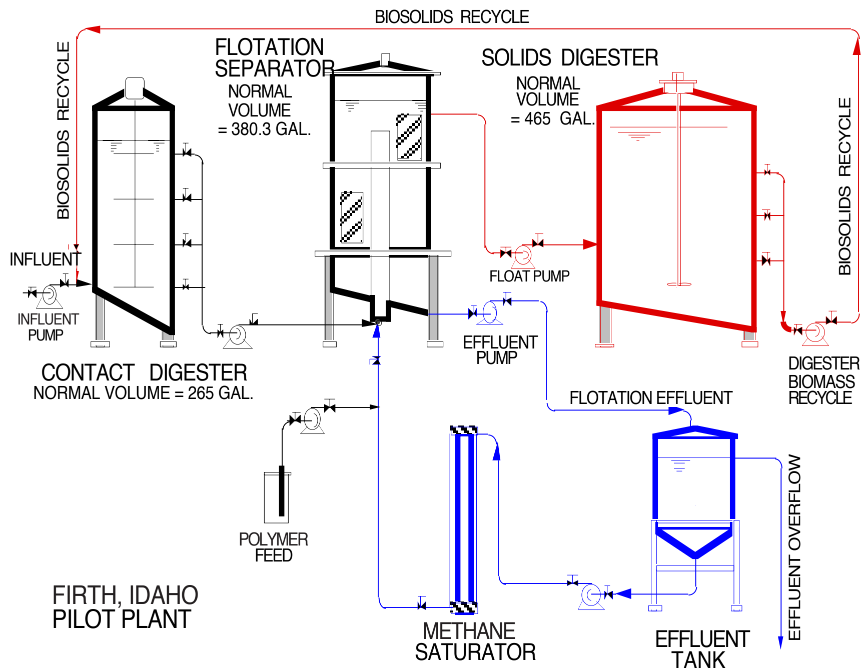
The process minimizes the total digester volume while maximizing the conversion of particulate solids to gas and soluble products. The ratio of the SRT to HRT is maximized.

THE CLEARCYCLE™ PILOT PLANT

The pilot plant used anoxic gas flotation (AGF) to provide solids separation. The ClearCycle process was used to minimize the HRT of the process by degrading the slowly degradable particulate material in a separate solids holding digester. Methane gas was delivered by gas cylinder rather than utilizing the methane gas produced by the digester.

A schematic of the ClearCycle™ pilot plant is shown in Figure 1, below:

FIGURE 1 PILOT PLANT PROCESS SCHEMATIC



THE PILOT PLANT CONSISTED OF A CONTACT DIGESTER, FLOTATION SEPARATOR AND A SOLIDS HOLDING DIGESTER.

The pilot plant consisted of a baffled plug flow anaerobic digester with mixing between each baffle. The contact digester had a maximum working volume of 265 gallons. The influent waste was mixed with return flow from the solids holding digester. Anaerobic degradation of the soluble COD (SCOD) and the easily degradable particulate COD (PCOD) occurs within the contact digester. The quantity of biomass returned from the solids digester to the contact digester must be sufficient to accomplish the task of degrading the COD without depressing the pH of the contact reactor to values below 6.5. Sufficient alkalinity must be obtained to buffer the organic acids produced during degradation. A large methanogen population will assist in controlling the pH by rapidly removing the organic acids. In addition, alkalinity may be obtained from the following sources: (1) created through the degradation of the influent waste, (2) transferred from the solids holding digester in the recycle flow, or (3) added to the influent throuth the addition of chemicals or treated effluent.

The biomass which is recycled from the solids holding digester to the contact digester must be sufficient to maintain a microorganism to food ratio required for the consumption of the easily assimilated food.   Values between 4 and 6 g/g COD are common.

After substantial digestion of the influent soluble waste within the contact reactor, the waste is transferred to the flotation separator. The biomass and undigested solids are concentrated in the separator “float”. The pilot plant flotation separator had a volume of

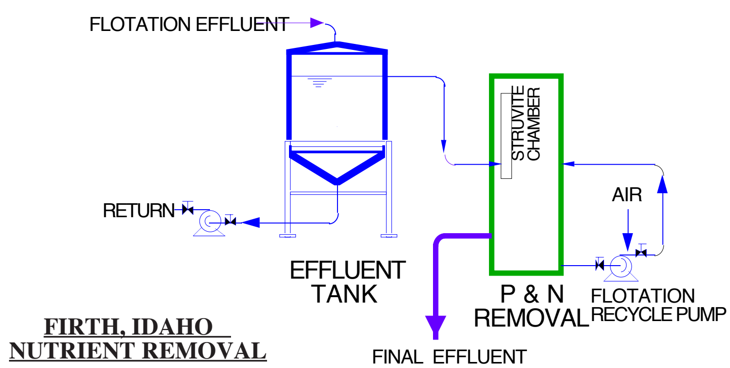
380 gallons and a surface area of eleven square feet. The liquid effluent from the separator was transferred to a effluent holding tank. A portion of the effluent was returned to the flotation separator to provide the dissolved gas, and the elutriation of solids within the separator. The remaining effluent exited the system to the inorganic nutrient removal process.

The solids which were concentrated in the flotation separator were pumped to the solids holding digester. The function of the solids holding digester was to convert the slowly degradable solids to gas and soluble products in the presence of a concentrated biomass. Once the slowly degrading solids were converted to soluble products and gas, the biomass was returned to the contact digester for elutriation of the soluble products created in the solids holding digester.

A SEPARATE NUTRIENT REMOVAL PROCESS WAS ALSO TESTED

The effluent discharged from the holding tank was considered the final ClearCycle™ process effluent. The effluent received further treatment for phosphate and nitrogen removal. Treatment was provided in a tower which was mixed with induced air. A schematic of the process is shown below:

FIGURE 2 NUTRIENT REMOVAL PILOT PLANT



Sodium hydroxide was added to the effluent from the effluent holding tank. The pH was raised from approximately 7.2 to an average value of 8.8. A circulation pump induced a small amount of air sufficient to float precipitated solids and remove some of the ammonia nitrogen. The detention time of the tank (2 hours) and the pH was sufficient to achieve struvite precipitation. Soda ash, precipitated "white COD", and struvite were accumulated in a float. The float also contained organic material which would require further digestion for complete stabilization. It is proposed that the float be digested with waste solids from the digester prior to final drying and sale as a soil conditioner. The effluent from the nutrient removal process was designated the "total process effluent".

Pilot Plant Operation

THE PILOT PLANT WAS OPERATED ON A 24 HOUR PER DAY BASIS, SIX DAYS A WEEK

The plant was operated on a continuous basis for approximately 24 hours each day. The pilot plant was operated for six days each week. On late Saturday the pilot plant was shut down when the manufacturing plant ceased operation. Early Monday morning the pilot plant was started up when production resumed.

Samples were taken daily of the influent waste, solids holding digester, contact digester effluent, separator float, ClearCycle™ effluent, and final tower effluent. Samples were collected by both Cyclus EnviroSystems and Idaho Supreme Potatoes' personnel. Standard Methods were used for all analysis by both firms. Analytical results for the same day were averaged. The samples were analyzed for total & volatile solids, COD, TKN & ammonia, total phosphorus, and ortho-phosphate.

The pilot plant was operated continuously from November 18, 1996 to February 19, 1997 with the exception of November 28 through November 30 (Thanksgiving) and the manufacturing holiday break from December 22, 1996 through January 5, 1997.

No attempt was made to optimize the performance of the nutrient removal facilities. The ClearCycle™ process was operated under a variety of conditions to evaluate the effluent quality as a function of organic loading. Influent temperature and pH were varied to assess the impact on process performance. The influent flow was also altered to change the process loading.

The starting biomass consisted of the bacteria from the previous pilot operation which treated french-fry potato waste. Prior to controlled operation, 55 gallons of biomass was wasted. During the entire period of operation an average of 21 gallons of solids were wasted from the digester each week (3.4 gallons per day). The average SRT for the entire operating period was approximately 150 days. From week 8 through week 14, an average of 37.7 gallons per week of digester solids were wasted. During this period, the solids retention time approximated 80 days. During the entire period the digesters total solids concentration increased from 3.8% to 3.88% total solids. The total solids wasted was less than 6% of the total influent on a total solids basis during the last 6 weeks of operation.

The flotation unit was larger than necessary when compared to the other processing units. Consequently, the flotation unit operating parameters were never stressed during the pilot operation.

The table below presents the pilot plant operating parameters during the entire period by operating week.

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TABLE 2. OPERATING FLOW AND TEMPERATURE

Operating Period	Influent Flow (L/day)	Recirculating Flow (L/day)	Total Flow to Contact (L/day)	Recycle Ratio	Contact Temperature (°F)	Digester Temperature (°F)	Waste Solids (L/day))
Week 1	3175	2903	6078	0.91		91	
Week 2	4355	3629	7983	0.83		96	
Week 3	3266	3266	6532	1.0	89	93	
Week 4	1973	2177	4150	1.1	89	92	
Week 5	1606	1633	3239	1.02	90	92	
Week 8	1429	1633	3062	1.14	94	95	6.3
Week 9	1361	2087	3447	1.53	96	95	15.8
Week 10	2023	2177	4200	1.08	101	98	41.0
Week 11	2155	1905	4060	0.88	104	99	37.8
Week 12	1769	1633	3402	0.92	102	94	37.8
Week 13 & 14	1210	1089	2298	0.90	99	69	3.8
Average	**2211**	**2194**	**4405**	**1.03**	**95.8**	**94.7**	**10.8**

Pilot Plant Operating Results

HYDRAULIC RETENTION TIMES

The influent flows presented above resulted in average hydraulic retention times in the contact digester, based on total influent and recirculation flow to the contact reactor, of 0.13 to 0.44 days. This is the actual resident time in the contact reactor. The detention time based on influent flow values alone is approximately double the actual detention time. The detention time of the contact reactor, based on influent flow values, varied from 0.23 days to 0.83 days.

The hydraulic retention time of the solids holding digester, based on recirculated solids flow, varied from 0.5 to 1.6 days. The total detention time provided by both digesters, based on the influent flow values, varied from 0.6 to 2.29 days.

The table below presents the actual hydraulic retention time of the contact digester, and the solids holding digester. The equivalent hydraulic retention time, based on influent flow, for the contact reactor and both digesters is also presented.

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TABLE 3. OPERATING HYDRAULIC RETENTION TIME (DAYS)

Operating Period	HRT Contact Reactor (days)	HRT Solids Digester (days)	Eq. HRT[a] Contact Reactor (days)	Eq. HRT[b] Both Reactors (days)
Week 1	0.17	0.6	0.32	0.9
Week 2	0.13	0.5	0.23	0.6
Week 3	0.16	0.5	0.31	0.9
Week 4	0.24	0.8	0.51	1.4
Week 5	0.31	1.1	0.63	1.7
Week 8	0.33	1.08	0.70	1.94
Week 9	0.30	0.85	0.74	2.03
Week 10	0.24	0.81	0.50	1.37
Week 11	0.25	0.94	0.48	1.31
Week 12	0.29	1.08	0.57	1.57
Week 13 & 14	0.44	1.61	0.83	2.29
Average	**0.26**	**0.90**	**0.53**	**1.46**

a. Equivalent HRT is based on influent flow and is not the actual detention time.

b. Equivalent HRT is based on influent flow and is not the actual detention time.

OPERATING PH VALUES

The pH of the contact reactor averaged 6.87 throughout the operating period. During the period when *no* sodium hydroxide was added to the influent, the contact reactor had an average pH of 6.7. During the remainder of the operation, the pH in the contact reactor averaged 7.0, due to the addition of small quantities of sodium hydroxide.

The solids holding digester had an average pH of 7.16 throughout the operating period. The pH was 7.09 during the period when *no* buffer was added, and 7.21 during the period when buffer was added. The pH of the solids holding digester was the highest during the weeks with low organic loadings. At lower loadings, more of the organic acids were converted to gas resulting in higher pH values.

The effluent pH was slightly higher than the solids holding digester's pH values. The average effluent pH throughout the operating period was 7.16. The highest effluent pH values occurred during periods of low organic loading. Average weekly values of 7.4 occurred during the periods with the lowest loading. The effluent pH during the weeks without influent buffering averaged 7.03.

The final effluent from the nutrient removal tower averaged 8.73 throughout the operating period.

TOTAL AND VOLATILE SOLIDS

The total solids content of the influent waste averaged 11,400 mg/L. The concentration in the contact reactor averaged 21,600 mg/L due to the addition of recycled solids from the solids storage digester. The solids holding digester's total solids concentration increased from an initial value of 38,000 mg/L to 43,000 mg/L during week 10. Solids wasting during the latter weeks of operation resulted in a gradual decline in the digesters total solids concentration to a value of 38,800 during the final week of operation.

The effluent solids concentration averaged 2,850 mg/L throughout the operating period. The effluent solids were 87% fixed or inorganic solids. The average total solids reduction was 75.1%. The volatile solids reduction was 96% with only 4% of the influent solids being discharged with the effluent. A 20% fixed solids loss occurred, which was approximately equal to the waste solids value of 6% of the influent solids.

There was little difference in the percent of the total solids that were volatile solids. The influent averaged 73.4% volatile. The contact reactor averaged 72.18% volatile solids, whereas the solids holding digester had a 74% volatile solids content. The effluent had the lowest percent volatile solids with a value of 13.3%. A vast majority of the solids lost in the effluent were inorganic solids.

COD (CHEMICAL OXYGEN DEMAND)

The influent COD averaged 12,121 mg/L throughout the operating period. The weekly average values did not vary significantly throughout the operating period. The average daily COD load was 26.8 Kg/day. The COD concentration of the contact reactor averaged 33,600 mg/L. The digester COD concentration averaged 57,360 mg/L, whereas the float concentrations averaged 61,570 mg/L. The degradation of 4,200 mg/L of COD in the stabilization digester was equivalent to a mass loss of 7.5 Kg of COD. The average daily loss was 8.33 Kg/ day in the stabilization digester. The degradation was equivalent to 36% of the total COD removed by the process.

The effluent COD values were the only COD values to vary significantly throughout the pilot period. The average effluent COD was 1,416 mg/L. Average weekly effluent COD values varied from a low of 319 mg/L to a high of 2,403 mg/L. The effluent COD values varied directly with the organic loading. The COD discharged in the effluent averaged 3.1 Kg/day, resulting in an average mass conversion to gas of 88.4%. Average weekly COD removal rates varied from a low of 80% to a high of 97%. The effluent removal rates were slightly greater after passing through the nutrient removal tower. The average COD loss through the effluent tower was 100 mg/L.

TOTAL NITROGEN (TKN) AND AMMONIA NITROGEN

TKN values were obtained on the influent, effluent, and tower effluent. The average influent TKN was 797 mg/L whereas the effluent averaged 564 mg/L. A TKN reduction of 30% was obtained through the ClearCycle process. This is equivalent to the values obtained in earlier pilot operations. The exact mechanism remains to be defined. The average TKN concentration from the tower effluent was 502 mg/L. The additional 63 mg/L loss was through the formation of struvite accompanied by some low temperature ammonia stripping. Higher temperature operation accompanied by the addition of magnesium and phosphate would have significantly improved average nitrogen removals through the nutrient removal tower.

The influent ammonia concentration averaged 83 mg/L. The ammonia in the contact reactor averaged 377 mg/L, whereas the concentration in the solids digester was 390 mg/L. The effluent ammonia concentration averaged 402 mg/L. Approximately 160 mg/L of the effluent TKN was not in the ammonia form. An additional 35 mg/L of ammonia was lost through the nutrient removal tower.

PHOSPHORUS

The influent total phosphorus concentration averaged 131 mg/L with 110 mg/L being ortho-phosphate. Approximately 21 mg/L was organic phosphorus. The ClearCycle™ effluent contained 88 mg/L total phosphorus with 40 mg/L being ortho-phosphate. The balance of 48 mg/L was assumed to be an inorganic precipitate. Effluent from the nutrient removal tower contained 53 mg/L of total phosphorus having an ortho-phosphate concentration of 17 mg/L. The balance of 36 mg/L was assumed to be the same inorganic phosphate precipitate. Overall the process removed 60% of the total phosphorus.

GAS QUALITY

The biogas quailty from the contact reactor was not the same as the biogas quality from the solids holding digesters. Some of the difference can be explained by the pH difference between the digesters. The contact reactor had an average pH of 6.87 while the solids digester had a pH of 7.16. The difference of 0.3 pH units will effect the percentage of the various gases that are in the ionized as opposed to the unionized form.

The carbon dioxide concentration of the gas from the contact reactor averaged 43.25%, whereas the carbon dioxide concentration of the gas from the solids digester was only 32.6%. The hydrogen sulfide concentration was much higher in the contact reactor. The hydrogen sulfide concentration in the contact reactor's gas averaged 2,560 mg/L as opposed to the solids holding digester's gas which had a lower concentration of 1,660 mg/L. Both values were very high when compared to other substrates of equal strength.

GAS PRODUCTION

The gas production was monitored throughout each day of operation. The table below presents the gas production from each digester.

TABLE 4. BIOGAS PRODUCTION

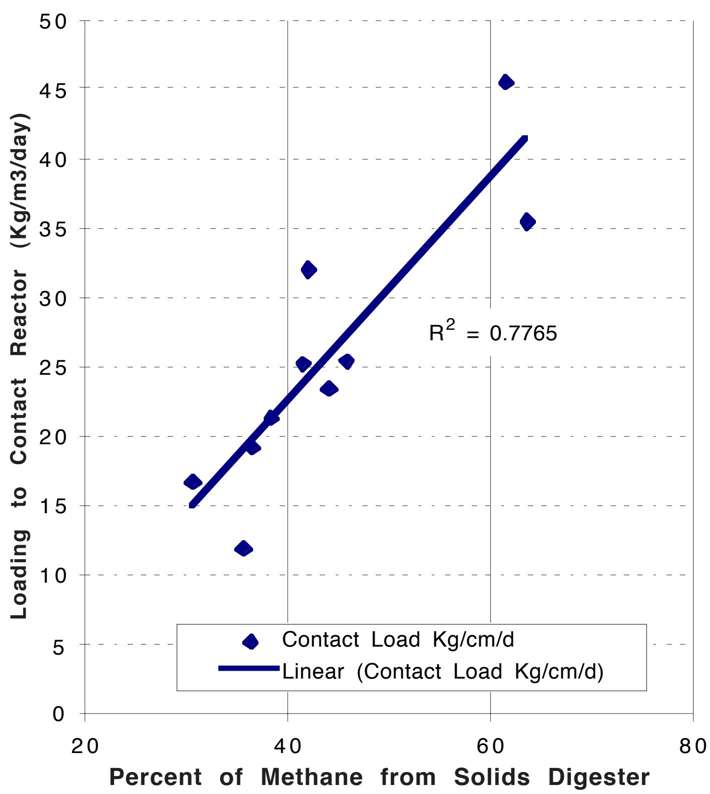
Operating Period	Contact Reactor Biogas (L/day)	Solids Digester Biogas (L/day)	Total Biogas (L/day)	Contact Reactor Methane (L/day)	Solids Digester Methane (L/day)	Total Methane (L/day)
Week 1	2956	1784	4382	1670	1204	2874
Week 2	2718	3624	6341	1536	2446	3982
Week 3	1931	2803	4733	1091	1892	2983
Week 4	2582	3341	5922	1459	2255	3714
Week 5	3312	2174	5486	1871	1468	3339
Week 8	3539	1699	5237	1999	1147	3146
Week 9	2859	1047	3907	1616	707	2323
Week 10	4020	2831	6851	2271	1911	4182
Week 11	5152	3029	8182	2911	2045	4956
Week 12	4105	2123	6228	2319	1433	3752
Week 13 & 14	2284	1053	3584	1290	711	2001
Average	**3223**	**3219**	**5532**	**1821**	**1565**	**3386**

Gas production was greatest when sodium hydroxide was added to the influent to increase the very low influent pH values. Methane gas production was greatest during the high temperature operating periods. Since COD reductions were not significantly greater during the high temperature operating periods the greater gas evolution was a function of the solubility.

The specific methane production values were only 60% of the theoretical maximum. This was partially due to the fact that methane gas production was not measured in the flotation unit, dissolved methane gas was lost in the effluent, and a significant amount of the COD substrate was used to produce the large quantities of hydrogen sulfide gas.

The quantity of methane gas produced by the solids digester varied with the organic loading. At high loadings a larger percentage of methane gas was produced by the stabilization digester. During high loadings, organic material that was not degraded in the contact reactor were removed by the flotation unit and degraded in the solids holding digester. The Figure below shows the relationship between organic loading and the percentage of the total methane gas that was produced by the solids holding digester. Approximately 50% of the methane gas is produced from the solids holding digester at an organic loading of 30 Kg/m^3/day. At lower loadings, a larger percentage of the methane gas is produced in the contact reactor.

FIGURE 3 Percentage of Methane Gas from Solids Holding Digester



ORGANIC LOADINGS AND COD REMOVAL RATES

The COD removal rates and effluent clarity were dependent on both the organic loading rates and the temperature contact reactor. The table below presents the average weekly COD loadings, effluent clarity, and total COD reductions.

TABLE 5. ORGANIC LOADINGS AND COD REDUCTIONS

Operating Period	COD Reduction (%)	Contact Reactor Loading Kg/m^3/ day	Total Process Loading Kg/m^3/ day	Solids Ratio Digester to Influent	Contact Tempera ture ° C	Effluent Clarity (inches)
Week 1	80	32	11.6	5.3	32	
Week 2	80	45.5	16.5	4.4	32	
Week 3	82	35.6	12.9	5.1	32	12
Week 4	81	24.6	8.9	4.8	32	10
Week 5	87	23.5	8.5	4.7	32	10
Week 8	*94*	*19.3*	*7.0*	*4.3*	*35*	*17*
Week 9	95	16.8	6.1	6.9	35	14
Week 10	88	25.4	9.2	5.3	38	9
Week 11	84	25.3	9.2	4.6	40	5
Week 12	85	21.4	7.3	4.6	39	6
Week 13 & 14	*97*	*12.0*	*4.3*	*5.3*	*37*	*11*
Average	**86.5**	**25.59**	**9.24**	**5.05**	**34.9**	**10.6**

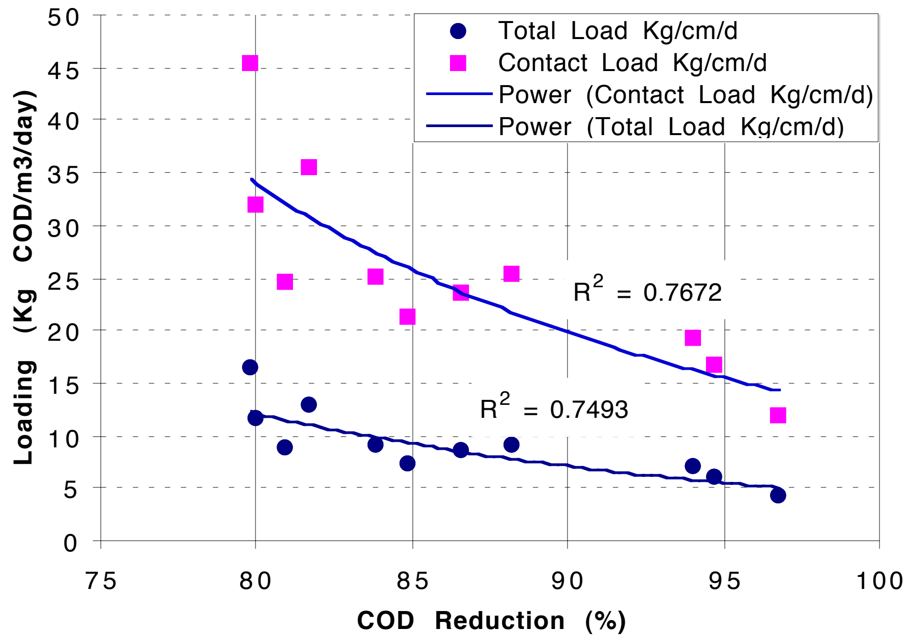
As can be observed in Table 5, the COD reduction is primarily dependent on the organic loading to the process.

Higher temperatures (>102°F) adversely effect the clarity of the effluent and process performance. The change to higher operating temperatures adversely effected the process by changing the characteristics of the biomass.

The data acquired from the pilot operation established the relationship between the organic loading and effluent quality. Figure 4 presents the relationship in graphical form. Two relationships are presented. The first predicts the percent COD reduction based on the loading to the contact reactor. The second predicts the COD reduction based on the loading to the entire process. It should be noted that the COD reduction is more sensitive to the contact reactor loading. Consequently, the contact reactor loading will be the controlling factor in the design.

The hydraulic retention time of the digester must be doubled to increase the COD reduction from 80% to greater than 95%.

FIGURE 4 COD REDUCTION BASED ON LOADING



Conclusions

The pilot plant was operated successfully for 3.5 months. During that time it was established that the organic loading to the process was the primary determinant of the COD reductions and the effluent quality achieved. To achieve COD reductions greater than 95% the loading to the contact reactor must be less than 15 Kg/m^3/day. For COD reductions greater than 95%, the loading to the *total process* must be less than, or equal to 5 Kg/m^3/day.

The operating temperature should be maintained at 95° F to 100° F. Minor increases or decreases in temperature can take place without upsetting the process. A reduction in effluent quality will occur when operating outside the optimum temperature range.

The influent pH should be buffered to improve process performance. Chemical addition is not required. Since the process is controlled by *loading*, recycling a portion of the treated effluent, or contact digester effluent, to improve the influent pH will be the least expensive option. Recycling the effluent will increase the flow and provide the necessary alkalinity without increasing the loading. Sufficient alkalinity is created through waste digestion to buffer the influent.