Résumé

La rentabilité d'exploitation de l'installation d'ozonation du Service des eaux de Monroe, Michigan, a fait l'objet d'une étude après dix années de service très satisfaisant. Afin de déterminer le coût de cette méthode mise uniquement en oeuvre dans le but d'améliorer les propriétés organoleptiques de l'eau potable, on a procédé à l'analyse des frais fixes et variables, ainsi qu'à une étude de rentabilité de l'installation au niveau de sa fiabilité permanente, de sa facilité d'opération et de son efficacité constante vis-à-vis des paramètres fixés. L'utilité des nombreux effets secondaires résultant de l'ozonation est également mentionnée.

Zusammenfassung

Nach bisher 10-jährigem, erfolgreichem Betrieb wurde die Ozonanlage der Monroe Wasserwerke betriebswirtschaftlich untersucht. Um die Kosten der Wasseraufbereitung (Geschmack + Eigenfarbe) zu bestimmen, wurden die stehenden und laufenden Kosten analysiert, wie auch Faktoren wie Betriebssicherheit, leichte Bedienbarkeit, konstante Wirksamkeit im Hinblick auf die Auslegungs-Parameter. Aufgeführt werden ebenfalls die zahlreichen nützlichen Nebeneffekte der Ozonung.

Ozone Application For The Improvement Of UASB Reactor Effluent
I. Physical-Chemical And Biological Appraisal

T.M.T. Gasi[1], L.A.V. Amaral[1], C.E.M. Pacheco[1], A.G. Filho[1], A.D. Garcia, Jr.[1], S.M.M. Vieira[1], R. Francisco, Jr.[2], P.D. Orth[2], M. Scoparo[2], M.S.R. de S. Dias[2] & M.L. Magri[2]

[1] CETESB - Cia. de Tecnologia de Saneamento Ambiental, Av. Prof. Frederico Hermann Jr., 345 Sao Paulo - 05459 - SP/BRAZIL

[2] FILSAN Equipamentos e Sistemas S.A., Sao Paulo, SP, Brazil

Received for Review : 21 July 1989
Accepted for Publication : 17 April 1990

Abstract

Ozonation can improve the effluent characteristics of UASB (upflow anaerobic sludge blanket) reactors treating domestic sewage, by removing organic matter, solids, surfactants, color and microorganisms. In Brazil, part of the effluent of a 120 m^3 UASB reactor, fed with screened domestic sewage at an hydraulic retention time of 7 hours, was post-treated in a two-column ozonation system of 300 liters total volume. With a contact time of 50 minutes and ozone application dosage of 16.7 mg/L, the following removals were obtained at the ozonation step: 51% BOD, 56% COD, 76% TSS, 62% color, and 91% surfactants. Pathogens and indicator organisms were inactivated to over 99.9%. Ozonation completely destroyed *Salmonella*, protozoa cysts and helminth eggs and larvae.

Introduction

Conventional methods for domestic sewage treatment normally do not remove pathogenic microorganisms, except for well designed and operated stabilization pond systems. Better knowledge of etiological agents such as viruses and bacteria, as well as stricter regulations for receiving waters in developed nations, led to the understanding that disinfection is the most important unit process in the wastewater treatment system. As a matter of fact, sewage treatment should act as a barrier against dissemination of enteric diseases.

In Brazil, little has been done to assure proper sewage disposal for its 140 millions inhabitants. In 1980, the national census reported that only 27.7% of the houses were connected to sewerage networks, mostly with no final sewage treatment; 15.5% had septic tanks and 28.9% had rudimentary pits; 21.9% of the houses did not have sanitary installations at all. This situation partly explains the high mortality and morbidity rates still occurring in the country. Besides the lack of political decision, sanitary devices and conventional sewage treatments are costly, and this seems to be one of the main impairments for the adoption of such technologies. Consequently, a rising demand for low-cost alternatives is brought about. In addition, appropriate technological solutions for sewage treatment must take into account the high population density of the Brazilian metropolitan areas, where 30% of the country's total population are found.

The anaerobic upflow sludge blanket reactor (UASB) is an interesting option for domestic sewage treatment. It has been studied since 1984 by CETESB (the Environmental Protection Agency for Sao Paulo State), and proved its feasibility at bench and pilot scales. The biodigester, however, produces an effluent still contaminated with pathogens and, in order to protect public health, disinfection is imperative. Many disinfection technologies, such as ozonation, chlorination, ultraviolet radiation, and sand filtration were considered. For ozonization studies, FILSAN Systems and Equipments S.A. provided installations and technology. This paper reports the improvement of UASB reactor effluent by application of ozone.

Materials And Methods

Ozonation studies were performed with the effluent of an UASB reactor running with domestic sewage. The reactor was designed and built by CETESB, in Brazil. The upper part of the 120-m^3 cylindrical biodigester was occupied by a sedimentation chamber which overlies the digestion compartment. The main design parameters were:

- sewage flow rate of 30 m^3/h,
- hydraulic retention time (HRT) ranging from 4 to 7 hours,
- settler surface application rate of 0.7 $m^3/m^2/h$, and
- biogas production capacity of 60 Nm^3/day.

Prior to the anaerobic digestion, the domestic sewage was screened and gritted, as shown in Figure 1. The system started operating in December 1986 and, during the ozonization tests between August and September 1987, the anaerobic reactor already had reached steady state.

The post-treatment tests were conducted with an ozonation unit FILZON, Model THF-05, designed and built by FILSAN Systems and Equipments S.A. Figures 2 and 3 show the ozonation system and details of the contact columns.

Ozone was generated in an air flow which had been filtered, compressed and dried to a dew point near minus 50°C. Operational conditions were:

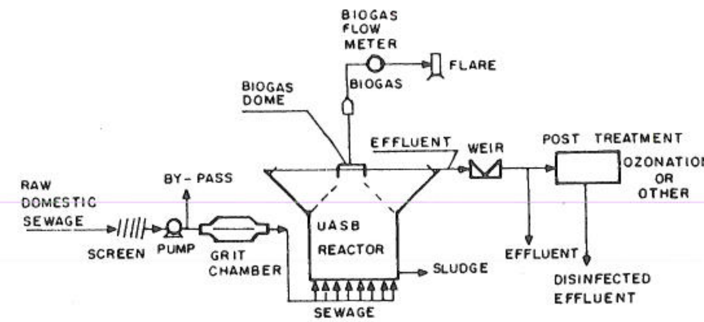

Figure 1. Diagram of anaerobic treatment of domestic sewage, with UASB Reactor.

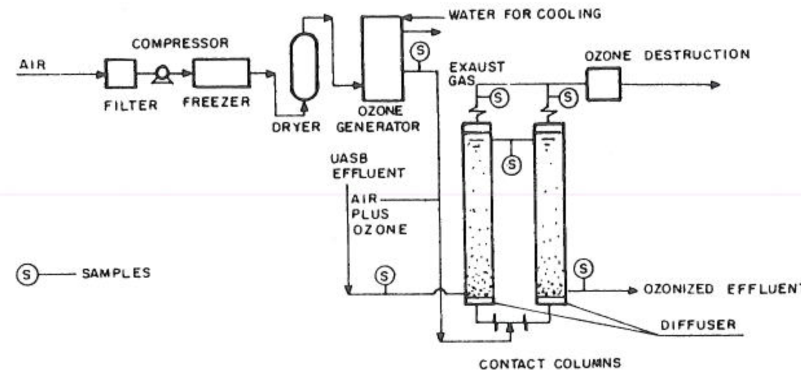

Figure 2. Diagram of the pilot plant ozonation facility.

- air pressure of 2.0 kgf/cm^2,
- air flow between 30 and 40 NL/min, and
- average internal temperature of 28°C.

Contact between UASB reactor effluent and carrier gas plus ozone was achieved in two 150-L PVC contact columns, placed in series. The gas inlets were located at the base of the columns, and the gas flow was admitted through fine bubble diffusers made of sintered glass with 50-micron porosity. Part of the UASB reactor effluent was diverted to a holding tank and then pumped to the first contact column at a constant rate. The sewage flow rate was controlled through a flow-meter and a by-pass. In the first column, the contact between liquid and gas flows was cocurrent, and in the second one the contact was counter-current. Both lines of carrier air plus ozone had flow meters and pressure gauges, allowing proper gas flow rate control.

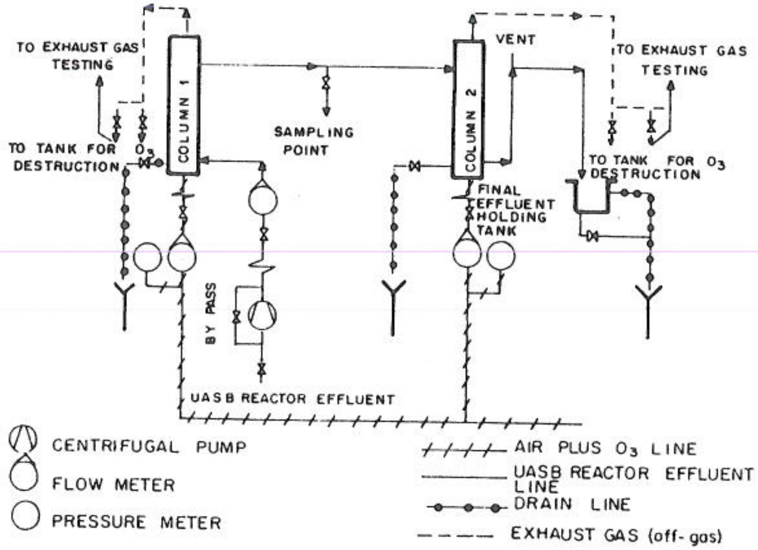

Figure 3. Details of the ozone contact columns.

The ozone output was controlled by handling the voltage output of the variable transformer in the generator unit. Ozone production was measured twice a day, by bubbling the oxidant gas into a graduated sampler containing KI solution and analyzing the liberated iodine by titration with $Na_2S_2O_3$ solution in the presence of starch indicator. Ozone concentration in the inlet and exhaust gases also was determined iodometrically. Exhaust gases were sent to a tank containing sulfide solution, in order to destroy the remaining ozone.

The applied ozone dose was calculated according to the equation:

$$D = P \cdot a / Q_L$$

where:

- D = applied ozone dose, in mg $O_3/L_{liq.}$;
- P = ozone production, mg/h;
- a = percent ozone applied to each column
  (for column 1, a = 0.66)
  (for column 2, a = 0.33);
- Q_L = liquid flow rate, $L_{liq.}/h$.

Two ozonation experiments were conducted, at the conditions shown in Table 1.

The ozonation system was operated over two months, 5 weekdays, from 8:00 a.m. to 4:00 p.m. Sampling always started after a period of 4.5 times the hydraulic retention time, at least, to assure that the process was in a stable condition.

TABLE 1. CONDITIONS FOR OZONATION EXPERIMENTS

Experiment	Number of Tests	UASB Reactor Effluent Flow Rate	Total Contact Time	Total Ozone Application Dosage
1	5	600 L/h	30 min	15.9 mg/L
2	8	360 L/h	50 min	16.7 mg/L

Liquid samples composed during four hours were collected in three points: UASB reactor effluent prior to ozonation, first contact column effluent, and second contact column effluent. During collection, the samples were kept refrigerated. Preservation was provided according to *Standard Methods for the Examination of Water and Wastewater*, 15th edition (6). Glassware and materials used for bacteriological analyses were previously sterilized.

The analyses were performed at the central laboratories of CETESB, according to the procedures in "Standard Methods" and CETESB rules, except for parasitological analyses, which used the Faust method with zinc sulfate (9).

Parameters analyzed for all liquid samples were the following: ozone residual, pH, BOD_5 (biochemical oxygen demand), COD (chemical oxygen demand), TSS (total suspended solids), color, turbidity, total nitrogen (Kjeldahl), nitrates, total phosphorus, sulfides, surfactants, total coliforms, fecal coliforms, fecal streptococci, *Clostridium perfringens*, *Salmonella*, coliphages, helminth eggs and larvae, and protozoa cysts. Viability of helminth eggs was not tested.

Results

Mean results obtained during the first ozonation experiment are shown in Table 2. The overall contact time was 30 minutes and ozone application was 10.6 mg O_3/L in the first contact column and 5.3 mg O_3/L in the second. Before ozonation, the anaerobic reactor effluent presented the following characteristics: 126 mg COD/L, 42 mg BOD_5/L, 51 mg TSS/L, 26 mg Pt/L as real color, 21 NTU turbidity, 4.63 mg/L of surfactants as MBAS, 31 mg total nitrogen/L, 4.02 mg total phosphorus/L and no sulfides. From a microbiological point of view, the effluent was very contaminated, showing a great number of total and fecal coliforms (1.27×10^7 and 1.60×10^6 MPN/100 mL, resp.), fecal streptococci (9.8×10^5 MPN/100 mL) and *Clostridium perfringens* (1.40×10^5 MPN/100 mL); *Salmonella* was present in 75% of the samples. Additionally, the anaerobic effluent presented 6.20×10^4 PFU/100 mL coliphages and a small concentration of helminth eggs and larvae (mean of 1.8/500 mL).

The UASB reactor reduced protozoa levels and the effluent was free of cysts. Ozonation removed between 40% to 60% of organic matter, suspended solids and color; surfactants removal was of 67%. Microorganisms were inactivated up to 99.5%, but *Salmonella* was still present in one-third of the final ozonized effluent samples, which contained no residual of ozone.

Table 2 - Mean Results of First Ozonation Experiment

Parameter	UASB Reactor Effluent	1st Contact Column Effluent	2nd Contact Column Effluent	% Removal in the 1st Column	% Removal in the 2nd Column	% Removal Total
Flow rate (l/h)	600	600	600	-	-	-
Ozone appl. (mgO_3/l)	-	10.6(2)	5.3(3)	-	-	-
Contact time (min)	-	15	15	-	-	-
pH	6.3	6.8	7.1	-	-	-
COD (mg/l)	126	81	75	36	8	41
BOD_5 (mg/l)	42	23	21	45	8	49
TSS (mg/l)	51	27	23	47	14	55
Colour (mgPt/l)	26	18	11	31	39	58
Turbidity (NTU)	21	18	16	13	13	24
N-Total (mg/l)	31	27	26	15	3	17
$N\text{-}NO_3$ (mg/l)	0.05	0.21	0.21	-	-	-
P-Total (mg/l)	4.02	3.73	3.41	7	9	15
Surfactants (mg/l)	4.63	1.93	1.52	58	21	67
Total Coliforms*	$1.2x10^7$	$1.9x10^6$	$5.5x10^4$	83.68	97.16	99.54
Fecal Coliforms*	$1.6x10^6$	$3.4x10^5$	$1.1x10^4$	78.88	97.61	99.28
Fecal Streptococci*	$9.8x10^5$	$2.0x10^5$	$4.9x10^3$	79.94	97.49	99.50
C. perfringens*	$1.4x10^5$	$5.2x10^5$	$7.8x10^5$	NR	NR	NR
Salmonella (1)	present in 75% of the samples	present in 50% of the samples	present in 33% of the samples	33.33	50.00	66.67
Coliphages (PFU/100 ml)	$6.2x10^4$	$5.4x10^3$	300	91.35	94.48	99.52
Helminth eggs/larvae**	1.8	0	0.2	100.00	-	88.89
Protozoa cysts**	0	0	0	-	-	-

Results are mean of 5 values/* = MPN/100 ml/NR = no removal/** = N/500ml/ (1) = mean of 4 values/(2) 10.4 to 10.7/(3) 5.2 to 5.3

Table 3 summarizes the results obtained in the second set of experiments. For these experiments, the UASB reactor effluent characteristics were: 120 mg COD/L, 41 mg BOD_5/L, total suspended solids of 34 mg/L, color of 50 mg Pt/L, turbidity of 15 NTU, 30 mg N-Total/L, 3.68 mg P-Total/L, 5.30 mg surfactants/L and no sulfides. Microbiological parameters were again very high: 2.0 x 10^7 MPN/100 mL total coliforms, 3.5 x 10^6 MPN/100 mL fecal coliforms, 9.6 x 10^5 MPN/100 mL fecal streptococci, 8.0 x 10^4 MPN/100 mL *C. perfringens* and 6.4 x

10^4 PFU/100 mL coliphages; *Salmonella* was found in 85.7% of the samples and there were counted 1.25 helminth eggs and larvae/500 mL and 0.13 protozoa cysts/500 mL. All these values are the means of 8 or 7 results. Removals of organic matter, solids, color, turbidity and surfactants were improved: 56% COD, 53% BOD_5, 62% TSS, 63% color, 37% turbidity and 90 % surfactants.

Table 3 - Mean Results of Second Ozonation Experiment

Parameter	UASB Reactor Effluent	1st Contact Column Effluent	2nd Contact Column Effluent	% Removal in the 1st Column	% Removal in the 2nd Column	% Removal Total
Flow rate (l/h)	360	360	360	-	-	-
Ozone appl. (mgO_3/l)	-	11.1(1)	5.6(2)	-	-	-
Contact time (min)	-	25	25	-	-	-
pH	6.4	7.0	7.5	-	-	-
COD (mg/l)	120	65	53	46	19	56
BOD_5 (mg/l)	41	22	20	47	10	53
TSS (mg/l)	34	16	13	54	17	62
Colour (mgPt/l)	50	19	19	61	3	63
Turbidity (NTU)	16	12	10	26	15	37
N-Total (mg/l)	30	26	28	6	1	7
$N\text{-}NO_3$ (mg/l)	0.05	0.31	0.94	-	-	-
P-Total (mg/l)	3.68	3.23	3.15	12	2	14
Surfactants (mg/l)	5.30	0.69	0.53	87	22	90
Total Coliforms*	$2.0x10^7$	$4.2x10^4$	$1.6x10^4$	99.79	60.93	99.92
Fecal Coliforms*	$3.5x10^6$	840	84	99.98	89.98	99.998
Fecal Streptococci*	$9.6x10^5$	2427	66	99.75	97.29	99.993
C. perfringens*	$8.0x10^4$	$1.8x10^4$	2070	77.93	88.33	97.42
Salmonella	present in 85.7% of the samples	absent	absent	100.00	-	100.00
Coliphages (PFU/100 ml)	$6.4x10^4$	370	24	99.34	93.57	99.96
Helminth eggs/larvae**	1.25	0	0	100.00	-	100.00
Protozoa cysts**	0.125	0	0	100.00	-	100.00

Results are mean of 7-8 values/* = MPN/100 ml/ ** = N/500 ml/ (1) 7.2 to 13.7/ (2) 3.6 to 6.9

Pathogenic and indicator organisms were destroyed to over 99.9%; salmonellae and parasites were completely removed. No ozone was detected in final effluent.

Discussion

FIRST TEST

Conditions

30 min contact time and applied O_3 15.9 mg/L. It was observed that ozonation was able to reduce levels of sewage chemical contaminants, mainly in the first ozone contact column. Total removals were: 41% COD, 49% BOD_5, 55% TSS, 58% color and 67% surfactants. As expected, nutrient removal was negligible (17% total nitrogen and 15% total phosphorus). The ozonation system also provided an effluent with less variation in quality, when compared to the UASB reactor effluent. Levels of pathogens and fecal indicator organisms were not significantly reduced as well. Final effluent still contained bacteria at counts as high as 10^3 to 10^5/100 mL; the pathogenic *Salmonella* was found in 33% of the samples. The reduction of viruses, measured as coliphages, was noticeable, from 6.2 x 10^4 PFU/100 mL to 300 PFU/100 mL in the final effluent.

SECOND TEST

After raising the hydraulic retention time from 30 min to 50 min, and keeping the overall ozone application at about the same level (16.7 mg O_3/L, at the second test), the quality of the final effluent improved significantly. Reductions achieved were: 56% COD, 53% BOD_5, 62% TSS, 63% color, and 90% surfactants. As was noticed at the first test, physical-chemical parameters were mainly removed in the first contact column and ozonation produced an effluent more steady in quality.

Figure 4 shows pH variations for biodigester effluents at the first and second column outlets; the pH was raised from 6.4 to 7.0 and to 7.5. This figure also shows patterns of COD and BOD_5 variations. Forms of nitrogen were not studied; however, it was possible to verify that total nitrogen actually remained the same, and nitrification of the final effluent was observed to some extent.

Relationships between percent removal of COD, TSS and surfactants versus applied ozone doses are shown in Figure 5. The least squares method was used to relate data, and significance of the correlations was tested with Student's t statistics at confidence levels of 10% or less for a two-tailed test. The correlation between COD removal times applied ozone and between surfactants removal times applied ozone both were significant at a level of 1%. TSS times applied ozone was significant within a confidence level of 10%.

The same procedure was used to relate the physical-chemical parameters in the final effluent. Significant relationships were found for the following pairs of data: COD versus BOD_5, turbidity versus TSS (both significant at a level of 10%) and TSS versus COD (significant at a level of 2%).

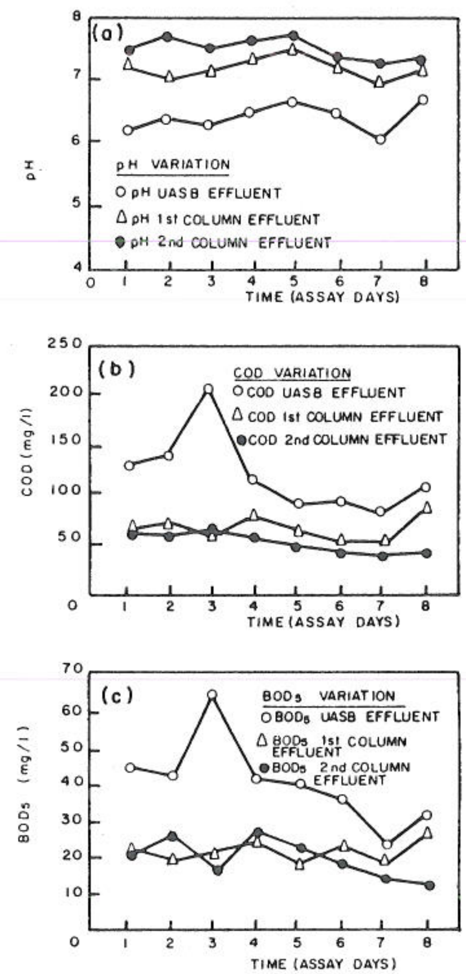

Figure 4. Patterns of (a) pH variation, (b) COD variation, and (c) BOD_5 variation on second ozonation test (HRT = 50 min, 16 mg O_3 applied/L).

Microbiological characteristics of final ozonized effluents showed that a high quality effluent was obtained. This is particularly true in Brazil, where legislation still allows 5,000 MPN/100 mL of total coliforms and 1,000 MPN/100 ml of fecal coliforms in rivers appointed for public consumption after conventional water treatment, for crop irrigation and for primary contact recreation (7). The ozonized effluent contained: fecal coliforms = 84 MPN/100 mL, fecal streptococci = 66 MPN/100 mL and coliphages = 24 PFU/100 mL; *Salmonella* and parasites were absent. It was interesting to note that total coliforms counts consistently were high (mean of 1.6 x 10^4 MPN/100 mL, ranging between limits of 800 and

50,000 MPN/100 mL. It should be emphasized that total coliforms are not recognized as a good parameter for attesting to sewage treatment efficiency; as a matter of fact, even in water bacteriology, total coliforms are regarded more as presumptive evidence of fecal pollution than as definitive indicators (1).

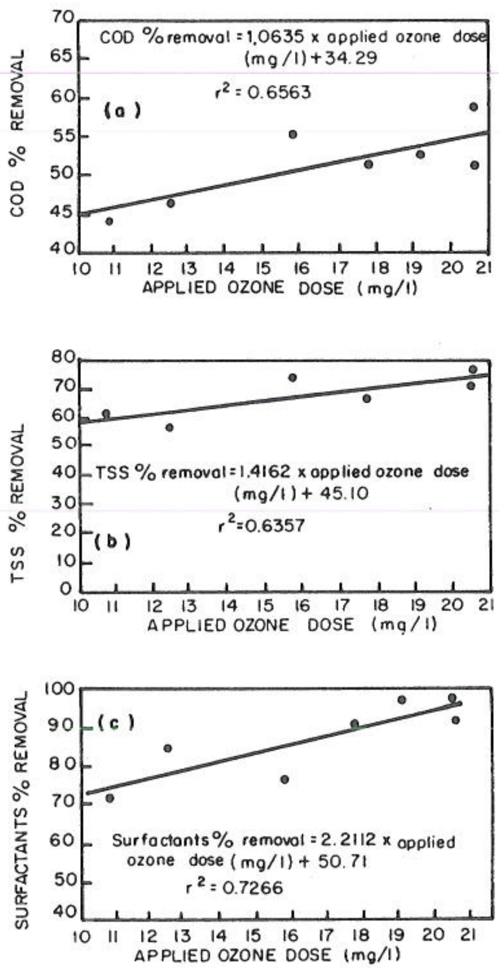

Figure 5. Correlations between (a) % COD removal x applied ozone dose, (b) % TSS removal x applied ozone dose, and (c) % surfactants removal x applied ozone dose, in the second ozonation test (HRT = 50 min, 16.7 mg O_3 applied/L).

Under ozonation test conditions, total coliforms definitely did not portray the removal of fecal indicators and pathogenic organisms. *Clostridium perfringens* also were found in relatively great numbers in the final effluent (2,070 MPN/100 mL, range from 13 to 8,000 MPN/100 mL. This bacterium is an anaerobic spore-forming one, and is more resistant than fecal coliforms and fecal streptococci to antagonistic substances; it may thus not reflect the true degree of pathogenic contamination (1). It was important to verify that *Salmonella* and parasitic forms were completely eliminated; the removals occurred in the first contact column, and the second contactor may be seen as a safety factor in case of pathogens survival in the intermediate effluent.

Correlation between microbiological parameters also was tested with the least squares method for values observed in final effluent; Table 4 shows the determination coefficients obtained. It may be seen that only the relationship between fecal streptococci and coliphages was good; the significance level obtained for the correlation coefficient was 2% according to the Student's t test.

Table 4. VALUES OF DETERMINATION COEFFICIENTS (R^2) FOR MICROBIOLOGICAL PARAMETER RELATIONSHIPS IN FINAL OZONIZED EFFLUENTS (HRT= 50 min, 16.7 mg/L O_3 applied)

	Total Coliforms	Fecal coliforms	Fecal Streptococci	*Clostridium perfringens*
Total Coliforms	---			
Fecal Coliforms	0.0571	---		
Fecal Streptococci	0.1258	0.1927	---	
Clostridium perfringens	0.0328	0.0541	0.0719	---
Coliphages	0.0137	0.0670	0.8183	0.4891

Figure 6 shows a line of best fit and its corresponding equation. A correlation between counts of *C. perfringens* and coliphages also was observed in the final ozonized effluent, but was of less statistical significance (10% of confidence level). These findings are supported by literature which explains that fecal streptococci are better indicators of excreted viruses, due to the fact that both survive longer than fecal coliforms. *C. perfringens* is a resistent bacterium and correlation to coliphages thus may be explained (1).

The influence of applied ozone doses upon survival of indicator organisms also was studied. Logs of fecal streptococci counts and of coliphage counts tended to decrease with increasing applied ozone doses; the significance levels of these trends were 1% and 0.1%, respectively. Lines of best fit and equations are presented in Figure 7. The corresponding relationship for *C. perfringens* was not of statistical value. Survivals of coliforms did not show correlation to applied ozone. This indicates that coliphages and also fecal streptococci would be better parameters for microbiological ozonation monitoring than fecal or total coliforms.

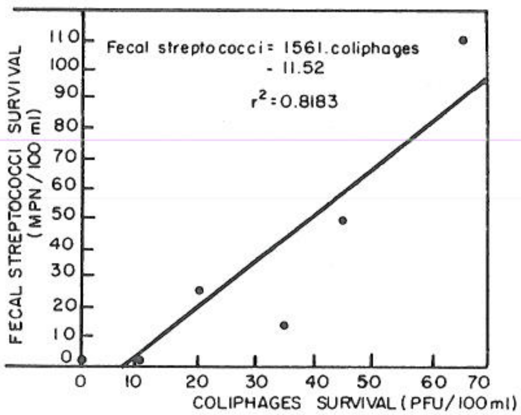

Figure 6. Correlation between fecal streptococci x coliphages in final ozonized effluent (HRT = 50 min, 16.7 mg O_3 applied/L).

Correlation between physical-chemical and microbiological parameters also was tested. It was found that coliphage survival fitted well with percent COD removal and percent surfactants removal. These findings are presented in Figure 8, including lines of best fit. Determination coefficients were, respectively, 0.7083 (level of significance = 1%) and 0.5486 (level of significance = 10%).

Conclusions

The study of ozonation to improve anaerobic domestic sewage effluent from an UASB reactor led to the following conclusions:

1) At operational conditions of 30 min overall hydraulic retention time in ozone contactors and average applied ozone dose of 15.9 mg/L, removals of organic matter, suspended solids, color and surfactants were noticed. Indicator and pathogenic microorganisms survived the ozonation well, showing that disinfection did not succeed.

2) At test conditions of 50 minutes overall hydraulic retention time and applied ozone dose of 16.7 mg/L, better removals of organic matter, total suspended solids, color and surfactants were noticed. A high microbiological quality effluent was obtained, with complete destruction of *Salmonella* and parasites and good reduction of coliphages.

   - total coliforms proved not to be suitable indicators for ozonation microbiological efficiency.

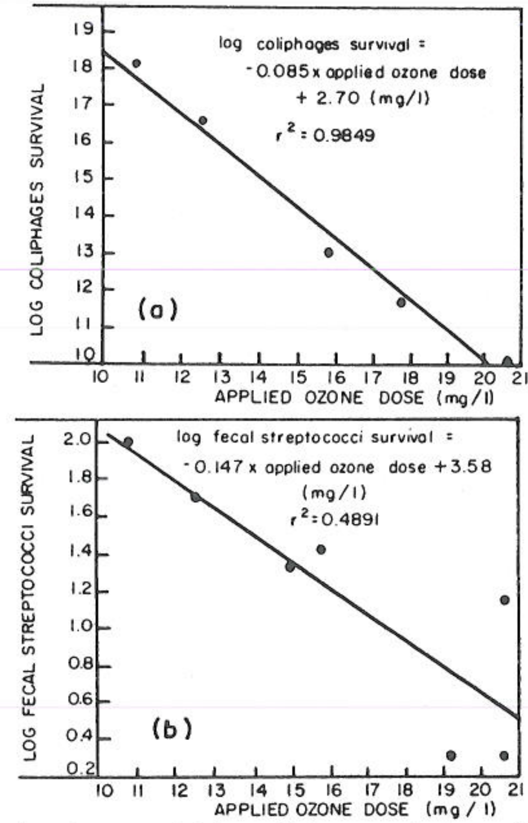

Figure 7. Correlations between (a) log coliphage survival x applied ozone doses and (b) log fecal streptococci survival x applied ozone doses (HRT 50 min, 16.7 mg O_3 applied/L).

   - there was a good relationship between fecal streptococci and coliphage survivals in the final ozonized effluent;
   - increasing applied ozone doses affected the survival of coliphages and fecal streptococci negatively;
   - it was possible to relate percent COD removal to coliphage survival. It seems that both parameters would be suitable indicators of ozonation performance when treating domestic sewage UASB reactor effluents.

Acknowledgments

We would like to thank Physical-Chemical, Microbiological and Technological Laboratories of CETESB, Eng. Jonas Klimavicius from FILSAN for designing and building the ozone pilot plant, and ISAM-Environment Sanitation Institute/PUC-Pontifical Catholic University of Parana State for access to their microcomputer facilities.

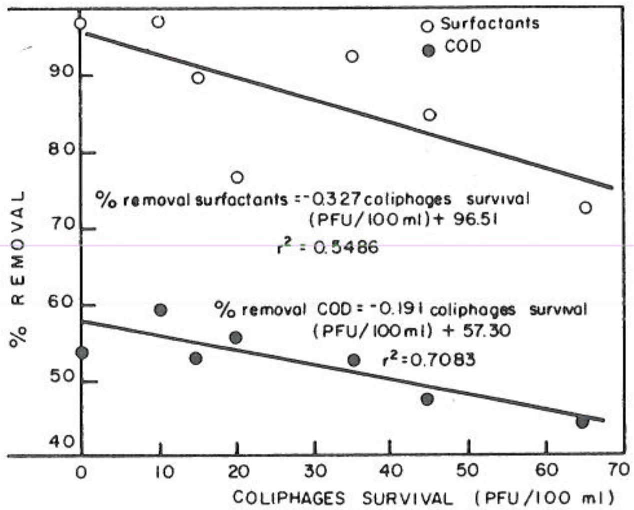

Figure 8. Percent removal of surfactants and COD versus coliphage survival (HRT = 50 min, 16.7 mg O_3 applied/L).

References

1. FEACHEM, R.G. et al., *Sanitation and Disease - Health Aspects of Excreta and Wastewater Management* (Chichester, UK: John Wiley & Sons, 1983).
2. STOVER, E.L.; JARNIS, R.N., "Obtaining High Level Wastewater Disinfection With Ozone", J. Water Poll. Control Fed. 53(1):1637-1647 1981.
3. IBGE, Brazil, "Cenco Demografico Familias e Domicilios", in *IX Recenseamento geral do Brasil - 1980, Vol. 1, No. 1*, Rio de Janeiro, IBGE, 1983.
4. VIEIRA, S.M.M.; SOUZA, M.E., "Development of Technology for the Use of UASB Reactor in Domestic Sewage Treatment", Water Sci. Technol. 18(12):109-121 (1986).
5. VIEIRA, S.M.M., "Anaerobic Treatment of Domestic Sewage in Brazil - Research Results and Full-Scale Experience", in: *Anaerobic Digestion 1988*, E.R. Hall & P.N. Hobson, Editors (Oxford, UK: Pergamon Press, 1988), pp. 185-196. (Proceedings of the International Symposium on Anaerobic Digestion, 5, Bologna, 1988).
6. APHA - AMERICAN PUBLIC HEALTH ASSOCIATION, United States, *Standard Methods for the Examination of Water and Wastewater, 16th Edition*, (Washington, DC: Am. Public Health Assoc., 1985).
7. CETESB - COMPANHIA DE TECNOLOGIA DE SANEAMENTO AMBIENTAL, Brazil, *Legislacao - Controle da Poluicao Ambiental*, Sao Paulo, Convenio CETESB/ASCETESB, 1986.
8. BERQUO, E.S.; SOUZA, J.M.P.; GOTLIEB, S.L.D., *Bioestatistica Sao Paulo, E.P.U., 1980.*

9. PESSOA, S.B., *Parasitologia Medica* (Rio de Janeiro, Brasil: Ed. Guanabara, 1954).

Key Words

Ozone, Upflow Anaerobic Sludge Blanket Reactor, Sewage Treatment, Disinfection, Pilot Plant Study, Organic Matter Removal, Suspended Solids, Surfactant Removal, Color Removal,

Résumé

L'ozonation est en mesure d'améliorer la qualité des effluents des réacteurs à lit de boue anaérobie (UASB) traitant les eaux résiduaires domestiques, en éliminant les matières organiques et substances solides, les tensides, ainsi que la coloration et les microorganismes. On a procédé au Brésil au post-traitement d'un effluent partiel - provenant d'un réacteur UASB de 120 m^3 alimenté par des eaux résiduaires domestiques soumises à un temps de rétention de 7 heures - en l'exposant à une ozonation dans un système à deux colonnes d'un volume total de 300 litres. Avec un dosage de 16,7 mg/L et un temps de contact de 50 min, les diminutions suivantes ont été obtenues: DBO 51%, DCO 56%, substances solides en suspension 76% coloration 62%, et tensides 91%. Les germes pathogènes ont été inactivés à raison de 99,9%. L'ozonation élimina entièrement les salmonelles, kystes de protozoaires, ainsi que les oeufs et larves des ascaris.

Zusammenfassung

Durch den Abbau von organischen Stoffen, Feststoffen, Tensiden, Färbungen und Mikroorganismen kann man mittels Ozonung die Qualität von UASB-Siedlungs-Abwässern erheblich verbessern (UASB = Upflow Aerobic Sludge Blanket, Belebt-Schlamm Gegenstrom). In Brasilien wurde ein Abwasserteilstom aus einem 120 m^2-Becken, in dem gesiebte Siedlungsabwässer 7 Stunden verweilten, in einem 2 Kolonnen-Ozonungssystem mit einem Gesamtvolumen 300 L nachbehandelt.

Bei einer Dosis von 16,7 mg/L und einer Kontaktzeit von 50 min, wurden folgende Ergebnisse erzielt (% Abbau): BSB 51, CSB 56, Susp. Feststoffe 76, Farbe 62, Tenside 91% und pathogene Keime 99,9 Salmonellen, Amöben und Eingeweidewürmer (Eier und Larven) wurden vollständig vernichtet.