Management of pig manure in anaerobic lagoons with added exogenous biological activators

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Abstract. Redox potential, pH, Tº; sulfides concentration, BOD_5, COD, *Escherichia coli,* and coliforms NMP (most likely number method) were determined in the substratum of stabilization lagoons using an addition of commercial bacterial preparation as an enzyme-suppling activator. Three lagoons of 250 m^3 capacity received an addition of 285 g of concentrate, containing of 1.5 x 10^9 microorganisms/g without excipients, on 1st September 2014 (treatment T1). Three other lagoons were untreated (T2). At 30 and 60 d after the said aggregation 10 samples per lagoon in each treatment were collected for analysis. The T1 samples showed higher Tº, which favors the growth of methane-producing bacteria; and the stable redox values observed in T1 correspond to a reducing environment rich in H_2 gas suitable for the growth of strictly anaerobic microorganisms. The latter was also indicated by decreased formation of H_2S, and lower values of BOD_5, COD. *E. coli* and total coliforms. Further reductions of BOD_5 and COD occurred from day 30 to day 60 post aggregation. The lower pH observed in the substratum of T1 lagoons was beneficial to the sulfide-oxidizing bacteria and prevented the formation of odors associated with the release of H_2S. These results indicate that the addition of biological activator of enzymatic activity to the small lagoons can be expected to accelerate anaerobic depuration, eliminating OM, and shorten retention time.

Keywords: Anaerobic depuration, Biological activators, Manure lagoons, Pigs

Manejo de estiércol porcino en lagunas anaeróbicas con agregado de activadores biológicos exógenos

Resumen. Se estimó el pH, el T°, el potencial redox, la concentración de sulfuros, BOD_5, COD, *Escherichia coli* y coliformes NMP (método de número más probable) en el substrato de lagunas de estabilización, usando una preparación bacteriana comercial como activador biológico enzimático. Tres lagunas de estabilización, usando una preparación bacteriana comercial como activador biológico enzimático. Tres lagunas de 250 m^3 capacidad recibieron la adición de 285 g de un concentrado, aportando 1.5 x 10^9 microorganismos/g sin excipientes, el 1º de septiembre de 2014 (tratamiento T1). Otras tres lagunas se dejaron sin tratar (T2). A los 30 y 60 d de dicha agregación se recogieron 10 muestras por laguna en cada tratamiento para análisis. Las muestras de T1 mostraron Tº más alto, lo que favorece el crecimiento de bacteria metanogénica y los valores redox observados en T1 corresponden a un ambiente reductor con abundante gas H_2 y apto para el crecimiento de microorganismos estrictamente anaeróbicos. Este último fue indicado también por menor formación de H_2S y valores menores de BOD_5, de COD y de *E. coli* y coliformes totales. Reducciones adicionales de BOD_5 y COD ocurrieron desde 30 hasta 60 d post-agregado. El pH más bajo observado en el substrato de las lagunas T1 resultó beneficioso para las bacterias sulfuro oxidantes y previno la formación de olores asociados con la liberación de H_2S. Estos resultados indican que el agregado del activador biológico con actividad enzimática a las lagunas pequeñas debería acelerar la depuración anaeróbica, eliminando retención de la materia orgánica, así como acortando el tiempo de retención.

Palabras claves: Activadores biológicos, Depuración anaeróbica, Laguna de estiércol, Porcinos

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Introduction

Stabilization lagoons are a simple technique for treating agricultural effluents. The basic principle of these lagoons is to retain the effluents during sufficient time to allow the degradation of organic matter (OM) by microbial activity. Their construction is very simple and involves digging a hole of the desired dimensions and sealing it to prevent infiltration. Operating costs are low compared with those of other systems. This lower cost of operation is compatible with good performance and these simple systems are generally as efficient as the conventional ones. Treatment lagoons can be classified by the type of biodegradation (aerobic, anaerobic or facultative), the discharge frequency and the spatial arrangement (Nizami and Korres, 2009; Xie and Lawor, 2011).

The excreta (feces and urine) are animal excretory products resuting from ingestion and digestion of food. The slurry/manure includes the deposition of feces and urine + uneaten food remains + wasted drinking water and water for washing. The effluent is wastewater having undergone a period of treatment (Murto and Björnsson, 2004; Nizami and Korres, 2009).

In the slurry the preparation of wash water varies depending on the type of washing procedure used by the farm. This ratio varies from about 1: 6 to 1:18 (18 L of wash water to 1 L of slurry). The producer can get an idea of this relationship based on the average monthly expenditure of water or estimate the ratio based on physical appearance of the slurry.

Biochemical oxygen demand (BOD) is defined as the amount of OM capable of being oxidized by the biological agents present in a liquid sample. The summation of the carbonaceous and nitrogenaceous biochemical demand for oxygen is expressed as BOD_5**.** Chemical oxygen demand (COD) is a measure of the amount of OM capable of being oxidized by chemical means in a liquid sample. It is used to measure the degree of contamination and is expressed as mg O_2/L or mL O_2/L. The BOD_5 indicates the amount of biodegradable OM contained in an effluent under study. The COD measurement indicates the amount of non-biodegradable OM in a water sample. The difference is that the amount of oxygen refers, in the case of BOD_5, to that required by the biological degradation of OM; while in the case of COD to that required by the chemical degradation of OM. The calculation of BOD_5 depends on determining the oxygen content of a water sample after being left for a certain time (five days is the standard) compared to another sample preserved during this same period at a given temperature (20°C) enclosed in motionless air and in the dark, in order to avoid oxygen formation by photosynthesis. The difference between the two samples represents the five-day BOD content (BOD_5) (Kanth and Bergström, 2010; Xie and Lawlor, 2011).

Average on farm values are 0.25 kg of BOD and 0.75 kg of COD generated, per 100 kg of animal liveweight daily (Madsen and Holm-Nielsen, 2011; Menardo and Gioelli, 2011).

The redox potential is a measure of electron activity, which is related to the pH and oxygen content. It is analogous to measuring pH and proton activity. As potentially oxidizable OM oxidizes and decomposes, reducing reactions tend to decrease. The substance with more negative reduction potential is to be oxidized. It is, therefore, important to know the normal values of redox potential. For example, hydrogen sulfide H_2S a powerful reductant, is oxidized to S^0 + 2e (Herrero, 2008; Murto and Björnsson, 2004). The pig manure in the stabilization lagoons, is used by anaerobic and facultative bacteria to produce volatile organic acids. Anaerobic bacteria transform the organic acids into CH_4 and CO_2. This stage of depuration is essential for the subsequent removal of OM, and contributes to the lower BOD_5 and COD of the substratum due to the action of aerobics bacteria and redox reactions. The methane producing bacteria are very sensitive to pH <7. At pH values below 6.8, CH_4 production begins to decline. When this occurs, accumulated organic acids with unpleasant odors in addition to other released compounds such as H_2S, mercaptan and skatole, also of offensive odor, indicate malfunction of the lagoons (Demirel and Scherer, 2008; Herrero, 2008; Kanth and Bergström, 2010). If these lagoons operate with too short retention time, the hydrolytic acidogenic phase may develop, but with little formation of methane, which is slow; and the presence of such odors indicates little removal of OM (Herrero, 2008; Kanth and Bergström, 2010). Biological substrates designed for managing manure in lagoons are highly concentrated products containing selected strains of bacteria and auxiliary enzymes capable of initiating biological actions immediately to prevent the formation of odors caused by organic and inorganic compounds. The bacteria in the products are dried in a special process and reactivated with ease by mixing with water and allowing rehydration time. The bacteria in these products are more competitive than those originally present in the manure, and being better adapted, they take control of the decomposition process. These bacteria change the nature of the odor-causing compounds through processes of hydrolysis and biological oxidation. As a result of these reactions pathogens are suppressed; the BOD_5 and COD of the manure are drastically reduced and a reduction in the volume of solids of up to 40%, can be expected in several weeks time. Furthermore, odors are significantly reduced not only in the storage place, but once scattered in the field.

In this study, pH, T°, redox potential, concentration of sulfides, BOD_5, COD, *Escherichia coli* and coliforms NMP (most likely number method) were estimated in substratum samples from stabilization lagoons using a commercial bacterial preparation as a biological activator processing enzyme action.

Materials and Methods

The experiment was conducted during September and October of 2014 at a location of Latitude 36° 46' S; Longitude 64° 16' W. Six anaerobic stabilization lagoons of 250 m^3 average area that began filling in the previous months of January and February were used. Three lagoons of Treatment 1 (T1) received on September 1 an addition of 285 g of a concentrate of 1.5×10^9/g of microorganisms without excipients (inert ingredients). The other three lagoons of Treatment 2 (T2) received no addition. At 30 and 60 d following aggregation of external biological substrate, 10 samples per lagoon of each treatment were collected and the organic substratum evaluated for pH, T°, redox potential, concentration of sulfides, BOD_5, COD, *E. coli* and coliforms NMP. The instrumentation used included a ADWA laptop Instruments Kit. Bulgary 111 pH/°C for pH measurement; a digital Siemen Senz Pal Tester for electric conductivity and a portable digital dissolved oxygen meter JPB - 607 for BOD_5. These instruments are described in the Annual Book of ASTM Standards, Section 11 - Water and Environmental Technology (2013). The analysis of the data corresponded to a Student T test (degrees of freedom ∞).

Results and Discussion

The results presented in Table 1, show significant advantages for T1 over T2 in all eight variables studied. This indicates greater OM stabilization with formation of end products CO_2 and CH_4. Also methane bacteria grow best at the higher T° observed for T1 with respect to the control treatment at 30 and 60 d after addition of the activator.

The stable redox values observed in T1 correspond to a reducing environment, rich in

Table 1. Mean variables ± 1 standard deviation

Indicators contamination	30 d of initiation		60 d of initiation	
	T1	T2	T1	T2
T° (°C)	24	18	32	27
	(± 0,3) ***a***	*(± 0,2)* ***b***	*(± 0,2)****a***	*(± 0,4)****b***
pH	6,9	6,0	7,0	6,3
	*(±0,02)****a***	*(±0,04)****b***	*(±0,01)****a***	*(± 0,05)****b***
Redox Potential (volts)	-0,49	-0,42	-0,52	-0,54
	(± 0,001) ***a***	*(±0,003)* ***b***	*(±0,002)* ***a***	*(±0,003)* ***b***
Sulfides (mg/L)	123	206	0,61	146
	(± 10) ***a***	*(± 17)* ***b***	*(±0,01)* ***a***	*(±) 11* ***b***
BOD_5 (mg/L)	4547	10903	717	7762
	(±114) ***a***	*(±203)* ***b***	*(± 21)* ***a***	*(± 186)* ***b***
COD (mg/L)	7561	15977	2107	5681
	(±177) ***a***	*(±243)* ***b***	*(±97)* ***a***	*(±134)* ***b***
Escherichia coli (Col/100 ml)	866	1412	171	433
	(± 49) ***a***	*(±75)* ***b***	*(±11)* ***a***	*(±38)* ***b***
Coliforms NMP (Col/100 ml)	4765	9670	551	4530
	(±102) ***a***	*(±246)* ***b***	*(± 31)* ***a***	*(±189)* ***b***

[a, b]Values with same letter in the row are not statistically different (P< 0,05).
Distribution of critical values "t" from equal variance and one - direction test.

hydrogen gas, and therefore, suitable for the growth of strictly anaerobic microorganisms. This resulted in lower H_2S levels and <BOD_5<COD <*E. coli* and total coliforms. Further reductions of COD and BOD_5 occurred between the 30-d and 60-d measurements. A higher pH in T1 benefited the presence of bacteria that oxidize sulfide, thus, avoiding the formation of odors associated with the release of H_2S.

Redox potential values under--200 mV correspond to anaerobic processes, those between 0 and--200 mV are transitional, while positive values indicate aerobic processes.

Biological substrates designed for managing manure fermentation in lagoons are highly concentrated products containing selected strains of bacteria and auxiliary enzymes capable of immediate initiation of biological actions for positive control of odors caused by undesirable organic and inorganic compounds.

Addition of biological activators possessing enzymatic action fosters the anaerobic depuration, with elimination of OM, and decreses retention times in small lagoons. In the effluent from an anaerobic lagoon with external biological substrates, such as that of T1, the efficiency can reach 80% removal of OM, and still show high levels of BOD in the aerobic surface water space. Moreover, the non-degraded solids settle to the bottom, resulting in formation of a layer of sludge. With increasing storage time of sludge in the lagoon floor, OM decreases due to the anaerobic degradation to which it is subjected.

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