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Removal of organic matter and nutrients from a porcine effluent, through geo-containment filtration

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Summary: *The intensive porcine productions generate effluents with high contents of solids, organic matter, phosphorus and nitrogen; constituting a source of contamination when they are not treated accordingly. Geocontainment filtration is a technology that allows to retain solids and thereby reduce the concentration of organic matter and nutrients in liquid effluents. The objective of the work was to evaluate the removal of the solid fraction of porcine effluents, through a filtration with addition of coagulants ($FeCl_3$) and flocculants (cationic polymer).A filtering device was used to simulate the real load conditions in geocontainers: turbulence, flow and pressure. Three treatments were performed with 3 replicas: untreated raw effluent (T_0), filtered effluent without the addition of chemicals (T_1), filtered effluent with addition of chemicals (T_2), filtered effluent with 20% more chemicals than T_2 (T_3). The physical effluent and each of the treatments were used to perform physical, microbiological and parasitological determinations by reference methods, in order to evaluate the removal percentages of each one. Data were analyzed by the Prism 5 program, through a one-way ANOVA and the Bonferroni test was used to perform multiple comparison tests between treatments. The statistical analysis showed that there were significant differences ($p < 0.05$) between the treatments T_0 and T_2 / T_3 in the following parameters: pH, chemical oxygen demand (COD), total phosphorus (PT), electrical conductivity (CE), nitrogen total (NT), total solids (ST), total suspended solids (SST), for soluble ions Ca, Cu, Mn, Mg, and for total ions Zn and Cu.T_2 and T_3 treatments achieved a removal in most of the parameters analyzed, demonstrating that geocontainment with the addition of coagulant and flocculant is a technology that can be used to retain solids and nutrients from a porcine effluent.*
Keywords*: Geocontainment, Pork slurry, Effluent filtration*

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I. Introduction

Swine production at the national level is recovering and constantly growing in Argentina. Today, the existence at the country level of 3,437,000 heads, and a number of mothers in a commercial stratum of 345,000 [1]. Intensive livestock farms are characterized by a high animal load, with a high consumption of high quality food resources and on small areas. One relevant externality of the productive system is the organic waste that is generated. The management of waste in confined productions of pigs acquires greater environmental relevance every day. The effects of the intensification of production are magnified with the increase of the volumes generated, the proliferation of vectors, the emission of unpleasant odors and the contamination of natural resources. The residues of intensive pig farms, is called slurry, it is defined as a mixture of solid and liquid waste from animals along with food remains, remnants of drinking water, and washing water from the farm [2]. The inadequate management of effluents from intensified pig production is a serious problem due to its undoubted and proven environmental impact [3].

A commonly used practice for the treatment of effluents is the system of anaerobic lagoons, which are emptied every one or two years [4]. Another common management is the discharge of effluents to water courses directly or indirectly; as well as the use of effluents as biofertilizers. The treatment of excreta, in general, consists of reducing the organic load they contain. The treatment systems vary according to the type of production, region and country [4]. Some of the alternatives for the treatment of porcine waste, environmentally accepted, are the biological processes, such as anaerobic digestion and composting [5, 6]. Another alternative method for the removal of solids in porcine effluents is geofiltration, using closed structures built with high-resistance geo-textiles and the use of chemical agents. The mixture of coagulants and chemical flocculants improves the liquid / solid separation efficiency and increases the rate of dehydration of the filtration process [7, 8, 9].According to Perez and Urrea (2011) [10] coagulation is the destabilization of colloidal particles caused by the addition of a chemical reagent called coagulant, to enhance the stage of decantation or thickened in which these particles must be separated from water.This occurs adding to the dispersion ions of opposite sign to the colloid, that is to say a coagulant. When the coagulants are added, hydrolysis occurs, with the formation of insoluble colloidal hydroxides, promoting precipitation. Flocculation is the agglomeration of destabilized particles in microfloccles and then in larger flocs that tend to settle to the bottom of the containers. In the flocculation process it is important to achieve the formation of the flock of greater weight and possible cohesion, since these characteristics facilitate its elimination. The filtration is based in high strength permeable geotextiles with designed retention properties manufactured in closed structures (containers). Geotextile containers are commercially available in variable lengths and in circumferences of 9 to 27 m (30 to 90 feet). In a geotextile container, the filtration effluent is pumped through the filling ports within the container to retain the solids in the interior while the water is discharged through the surface of the container. The geotextile fabric of the container is inert to biological degradation and resistant to chemical products. Filtration with geotextiles operates in four solid-water processes to occur within: suspension, sedimentation, deposition (or settlement) and consolidation.Several authors studied the efficiency of this technology for the removal of nutrients in porcine effluents [11, 8, 12] and Vanotti and Hunt, (1999) [13]treated he removal of the solid fraction and nutrients from porcine effluents, through a filtration with the use of coagulants and flocculants

II. Materials And Methods

The effluent was collected from a pig establishment located on 25 de Mayo, Buenos Aires province, Argentina. The pig hatchery has a cement floor, which is washed with a pressure washer, dragging the manure and food remains to a common storage pit. To select the doses of coagulant ($FeCl_3$) and flocculant (cationic polymer), the Jar-test laboratory equipment for coagulation and flocculation tests was used. Once the dose of chemical additives was selected, a filtering device was used to simulate the real load conditions in geo-filtration: turbulence, flow and pressure.The selected treatments were: untreated raw effluent (T_0), filtered effluent without the addition of chemicals (T_1), filtered effluent with addition of chemicals (T_2), filtered effluent with 20% more chemicals than T_2 (T_3). Four treatments were performed with three replications. The following determinations were analyzed in the raw effluent and in the treated ones, by reference methods [14]: pH, electrical conductivity (CE), humidity (H), total organic carbon (TOC), ammonium (NH_4^+), nitrogen total (NT), total phosphorus (PT), total solids (ST), volatile solids (SV), total suspended solids (SST), suspended volatile solids (SSV), chemical oxygen demand (COD), soluble ions (Ca, Mg, Mn, Fe, Cu, K, Na, Zn) total ions (Ca, Mg, Mn, Fe, Cu, K, Na, Zn). The determination of total pathogens (aerobes, E. coli, total coliforms and Salmonella spp.) was performed using the method proposed by Fasciolo et al (2005) [15]. Parasitological parameters were determined with a sedimentation technique [16, 17].

Description of the filtering pilot device

The filtration of the solids by geocontainers was estimated using three replicates in each test by means of a device constructed for this purpose. The use of the device allows the measurement of solids (total and suspended) and volumes of effluent and filtrate. The geotextile fabric used to make the test geocontainers was 0.5x0.5m, with a hydraulic permissiveness of 12 l / m / s^2 and an apparent pore size of 250 μm. The device consists of a graduated tank of 200 l with mechanical agitation, connected to a manual diaphragmatic pump through piping. The effluent was boosted to the test geocontainer located on an elevated platform. The circulation was controlled by a 3-way valve, which allowed to replicate the turbulence, flow rate and residence times in real-scale pipes. The pressure exerted by the effluent on the geocontainer was measured by means of a manometer. Where the 3-way valve was placed in loading position, the manual pump was activated to drive the effluent to the geocontainer located on the platform, the pumping continued until the pressure gauge registered the 3.8 psi pressure (this measure is directly proportional to the maximum load height of the test geocontainer). Once this pressure was reached, the pumping stopped and the geocontainer was left to rest for 20 minutes. Samples were collected from the filtered effluent for physical-chemical determination. This procedure was repeated twice more for each treatment. The data were analyzed by the Prism 5 program, through a one-way ANOVA and the Bonferroni test was used to perform multiple comparison tests between treatments.

III. Results & Discussion

Characterization of porcine effluent

Table 1 shows the physical, chemical, microbiological and parasitological parameters evaluated in the effluent. When analyzing the results, a high content of nutrients in the effluents was evidenced,this situation being due to the fact that production of monogastricanimals, has a low nutrient retention, due to the type of digestive system that has. In pigs, of each gram of protein consumed by the animal, only 33% is used to form tissue (meat) and the rest is eliminated in the form of by-products, where the soluble chemical forms of the macronutrients (N, P, K) from the hydrolysis of the protein consequently generate high loads in liquid droppings.

Table 1: *Initial characterization of porcine effluent*

Variables	Units	PorcineEffluent (T_o)
pH		5.78 ± 0.03
Ce	ms/cm	3.80 ± 0.10
ST	%	0.71 ±0.04
SV	%	62.7± 2.7
SST	%	3.66 ± 0.76
SSV	%	3.07 ± 0.74
Pt	mg/l	59.44 ± 1.98
Nt	%	0.06 ± 0.01
$N\text{-}Nh_4^+$	mg/l	0,04 ± 0.0
Cu sol.	mg/l	0.11 ±0.0
Mn	mg/l	1.48 ± 0.36
Fe	mg/l	4.95 ± 0.05
Zn	mg/l	0.08 ± 0.0
Ca	mg/l	84.3 ± 4.5
Mg	mg/l	60.3 ± 1.5
Na	mg/l	362 ± 15.7
K	mg/l	331 ± 6.0
Density	g/ml	1.0 ± 0.1
Salmonella		Absence
E. Coli		Presence
FecalColiforms	ufc/ml	$2.4x10^4$
Coccidios		Presence
Helmintos	Eggs/l	150
DQO	mg/l	10131 ±1

According to the data obtained from this study, it can be observed that nitrogen is mostly present in ammoniacal form, with 66% of total nitrogen being accounted for, which comes mainly from the decomposition of urea [18]. This can be explained because the nitrogen excreted in the urea form (urine) is rapidly degraded within the pit to ammoniacal nitrogen; however, organic (fecal) nitrogen undergoes slow degradation. Therefore, the content of ammoniacal nitrogen in the pit will increase with the time of permanence within limits, while the organic nitrogen will decrease slowly [19, 20].

The phosphorus values found were high, this phenomenon is explained because phosphorus is excreted as phytic acid. This organic acid contains phosphorus in its structure and it is present in vegetables, especially seeds and fiber. Most of the pigs in confinement are fed mainly with cereals such as corn and soy; and the phytate phosphorus of these foods is not available for intestinal absorption by these non-ruminant animals, so the unabsorbed phytate passes through the gastrointestinal tract, raising the amount of phosphorus in the manure. There were high concentrations of Na and K, both elements are added in the diets to improve the rate of growth and avoid possible symptoms due to the deficit of these minerals. It is estimated that the pig excretes 66% Na and 59% K, of the total consumed in the ration. With regard to the content of pathogenic microorganisms in the crude effluent, it was possible to verify the presence of*E.coli* and the absence of *Salmonella* spp. It is important to evaluate these microorganisms when working with animal manures, since they can be pathogenic bacteria for humans and animals, being of special interest the presence of *Salmonella* spp. This microorganism is one of the main agents of foodborne diseases and can be a normal inhabitant of the digestive tract of animals that include birds, cattle and swine, among others [21].On the other hand, the laboratory analysis carried out to evaluate the parasitological content showed the presence of Helminth eggs and Coccidia. The importance of studying this type of parasite results in the fact that, like the protozoa, the helminths are pathogenic for humans. The epidemiological characteristics that make the enteric pathogenic helminths causing infection by contact with contaminated water, are their high persistence in the environment, low infectious dose, low immune response and the ability to remain in the soil for long periods of time [22].

Porcine effluent physical-chemical treatment

Table 2 presents the results for treatments 2 and 3. Statistical analysis showed that there were significant differences ($p < 0.05$) between treatments T_0 and T_2 / T_3 in the following parameters: pH, COD, PT, Ce, NT, ST, and SST, for soluble ions Ca, Cu, Mn, Mg, and for total ions Zn and Cu.The treatment T_1 did not show significant differences in their percentages of nutrient and organic matter removal

Table 2: *Physical chemical characterization of filtered porcine effluent with addition of chemicals.*

Variables	Units	FiltrationwithChemicalTreatment			
		Filteredeffluent (T_2)	% removal	Filteredeffluent (T_3)	% removal
pH		5.27 ±0.07	-	5.1 ±0.02	-
Ce	ms/cm	4.64 ± 0.07	-	4.6 ±0.02	-
SV	%	28.68 ±9.70	54.3	16.7 ± 19.9	73.3
ST	%	0.33 ±0.01	53.5	0.3 ± 0.07	53.5
SST	%	0.42 ±0.16	88.5	0.5 ±0.23	85.5
SSV	%	0.38 ±0.14	87.6	0.3 ± 0.10	89.9
Pt	mg/l	17.5 ±1.13	70.5	16.4 ±0.98	72.3
NTk	%	0.04 ±0.0	33.3	0.04 ±0.0	33.3
N-Nh_4^+	mg/l	0.04 ±0.0	0	0.04 ±0.0	0
Cu	mg/l	0.05 ±0.01	90.9	0.05 ±0.01	90.9
Mn	mg/l	0.32 ± 0.0	25	0.38 ±0.11	11.6
Fe	mg/l	3.26 ± 10.4	26.3	4.73 ±4.7	83.3
Zn	mg/l	0.10 ±0.03	87	0.07 ±0.02	91
Ca	mg/l	14 ±1.73	43.2	16.6 ± 3.79	32.4
Mg	mg/l	9 ±0.0	20.3	10.3 ± 2.31	8.8
Na	mg/l	75 ± 1	16	83.3 ±20.5	6.7
K	mg/l	41.3 ±1.53	24.8	47.3 ±13.8	13.9
DQO	mg/l	5778 ± 377	42	6053 ± 327	40.2
Cu sol.	mg/l	0.02±0.01	81.8	0.03±0.0	72.7
Salmonela		Absence	-	Absence	-
E. Coli		Presence	-	Presence	-
Helmintos	Huevos/l	Absence	-	Absence	-
coccidios		Absence	-	Absence	-

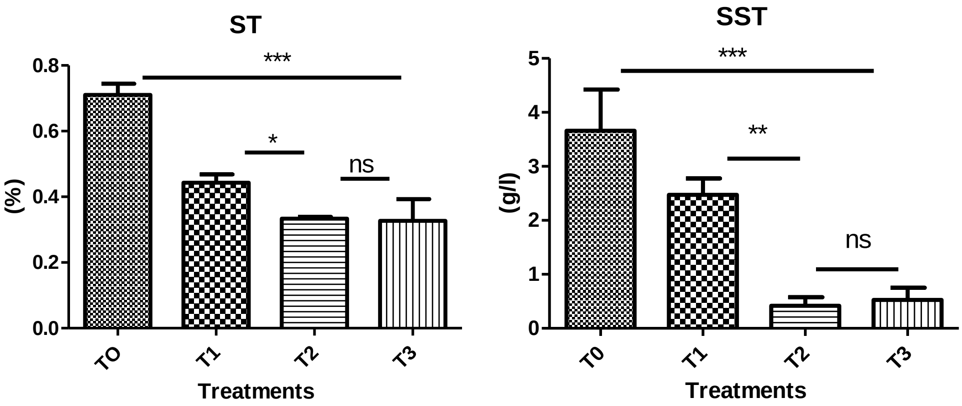

Figure 1: Concentration of Total Solids (ST) and Total Suspended Solids (TSS) in%. The horizontal bars represent the standard error during the experiment. *** $p < 0.0001$; ** $p < 0.05$; ns: not significant. (Bonferroni test) treatments

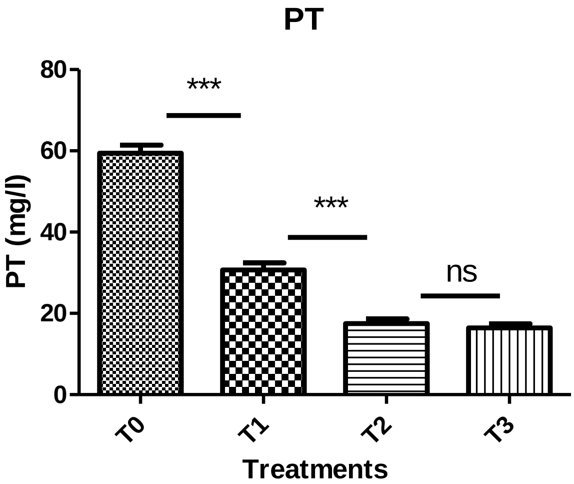

Figure 2: Average values of total phosphorus. The horizontal bars represent the standard error during the process. *** p <0.0001; ns: not significant. (Bonferroni test)

In the present study, a removal of TSS of 88.5 and 85.5% was found for T_2 and T_3 respectively, the percentage of removal was higher than that found by Singh et al 2006[8] when evaluating on a pilot scale the removal of TSS in porcine effluents (76%). The same behavior was evidenced with the COD, where the present work was achieved removals of 42% for T_2 and 40% for T_3; while in the study carried out by Singh et al 2006 [8], a removal percentage for the COD of 27% was obtained. These differences may be due to the elapsed storage time of the effluent in the pit. The greater the time storage of the effluent, the greater the solubility of the organic matter in it; consequently, the efficiency of the separation and the elimination of the firmness of the chemical treatments will decrease. This may be due to the fact that an important part of the organic matter of the pig is solubilized, making it difficult to separate it and, consequently, their treatment.

The removal of PT content was studied, finding values of 70.5 and 72.3% removal for T_2 and T_3 respectively. Baker et al. (2002) [11]found percentages of removal for the PT of 88%; when evaluated by means of suspended geo-membrane for the separation of solids in lagoon muds of porcine and bovine productions. On the other hand, Singh et al 2006 [8], described a 75% removal of the PT, working with pig effluents on a pilot scale. The high percentages of elimination in these works, are due to the majority of total phosphorus is associated with the fraction of solids in suspension of the effluents [8]. Therefore, if high removals of SST occur, as found in the present study, a decrease in PT is expected. On the other hand, Vanotti and Hunt, (1999) [13] demonstrated the utility of polymers to increase the efficiency of the separation of solids in pig slurry. With solids, there is an important capture of organic nutrients (nitrogen, phosphorus, etc.) associated with the grouping of small particles.

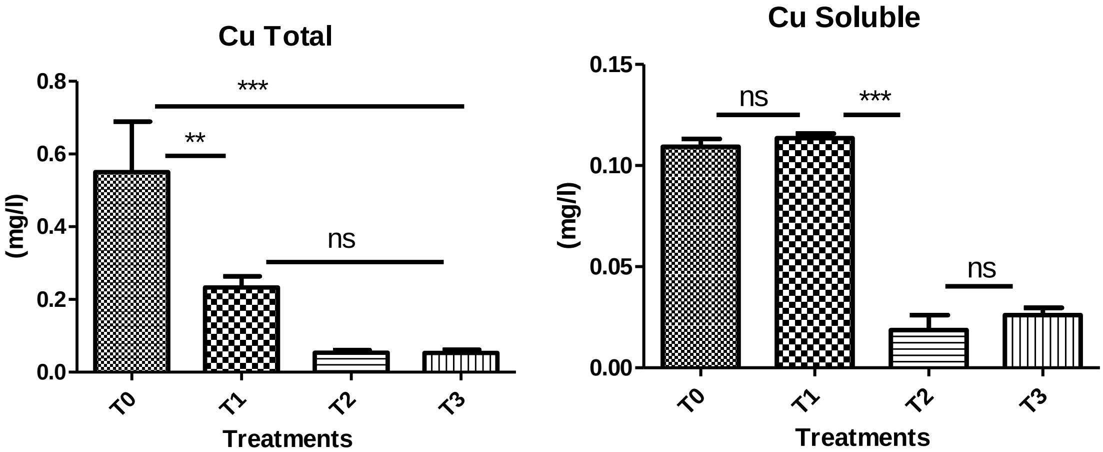

Figure 3: Average values of total and soluble copper. The horizontal bars represent the standard error during the experiment. *** p <0.0001; ** p <0.05; ns: not significant. (Bonferroni test)

With respect to total Cu in T_2 and T_3 there was a 90.9% removal in both treatments. Soluble Cu (Table 2) showed a decrease of 72.7% for T_2 and 81.8% for T_3. These percentages of removal are important in this type of effluent, as this metal is introduced to the pig, both in the antiparasitic and in the food rations; being able in some cases to reach values that far exceed the limits of inhibition for biological treatments [23], which could be used as secondary treatments after the geocontainers. The high percentage of removal found for Cu in this study, may be due to the fact that this compound is mainly associated with the solid fraction of the effluents. Regarding the parasites, geocontainment treatment proved to be effective in retaining all the Helminths and Coccidia present in the porcine effluent (Table 2).

IV. Conclusions

The treatments T_1 did not show significant differences in their percentages of nutrient and organic matter removal, while the treatments T_2 and T_3 achieved a removal in most of the parameters analyzed. Greater removals were evidenced when the geocontainer is utilized with the use of coagulants and flocculants. On the other hand, a removal ofHelminth eggs andCoccidia was found. Porcine effluent is complex and has high concentrations of nutrients and organic matter; Geocontainment proved to be technically viable as a system that partially treats porcine effluents. Therefore, it is feasible to integrate this technology, as a primary system, into the chain of treatments for intensified pig establishments.

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