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APPLICATION OF MEMBRANE PROCESSES IN TREATMENT OF SLURRY FROM HIGH-DENSITY PIG FARMING

ZASTOSOWANIE PROCESÓW MEMBRANOWYCH DO OCZYSZCZANIA GNOJOWICY POCHODZĄCEJ Z WIELKOPRZEMYSŁOWEJ HODOWLI TRZODY CHLEWNEJ

Abstract: The aim of the study was to determine the effectiveness of integrated system: ultrafiltration and two-step reverse osmosis to recover water from pig slurry. The natural separation *ie* sedimentation and floatation were used to prepare feed for membrane treatment. Obtained supernatant was introduced to pilot scale installation for membrane filtration equipped with ceramic UF membrane of pore size 5 nm. The cleaned stream was polished on polyamide RO membranes. The capacity of the process and the quality of cleaned streams were used to evaluate the effectiveness of the treatment. Washing of the ceramic membrane via back flushing with water and chemicals *ie* 0.5% solutions of sodium hydroxide and nitric acid was also performed. The study revealed that proposed system was suitable to recover water from pig slurry. The final product is of good quality and can be reused on farms *eg* for washing of animals, farmhouses or in heating/cooling systems. The additional advantage is the concentration of organic compounds and nutrients in the form of retentate, which can be still used for fertilization or agricultural biogas production.

Keywords: pig slurry, ceramic ultrafiltration, reverse osmosis, slurry treatment

Slurry is produced during non-bedding livestock farming on industrial farms. It is a liquid mixture of animal feces, urea and technological water [1, 2]. Slurry properties are depended on various factors among which number and age of animals, type of a feed, amount of water used for washing of farmhouses and animals, storage method, season and atmospheric conditions are the most important [3, 4].

Slurry management and utilization methods need to be developed and improved. Nowadays, slurry is mainly used for fertilizing purposes (*ca* 30% of total production), and, in much lower extent, for biogas and compost production. The attention of slurry management methods discussed in literature is usually focused on nutrients *ie* nitrogen and phosphorus or organic matter recovery [5-7], while the possibility of water production is omitted. The amount of water in slurry can reach up to 99%, thus it can be considered as a source of useable water. Such an assumption can be pursued with the application of membrane processes, which are already widely used in water and wastewater treatment [8, 9]. Low-pressure membrane processes *ie* micro- and ultrafiltration practically guarantee the rejection of microorganisms, what results in production of sanitary safe fertilizing stream. Moreover, their combination with high-pressure membrane techniques *ie* nanofiltration and reverse osmosis can result in the recovery of water of useable quality [10-13].

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The aim and the methodology of the study

The aim of the presented study was to determine the effectiveness of integrated system comprised of ultrafiltration and two-step reverse osmosis to recover water from pig slurry. The natural separation processes *ie* sedimentation and floatation were used to prepare feed for membrane treatment. Obtained supernatant was introduced to the pilot scale installation for membrane filtration. The system was equipped with ceramic, tubular, ultrafiltration membrane of separation area 0.2 m² and pore size 5 nm (by Pall). The process was carried out at the pressure 0.3 MPa. The cleaned stream *ie* permeate was next introduced to laboratory membrane installation KMS Cell CF1 (by Koch) and polished on flat sheet, polyamide reverse osmosis membranes of effective separation area 28 cm² (by Koch). The polishing operation comprised of two-steps which were carried out at pressure 2.0 MPa. The capacity of the process and the quality of cleaned streams were used to evaluate the effectiveness of the treatment. Additionally, washing of the ceramic membrane via back flushing with water and chemicals *ie* 0.5% solutions of sodium hydroxide and nitric acid was performed and the initial flux recovery was established.

Following parameters were determined in all process streams: pH, conductivity, dry mass, COD, TOC, TC, N_{tot}, N-NH₄⁺, P-PO₄³⁻, Cl⁻, SO₄²⁻. COD, concentrations of P-PO₄³⁻, N_{tot} and N-NH₄⁺ were determined according to Hach Lange methodology. Concentrations of Cl⁻ and SO₄²⁻ were measured using ionic chromatograph DX 120 by Dionex. Particular forms of carbon were analyzed with the use of Multi N/C analyzer by Jena Analytic.

Results and discussion

Membranes performance

In Figures 1-3 the comparison of water and slurry fluxes measured for membranes (1) before the slurry treatment (deionized water) (2) during treatment (slurry) (3) after treatment (deionized water) (4) after chemical cleaning (deionized water - only for ceramic membrane) is shown.

It was observed that the filtration of slurry caused a significant decrease of UF membrane capacity (the ratio of slurry flux to initial deionized water flux - 0.7%) (Fig. 1). The measurement of water flux after the treatment process preceded with 1-hour backflushing with water showed 12% recovery of the initial value. It indicated on the irreversible character of membrane fouling caused mainly by the deposition of impurities in membrane pores. Thus, the membrane was cleaned chemically using 0.5% solutions of, first, sodium hydroxide and, next, nitric acid. Every washing step was carried out for 15 minutes. It allowed to recover 70% of the initial membrane capacity.

The filtration of permeate from UF also caused the decrease of 1st step RO (*Reverse Osmosis*) membrane capacity (23% of initial value) (Fig. 2). However, simple flushing of membrane with water enabled the total capacity recovery. Moreover, the measured water flux after the process was higher than the initial one. It could have been caused by several reasons. Firstly, only the reversible membrane fouling occurred and impurities were deposited on membrane surface forming washable filtration cake. Secondly, adsorption of

some compounds (either organic or inorganic) could have modified membrane surface increasing the hydrophilicity of membrane material. Thirdly, the diffusion of compounds through the membrane could loosen its polymeric structure.

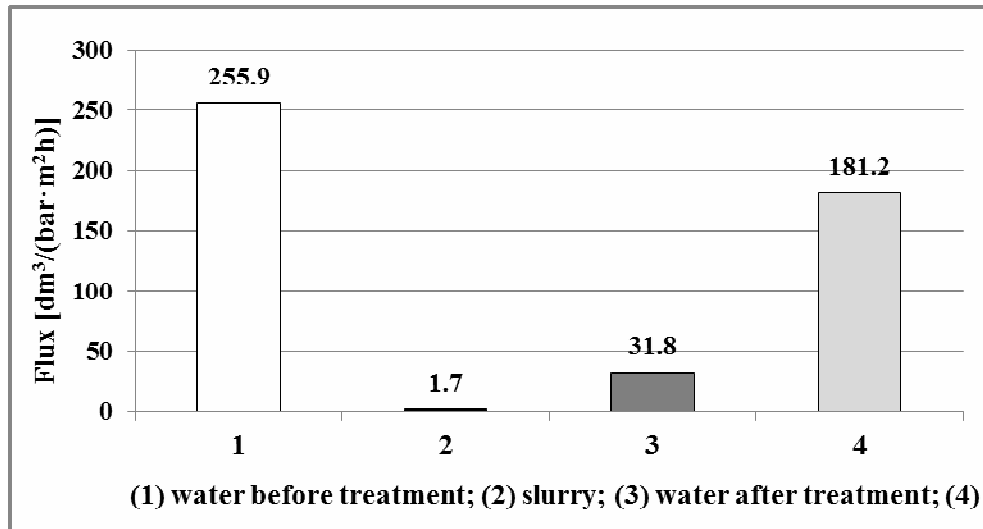


Fig. 1. Fluxes measured for ceramic UF (ultrafiltration) membrane

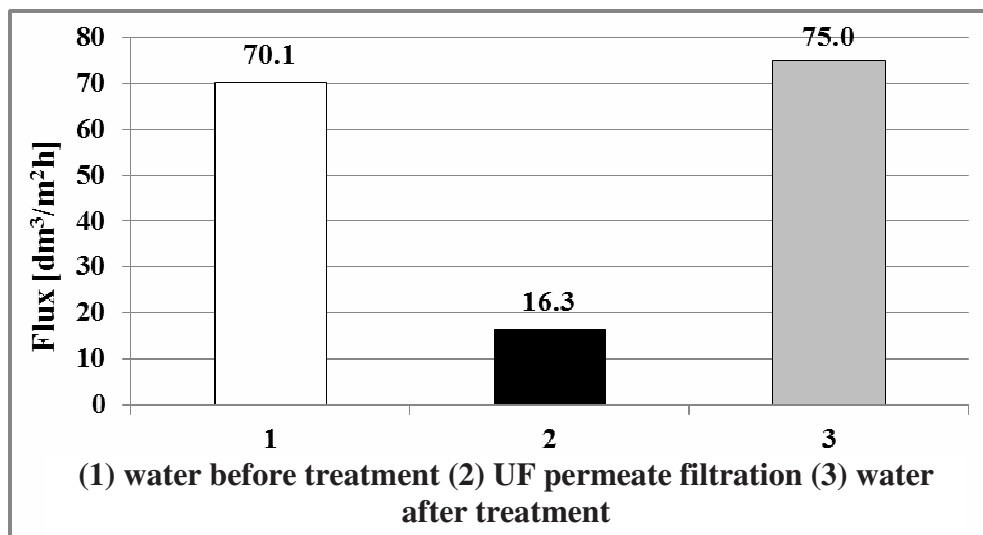


Fig. 2. Fluxes measured for polyamide 1st step RO membrane

The final polishing of treated slurry via 2nd step RO caused the lowest decrease of membrane capacity (83% of initial value) (Fig. 3). The flushing of membrane with water

enabled almost 98% of initial capacity recovery. In case of this membrane, water flux after the process was slightly lower than at the beginning. As higher molecular weight compounds were already removed during the 1st step RO treatment the formation of protective filtration cake layer was limited. Besides, smaller particles did not affect membrane structure. Thus, slight membrane fouling occurred.

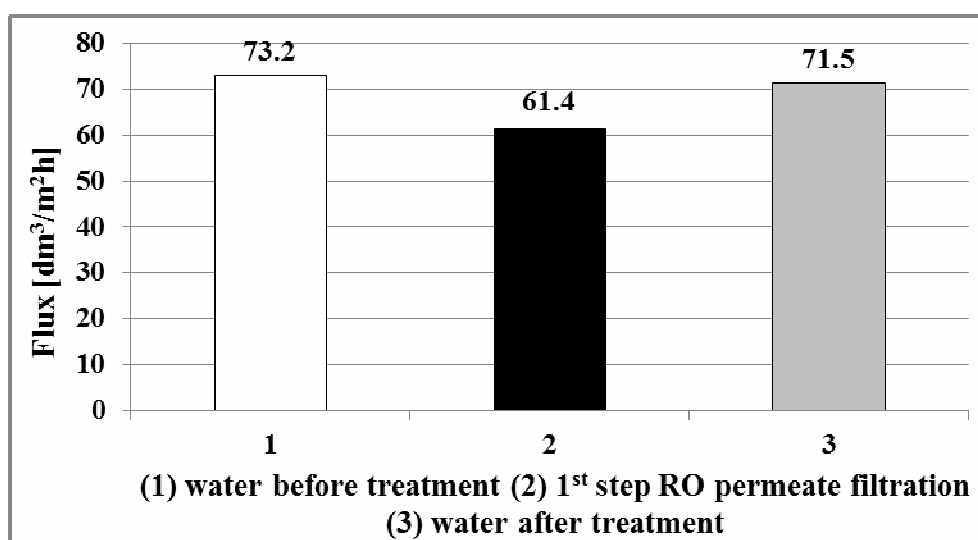


Fig. 3. Fluxes measured for polyamide 2nd step RO membrane

Quality of process streams

In Table 1 the comparison of crude slurry, supernatant and cleaned process streams including retention rates is shown.

Table 1

Comparison of process streams parameters

Parameter	Unit	CS	SN	R [%]	UF P	R [%]	RO1 P	R [%]	RO2 P	R [%]
pH	-	5.98	6.08	-	6.37	-	6.47	-	8.65	-
Cond.	[mS/cm]	18.8	18.1	-	16.3	-	1.6	-	0.062	-
COD	[g/dm ³]	38	29	23	18	39	0.953	95	<5	99
N-NH ₄	[mg/dm ³]	2095	1961	6	1490	24	126	92	7.8	94
N _{tot}	[mg/dm ³]	2550	2367	7	1560	34	178	89	9	95
P-PO ₄	[mg/dm ³]	695	578	17	354	39	5.2	99	0	100
Cl ⁻	[mg/dm ³]	1022	1004	2	951	5	164	83	2	99
SO ₄ ²⁻	[mg/dm ³]	300	294	2	284	3	8	97	0	100
TC	[mg/dm ³]	11871	8904	25	4390	51	227	95	4.24	98
TOC	[mg/dm ³]	11508	8779	24	3821	56	202	95	2.1	99
d.m.	[%]	4.2	1.4	67	0.7	51	n/a	n/a	n/a	n/a

CS - crude slurry, SN - supernatant, P - permeate, R - retention rate, n/a - not analyzed; d.m. - dry matter

It was found that natural separation processes *ie* sedimentation and flotation already caused the reduction of COD, phosphates and carbon concentrations. Ultrafiltration influenced mainly on organic compounds and phosphates content. Besides, the decrease in ammonium nitrogen was observed what was related to the emission of the compound during the treatment. The retention rates obtained for 1st RO step were in the range of 83% (Cl⁻) to 99% (P-PO₄). Despite such high impurities rejection the quality of the permeate was still poor, thus it was decided to polish it via 2nd RO step. The retention rates obtained in the final treatment process varied from 94% (N-NH₄) to 100%. The final product quality was found to be satisfactory considering its further use on farms *ie* washing of animals and farmhouses, fields irrigation or heating/cooling purposes.

Conclusions

The study discussed the possibility of application of integrated membrane processes *ie* ultrafiltration/two step reverse osmosis for recovery of water from pig slurry. It was found that the proposed system was suitable for that purpose. The final product was good quality, sanitary safe water that could be successfully reused on farms. The ratio of 2nd RO step permeate volume to crude slurry volume was equal to 15%.

The highest decrease in membranes capacity was observed for UF membrane, next for 2nd RO and finally for 1st step RO. The fouling of UF membrane was significant and irreversible *ie* washing of membrane via backflushing with water did not improve significantly its capacity. The cleaning of membrane with chemicals *ie* 0.5% solutions of NaOH and HNO₃ enabled to recover membrane capacity up to 70% of the initial one. In both RO processes the decrease of membranes capacity was observed, however simple flushing of membranes with water enabled the total recovery of the initial water flux. Moreover, in the 1st RO process the increase of capacity was observed. It could have been caused by several reasons *ie* the occurrence of only reversible membrane fouling, adsorption of some compounds (both, organic and inorganic) that modified membrane surface increasing its hydrophilicity or the diffusion of compounds through the membrane loosen its polymeric structure.

Acknowledgements

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ZASTOSOWANIE PROCESÓW MEMBRANOWYCH DO OCZYSZCZANIA GNOJOWICY POCHODZĄCEJ Z WIELKOPRZEMYSŁOWEJ HODOWLI TRZODY CHLEWNEJ

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Abstrakt: Celem przeprowadzonych badań było określenie efektywności zintegrowanego systemu ultrafiltracji/dwustopniowa odwrócona osmoza do odzysku wody z gnojowicy trzody chlewnej. W celu przygotowania nadawy do procesu oczyszczania wykorzystano procesy naturalnej separacji, tj. sedymentację i flotację. Otrzymaną ciecz nadosadową wprowadzono na pilotową instalację do filtracji membranowej wyposażoną w ceramiczne membrany ultrafiltracyjne firmy Pall o rozmiarze porów 5 nm. Strumień oczyszczony był następnie doczyszczany na poliamidowych membranach osmotycznych firmy Koch. Efektywność procesu oceniano na podstawie wydajności oraz jakości oczyszczonych strumieni. Zbadano także wpływ mycia membran ceramicznych za pomocą płukania wstecznego wodą oraz środkami chemicznymi (0,5% roztwory wodorotlenku sodu i kwasu azotowego) na przywrócenie początkowej wydajności membran. Badania wykazały, iż proponowany system może zostać zastosowany do odzysku wody z gnojowicy. Jakość końcowego produktu pozwala na jego ponowne wykorzystanie np. do mycia zwierząt i obiektów hodowlanych czy w systemach grzewczo-chłodzących. Dodatkową zaletą jest zatężenie składników odżywczych w formie retentatu, który wciąż może zostać użyty do celów nawozowych lub też w produkcji biogazu rolniczego.

Słowa kluczowe: gnojowica świńska, ceramiczna ultrafiltracja, odwrócona osmoza, oczyszczanie gnojowicy