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Use of reverse osmosis to modify biological wastewater treatment

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ABSTRACT

Introduction. The article reports on new research into improved reverse osmosis techniques and their expanded application in wastewater treatment practice. The results of experiments aimed at determining the operational characteristics of membrane facilities that treat wastewater are presented. A new method utilising reverse osmosis to decrease concentrate effluents is proposed. Flow diagrams and mass balance equations are used to demonstrate the principles underlying the new techniques.

Objectives — development of reverse osmosis techniques as a novel tool for improving and modifying existing biological wastewater treatment schemes; economic evaluation of advantages in combining reverse osmosis with biological treatment processes in wastewater treatment applications; development of the required operational modes for membrane units used to treat wastewater.

Materials and methods. A state-of-the-art review describes examples of the application of reverse osmosis in current wastewater treatment practices. Results of experimental research providing data for determining membrane operational parameters are presented. Analysis of results and their discussion are presented.

Results. A new membrane technique that provides high product water quality and utilisation of concentrate effluents, as well as efficient removal of ammonia from reject water following sludge dewatering, is proposed. The presented results confirm the economic advantages and efficiencies of reverse osmosis applications in wastewater treatment facilities.

Conclusions. The conducted investigations confirmed the high efficiency of the reverse osmosis membrane in removing all major impurities contained in wastewater following sludge digestion and during biological treatment. The use of membrane techniques thus provides efficient and reliable operation of wastewater treatment facilities. Reverse osmosis concentrate effluent can be utilised by blending with sludge or used in fertiliser production.

KEYWORDS: reverse osmosis, wastewater treatment, wastewater sludge digestion, dewatering reject water, ammonia nitrogen

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Применение мембранных установок обратного осмоса в схемах биологической очистки сточных вод

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АННОТАЦИЯ

Введение. Представлен подход к изучению технологии обратного осмоса применяемой в системах очистки хозяйственно-бытовых и промышленных сточных вод. Приведены результаты экспериментов, направленных на изучение режима работы обратноосмотической установки при очистке сточных вод. Предложена методика утилизации концентрата, образующегося в процессе обработки исходной воды. Приведены блок-схемы массового баланса загрязняющих веществ в предлагаемой схеме очистки.

Материалы и методы. Наиболее распространенным подходом являются технологии обратного осмоса, как одной из альтернатив модернизации очистных сооружений. Рассмотрена технико-экономическая оценка применения установок обратного осмоса для очистки сточных вод. Исследованы режимы работы установки.

Проведен анализ литературы по применению мембранных установок для очистки сточных вод. Произведены экспериментальные исследования режимов работы мембранных установок при очистке сточных вод. Проанализированы полученные экспериментальные данные.

Результаты. Одним из преимуществ разработанной методики является эффективная очистка иловой воды, утилизация концентрата обратного осмоса и получение качественной воды, используемой для технологических целей на очистных сооружениях. В ряде случаев данные подтвердили технологическую обоснованность применения рассматриваемой технологии, а также ее явные преимущества перед биологическими методами по таким показателям как надежность и эффективность.

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Выводы. В строительстве устройства обратного осмоса при удалении основных загрязняющих веществ из обрабатываемой воды, образующейся при анаэробной стабилизации осадка сточных вод, могут обеспечить более стабильное и эффективное функционирование очистных сооружений. Концентрат, полученный при использовании мембран обратного осмоса, может быть использован для производства удобрений или смешан с обезвоженным осадком для его последующей утилизации.

КЛЮЧЕВЫЕ СЛОВА: обратный осмос, очистка сточных вод, сбраживание осадка сточных вод, иловая вода, аммонийный азот

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INTRODUCTION

Due to the urgent need to prevent eutrophication of surface water, necessitating the efficient removal of nitrogen and phosphorus from municipal and industrial wastewater, biological treatment technologies are increasingly employed. In order to increase the efficiency by which ammonia cam be removed from sewage, various technologies are presently being developed and applied. This, in turn, requires additional financial support for the modernisation of Wastewater Treatment Plants (WWTPs) [1–14]. Figure 1 shows a conventional biological WWTP flow diagram illustrating all necessary processes used for sewage and sludge treatment. In this article, however, a novel approach to removing ammonia nitrogen and other pollutants using membrane reverse osmosis (RO) techniques is presented. RO is known to be an efficient tool for removing different kinds of contaminants and thus to be capable of being applied to treat water and sewage [14–18]. Many RO installations are already being used for the final treatment of biologically treated wastewater allowing its reuse for technological purposes [1, 15, 18]. A flow diagram demonstrating RO post-treatment processes is shown in Fig. 2. The main disadvantage of applying RO in WWTP schemes is the existence of concentrate flows that cannot be discharged since containing all removed pollutants — in particular, nitrogen and phosphorus. The novel approach presented in this article proposes a technique for concentrate utilisation that increases potential RO recovery up to 0.99. The RO concentrate containing removed ammonia and other pollutants is added to raw sludge and withdrawn from the process together with dewatered sludge.

Conventionally, biological treatment of wastewater is associated with the production of excess sewage sludge as a by-product, with large WWTP installations using anaerobic sewage sludge digestion. The biggest advantage of this is the production of heat and electric energy from biogas. During the final dewatering of digested sludge, highly concentrated reject water is produced in which the concentration of ammonia reaches 500–2000 mg N-NH4+/L. Typically, this is returned to the main processing line of a WWTP without any further treatment (Fig. 1). Extremely high concentrations of ammonia in wastewater require the development of

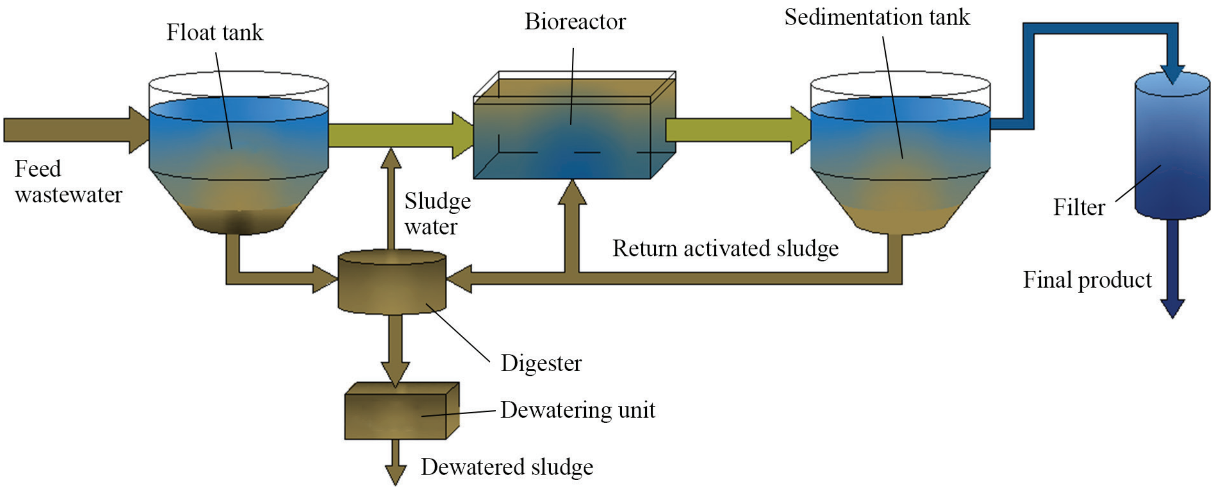

Fig. 1. Conventional wastewater treatment flow diagram

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efficient new tools for its reduction. However, improvements to biological reactors for ammonia removal, such as Membrane Biological Reactors (MBR), bio-augmentation reactors, etc., may lead to an unacceptable increase in financial investments [10–14].

A novel approach to removing ammonia nitrogen from reject water using a reverse osmosis (RO) membrane treatment technique is presented as follows. RO is known as an efficient tool for removing different kinds of pollutants and contaminants from wastewater and has been shown to be successfully applied to improving the quality of biologically-treated wastewater [15–18]. The flow diagram illustrated in Fig. 3 shows the treatment of reject water from dewatered sewage sludge using RO membranes. Here, the RO unit is operating in circulation mode, allowing the volume of reject water to be decreased by 4–10 times. RO concentrate is withdrawn together with the sludge; the membrane product can be added to the feed water or to the treated water, depending on ammonia concentration.

A new field of application proposes the use of RO to treat reject water generated during sewage sludge stabilisation in biological WWTPs. The RO unit can be used for technical purposes with the concentrate being returned to be mixed with sludge, thus increasing its nitrogen and salt content. This way, ammonia nitrogen can be eventually withdrawn along with the dewatered sludge. A schematic flow diagram of RO treatment of reject water in terms of salt balance is presented in Fig. 3.

The novel approach developed by the authors allows RO recovery to be increased up to 0.99 and retentate withdrawn from the process together with sludge [19, 20]. The proposed flow diagram of the RO treatment process for wastewater reuse and RO concentrate utilisation is shown in Fig. 4. The first-stage membrane is used to treat wastewater and remove ammonia. Concentrate produced by the first-stage membrane is then further treated by a second-stage membrane, which is used to decrease the flow of concentrate to achieve a recovery value of 0.99. Product flow after the second RO stage is mixed with the feed wastewater.

Experimental research was carried out in order to evaluate the efficiency of the membrane for removing

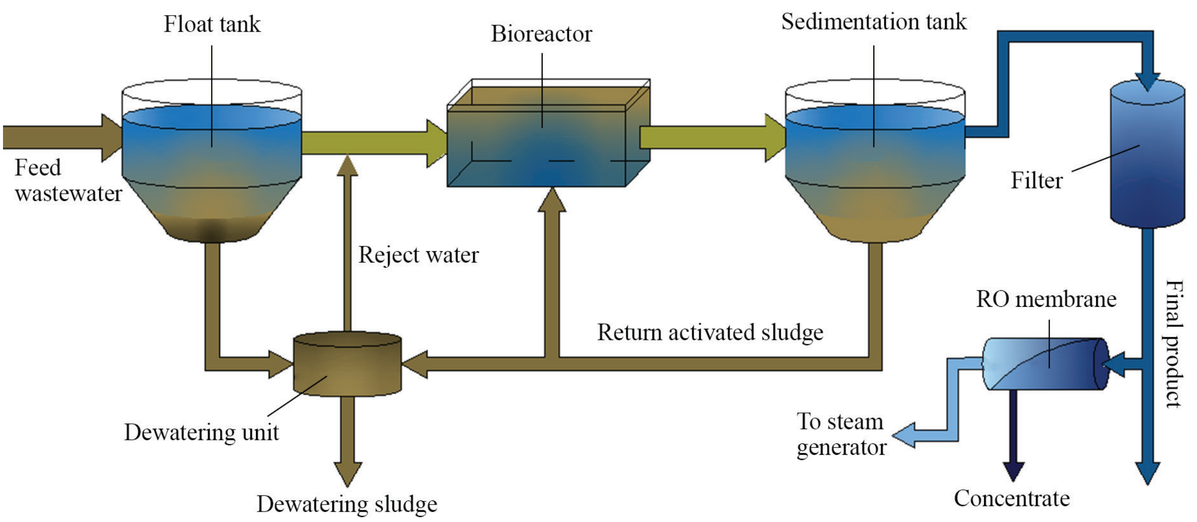

Fig. 2. RO post-treatment of biologically-treated wastewater

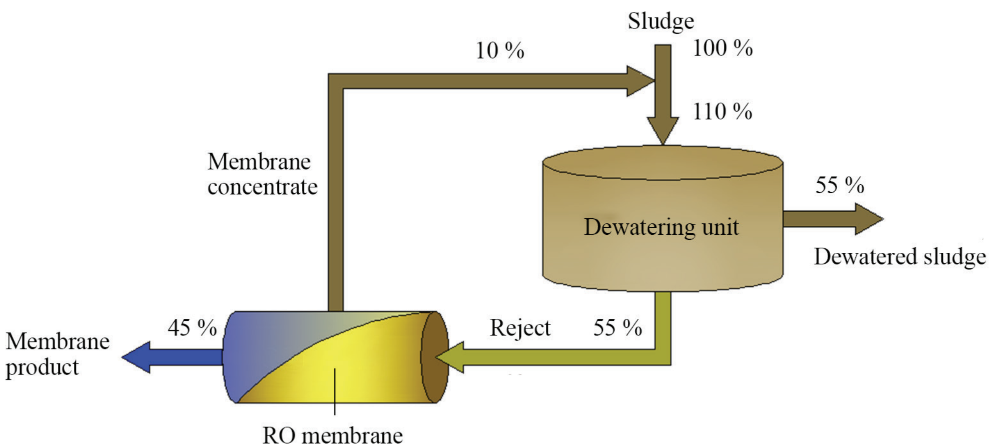

Fig. 3. Principles of RO concentrate disposal

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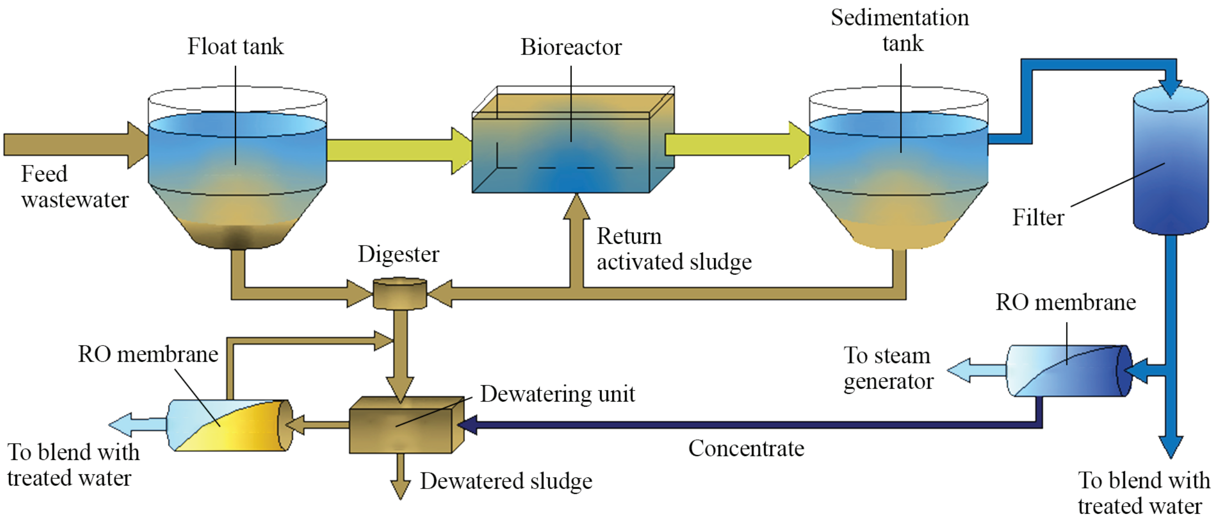

Fig. 4. The newly-proposed solution for reuse of biologically-treated wastewater for boiler feed and steam production

primary wastewater pollutants such as: ammonia nitrogen, nitrate, BOD, phosphate etc. The experimental RO treatment parameters allowed optimum recovery and product flow values to be determined along with membrane characteristics (rejection, pressure) in order to provide efficient treatment and utilisation of the concentrate. The main aim of the research was to develop relationships between the removal and recovery of ammonia and other pollutants using membranes. Additional goals included the determination of the maximum value-mass balance for evaluating the characteristics of membrane units and carrying out economic comparisons between MBR, augmentation reactors and RO post treatment of biologically treated water.

EXPERIMENTS DESCRIPTION, MATERIALS AND METHODS

The experimental program carried out was aimed at developing relationships between concentrations of different pollutants in RO product water versus membrane unit recoveries. The developed relationships can be used for the design of RO wastewater treatment units in order to determine the required membrane type, surface and recovery capacity. Wastewater treatment by RO can be divided in two stages: stage 1 provides wastewater treatment and production of quality treated water, while stage 2 allows RO unit recovery to be increased up to 0.99 and higher to decrease concentrate flow. Product water from the second stage can be added to the feed water. The experimental program consisted of 3 experimental series:

Series 1: To develop dependencies between membrane removal efficiencies and membrane product flow of main wastewater pollutants alongside membrane unit recovery. These results provide characteristics of the membrane unit that ensures quality treated water in the first stage of membrane treatment.

Series 2: Treatment of the first stage concentrate to achieve a recovery rate up to 0.99; prognosis of product water and chemical content of concentrate.

Series 3: To develop dependencies between membrane removal efficiencies and membrane product flow and recovery during sludge dewatering retentate treatment.

Experiments were conducted using two different laboratory membrane units to treat wastewater at the first and second stages. The flow diagrams of both units were similar.

A flow diagram of this experimental procedure is presented in Fig. 5. Feed water is pumped from feed water tank *1* into membrane module *3* using centrifugal pump *2*. The working pressure value was *8* bars. In RO module, feed water stream was separated into two streams: product water and concentrate streams. Product water was forwarded to product tank *4* while concentrate was returned to the feed water tank *1*. Feed water volume was decreased 10 times throughout test runs. In the first experimental series, feed water volume equalled 100 litres and by the end of each test run concentrate volume equalled 10 litres. Low pressure RO membrane elements were used (model 4040 BLN) supplied by CSM (Korea). The membrane surface in the 4040 modules was 10 square meters. By comparison, membrane elements with nanofiltration membranes (4040 90 NE) and high-removal RO membranes (4040 BE) were tested. The cross-flow value in the test unit was 300 litres per hour.

The recovery value is determined as a ratio of the product flow rate to the feedwater flow rate value (Qp/Qf).

In our experiments, the recovery value was calculated as the ratio of product water volume collected relative to the product water tank to the volume in the feed water tank (Fig. 5). The ratio of a feed water volume in feed water tank at the beginning of the experi-

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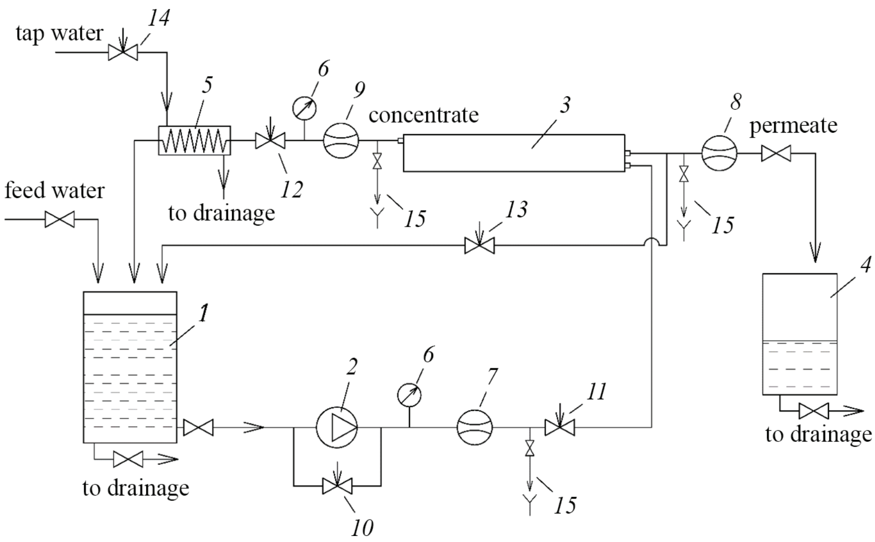

Fig. 5. Schematic flow diagram of laboratory RO unit used in experiments: *1* — feed water tank; *2* — pump; *3* — spiral wound membrane module; *4* — permeate tank; *5* — heat exchanger; *6* — pressure gauge; *7* — feed water flow meter; *8* — permeate flow meter; *9* — concentrate flow meter; *10* — by-pass adjusting valve; *11* — feed water adjusting valve; *12* — concentrate adjusting valve; *13* — cooling water adjusting valve; *14* — sampler

ment test run to the volume of concentrated feed water in the feedwater tank during the test run was defined as a volume reduction coefficient *K*. The recovery value defined as Q_p/Q_f is connected with the *K* value throughout the equation:

$$Qp/Qf = 1 - 1/K.$$

Membrane rejection is the characteristic capability of the membrane to reject different species that are dissolved in water. Membrane rejection is determined as the ratio of impurities contained in the feed water that passed through membrane together with the permeate: $R = Cf - Cp/Cf$ x 100 %, where *Cf* and *Cp* are the concentration values of impurities in feed water and product water respectively.

If the concentration values of different impurities in the feed water and the values of their rejection are known, it will be possible to predict concentration values of these impurities in the product water following membrane treatment. It is also noteworthy that product water constantly permeates through the membrane and is withdrawn from the membrane unit; therefore, the concentration values of rejected impurities in the concentrate flow constantly increase. Thus, the concentration values of impurities penetrated through membrane also increase. As a result, the "rejection" value of membrane unit (unlikely Membrane Rejection characteristic) depends on Recovery. This article was aimed at determination of "rejection" values of Reverse Osmosis membrane unit at high recoveries and maximum allowed recoveries that can be maintained during membrane treatment of wastewater.

During conducted test runs, samples of product water and concentrate were withdrawn from the feed water and product water tanks (Fig. 5) and the calculated ratios of their volumes related to different volume reduction coefficient *K* values. Chemical compositions of feedwater, product water and concentrate corresponding to various values of *K* are presented in Table 1.

In order to demonstrate a high recovery value up to 0.99, the second-stage membrane unit was tested. The flow diagram of the second stage test unit was the same as shown in Figure 5. Concentrate from the tank (1) following the first series (10 litres) was used in the second experimental series. The tank volume in the second stage membrane unit was 10 litres. First-stage concentrate (feed water) from tank (1) was pumped to the membrane module. Small nanofiltration membrane modules (1812 standard) model were used. The membrane surface in the module was 0.5 m^2. Nanofiltration (1812 90 NE model) and low-pressure RO (1812 BLN) membranes were used. These modules were manufactured and supplied by CSM, Korea. In the second-stage unit, a small pump produced by C.C.K., model R0 900, was used. The cross flow was 50 litres per hour, while the working pressure was 7 bars. Wastewater following secondary sedimentation was taken from the wastewater treatment facilities.

Table 1 presents wastewater composition and some examples of product water and concentrate compositions measured at different recovery

For the third experimental series, reject water following sludge dewatering was used. Excess sewage sludge with whey and flotation sludge in a dairy WWTP was stabilised in an anaerobic digestion chamber and dewatered with a centrifuge. The amount of reject water following sludge dewatering measured in the dairy WWTP during the research period was up to 10 % of the total amount of raw dairy sewage. The average concentrations of pollutants in reject water that were used

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Table 1. Wastewater chemical composition and composition of product and concentrate at different recovery rates

№	Components	Wastewater after biological treatment	Low pressure RO membrane				Nanofiltration membrane		Regenerations (permiHad discharge)
			RO product (recovery 0.5)	RO concentrate (recovery 0.5)	RO product (recovery 0.9)	RO concentrate (recovery 0.9)	NF product (recovery 0.99)	NF concentrate (recovery 0.99)	
1	pH	7.9	6.65	7.6	6.8	7.7	7.1	8.0	6.5…7.5
2	NH_4^+, ppm	1.27	0.15	2.6	0.5	10.1	3.5	97	0.189
3	$(PO_4)^{3-}$, ppm	0.17	0.02	0.13	0.18	1.6	1.5	8.32	0.4
4	TOC, ppm	190	32	220	48	384	—	—	
5	BOD, ppm	7.24	0.7	7.7	2.16	13.8	4.64	114.5	
6	$(SO_4)^{2-}$, ppm	23	0.12	29	0.67	226	5.9	218	
7	Cl^-, ppm	266	29	416	411.4	3942	795	5822	—
8	Oil, ppm	4.1	0.02	7.7	0.2	31.1	—	—	
9	Detergents, ppm	1.8	0.05	2.5	0.25	10.2	—	—	
10	TDS, ppm	465	50	1280	250	3580	1215	17160	

in laboratory experiments were: COD — 1830 mg O_2/L; TOC — 155.3 mg/L; ammonia nitrogen — 1537.6 mg N-NH_4^+/L; total phosphorous — 137.I mg P/L.

DISCUSSION OF THE RESULTS

Figure 6 shows the results of test unit operation in terms of the influence of ammonia and other pollutant concentrations on recovery. The higher recovery is the larger concentration value of different pollutants in the product water. Recovery is defined as the ratio of product flow to the feed water flow. In our experiments, recovery is calculated as the ratio between the water volume in Tank 1 at a certain moment of experiment to the initial feed water volume in the Tank 1 in the beginning of the experiment.

Figure 7 shows the calculated results of membrane removal efficiencies (rejection values) of different pollutants versus recovery. In order to determine the required recovery value, providing efficient removal of all pollutants and ensuring high product water quality, we proposed a development of the obtained relationships (Fig. 7) to show the dependence of specific concentration values (C/C_{reg}) and recovery values, as shown in Fig. 8. A specific concentration value is defined as the ratio of C/C_{reg}, where C is the concentration of the removed pollutant in the initial feed water to C_{reg} — a value required by discharge regulations. When

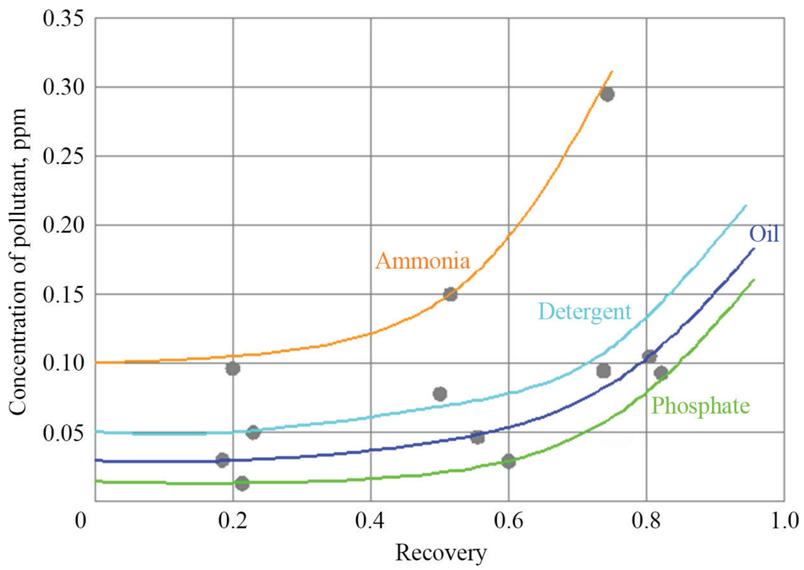

Fig. 6. Concentration values of different pollutants in RO product water versus recovery

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the concentration of the pollutant in the product water reaches the regulation value, the value C/C_{reg} equals 1. Thus, the recommended recovery can be determined by the cross point of the curves yielding concentration versus recovery curves and the line parallel to the abscissa corresponding to $C/C_{reg} = 1$. Since the rejection of different ions by low-pressure membranes depends significantly on the working pressure, while osmotic pressure increases with water salinity, a number of experiments were conducted in order to determine the influence of feed water salinity (TDS value) on ammonia rejection. Figure 9 shows the dependencies between ammonia rejection and recovery in different cases of wastewater TDS. An addition of sodium chloride to the feed water was performed.

In order to predict the concentrations of ammonia in RO product water, the obtained data was presented in terms of membrane removal relationship (*R*, %) and concentration factor *K* (Fig. 10). The concentration factor *K* is defined as the ratio of initial feed water volume in Tank 1 (Fig. 5) at the beginning of the experiment and the volume of concentrate in the feed Tank 1 at a certain moment of the experiment. The concentration factor *K* value is connected with the recovery value Rec. according to the following equation: Rec. = $K - 1/K$.

This approach enables us to present dependence of rejection *R* versus *K* as an exponential function:

$$R = c \; x \; K^b,$$

where *R* — membrane ammonia removal, %; *K* — concentration factor that is related with recovery (Rec.) by the following equation: $K = (1/1 - \text{Rec.})$; *b* — power index that can be determined using empirically obtained dependencies:

$b = -0.000248$ (TDS – 430) for wastewater with TDS value 600–1500 ppm;

$b = -0.000115$ (TDS + 220) for wastewater with TDS value 50–600 ppm;

c — empirical coefficient value that can be determined from the following empirical dependencies:

$c = 0.00485$ (2337 – TDS), for wastewater with TDS value 600–1500 ppm;

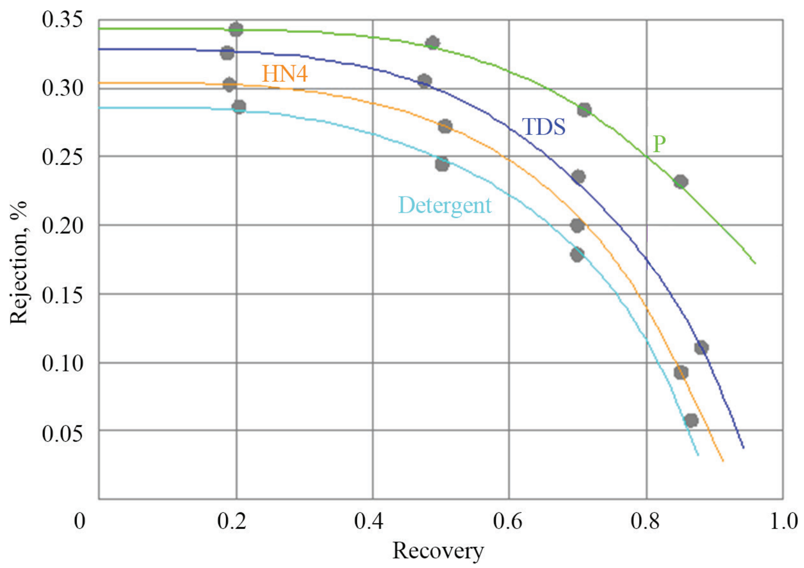

Fig. 7. Removal efficiencies of different pollutants versus recovery. Low-pressure RO membrane, BLN type (CSM, Korea)

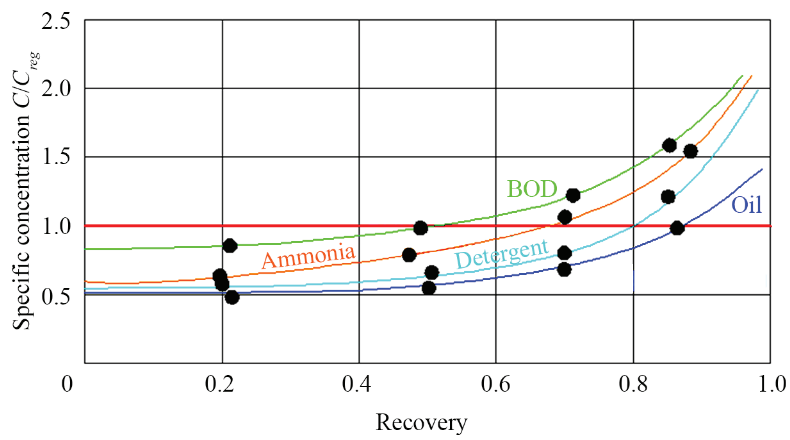

Fig. 8. The C/C_{reg} value versus recovery (*C* — concentration values of pollutants, ppm; C_{reg} — the value required by water discharge regulations)

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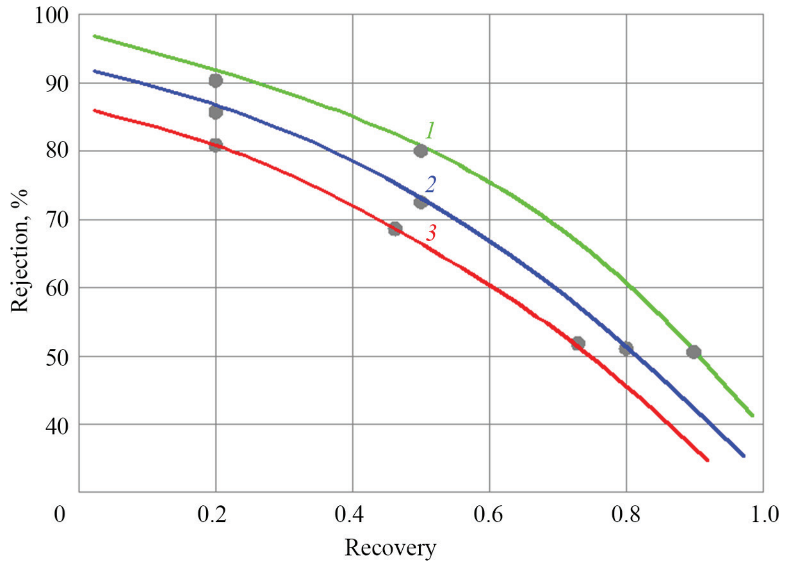

Fig. 9. Influence of feed water TDS on ammonia removal efficiencies: dependencies between ammonia removal by low-pressure RO membrane on the recovery rate for different feed water TDS values: *1* — feed water TDS 770 ppm; *2* — feed water after addition of 3000 ppm of NaCl; *3* — feed water after addition of 6000 ppm of NaCl

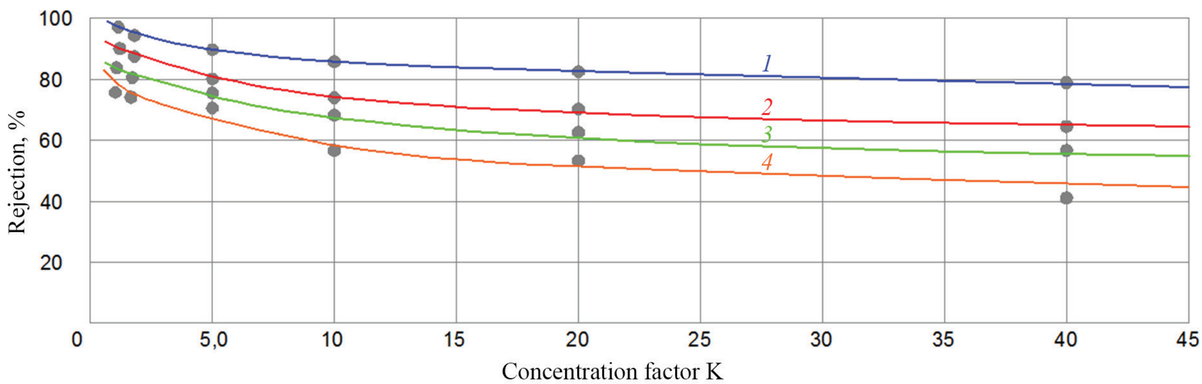

Fig. 10. Ammonia removal versus concentration Factor K and feed water TDS: *1* — TDS — 300 ppm; *2* — TDS — 500 ppm; *3* — TDS — 750 ppm; *4* — TDS — 1000 ppm

$c = 0.008\ (3000 - \text{TDS})$, for wastewater with TDS value 50–600 ppm.

After product quality water is produced, the problem of concentrate (retentate) handling and utilisation must be faced. As is shown in Fig. 8, the recovery value for wastewater treatment typically ranges between 0.8–0.9. As was suggested above, concentrate flow can be treated (decreased) by introducing an additional membrane step to increase the recovery value up to 0.99. In our experiments, the initial amount of wastewater was 100 litres. After the amount of concentrate in the Tank 1 reached 10 litres, the experiments were stopped and the concentrate was moved to another test unit. The same flow diagram was used in the second test unit, as shown in Fig. 5. The volume of Tank 1 was 10 litres. A small gear pump and spiral wound modules of 1812 standard were used with low pressure and nanofiltration membranes. Since the TDS value of circulating concentrate increases throughout the test runs, membrane product flow constantly decreases and concentration values of different pollutants in product water constantly increase. Figure 11 shows that the dependencies between TDS, ammonia and phosphate concentrations increase in wastewater concentrate (Fig. 11, *a*) and retentate following sludge dewatering (Fig. 11, *b*).

Figures 12–15 demonstrate reduction of specific product flow throughout test runs of wastewater treatment both at the first and second stages. Figure 12 shows a decrease in the specific product flow of different membranes with an increase in feed water TDS. Figure 13 demonstrates a reduction of specific product flow versus recovery during wastewater concentrate treatment at the second stage. Figure 14 shows the results of product flow measurements on both stages for different wastewater TDS values. The TDS values were changed by the addition of different amounts of sodium chloride to the feed water in Tank 1 (Fig. 5). Figure 14 shows the dependencies between specific product flow

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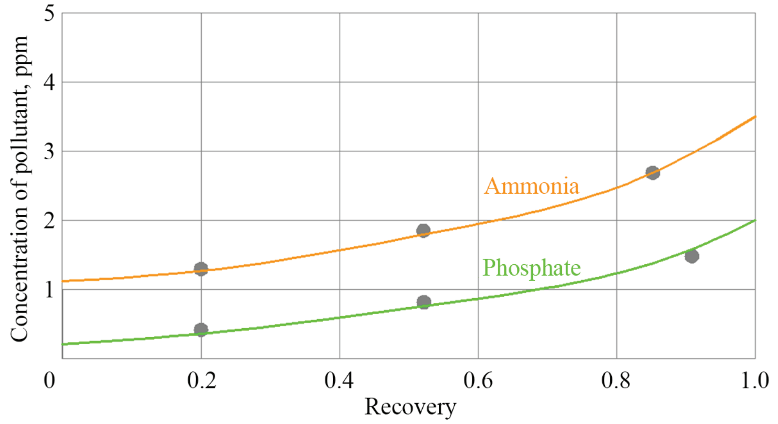

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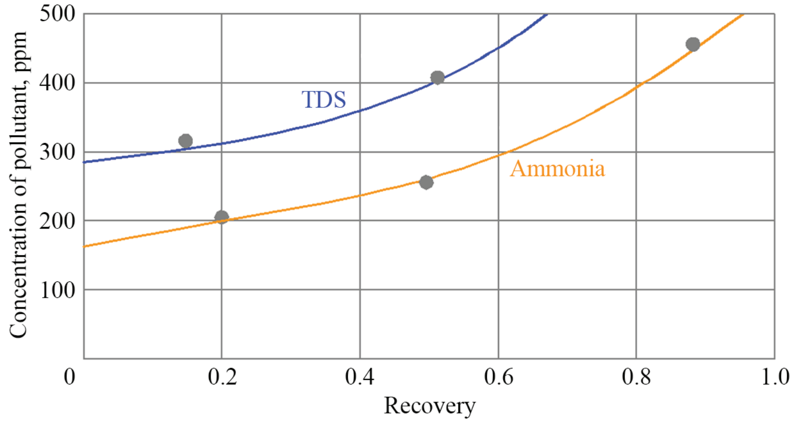

b

Fig. 11. Ammonia and phosphate concentrations in the second stage product versus recovery: *a* — treatment of wastewater retentate after the first stage treatment; *b* — treatment of reject after digested sludge dewatering

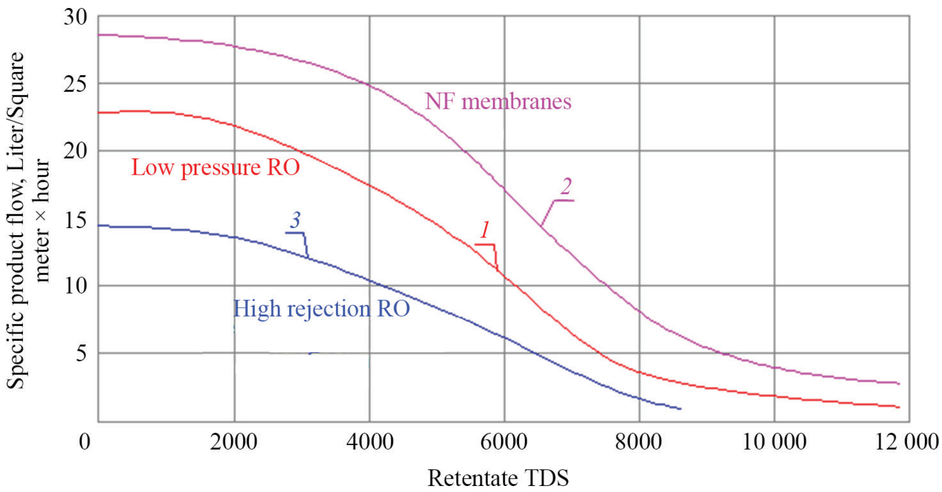

Fig. 12. Treatment of biologically treated wastewater at high recoveries. Dependencies between specific product flow rate: and feed water TDS for different membrane types: *1* — low pressure RO, BLN type; *2* — nanofiltration membrane, 90 NE type; *3* — high removal membrane, BE-type. Membranes produced by CSM (Korea)

rates of RO and NF membranes and recovery for different feed water TDS values. It is obvious that product flow dramatically decreases when recovery values reach 0.95–0.99. It seems reasonable to use nanofiltration membranes at the second stage to reduce membrane costs. Figure 15 shows the dependencies between specific product flow throughout the whole process both

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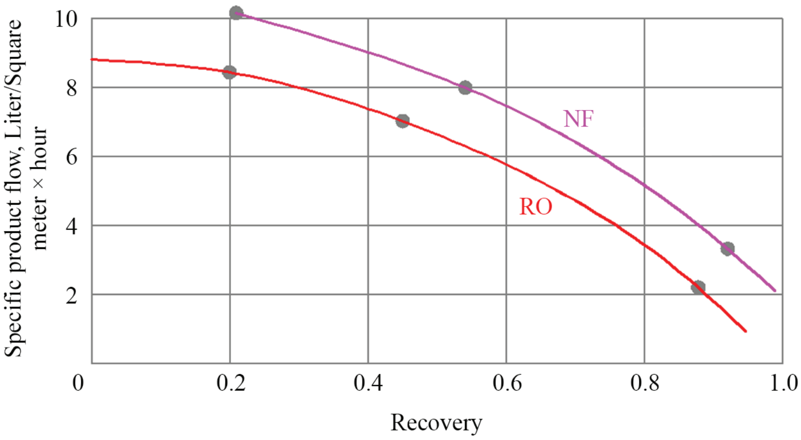

Fig. 13. Specific product flow rate at the second stage versus recovery

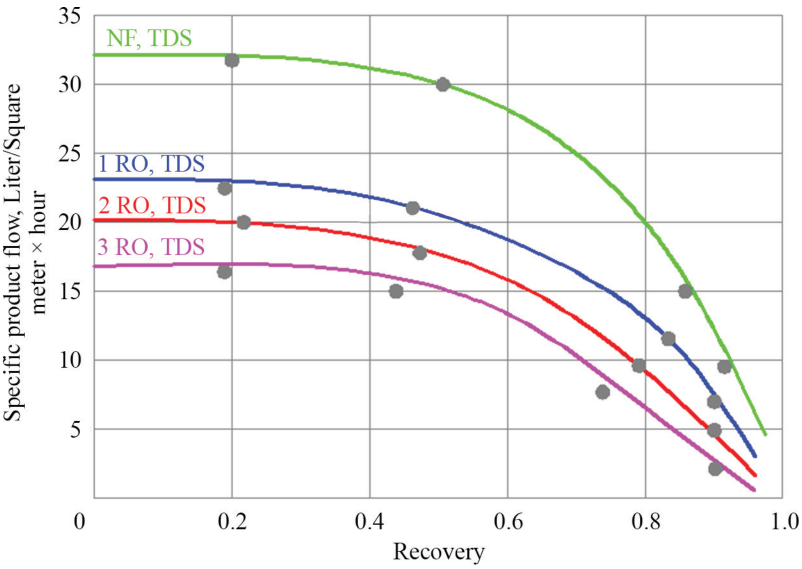

Fig. 14. Dependencies between specific product water flow rates and recovery for different feed water TDS values: *1* — 300 ppm; *2* — 600 ppm; *3* — 1000 ppm

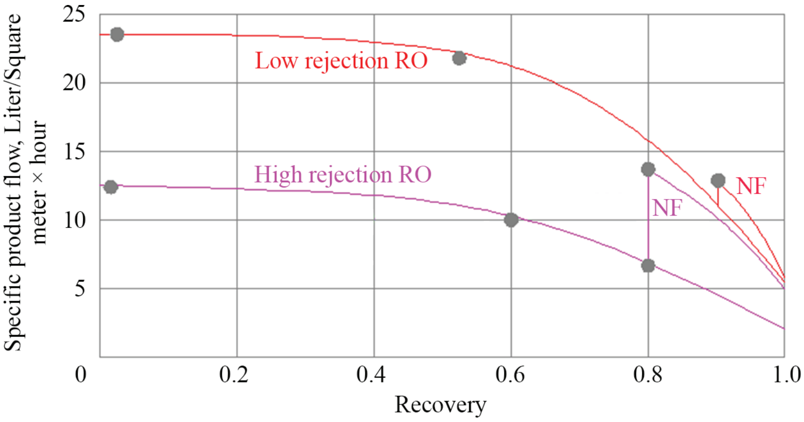

Fig. 15. Reduction of specific product flow of membranes versus recovery throughout wastewater treatment at high recoveries using different membranes and concentrate utilisation

for the first and second stages as well as for different membrane applications.

Figures 10–15 demonstrate an experimental approach to determining the required membrane characteristics for designing a membrane unit for wastewater treatment and concentrate utilisation. The main characteristics to be determined are: product quality, specific product flow and required recovery, as well as membrane types at the first and second stage membrane units. Figure 10 demonstrates an example for determining the required recovery value at the first stage. Ammonia concentration on the second stage for selected recovery can be determined as shown in Fig. 11. The second stage product water can be added to the feed water.

The second stage concentrate is added to sludge that is forwarded to a dewatering unit according to Fig. 2.

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The suggested improvement of conventional biological wastewater treatment includes the use of RO for wastewater post-treatment and the utilisation of RO concentrate and retentate following sludge dewatering using an additional RO step (Fig. 4).

Figure 16 consists of a flow diagram of wastewater treatment and concentrate utilisation as well as mass balance considerations for determining the required RO unit parameters to treat reject water following sludge dewatering. The determination of required RO parameters and mass balance during treatment of reject water following digested sludge dewatering is shown in Fig. 17.

When describing applications of RO tools for treating wastewater and reject water from sewage sludge dewatering, it was assumed that the feed water stream has been adequately pre-treated using ultrafiltration. Moreover, suspended colloidal, organic and bacterial fouling, as well as scaling, can occur on the membrane surface when high recovery rates are achieved. A great deal of research work was carried out by our team in order to investigate fouling and scaling processes [12, 13]. As

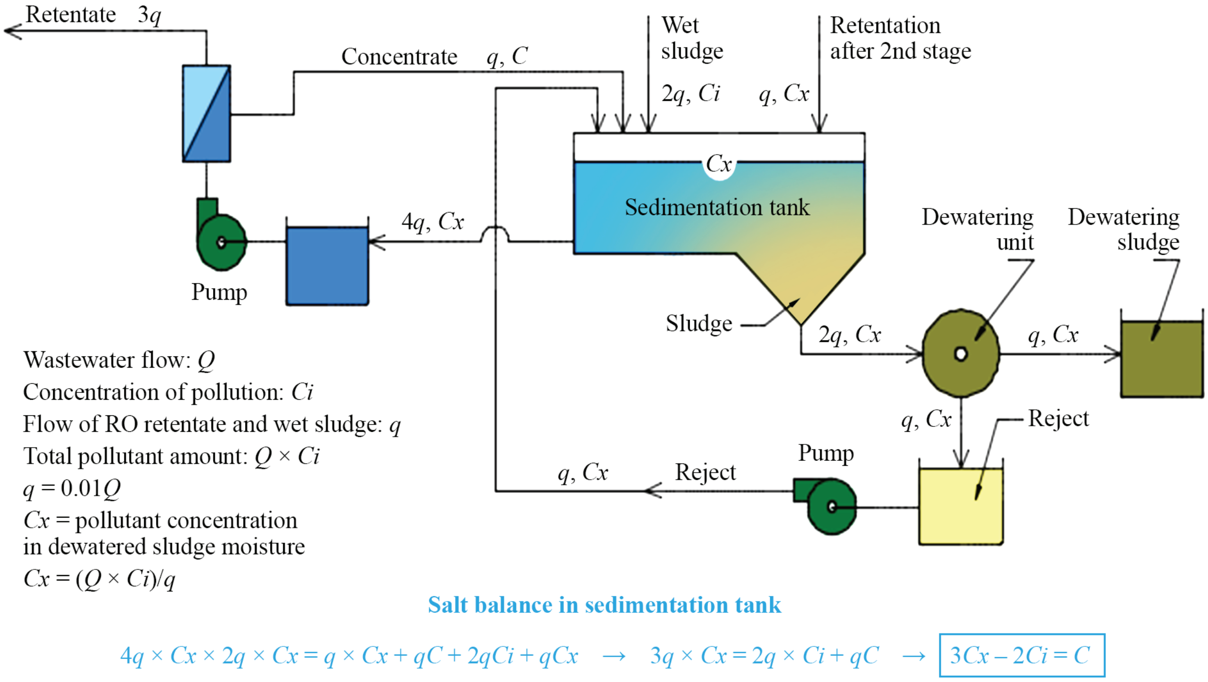

Fig. 16. Dissolved contaminants concentrations balance in the sludge sedimentation tank

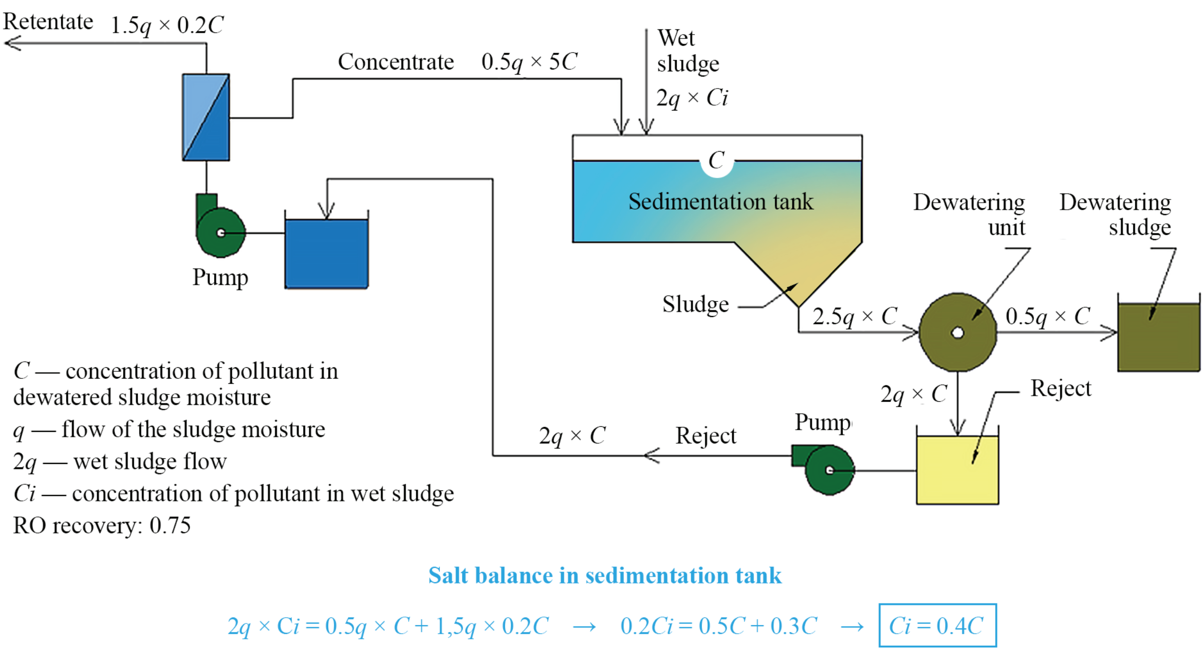

Fig. 17. Flow diagram and salt balance of reject water after digested sludge dewatering treatment by RO

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a result, "open channel" modules were developed that can be operated using feed water with high fouling and scaling potential without the risk of decreasing membrane performance [12]. Even direct wastewater treatment without a biological step was successfully carried out through the use of newly developed "open channel" modules [12].

The experiments conducted in this article provided no evidence of scaling and low-solubility salt deposition from the concentrate volume. The developed "open channel" RO modules [12] can be used to ensure the safe operation of the RO unit at high recovery rates. For higher concentrations of calcium in the feed wastewater, deposition of calcium carbonate can occur on the membrane surface and in the concentrate flow at high recovery rates. Thus, a new technique is proposed and developed for withdrawing excessive hardness from RO concentrate and reducing concentrate and TDS hardness at high recovery rates [13].

The presented data show that the application of RO techniques provides more economical and reliable solutions than biological tools. Future research will provide economic and technical survey and analysis to evaluate and compare modern methods for reducing ammonia and other biogenic elements in wastewater effluents.

CONCLUSIONS

Principles of the use of RO techniques in wastewater treatment schemes for improving product water quality are presented. RO concentrate, which contains ammonia nitrogen and other pollutants, is added to the sludge and withdrawn along with the dewatered sludge.

The study showed the high efficiency of RO in removing the primary pollutants from reject water generated during anaerobic sewage sludge stabilisation in a dairy WWTP.

The research indicated that the full-scale use of RO in dairy WWTPs would result in a significant decrease of contamination load in reject water. This could ensure the stable and efficient functioning of dairy WWTPs without the necessity of biological stage modernisation. Concentrate produced during RO treatment can be used for fertiliser production or blended with dewatered sludge prior to final reuse.

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