Treatment of Barbital and Triazine from the Surface Water Using a Reverse Osmosis (RO) Process Containing SW-40-HRLE-400-Polyamide Membrane

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Abstract: In this study, barbital and triazone samples taken from surface water located in Manisa-İzmir Turkey were treated using a RO membrane reactor process. No significant effect of feed pressure on permeate flow rate was detected. An increase in barbital and triazone concentration did not significantly vary the permeate flow rate. No significant variations of barbital and triazone rejections were detected versus feed increasing pressure at constant barbital and triazone concentrations, and no significant effects of temperature increase on the rejections of barbital and triazone were detected. The effect of increasing feed pressure did not significantly correlate with e-water recovery (rejection) from the permeate and pollutant recoveries from the retentate. The total cost was calculated as Euros 0,306 to treat 1 m^3 surface water from barbital and triazone.

Keywords: Barbital, Triazine, Reverse osmosis, Surface water.

1. INTRODUCTION

The presence of micropollutants containing organic properties in potable and surface water is accepted as a very important problem in the aquatic acecystem ana environment [1) Especially, organic micropollutants were extremely soluble and they were transported to sources based on potable water [2]. The organic chemicals alone or together in the surface water affect the human health negatively [3]. Drinking water sources should be (i) clean and (ii) some novel advanced novel remediation process should contain the remove all the organic ana inorganic impurities. Filtration is an important removal process utilised by some drinking water facilities in the world. This process clean the biological and physicochemical organic ana inorganics as a result of short retention, adsorption, and biological reactions occurring during surface waters [4]. All the micropollutants can not be removed by riverbank filtration and ultimate novel/advanced remediation processes should be applied. Reverse osmosis (RO) doesn't have physicochemical chains, and end impurities are not found in the permeate/effluent water of RO under steady-state conditions if the RO membrane type is suitable to the type of pollutants in the water and a pre- process such as disinfection was located to the treatment process [5-8]. RO is a physical pollutant separation process and the transferring of organic solutes veusus osmotic membranes generated based on solution-diffusion model [9, 10]. Complex solute-membrane relationships can advice or prevent the solution-diffusion mechanism in RO. These relationships exhibited steric, electrostatic and hydrophobic properties [11-13]. Solute-membrane mechanisms varied versus type of solute and physicochemical ingredients, water characterization and some operational properties [14, 15].

In RO a semi-permeable membrane between two low and high-concentration solutions, the water will naturally flow to the higher concentration side due to the osmotic property [16]. When the operating pressure equals the osmotic pressure of the more concentrated solution side, water flow stops. If the applied pressure is higher than the osmotic pressure, the water flow will be reversed. The feed water is pushed to the membrane by a high-pressure pump. In this process, the feed water divides into two parts of permeate and brine/retentate/concentrate water. Brine/retentate flow contains viruses, bacteria, and suspended solids that do not pass the membrane [16, 17]. From the retentates, some chemicals can be recovered and the treated water/permeate water can be reused [16, 17].

Barbital (or barbitone), marketed under the brand names Veronal for the pure acid and Medinal for the sodium salt, was the first commercially available barbiturate. It was used as a sleeping aid (hypnotic) from 1903 until the mid-1950s. The chemical names for barbital are diethylmalonyl urea or diethylbarbituric acid; hence, the sodium salt (known as medinal, a genericised trademark in the United Kingdom) is known also as sodium diethylbarbiturate [18]. The

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physicochemical properties of barbital were given in Table **1**.

Table 1: Physiochemical Properties of Barbital [18]

Molecular weight	184.19 g/mol
Physical appearance	White crystalline powder
Melting point	190°C
Octanol/water partition coefficient	0.65
Solubility	Water solubility is 0.04M
Presence of ring	Pyrimidine

Triazone is a stable solution resulting from a controlled reaction in an aqueous medium of urea, formaldehyde, and ammonia which contains at least 25% total N. This N source contains no more than 40%, nor less than 5%, of total N from unreacted urea and not less than 40% from triazone. All other N shall be derived from water-soluble dissolved reaction products of the above reactants. It is a source of slowly available N [19]. The physicochemical properties of the triazone were given in Table **2**.

Table 2: Chemical and Physical Properties of Triazone [19]

Density	1.1±0.1 g/cm3
Boiling Point	869.5±75.0 °C at 760 mm Hg
Melting Point	128°
Molecular Formula	$C_{48}H_{66}N_6O_6$
Molecular Weight	823.074 (g/mol)

Barbital was removed with a yield of 90% in a polyamide RO-Graphene oxid membrane at a pressure of 12 bar [20]. In a study performed by Bruner al al.(200) ultrafiltration (UF) followed by reverse osmosis (RO; UV/H_2O_2 followed by granular activated carbon (GAC) filtration, UV post-disinfection or by softening, aeration, rapid filters, and chlorine dioxide dosing treatment methods were used to remove the 0,34 mg/l barbital. Among these treatment methods, UV/H_2O_2 with subsequently activated carbon filtration exhibited high yields (89%) compared to the other treatment methods (56-69% yields) [21].

In this study, by using a thin film SW-40-HRLE-400–Polyamide membrane the barbital and triazone samples taken from surface water located in Manisa-İzmir were treated. The effects of some operational conditions on the recovery of the triazone and barbital from the retentate and the reuse of treated water from the permeate were investigated: Effect of feed pressure on permeate flow rate, effect of increasing feed concentration for barbital and triazone on permeate flow rate, variations of barbital and triazone rejections versus feed pressure at a constants barbital and triazone concentrations in the feed, effect of increasing barbital and triazone concentrations in the feed on the rejections barbital and triazone at constant feed pressure, effect of increasing pressure and pollutant concentrations on the triazone and barbital concentrations in the permeate, relations between retentate water flow rates and increasing pressure at constant triazone and Barbital concentration, Effect of increasing feed pressure on the water recovery (rejection) at constant barbital ana triazone concentrations and Effect of operating pressure on water flux were investigated. The total cost of RO was calculated based on capital ana operational expenses.

2. MATERIAL AND METHODS

2.1. RO Membrane Characteristics and Allowed Limits of Operation

RO Membrane was SW-40-HRLE-400–Polyamide thin-film composite, the maximum operating pressure was 50 bar, the maximum operating feed flow was 0,456 m3/min, the minimum operating feed flow rate was 0,00256 m^3/min, the maximum pressure drop per pollutant was 0.018 bar, Maximum operating temperature 50 ◦C, and the RO length was 1 m. The active area of the RO membrane was 0.657 m^2 while the pore diameter was 0.9 microns.

2.2. Methodology of the Continuous Operation of RO

In order to detect the effective operating parameters on the performance of the RO treating micropollutants namely barbital and triazone feed pressure were adjusted between 5 bar and 50 bar. The barbital ana triazone concentrations were adjusted between 3 and 50 mg/l by diluting the surface water and the RO was continuously operated at certain constant operating pressures. Water recoveries from the permeate and pollutant rejections from the retentate/ concentrate were recorded at different operational conditions. The water temperature and pH were fixed at 20 °C and 7.0, in some experiments.

2.3. Operation of RO

The RO process has a pump with a power of 0.89 kW that transport the raw wastewater to the RO process with a mixer on the RO process for wastewater mixing and preventing the accumulation of fine particles, a second tank in the RO with a power of 0.34 kW, four microfilters that remove the big suspended solids higher than 1 μm, a 7.09 kW high-pressure pump which is connected to a variable frequency drive to take in equilibrium the osmotic pressure. A valve at the end of the brine water pipe was used to adjust the membrane recovery ratio in each test.

2.4. Analytical Procedures

2.4.1. Measurement of Barbital and Triazone Concentrations

The concentrations of these chemicals were measured according to a modified method given by Albergamo *et al*., (2018) [22].

For analysis of barbital and triazone concentrations in surface water by injection, 998 μL samples were put to a 2 mL polypropylene syringe containing a 0.22 μm filter and filled with 10 μL standards to get a dose of 2 μg/L. The filtrate was transferred in 1.5 mL PP LC glass vials and analyzed. A solid-phase extraction method was validated for barbital and triazone measurement at all samples by using Oasis HLB from waters. The filters were put on a vacuum filter, with 5 mL of MeOH and fulled with 5 mL of deionized water. Samples and controls, 100 mL (n = 4) were transferred to a 250 mL bottle, filled to 50 mg/L with the stock mixture, and loaded onto the cartridges by using a vacuum pump. Then the filters were cleaned with 2 mL of deionized water and dried under vacuum for 20 min. The filters were diluted with 4 × 2.5 mL of MeOH by using a vacuum. The extracts were filtered with 0.22 μm filters and put in 15 mL PP tubes before dried to 0.5 mL under nitrogen gas. After drying process, the püre samples were put to 1.5 mL vials and remained in the dark at 2 °C. Before UHPLC analysis the püre samples were diluted in deionized water with mobile phase for chromatographic isolation. The assay ending with an factor of 40 and a dose of standards equal to 2 μg/l for the calibration tests.

2.4.2. LC Operational Matrix and HRMS Adjusting

The analyses were done using an UHPLC system containing a ToF/MS upgraded with an HD collision cell. Before MS detection the samples were transferred to a reversed-phase biphenyl LC column, containing a 2.6 μm particle diameter, pore thickness of 100 Å, and dimensions of 100 × 2.1 mm. The mobile phases were deionized water (eluent A) and MeOH (eluent B). The impact of acetic acid in eluent A were choseen as a measurable sample. The LC gradient was defined as B percentage was 0% at 0 min, 40% at 2.7 min, 100% at 4, and until 6 min. The total flow rate was 0.25 mL/min. The conditions at the beginning (100% A) were established for a 4-min assay between sequential injections. For the analysis, 30 μL of the sample were put for positive ESI condition, whereas 40 μL were tranferred for negative ESI condition. The temperatures were 40° and 15 °C, respectively. The MS detector was calibrated before analysis. This was generated by injection a 54 μM sodium acetate in H_2O: MeOH (1:1, v/v) using a tranferring of 25 μL and the sample was diluted to 20 μL. Positive and negative ESI were generated by adjusting the power of 30,000–60,000 FWHM. MS/MS results were taken into consideration and total ions are characterized by adjusting the energy, between 6 and 25 eV, respectively.

2.4.3. Screening and Quantification of the Organics

MS/MS results was obtaining by using TASQ, which is two-stage mathematical expression for the isolation and measurement of analysed chemicals. For identification mathematical formulas, times, and ions were used. To detect the optimum operational conditions all the standards were mixed in an auto MSMS ana the analytes peaks were recorded versus MS/MS acquisition rate based on sequential scans. These assays were carried out by using 20 eV energy during positive and negative separation. After confirmation of MS/MS spectra the fragments of the ions were added to the system. HRMS results were separated for the monoisotopic mass of the (de)protonated ions using [M+Na] , $[M+NH_4]^+$ and H−H+CH_3COOH]. Isolated chromatograms (EICs) based on the retention duration were deviated after 0.02 min from the retention time. Low *m* Sigma values (<100) exhibted good isotopic occurrence. For isolation ana measurement of ions deonized water transferred with 18 μg/L of barbital and triazone and diluted. The calibrations were performed with 2 μg/L standards. Calibration curves were extracted from different points of the measured doses wit 45% accuracy and r-squared data of 0.99. When identification was not performed with internal standards, calibrations were performed by using external standards.

2.4.4. Validation of the Method

The method was validated using direct and solid-phase extractions of influent and RO permeate. Linear value, isolation and concentration limits, and recovery percentages were compared and the effects of the operational matrix were evaluated in sequential days.

The quantification limits were identified with the low doses of the calibration lines based on peak with a mass capacity of ±2 m Da at a power of 30,000 FWHM. The ions were isolated from the CID MS/MS results with a mass capacity of ±5 m Da at power of 20,000 FWHM. The lowest S/N ratio was 3. For IQL identification, the q/Q ion ratio was chosen as ±30% from the from the optimum data. The detection limits (IDL) were 3.3 times lowest than the IQL.

During injection method, detection and quantification limits, recovery percentages, and identification in surface water (n = 3) were performed atsequential doses. In all analysis 2 μg/L standards were used. In order to detect the MQL levels in different operational condiditions, the minimal detection dose with 30% accuracy was used as limits. The recovery percentages were mentioned as the average value of the measured dosess in not spiked samples, while the real doses were equal to/or greater than MQL The precision in a day ana between days were calculated with the standard deviation values at spiked dose which is approximately s equal to MQL. Recovery percentages varied between 75% and 125% with RSD values lower than 20% indicating the repeatability of the analysis.

During validation of SPE method, detection limits, recovery percentages and precision values were carried out by analyzing of RO influent and permeate samples (n = 3). To these samples 50 ng/L standard volumes were added. For derivation of the MQLs and MDLs samples during SPE procedure the IDLs and IQLs were interpolated for the dilution and recovery percentages values. Recovery percentages and precision data were mentioned to validate the injection method of both pollutants.

3. RESULTS AND DISCUSSION

3.1. Effect of Feed Pressure on Permeate Flow Rate on the Treatment of 5 mg/l Barbital and 4 mg/l Triazone in RO

Figure **1** illustrated the effects of increasing pressure on permeate flow. A significant increase of feed pressure at constant 5 mg/l barbital and 4 mg/l triazone concentrations did not cause a significant elevation in the permeate flow (Figure **1**). Therefore an increase in feed pressure from 5 to 40 bar of the feed water was not affecting the wastewater transport through the RO membrane. A significant increase of pressure from 5 bar to 40 bar did not elevated the barbital and triazone accumulation on the membrane surface (their removal efficiencies were around 97% and 99%, data not shown). As a result; the wastewater permeation through the membrane was not retarded and inhibited.

3.2. Effect of Increasing Feed Concentration for Barbital and Triazone on Permeate Flow Rate at a Constant Feed Pressure of 30 bar, pH, and Temperature of 7.0 and 20 °C.

Figure **2** show the effect of increasing barbital ana triazone concentrations on the permeate flows. The permeate flow did not decrease significantly as the barbital and triazole concentrations were increased from 3 mg/l up to 50 mg/l measured at different times in the samples taken from the surface water. The feed pressure was adjusted to 30 bar and was maintained constant during the operation of RO. As a result, the

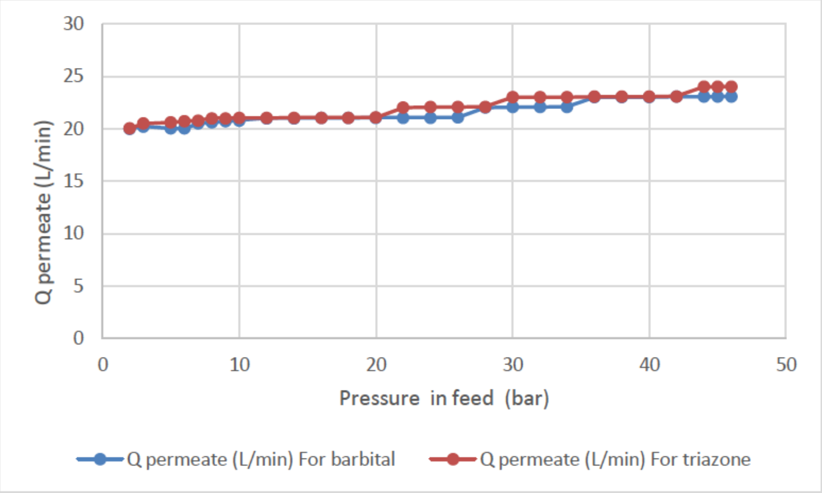

Figure 1: Variation of permeate flow rate versus feed pressure in the RO reactor treating 5 mg/l barbital and 4 mg/l triazone.

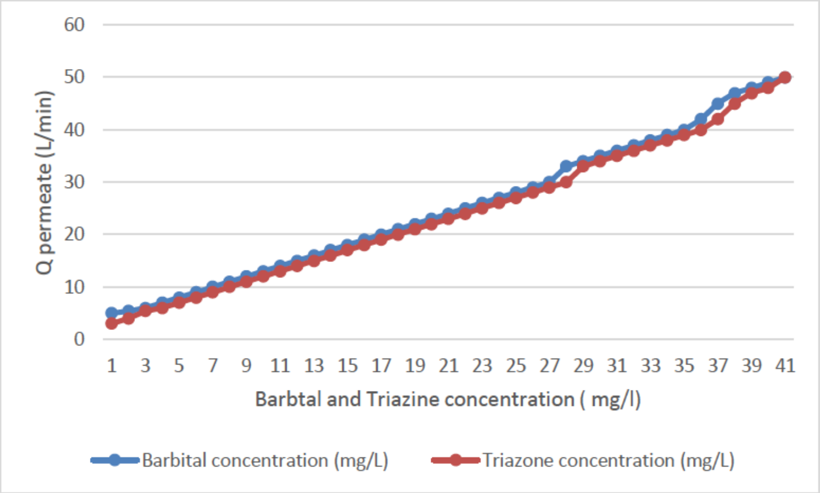

Figure 2: Effect of Barbital and Triazone concentrations in the feed on the permeate flow rate at a fixed feed pressure, pH, and temperature of 7.0 and 20 °C.

feed pressure did not affect the driving force applied to the feed water (Figure **2**). As the pressure was increased from 30 bar up to 45 bar the water flux did not elevate throughout the membrane surface. It is important to note that the osmotic pressure did not aise by increasing the barbital ana triazone concentrations from 3 mg/l up to 50 mg/l in the feed. As a result a problem originated from the difference between the osmotic pressure and pump pressure did not decrease, and a reduction in permeate flux did not occurs.

3.3. Variations of Barbital and Triazone Rejections Versus Feed Pressure at Constants Barbital and Triazone Concentrations in the Feed

Figure **3** exhibited the effects of increasing feed pressure on rejections of barbital and triazone. As shown in this Figure increasing feed pressure from 5 bar to 55 bar did not significantly affect the barbital and triazone rejections. At 15 bar pressure, barbital and triazone rejections were 89% while the barbital and triazone rejections were recorded as 99% at a feed pressure of 55 bar. This can be defined with no dilution of water in the permeate of RO since a significant increase in water flux was not detected. A significant correlation between barbital and triazone rejections and feed pressure at fixed pollutants concentration was not found. As barbital and triazone rejections increased at lower pressures; the barbital and triazone concentrations in the permeate not decreased. A slower increase in barbital and triazone rejections was not decreased as the feed pressure.

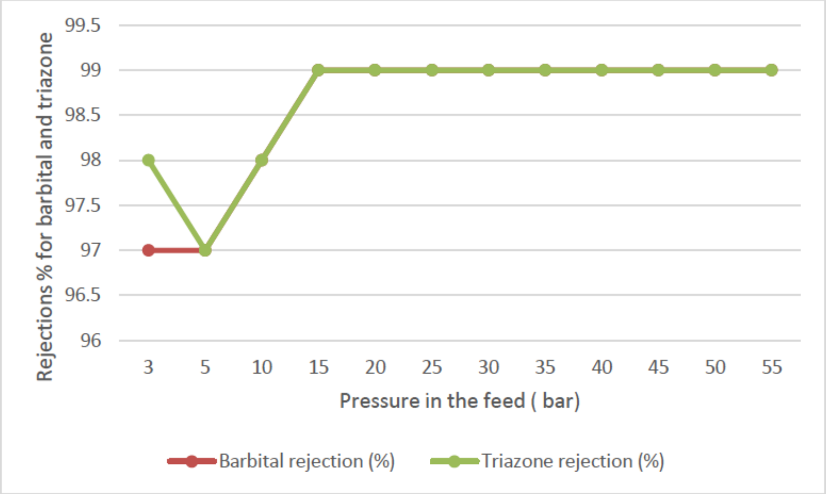

Figure 3: Effect of feed pressure on the barbital and triazone rejections at constant barbital and triazone concentrations in the feed at a pH and temperature of 7.0 and 21°C.

3.4. Effect of Increasing Barbital and Triazone Concentrations in the Feed on the Rejections of Barbital and Triazone at a Constant Feed Pressure

Figure **4** shows the ncreasing barbital and triazone concentrations, n the feed on the rejections of both micropollutantants at constant feed pressute. Increasing barbital and triazone concentration from 3 mg/l up to 50 mg/l in the feed did not reduce the diffusion coefficient of water and an increase in barbital and triazone solubilities were not detected (Figure **4**). This issue can be evaluated as follows: An increase in barbital and triazone throughout the passage in the RO membrane pores did not occur and therefore the permeate concentration was not affected negatively. In this regard, the maximum barbital and triazone rejections are around 98% and 99% at a constant pressure of 30 bar in the feed.

3.5. Effect of Increasing Pressure and Pollutant Concentrations on the Triazone and Barbital Concentrations in the Permeate at Constant Pollutant Concentrations

Figure **5** exhibited the impact of increasing pressure, triazone and barbital concentrations in the feed on the pollutant concentrations in the permeate. As the pressure was increased from 10 bar to 50 bar and the pollutant concentrations were increased from 5 mg/l up to 50 mg/l. Under these conditions; the triazone and barbital concentrations in the permeate did not vary significantly (Figure **5**). As the concentrations in the influent increased in fixed feed pressure, the triazone and barbital concentrations in the permeate did not affected significantly (data not shown). As the pressure was increased to 50 bar at an inital triazone and barbital concentrations dose of 40 mg/l the concentrations of these micropollutants in the permeate did not increased significantly and remained around 1,2 mg/l when the pressure was 50 bar. Not a significant increase in the pollutant concentrations was detected. As a result, it can be concluded that a significant correlation between rejection yield and feed pressure was not detected (Figure **5**)

3.6. Relations between Retentate Water Flow Rates and Increasing Pressure at Constant Triazone and Barbital Concentration of 45 mg/l

In Figure **6**, the effect of pressure in the feed on the flow rate in the retentate/concentrate was showed at

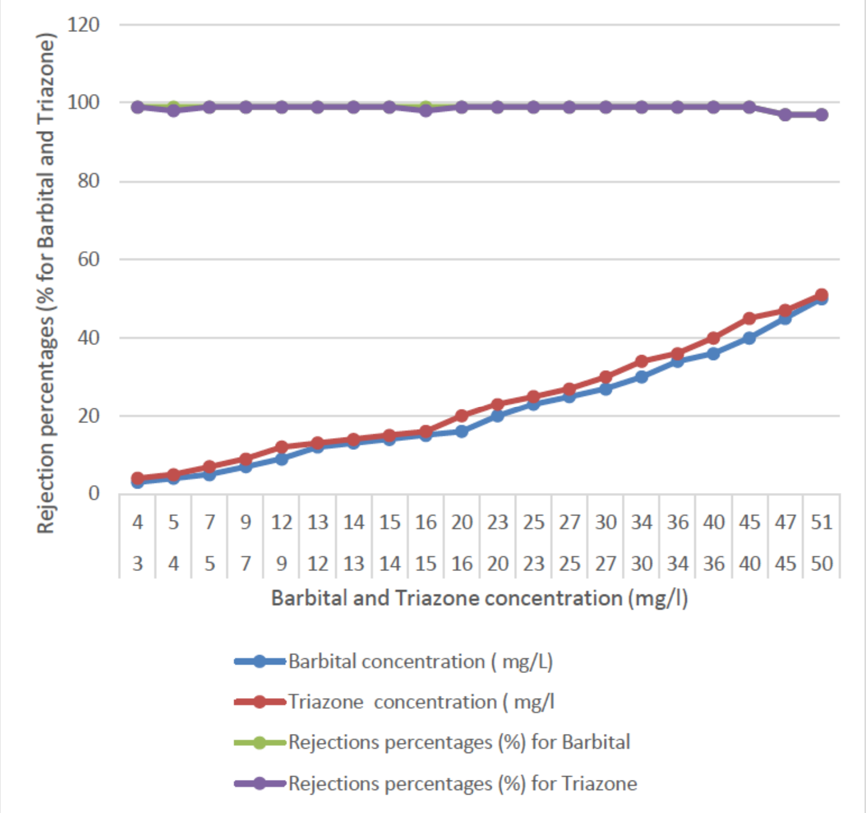

Figure 4: Effect of triazone and barbital concentrations in the feed on barbital and triazone rejections at a constant pressure in the feed at a pH and temperature of 7.0 and 20 °C.

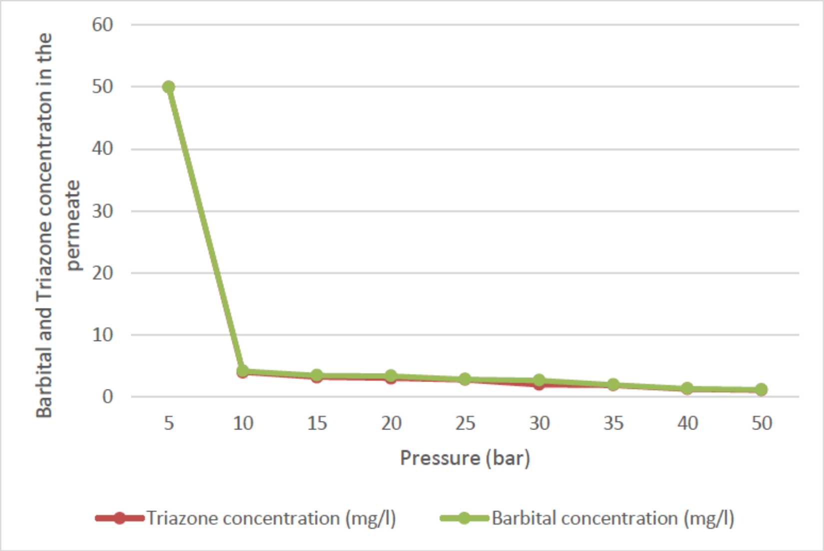

Figure 5: Effect of increasing pressure and triazone, barbital concentrations in the feed on the pollutant concentrations in the permeate at a pH and temperature of 7.0 and 21°C.

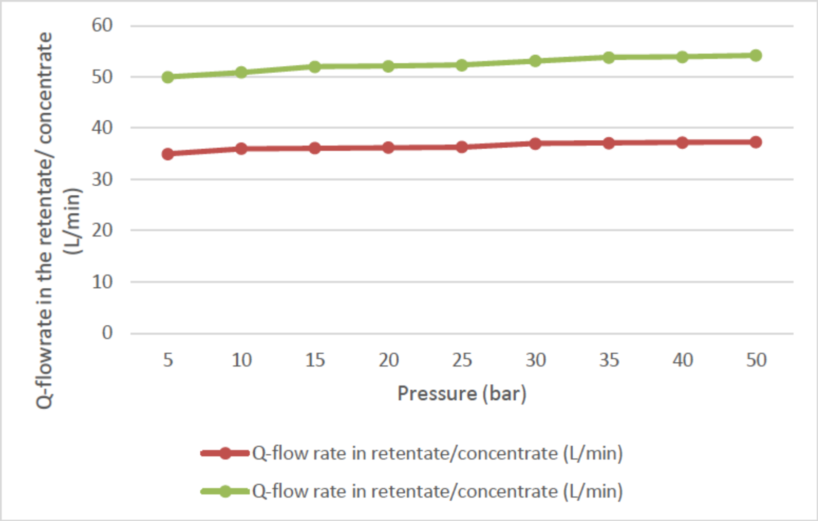

Figure 6: Effect of pressure in the feed on the flow rate in the retentate/concentrate at constant initial feed concentration, at a pH, and temperature of 7.0 and 20 °C.

constant initial feed concentration. In this study, it was found that increasing pressure did not significantly reduce the retentate flow rate in the effluent of RO. This can be attributed to a significant increase in water permeation was not detected depending on pressure increase and this phenomenon did not decrease the retentate flow rate (Figure **6**). The feed permeate flow and retentate flow did not raise by increasing the feed pressure. As a result, it can be concluded that with 15 bar feed pressure, the best water quality was obtained from the permeate for initial barbital and triazone concentrations of 35 and 50 mg/l.

3.7. Variation of Barbital and Triazine Concentration in the Retentate Versus Increasing Pressure at Constants Initial Pollutant Concentrations of 45 mg/l

In Figure **7**, the effect of pressure and pollutant concentrations in the feed on the triazone and barbital concentrations in the retentate was illustrated. It was not observed correlation between feed pressure and triazone and barbital concentrations in the retentate (Figure **7**). By increasing the feed pressure from 5 bar to 50 bar with 40 and 100 mg/l constant initial barbital and triazone concentrations; the water flux did not significantly increased in the retentate. Consequently

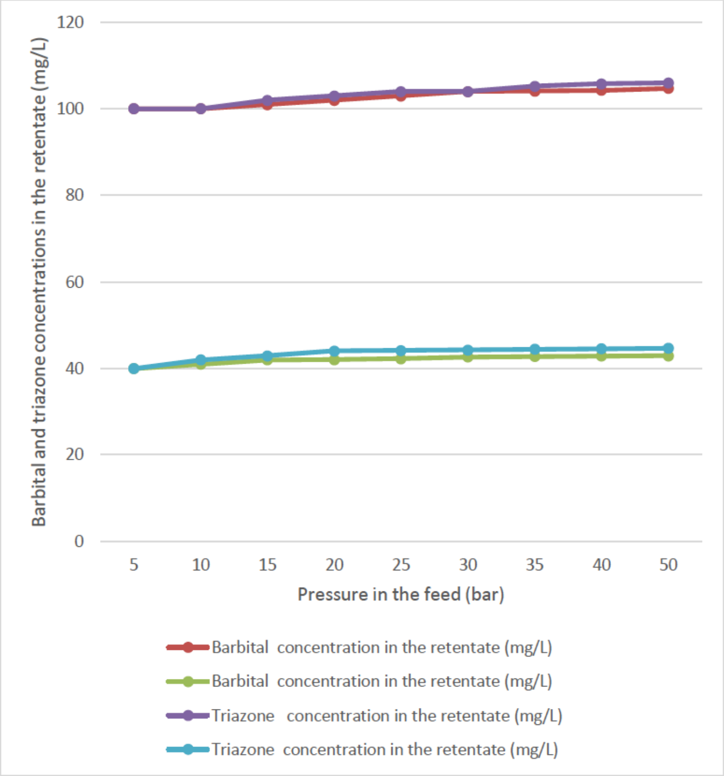

Figure 7: Effect of pressure and pollutant concentrations in the feed on the triazone and barbital concentrations in the retentate at pH and temperature of 7.0 and 20 °C.

the pollutant concentrations were not significantly increased in the permeate and the pollutant concentrations in the retentate. In other words, a correlation between the feed pressure and pollutant concentrations in the penetrate was not obtained.

3.8. Effect of Increasing Feed Pressure on the Water Recovery (Rejection) at Constant Barbital and Triazone Concentrations of 40 mg/l in the Feed

In Figure **8** the effect of feed pressure and feed concentration on the barbital and triazone recoveries

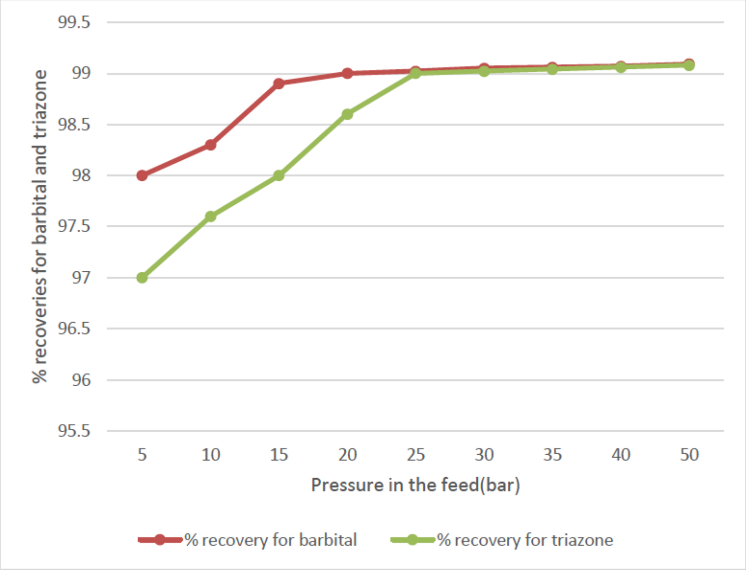

Figure 8: Effect of feed pressure and feed concentration on the barbital ana triazone recoveries from the RO membrane at a pH and temperature of 7.0 and 20 °C.

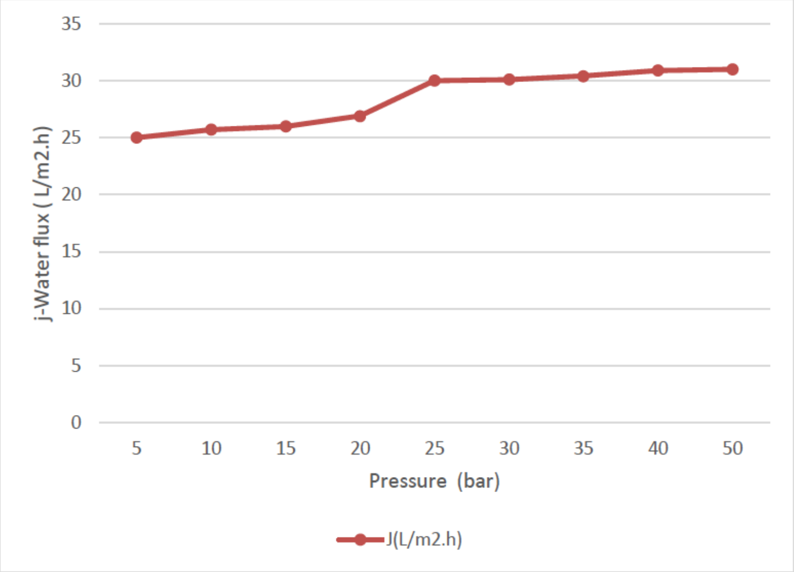

Figure 9: Effect of pressure on water flux at a pH and temperature of 7.0 and 20 °C.

from the RO membrane was shown. The increase of feed pressure from 5 bar to 50 bar did not affect significantly the water recovery percentages (Figure **8**). A significant correlation between pressure and water recovery was not detected.

3.9. Effect of Operating Pressure on Water Flux at Constant pH and Temperature (7,00; 20 °C)

Figure **9** exhibited the effect of increasing pressure on water flux. The feed water temperature was adjusted to 20°C during the continuous operation of RO. The slope of the plot given in Figure **9** determines the value of the water transport coefficient (K_w). Since a linear correlation between pressure and the water flow rate was not detected, therefore, K_w cannot be determined.

3.10. Effect of Increasing Feed Flow Rate and Pressure on the Specific Energy Consumption

The influence of increasing the feed flow rate and pressure on specific energy consumption were illustrated in Table **3** while the variation of pollutant concentration in the retentate versus pressure in the feed is shown in Figure **10**. Based on this table the increase of feed flowrate and pressure did not significantly increase the specific energy consumption since the producing high permeate flow rate at high pressures compared to low pressures flow rates did not increase the expenses originating from the energy to operate the pump at high pressures (Figure **10**). Increasing the pressure from 5 to 40 bar did not cause a remarkable increase in energy consumption.

Table 3: Effect of Increasing Operating Pressure and Flow Rate in the Feed on the Specific Energy Consumption

The flow rate in feed L/m^3)	Pressure (bar)	Cp = Pollutant concentration in the permeate (mg/l)	Cr = pollutant concentration in the retentate (mg/l)	Cw = pollutant concentration in the feed (mg/l)	Water recovery (%)	Pollutant rejection (%)	Energy consumption (Kwh/m^2)
2	3	1	38	40	98	99	2,99
5	6	1	38	40	98	99	3,01
8	15	1	38	40	98	99	3,02
10	20	1	38	39,9	98	99	3,06
12	25	1	38	39,9	98	99	3,09
15	30	1	38	39	97,6	99	3,15
20	40	1,1	37	39	97	98	3,56

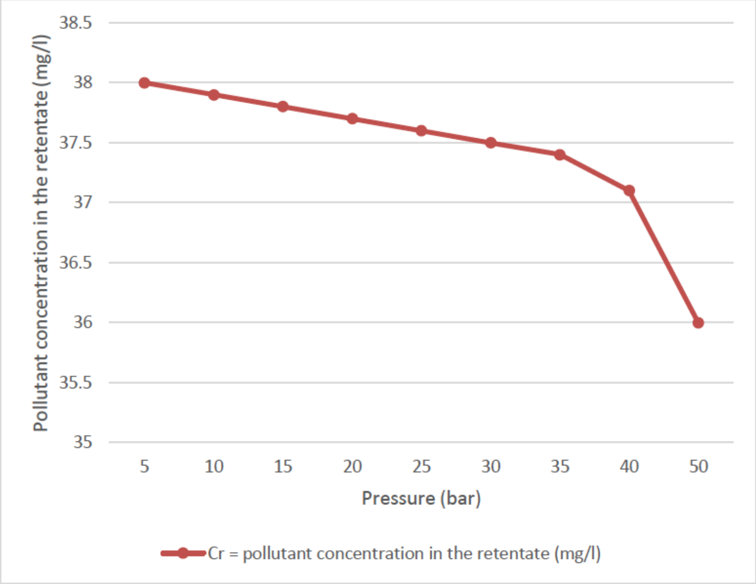

Figure 10: Variation of pollutant concentration in the retentate versus pressure in the feed.

3.11. Effect of Feed Temperature on the Pollutant Rejection and Water Recovery

Figure **11** shows the variations in pollutant rejection and water recovery versus increasing the feed temperature from 15 ◦C to 50 ◦C. With the increase feed temperature, the water recovery percentage did not significantly elevate in the permeate. This can be explained by not an important decrease in the viscosity and density of the water treated in RO as a result of increasing the feed temperature. Meanwhile, an enhancement of water permeation through the RO membrane pores was not expected with increasing the temperature. The increasing feed temperature shows a slight increase in pollutant rejection. The slight variation of pollutant rejection in retentate can be explained by an improvement of permeate pollutants types and properties resulting in retentate rejection.

3.12. Effect of Feed Temperature on the Specific Energy Consumption

Figure **12** assesses the relation between the feed temperature and specific energy consumption. This is

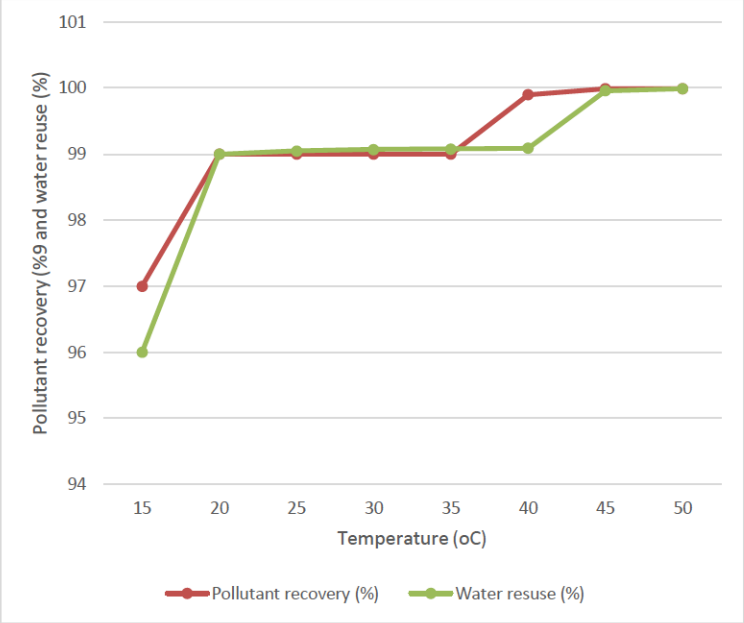

Figure 11: Effect of temperature on pollutant recovery and ana water reuse percentages.

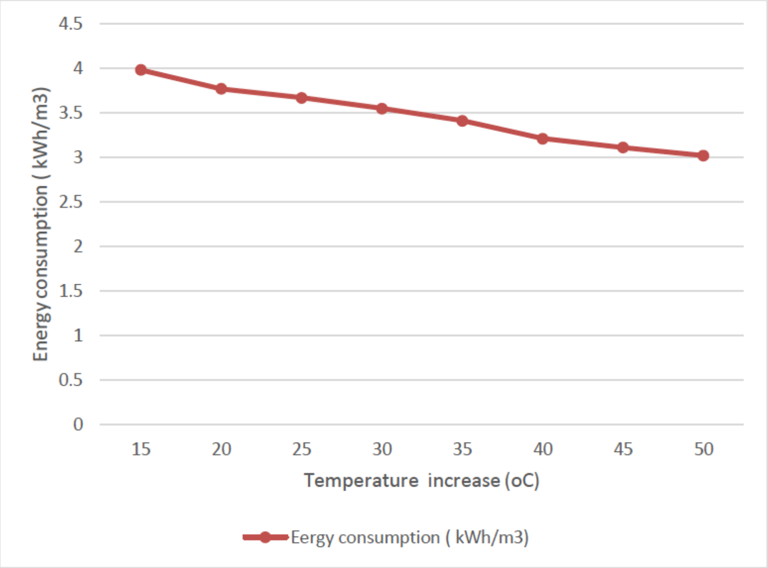

Figure 12: Effect of operating temperature on the energy consumption.

presenting a reduction of specific energy consumption due to increasing the supplied temperature. Figure **12** indicates a considerable drop of specific energy consumption for an increase of 10 ◦C. This might be attributed to the improvement of water flux through the membrane pores due to increasing temperature of the bulk fluid. This is also accompanying an increase of pore's size with high mobility of water due to reduced viscosity and density. Statistically, Figure **12** affirmed a sligty drop of specific energy consumption by 1,0% due to raise temperature from 15 °C to 50 °C. Therefore, it would be affordable to operate the RO process at elevated temperatures without exceeding the limited constrain of the membrane.

3.13. Cost Analysis in RO treating Barbital and Triazone

Capital and operational costs were taken into considerations: The life of the RO membrane was assumed to be 20 years and capital costs were calculated for first 7 years. In the calculation of capital costs; land, construction and water cost were not taken into consideration. Cartridge filters was used as pre-treatment step before RO ifluent. The capital cost included the cost of the RO membrane system and its land area. Operating costs included energy, membrane replacement, chemicals and pre-treatment costs.

At 99% of recovery rate and flux of 20 L/m^2 h, the capital cost was calculated as Euros 0.129/m^3. The energy and membrane replacement costs were Euros 0,012 /m^3, and 0,011 /m^3, respectively while the chemical, and cartridge filters cost were Euros 0,009 Euros/m^3 and Euros 0.007/m^3, respectively. The total cost was calculated as Euros 0,306 to treat 1 m^3 surface water. The treatment cost found in this study for RO was compared with some recent studies: Kárászová *et al*., [23] found a total cost of Euros 0,567 to treat the triazone from 1 m^3 surface water using RO. Iman *et al*., [24] calculated a cost of Euros 0,789 / m^3 to teat the 2 mg/l barbital from surface water. Albergamo *et al*., [25] found a cost of Euros 0,786 to remove 2,9 mg/l triazone from 1 m^3 drinking water. These total cost were lower than that found in our study.

CONCLUSIONS

In this study, feed pressure did not significantly affect the permeate retentate flows. Permeate flux exhibited a non-linearly not significantly dependent on feed water pollutant concentrations. Both feed pressure and feed pollutant concentrations have no important effects on barbital ana triazone rejections. A nonlinear and not significant relationship was found to be among feed pressure to barbital and triazone rejections in the retentate of RO membrane and water recovery from the permeate. No significant effect of increasing flow rate and pressure in the feed on the specific energy consumption. The specific energy consumption was 2.99 Kwh/m^2 at a flow rate and pressure of 2 L/m^3 and 3 bar, respectively. The specific energy consumption was 3.56 Kwh/m^2 at a flow rate and pressure of 29 L/m^3 and 40 bar, respectively. A slight drop in specific energy consumption by 1.0% was detected due to an increase in temperature from 15 °C to 50 °C. The total cost was Euros 0,306 to treat 1 m^3 surface water containing barbital and triazone using RO membrane process.

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