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STUDY RELATED TO THE TREATMENT OF THE GROUND WATER BY REVERSE OSMOSIS TO OBTAIN STEAM

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Abstract: *The paper presents the solution to treat water, from an underground source, by reverse osmosis. The water treatment is necessary to obtain steam which is used in a technological process. As the placement of the production unit is in a rural area where there is no potable water network, the same source is used both in the technological process and to provide the necessity of potable water in the unit. The follow-up of the operation of the treatment system by reverse osmosis was made throughout a six-month period, autumn-winter, monitoring both the parameters characteristic to obtain quality steam and the water potability parameters.*

Key words: *reverse osmosis, potable water, water treatment, membranes.*

1. Introduction to Water Treatment Solutions

Since the end of the 20th century, the water treatment using the membranes technique was used on a large scale. Among these are microfiltration, ultrafiltration, nanofiltration and the reverse osmosis.

The first application was microfiltration. It is made by the detention of impurities from the water source on the membrane surface. The process takes place under the action of a pressure gradient exerted transversally along the membrane. As the microfiltration membranes do not retain viruses although high pressures are necessary, the ultrafiltration was developed, a new membrane treatment process. It was used by the German army to analyse the bacteria from the potable water. The ultrafiltration process is considered a more special case of the reverse osmosis process. In order to provide continuity in the treatment processes through membranes, the nanofiltration process was developed, making the transfer from ultrafiltration to reverse osmosis. The first application of nanofiltration was the water softening, so it may be used mainly for the treatment of underground waters with relatively low total content of dissolved salts, but which shows a high hardness. [1]

The reverse osmosis is the reverse process of the osmosis phenomenon. The osmosis takes place naturally in various biological processes like absorption from

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soil of plants water. If in a recipient there are two watery solutions of various concentrations separated by a semipermeable membrane, in the osmosis process the water from the solution less concentrated will go through the semipermeable membrane towards the solution more concentrated until the two concentrations are equal. The pressure, to which the semipermeable membrane is subject until the osmotic balance is made, is called osmotic pressure. In order to make the reversal of the process, it takes an additional pressure. It will be exerted upon the part with more concentrated solution triggering the transfer only of the water molecules to the less concentrated solution. The additional pressure to be applied upon the less concentrated solution to make the passage of water through the semipermeable membrane is called operational pressure, which should be higher than the osmotic pressure.

Taking into account the high values of the operating pressure of the reverse osmosis process, the semi-permeable membranes used by them are incorporated in cases of various geometrical shapes, called modules. Currently four shapes of membrane modules are used: board and frame, tubular, capillary and spiral. A third of the membrane modules market is taken by the spiral modules.

2. Presentation of the Case Study

The analysed water treatment system is placed in an area with saline deposits, which makes the water source influenced by the soil characteristics. The water resulted from the treatment is mostly used to obtain the steam necessary in the technological process of the unit and a small part to provide the staff's needs.

Analysing the qualities of the water sources, the two deep wells it was found that the treatment method of water so as to correspond to the usage requirements is the reverse osmosis. In this situation was provided a reverse osmosis system with a pre-filtering level and three membrane modules. The studies made on various reverse osmosis systems showed that to increase the effectiveness and the life of membrane modules is necessary a pre-filtering level. In order to have a higher quantity of water produced and to decrease the quantity of concentrate exhausted in the sewerage system one of the three modules of the reverse osmosis system will be used for the recovery of the water resulted from the first two modules. They generate permeate directly from the source.

The reverse osmosis system includes: the pre-treatment level with the help of a filter with 5 micron cartridge, vertical centrifugal pump with low noise, Grundfos CR 10-14, to make the system's operating pressure, membrane modules, electro valves and valves for the operation adjustment and for sampling, gauges and flow meters to follow-up operation, automatic unit to determine conductivity, washing connections and frequency converter to set the pump of the deposits inhibitor. This equipment is mounted on a stainless steel structure. The reverse osmosis process operates automatically, being provided with a RO 1000 microprocessor to monitor and control the entire system. For the follow-up of its operation is provided a screen with two display lines that indicate successively the operation condition, the permeate conductivity, its temperature, the number of hours of operation and warnings in case of errors occurrence. An overview image of the reverse osmosis system – which is the object of the case study – is presented in figure1.

The filtering environment is provided in the first phase by two membrane modules connected in series with an actual area of a module of 37,2 m^2 incorporated in a tube with 0,203 m diameter and a length of 1,016 m.

Fig. 1. *Reverse osmosis system*

The resulted permeate is exhausted through a pipe with 28 mm diameter. Taking into account that the operating pressure of the reverse osmosis systems varies between 15 and 100 bars the membrane modules must be assembled and mounted in cases so as to resist the pressure. For the case studied the modules are incorporated in a glass fibre case with polyester insertion provided with fittings (see Fig. 2).

Fig. 2. *Module of reverse osmosis membranes [4]*

In order to increase the quantity of permeate resulted another module of membranes was provided which is fed from the pipe of concentrate of the first two modules. The latter has the same characteristics as the other modules of membrane.

3. Experimental Determinations and Interpretations

The operation of the reverse osmosis system was followed up during the autumn winter period, because in this period the quantity of precipitations is higher and it was found that they have a direct influence upon the source. In order to present the results obtained were chosen the determinations from February – a month with heavy precipitations and temperatures more positive than negative. The samples were taken from the source, from the first phase of the reverse osmosis system and from the second phase.

The parameters determined are those specific for the needs of technological water: electrical conductivity, pH, the iron and the copper. Taking into account the fact that the water source also serves the needs of potable water from the unit, the following were also observed: manganese, ammonium, nitrites, turbidity, the permanganate index, the hardness, chlorides and the copper.

Table 1 presents all parameters determined for the water source, as well as for the analysis method analysed.

As it may be seen, the quantity of manganese, ammonium and nitrites are under the detection limit, therefore they will not make the object of our study further on.

In order to obtain quality steam the permeate of the reverse osmosis system must comply with the quality requirements imposed by the specifications of the degasser and of the steam boiler used in the production line. The supply water of the equipment must be colourless, clear, without soluble substances, foaming agents and it must comply with the parameters presented in Table 2. In the following table (see Table 3) are listed the results obtained for the parameters of technological water, both in the first phase of the reverse osmosis system that generates 75% of the total quantity of permeate, and also the second phase which provides the rest of 25% of the total quantity of permeate. Taking into account that in the water source the quantity of copper is under the detection limit for the tests from the permeate samples no determinations have been made for this.

One may notice that both in the water source and in the permeate resulted from the reverse osmosis system the iron quantity is under the limits imposed by the degasser. Therefore, from this point of view the supply water complies with the quality requirements. Analysing the values obtained for pH both in the source and in the permeate is found the fact that not even the water source reaches the minimum value imposed by the equipment, this is why a special unit for the correction of the pH will be provided in the input in the degasser. Preventively on the outlet pipe from the degasser will provide another correction unit of the pH that will operate only if its correction is necessary once again.

The value of electrical conductivity in the water source is above the limits admitted by the degasser, but after the water treatment through the reverse osmosis system it is spotted a much reduced value that complies both with the requirements imposed by the degasser and those of the steam boiler.

Following the determinations made it is

Parameters of the water source Table 1

No.	Parameter	MU	Week				Analysis method
			I	II	III	IV	
1.	Manganese	mg/l	SLD	SLD	SLD	SLD	SR 8662-2/1997
2.	Iron	mg/l	0.022	0.02	0.02	0.021	SR ISO 6332/1996
3.	Ammonium	mg/l	SLD	SLD	SLD	SLD	SR ISO 7150-1/2001
4.	Nitrites	mg/l	SLD	SLD	SLD	SLD	SR EN 26777/2002
5.	pH		6.9	7.05	7	6.98	SR ISO 10523/2012
6.	Turbidity	NTU	0.90	0.80	0.72	0.92	SR EN ISO 7027/2001
7.	Electrical conductivity	μS/cm	2060	2400	2330	2384	SR EN 27888/1997
8.	Permanganate index	mgO_2/l	0.64	0.64	1.34	1.34	SR EN ISO 8467/2001
9.	Hardness	^oG	32.4	31.8	30.64	28.4	SR ISO 6059/2008
10.	Chlorides	mg/l	289	292	208	203	SR ISO 9297/2001
11.	Copper	mg/l	SLD	SLD	SLD	SLD	Law 485 / 2002

Quality requirements for the supply water of equipment Table 2

	pH	Electrical conductivity (μS/cm)	Copper (mg/l)	Iron (mg/l)
Degasser	>9	<500	<0.01	<0.05
Steam boiler	10÷11.8	30÷4000	-	-

Variation of parameters of permeate for the generation of steam Table 3

No.	**Parameter**	**MU**	**Week**								**Analysis method**
			I		**II**		**III**		**IV**		
1.	Iron	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	SR ISO 6332/1996
			0.01		0.01		0.01		0.01		
2.	pH		6.01	5.85	6.90	6.82	5.64	5.45	6.20	6.12	SR ISO 10523/2012
			5.97		6.88		5.59		6.18		
3.	Electrical conductivity	μS/cm	49.80	32.60	66.90	58.40	61.70	29.90	60.20	49.60	SR EN 27888/1997
			45.50		64.78		53.75		57.77		

found the fact that the implemented reverse osmosis system corresponds to the requirements imposed in the production process.

In order to follow-up the potability qualities of the permeate which is used as potable water in the unit were made determinations for the parameters specific to the potability requirements according to the legislation in force [2, 3]. Analysing the values obtained for the water source compared to the values regulated by Law 485 from 2002 and Law 311 from 2004 determinations have been made for: iron, pH, electrical conductivity, chlorides, the permanganate index, turbidity and hardness. They are listed in the following table with the values admitted by the rules in force. Table 4 presents the values obtained for the permeate of the system obtained 75% from the first phase and 25 % from the second phase.

One may notice that the iron, the electrical conductivity, the chlorides, the permanganate index and the turbidity are under the maximum values admitted by the quality of the potable water. But the pH and the hardness do not always frame in the values regulated by the legislation. In this situation additional correction measures must be provided. Analysing the level of retention of the reverse osmosis system for the parameters obtained, table 5 presents synthetically the level of retention of the agents from the system permeate.

Following the results obtained we can conclude the fact that a reverse osmosis system is effective when the quality parameters of the source present high values for the electrical sequence, chlorides, hardness and turbidity.

For the purpose of increasing the quantity of permeate obtained it is recommended, as in the studied case, to recirculate a part of the concentrate of the reverse osmosis system. But a disadvantage of the studied osmosis system is represented by the necessity to correct the pH and the hardness of the permeate.

Variation of parameters of permeate for the potability requirements Table 4

No.	**Parameter**	**MU**	**Week**								**Analysis method**
			I		**II**		**III**		**IV**		
1.	Iron	mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	SR ISO 6332/1996
			0.01		0.01		0.01		0.01		
2.	pH		6.01	5.85	6.90	6.82	5.64	5.45	6.20	6.12	SR ISO 10523/2012
			5.97		6.88		5.59		6.18		
3.	Electrical conductivity	μS/cm	49.80	32.60	66.90	58.40	61.70	29.90	60.20	49.60	SR EN 27888/1997
			45.50		64.78		53.75		57.77		

Retention degree from permeate of the reverse osmosis system Table 5

No.	Parameter	Week			
		I	II	III	IV
1.	Iron	54,44%	50,00%	50,00%	52,38%
2.	pH	12,89%	2,13%	19,42%	11,17%
3.	Electrical conductivity	97,58%	97,12%	97,35%	97,45%
4.	Chlorides	96,67%	96,50%	96,45%	96,44%
5.	Permanganate index	50,00%	43,75%	28,35%	45,76%
6.	Hardness	91,35%	90,56%	83,87%	74,64%
7.	Turbidity	91,11%	92,50%	91,66%	89,13%

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