Desalination and Water Treatment
www.deswater.com
6 (2009) 160–168

Feasibility evaluation for the industrial reuse of wastewater with moderate chloride concentration in central Italy

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Received 15 September 2008; accepted 30 April 2009

ABSTRACT

The herein presented case study deals with a technical-economic evaluation of industrial reuse of wastewater from an industrial district in Lazio region (central Italy). The wastewater is presently collected in a traditional activated sludge plant and disposed into a natural stream. The treated wastewater contains a typical chloride concentration ranging from 200 to 500 mg/L which largely complies with Italian standards for surface water disposal (1200 mg/L) but poses problems for its reuse inside the same industrial district.

This study evaluated the optimal chloride level required for its reuse by an analysis of the users, and led to a preliminary design of three possible options of a finishing stage allowing the reuse in a closed loop inside the district itself. They include two options of flocculation, flotation, disinfection and reverse osmosis (RO) with different capacities, both satisfying the planned water request thanks to a larger storage in the solution with the smaller plant. The third solution replaces the RO stage with the blending of supplementary flow from groundwater wells in order to reach the required concentration by simple dilution. The two RO solutions pursue the goal of a partial reuse so as to obtain low brine concentration achieving the compliance with the discharge standard in internal surface water, with significant cost savings.

Although the dilution solution turned out to be the cheapest at present Italian costs, the RO solution with the smaller plant scored also a moderate water unitary cost, which turned out to be lower than that of drinking water distributed in the same area. Notwithstanding, the cost is still higher than that of mere pumping paid by industrial users presently exploiting groundwater.

These results demonstrate that a correct financial policy is required to allow an equilibrate development of the exploitation of reused water.

Keywords: Industrial and civil wastewater reuse; Case study; Reverse osmosis; Blending

1. Introduction

Climatic changes, soil erosion, overexploitation of groundwater, saline intrusion into coastal groundwater and, in general, human impact over the territory, make the Mediterranean region and specifically the southern-central Italy one of the most sensitive areas to the risk of desertification.

To face the increasing water scarcity, the Italian legislation is changing from a traditional approach, favoring the exploitation of natural water sources, to a new tendency to evaluate and implement projects of wastewater reuse primarily for industrial and agricultural purposes.

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The treatment of sea water for drinking use is also increasing country-wide thanks to the fast development and cost decrease of the reverse osmosis (RO) technology.

Nevertheless, the lack of strict rules and financial disincentives for the industrial withdrawal of high quality groundwater put significant obstacles to the rational exploitation of the alternative sources. Specifically, the presence of moderate levels of chloride in wastewater is still considered an insurmountable obstacle to its reuse due to the cost of desalination which is considered too high compared to the pumping of freshwater from wells.

This case study is aimed to evaluate the possibility to reclaim the effluent of the wastewater treatment plant (WWTP) of the industrial district of Frosinone to reuse it inside the industrial district itself.

Presently all the available water sources are already exploited, and most of the industrial water is pumped by the available groundwater which is starting to show an alarming tendency to lower.

Since alternative water resources are not available, it is necessary to start optimizing the use of the available resources while exploring non-conventional alternatives.

A possible non-conventional source is represented by the effluent of the WWTP serving the industrial district itself.

This policy is advisable increasingly in Italy, since the desertification tendency presents yearly rates of increase of the greatest concern. The recycled water can be largely used inside a wide range of industrial applications which do not strictly require drinking-like quality.

This strategy can result in significant savings of exploited groundwater, allowing a restoration of the original groundwater levels and also the provision of the saved groundwater, after proper purification, to potable use. This can reduce the current drinking water shortage which presently forces to intermittent water supply in several urban areas nearby.

2. The served district

The industrial district of Frosinone, the most important among four in the province, extends in the middle of the mainly flat lands of the plain of Sacco River in the ''Liri-Garigliano'' basin in central Italy. Around 160 companies exist in the industrial area of Frosinone. The total number of employed is about 4000, which represents approximately 28% of the entire province. Moreover, thanks to the favorable position, the area has become, during the last few years, an important center of commercial attraction and development investment. Some factories have been converted into trade centers or directional centers for tertiary activities. The most represented industrial activities are chemical-pharmaceuticals, textiles, metal works, mechanics and logistics.

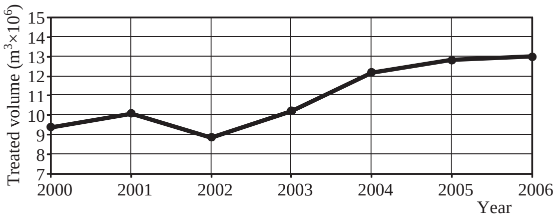

Fig. 1. Mean treated volumes in the last seven years.

2.1. The present WWTP

The present WWTP of the industrial site is managed by a Consortium of Industrial Development. Initially it was destined only for the treatment of industrial wastewater; later it was also used to treat wastewater from neighboring towns and villages, including parts of Frosinone itself.

The plant, the largest in the province, has a capability for 270,000 population equivalents (PE), with a maximum treated flow of approximately 50,000 m^3/d.

The wastewater treatment line includes pumping, fine screening, grit and oil removal, homogenization, primary sedimentation, activated sludge aeration, secondary sedimentation, tertiary coagulation-flocculation-sedimentation, hypoclorite disinfection and final sand filtration. The effluent is disposed in Sacco river 90 km before its confluence in Liri River. Currently the tertiary stage is not used and the chlorination is carried out only occasionally in the summer.

The sludge treatment includes static thickening, anaerobic digestion and mechanical dewatering. The produced biogas feeds a co-generation plants serving part of the electrical needs of the WWTP.

In the years 2002–2006 the plant has treated on average 11,000,000 m^3/year (Fig. 1), of which 70% industrial and 30% domestic. The plant is expected to reach 60% of the full capacity in 2020.

The treated effluent complies with all the regulation quality standards. There are only abnormal increases of BOD_5 and chlorides in the spring and summer which almost double the mean annual concentrations (Fig. 2). As for BOD_5, the reasons are related to sporadic bulking phenomena and anomalies in the aeration system.

As for chlorides, the cause is not related to wastewater salination, but only to increasing industrial

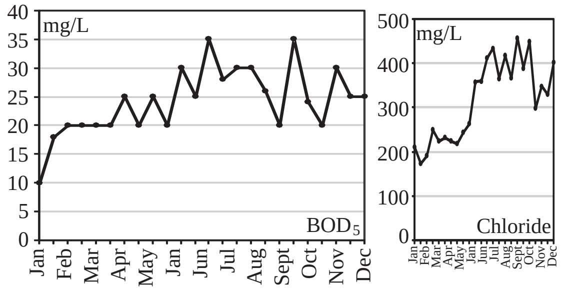

Fig. 2. Time distribution of BOD_5 and chlorides.

treatments discharging chlorides (food, textile and chemical sectors) and wastewater from newly served villages in the coastal zone.

Conversely, the effluent parameters require a finishing stage to allow for industrial water reuse.

3. Industrial water requirements

3.1. Current water sources

The currently exploited water sources in the Frosinone industrial area are:

– drinking water distributed by an inter-municipal water main;
– surface water from Sacco River;
– groundwater.

The inter-municipal water main distributes drinking water at a price of 0.6–0.7 €/m^3. Its use is limited to the productions aimed for human consumption, food cooking and air conditioning plants. The total withdrawn volume is about 550,000 m^3/year. The supply from Sacco river surface water is limited to 1,850,000 m^3/year withdrawn by a single textile factory owning specific abstraction rights.

The water volume withdrawn from groundwater has been estimated, by a balance between water captured by other sources and wastewater measured at the WWTP, as a value of 4,850,000 m^3/year, corresponding to 70% of the overall consumption.

3.2. Required quality standards for industrial water

Process water, are requested to have chemical-physical properties directly related to the specific industrial process they are involved in. The textile sector requires soft water with low chlorides to reduce detergent consumption and to prevent color alterations of the final product.

The pharmaceutical and food sectors require water with high microbiologic quality. It is thus very difficult to select a set of standard optimal for all the represented industrial sectors.

The quality of *cooling water* depends on the type of cooling system [1]:

(a) the *once through system* is the less demanding in terms of quality and the most demanding in terms of quantity because water is used once and then discharged;
(b) the *open cycle system* uses cooling towers where cooled water is recycled after adding makeup water to replace water lost from the system by evaporation, drift and leakage and to control concentration of salts or other impurities in the circulating water;
(c) the *closed cycle system* uses sealed circuits and heat exchangers, minimizing the required makeup water which replaces only the leakage.

In general, cooling water is requested to have low temperature, low presence of sediments and sludge and low tendency to fouling, scaling and corrosion. As for the temperature, groundwater is better than surface water having a constant temperature of about 10°C for the whole year, compared to surface water whose temperature varies depending on seasons and location [1]. As for fouling and scaling tendency, there are not significant differences among the different available sources, while the presence of sediments and sludge is higher in surface water. Also corrosion tendency is usually higher in surface water [2]. Finally, cooling water would be free of micro-flora and fauna to prevent biofouling, corrosion and hygienic risks for employees.

Boiler water would mainly have low hardness and silica content to prevent formation of deposits with low heat exchange [1].

Firefighting water is not required to have specific characteristics other than being promptly available in adequate quantity.

4. Planned reclamation treatments

The Italian technical regulation on water reuse (Ministry Decree May 2nd, 2006) states that, in case of industrial reuse, the quality standards of reclaimed water would be set in agreement by the provider and the final users, following the specific use needs. In the studied case, since the industrial activities are heterogeneous, the standards have been defined on a common base of minimal acceptable level, where the single factories are asked to introduce further treatment stages to reach the standards required by their specific uses.

The main properties to be respected by the reclaimed water were recognized to be:

– quality standards constant in time as much as possible;
– provision costs low enough to be competitive with the presently available alternative sources.

After a joint work with representatives of the industrial companies in the served territory, the parameters of the Italian technical regulation on civil water reuse were adopted. These standards (required for all the civil – other than drinking – water uses) set, among others, limits of 250 mg/L for chloride, 10 mg/L for total suspended solids (TSS) and 100 UFC/100 mL for *Escherichia coli*.

The effluent treated by the present WWTP appears to be already compliant with all the other required parameters of the Italian decree on water reuse of civil water.

To reach the compliance with these three parameters this study compared two possible options for a finishing stage of the effluent treated by the present WWTP. They share the same treatment stages but one of the two has a lower capacity (750 m^3/h instead of 1400 m^3/h) which is compensated by two additional tanks to equally satisfy the planned needs.

A third option was also studied, which includes simplified treatments to reach only the compliance with TSS and bacteria standards, and reaches the limits for chloride by blending a supplementary percentage of groundwater pumped by wells. The three solutions are herein presented and sized.

4.1. Definition of the finishing stage

For TSS, the present WWTP obtains final values stably lower than 30 mg/L, with rare exceedings. To reach the required value of 10 mg/L, a dissolved air flotation (DAF) treatment with preliminary coagulation-flocculation by aluminium sulphate and polyelectrolytes dosing was adopted. The flotation chamber with lamella modules has 3 m/h hydraulic load and 30 min residence time. Sizing, operation parameters, capital and running costs were evaluated for all the three solutions.

To reach the required limit of 100 UFC/100 mL of *E. coli*, a combined UV – peroxyacetic acid (PAA) disinfection stage was included for all the three solutions. The UV treatment is made, for all the three solutions, by channel units sized for an end-of-life dosage of 26 mJ/cm^2, while the PAA dosage is considered with 2 mg/L concentration and 15 min contact time. The dosage of PAA is done before the UV channel to allow the observed activation of PAA by UV radiation [3].

The most significant treatment, for the feasibility of the whole project, is the removal of chlorides, which is examined in the following section.

Removal of chlorides. The WWTP effluent contains a considerable amount of dissolved solids, mainly chlorides. Some of these salts are already present in distributed primary water, but most of them are residue from some industrial activities (textile, food production and chemical sectors).

The amount of Cl^- ions originated by industrial activities was estimated by the following mass balance equation:

$$\sum_{i=1}^{3} Q_i C_i + Q_{\text{civ}} C_{\text{civ}} + P = C_{\text{out}} \cdot \left(Q_{\text{civ}} + \sum_{i=1}^{3} Q_i \right) \quad (1)$$

where:

$Q_1 = 550{,}000\ m^3/\text{year}$ (estimated flux from water mains)
$Q_2 = 1{,}850{,}000\ m^3/\text{year}$ (estimated flux from Sacco River)
$Q_3 = 4{,}850{,}000\ m^3/\text{year}$ (estimated flux from groundwater)
$Q_{\text{civ}} = 3{,}750{,}000\ m^3/\text{year}$ (estimated flus from urban wastewater)
$C_1 = 12$ mg/L (mean Cl^- concentration in water mains)
$C_2 = 22$ mg/L (mean Cl^- concentration in Sacco River)
$C_3 = 25$ mg/L (mean Cl^- concentration in groundwater)
$C_{\text{civ}} = 50$ mg/L (mean Cl^- concentration in urban wastewater)
$C_{\text{out}} = 450$ mg/L (mean Cl^- concentration in the WWTP output)
P = chlorides residuating from industrial activities.

From (1) it can be derived that:

$$P = C_{\text{out}} \cdot \left(Q_{\text{civ}} + \sum_{i=1}^{3} Q_i \right) - \sum_{i=1}^{3} Q_i C_i - Q_{\text{civ}} C_{\text{civ}} \approx 4595\ \text{t/year}$$

The presence of chlorides in recyclable wastewater is reason of concern because they are unacceptable for most industrial activities and un-removable by ordinary treatments.

Since electro-dialysis cannot be effectively used for salt concentration under 300–500 mg/L and thermal treatments presents unaffordable energy costs, RO turns out to be the only feasible option thanks to the recent cost reduction due to the great development of this technology.

The blending with groundwater pumped from wells is a simpler option which allows a partial reuse of reclaimed wastewater. Both these solutions are presented in the following sections.

Dilution with supplemental groundwater. This simple option is allowed by the Italian general environmental law (Law Decree 152/2006) only if the dilution is aimed to allow the reuse of wastewater (the dilution of wastewater to be discharged is, conversely, forbidden).

The main advantage of this solution is the low cost, since no specific treatments are required and the pumping cost is minimal.

The main disadvantage is environmental, since the provision of supplemental groundwater reduces the availability of this limited resource for other uses.

The increase of Cl^- concentration in distribution water to 250 mg/L will also cause an increase in the WWTP effluent to be reclaimed. It can be estimated replacing, in the mass balance equation (1), the groundwater flux and concentration values with those of the reclaimed wastewater:

$$\sum_{i=1}^{2} Q_i C_i + Q_3 \cdot 250 + Q_{\mathrm{civ}} C_{\mathrm{civ}} + P = C'_{\mathrm{out}} \cdot \left(\sum_{i=1}^{3} Q_i + Q_{\mathrm{civ}}\right)$$

$$C'_{\mathrm{out}} = 550 \text{ mg/L}$$

$$C = C'_{\mathrm{out}} - C_{\mathrm{out}} = 100 \text{ mg/L} \quad \text{(expected concentration increase)}$$

The dilution ratio is determined by imposing two conditions:

- the recovered water can completely replace the supply from groundwater;
- the recovered water has a Cl^- concentration of 250 mg/L.

Analytically, these conditions are translated into the following equations:

$$\begin{cases} Q_r + Q_m = Q_3 \\ Q_r C'_{\mathrm{out}} + Q_m C_3 = Q_3 \cdot 250 \end{cases}$$

where:
Q_r = flux of reclaimed water;
Q_m = flux of groundwater used for blending.

The result is:

$$Q_r = \frac{(250 - C_3)}{(C'_{\mathrm{out}} - C_3)} \cdot Q_3 \cong 2{,}567{,}000 \text{ m}^3/\text{year}$$

$$Q_m = Q_3 - Q_r \cong 2{,}283{,}000 \text{ m}^3/\text{year}$$

Therefore, the dilution ratio between wastewater and reclaimed water is almost equal to 1 and the saved water resource percentage equals:

$$R_{\%} = \frac{Q_3 - Q_m}{Q_3} \cdot 100 \cong 53\%$$

Reverse osmosis (RO). The use of RO filtration in wastewater reclamation is increasing worldwide thanks to the reduction of costs coming from the development of this technology. In the treatment of brackish water, the newly available thin film composite membranes allow to reduce the required trans-membrane pressure (resulting in energy cost savings) and to increase the fouling and scaling control (resulting in longer membrane mean life).

The design value for brine concentration is probably the most important parameter affecting the fraction of treated wastewater to be effectively reclaimed and the sizing of the whole plant.

Brine disposal. From a law-compliance point of view, the disposal of the brine produced by RO plants is a topic problem, especially for plants located far from the sea, which is obviously the simplest and cheapest disposal site (off-shore marine disposal).

In this case, four possible options of brine disposal can be considered [4]:

- discharge into internal surface water, which is allowed if the salts concentrations of the brine comply with the required standards;
- underground injection, long used by refineries, which disposes the brine in selected underground sites whose impermeability prevents the pollution of groundwater resources;
- natural evaporation, carried out in open ponds by means of the solar radiation;

Table 1
Main features and test conditions of the adopted membranes

Model	Filmtec	BW 30-400/34i-FR	Nominal flux	J_V	40 m^3/d
Active surface	S_E	37 m^2	Rejection	R	99.5%
Test pressure	P	15.5 bar	Molar weight of dissolved solids	Avg MW	29.23 g/mol
Test NaCl concentration	C_{test}	2000 mg/L			

– thermal drying, used only when the high value of the dissolved solids makes allowance for the high required energy costs.

In the specific application the only feasible option is the disposal in the nearby Sacco River, since:
– the geologic structure does not present protected sites to be used for underground injection;
– the high market value of land doesn't allow an affordable provision of natural evaporation ponds;
– the thermal drying is not affordable for the excessive impact on the cost of reclaimed water.

This provision involves the compliance with the chloride concentration of 1200 mg/L required by the Italian environmental law for the discharge into surface water bodies which, in turn, involves the provision of a low recovery factor and thus a low ratio between recovered and treated water. The direct consequences are the implicit environmental guarantee over the risk of salination of the river and groundwater; some advantages in terms of plant simplification and cost reduction and, conversely, a reduced possibility of exploitation of the available wastewater.

Plant sizing. The RO stage has been sized following the Wa.T.E.R procedure of the United States Bureau of Reclamation [5] and tested with the ROSA 6.1 package [6]. Two solutions of RO treatment have been sized: option A, whose capacity equals the maximum distributed flow, and option B where the capacity equals the average daily distributed flow and the highest flows are allowed by specific compensation tanks.

The following operative parameters have been determined:
– feed flow of each filtration unit; bypass flow; permeate and brine flow;
– chloride concentration in permeate and brine;
– type and number of filtration modules and total filtration surface;
– required net driving pressure.

The main features and testing conditions of the adopted membranes are shown in Table 1.

The results of the sizing process are presented in Table 2 and show some significant aspects:
– in both the options, part of the input flow is bypassed so as to obtain the required chloride concentration of 250 mg/L in the reclaimed water;
– in both the options the calculated feed pressure equals 9 bar. This moderate value limits significantly the estimated energy costs.
– as already stressed, the brine concentration of chlorides was limited to 1200 mg/L to allow the discharge of brine in surface water (Sacco River).

5. Storage tanks

In option A, a flow which is higher than the average daily value is supplied by mean of specific compensation tanks to be adequately sized. Furthermore, a supplementary storage has to be provided for emergency and maintenance conditions in both the options.

Since both the WWTP outflow and the required distribution flow follow the same daily variation pattern, two compensation tanks are required in option A (Fig. 3): an input tank to compensate the variable WWTP outflow to the constant feed of the RO stage and an output tank to compensate the constant outflow of the RO stage to the variable flow required for the recovered water. The supplementary emergency storage is provided in the output tank for both the options.

Table 2
Sizing parameters of options A and B of RO stage

Option	Time span	Input flow (m^3/h)	Feed flow (m^3/h)	Output flow (m^3/h)	Required modules	Required surface (m^2)
A	0–24	1180	856	750	560	20,809
B	8–17	2172	1544	1400	1040	38,646
	17–8	558	396	360	256	9512

Fig. 3. Setup of input and output tanks for the reclamation stage.

The typical inflow and outflow daily patterns can be simplified in two constant values for daytime and nighttime. The typical values have been already shown in Table 2 (input and output flow).

For the day of maximum consumption of the last year a request of 18,000 m^3 was estimated.

The *compensation storages* required for option A were calculated by comparison between the integral diagrams of daily input and output volumes in the day of maximum consumption of the last year for both the input and output values. The calculation resulted in a requirement of 7150 m^3 for the input tank and 5850 m^3 for the output tank. No compensation storages are required for option B.

The supplementary *emergency and maintenance storage* was calculated, for both the options, so as to allow a stop of one of the two parallel lines of the RO plant for a maximum time of 8 h.

These hypotheses lead to the following results for the two options:

$$V_{\text{emerg}} = \frac{750 \times 8}{2} = 3000\ \text{m}^3 (\text{option A})$$

$$V_{\text{emerg}} = \frac{1400 \times 8}{2} = 5600\ \text{m}^3 (\text{option B})$$

No specific storage was provided for firefighting purposes since private firefighting water storage tanks are already available for all the served factories.

The calculated compensation and emergency storage volumes of the input and output tanks for options A and B are summarized in Table 3.

The input storage for option A will be an open basin sealed with polyetilene liner, while the output storage will be a closed reinforced concrete tank for both A and B options.

6. Cost analysis

The estimation of reclamation costs is the topic issue of every wastewater reuse project, since the final cost of the distributed water, to be compared among all the available source options, is the main feasibility criterion. The estimation included the following issues:

Capital costs:
- civil construction works;
- mechanical and electrical equipment; instrumentation;
- hydraulic and electrical connections among the treatment stages;
- land acquiring costs;
- overhead costs (taxes 20%, technical expenses 12%), unforeseeable costs 10%);

Operation and maintenance (O&M) costs:
- technical and administrative staff;
- electrical energy costs;
- required reagents and chemicals;
- disposal of produced sludge, scum and leftovers;
- ordinary and extra-ordinary maintenance of civil works and equipment.

The sum of the yearly O&M costs (CTE_i) and capital amortization costs (OACC_i) of all the treatment stages, divided by the yearly recovered water volume gives the total unitary cost of water (CTU) which usually represents the most used comparison parameter among different options.

The following expression was used to calculate the yearly amortization rate of capital costs:

$$a_n = \frac{i \cdot (1+i)^n}{(1+i)^n - 1} \cdot C_{0i}$$

Table 3
Summary of storage volumes for input and output tanks in options A and B

Option	Tank	Compensation (m^3)	Emergency (m^3)	Total (m^3)
A	Input	5850	0	5850
	Output	7150	3000	8150
B	Input	0	0	0
	Output	0	5600	5600

Table 4
Capital and running costs of dissolved air flotation (DAF) unit

Capital costs	Option A (€)	Option B (€)	Running costs	Option A (€)	Option B (€)
DAF unit	123,400	192,300	Electric energy	27,419	37,068
			Chemicals	63,050	63,050
Total	**123,400**	**192,300**	**Sludge disposal**	**32,387**	**32,387**
Yearly amortization	**12,290**	**19,158**	**Total**	**122,856**	**132,505**

where:
i = yearly interest rate interest (5.5%);
n = expected duration of each part (15 years for equipment and 30 years for civil works);
C_{0i} = capital cost of each part.

The final *CTU* value of the overall plant is calculated as:

$$\mathrm{CTU} = \frac{\sum_i \mathrm{OACC}_i + \sum_i \mathrm{CTE}_i}{V_{\mathrm{inf}}} \quad (2)$$

where V_{inf} is the yearly treated volume (m^3/year).

The estimated capital and running costs for DAF, RO, disinfection and tanks are reported, respectively, in Tables 4–7, with the yearly amortization values of the capital costs.

Basing on these values, the total unitary cost of water can be calculated with Eq. (2). The final costs (unitary water cost and initial investment) for the two options of RO and for the blending with supplemental groundwater are presented in Table 8 with the main design data.

7. Conclusions

The presented case study demonstrates that the effluent of an industrial WWTP in central Italy can be exploited as non-conventional water source for the needs of the industrial district itself. The exploitation of this source could save the limited available resources for other privileged uses like drinking water or irrigation.

Table 5
Capital and running costs of reverse osmosis (RO) unit

Capital costs	Option A (€)	Option B (€)	Running costs	Impianto A (€)	Impianto B (€)
Membranes	385,392	71,5728	Electric energy	364,286	275,238
Skid units	321,160	59,6440	Staff	160,764	160,764
Civil constructions	311,999	58,2529	Membrane replacement	128,464	126,176
Electric plant	223,070	334,567	Chemicals	36,240	35,593
Instruments	536,796	954,304	Filters replacement	61,182	57,783
High pressure pumps	320,907	570,502	General maintenance	12,554	22,315
Piping	288,472	538,194	Insurance fees	5022	8926
Preliminary filters	61,483	109,303	Laboratory costs	79,281	140,943
Membrane cleaning system	61,479	61,479			
Total	**2,510,758**	**4,463,047**			
Yearly amortization	**250,136**	**444,634**	**Total**	**847,792**	**827,733**

Table 6
Capital and running costs of disinfection unit

Capital costs	Option A (€)	Option B (€)	Running costs	Option A (€)	Option B (€)
UV and PAA disinfection plant	100,000	184,000	Electric energy	5520	11,038
			Reagents and chemicals	8672	17,345
Total	**100,000**	**184,000**	Maintenance and replacements	33,627	33,627
Yearly amortization	**9962**	**18,330**	**Total**	**47,818**	**62,010**

Table 7
Capital and running costs of tanks

Capital costs (input open tank)	Option A (€)	Option B (€)	Running costs	Option A (€)	Option B (€)
Land acquiring	32,480	0 €	Civil works maintenance	1815	1375
Excavation	16,731	0 €	Piping maintenance	3024	2293
Sealing (HDPE liner + geonet)	28,893	0 €	maintenance of Equipment and instruments	12,100	9171
Capital costs (output closed tank)	Option A (€)	Option B (€)			
Excavations	193,586	146,745			
Concrete	157,288	119,230			
Iron reinforcement	169,387	128,402			
Equipment and instruments	12,099	9172			
Civil workmanship	72,595	55,029			
Total	**683,099**	**458,577**			
Yearly amortment	**46,998**	**31,553**	**Total**	**16,939**	**12,839**

Table 8
Summary of main design data and costs

		RO option A	RO option B	Dilution
Q_{max} DAF	m^3/h	1180	2172	741
Q_{max} RO feed	m^3/h	856	1544	–
Q_{max} permeate	m^3/h	426	772	–
Q_{max} disinfection	m^3/h	750	1400	741
Q_{max} dilution	m^3/h	324	628	659
Q_{max} distributed	m^3/h	1400	1400	1400
Q_{max} brine to be disposed	m^3/h	430	772	
W input tank (open basin)	m^3	5850	–	–
W output tank (closed)	m^3	8150	5600	5600
Total unitary cost	€/m^3	0.279	0.319	0.061
Initial investment	€	3,417,000	5,298,000	658,000

There are not technological problems to reach the required quality standards. However, the cost of treatment (especially for the removal of chlorides) represents a significant limitation.

Comparing the two studied options of RO, the one which includes a lower capacity and two dedicated compensation tanks turned out to be significantly cheaper.

The unitary cost of reclaimed water (about 0.3 €/m^3) is affordable and lower than that of drinking water distributed in the same district (0.6–0.7 €/m^3), but higher than the costs of bare pumping of groundwater currently paid by the involved factories.

The option of blending with supplementary groundwater is an interesting transitory option which allows to halve the present withdrawal with a negligible increase of cost (from 0.05 to 0.06 €/m^3).

The option of complete treatment can only be pursued by establishing fare policies (rates or incentives) which take into right account the externalities of the industrial activities.

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