ELSEVIER

Desalination 185 (2005) 275–280

DESALINATION

www.elsevier.com/locate/desal

Zero discharge utilization of saline waters from "Wesola" coal-mine

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Received 28 February 2005; accepted 10 March 2005

Abstract

A conception of comprehensive utilization of saline waters from "Wesola" coal-mine was proposed. There the water from level 665 m, that contains about 35.45 g/L Cl^-, is pretreated by nanofiltration (NF) and then evaporated in twig towers while the water from level 465 m of about 2.25 g/L Cl^- content is desalinated and simultaneously concentrated by electrodialysis (ED) with univalent permselective membranes. Partially evaporated twig tower brine and ED concentrate undergo further thermal evaporation to NaCl concentration up to 300 g/L and then evaporation with salt (NaCl) crystallization. The NF retentate and post-crystallization lyes are mixed with power station ashes and applied as a hydraulic filling in the mine. The profitability of comprehensive utilization was also estimated. The value of evaporated salt produced ($1.68 million per year) was found to be close to the total cost of utilization ($1.71 million per year). The decrease of charge paid for chloride and sulfate discharge (estimated as $3.45 million per year) was then considered as the utilization benefit, resulting in high economical efficiency of the proposed conception.

Keywords: Desalination; Salt production; Electrodialysis; Nanofiltration; Evaporation; Twig tower; Integrated systems; Zero discharge technologies

1. Introduction

In Poland, most of the saline mine waters are directly discharged into rivers (mainly into the Vistula river) causing many ecological problems and greatly decreasing the coal mine profits because a high penalty for the discharge of chloride and sulfate ions has to be paid. Thus, a decrease in salt discharge is the main goal of mine water policy. Much research and analysis of the mine water question has led to the conclusion that saline mine water utilization

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Presented at the Conference on Desalination and the Environment, Santa Margherita, Italy, 22–26 May 2005. European Desalination Society.

doi:10.1016/j.desal.2005.03.082

is the only rational way for solving the above described problems [1,2].

Currently, the "Debiensko" plant, the only coal-mine waters utilization plant operated up to now, processes the untreated waters, which results in gypsum crystallization in the evaporation step and in many problems related to high magnesium content in the salt crystallization stage. To overcome these problems, a high-energy consumption evaporation method that tolerates gypsum crystallization, as well as crystallizer operating under low salt recovery conditions, are applied, causing low economical efficiency in the aforementioned plant [1,3,4].

At the "Wesola" coal-mine part of the saline mine waters is deposited underground together with the power station ashes as hydraulic filling to decrease the charge paid for chloride and sulfate ions discarding. The amount of such utilized saline water is however limited by the mining void capacity [5].

2. Wesola coal-mine water question

The prognosis of the "Wesola" coal-mine wastewaters quantity and its salinity for the 2005–2015 period are presented in Table 1. There it can be clearly seen that a significant reduction in the amount of salt discharged may be achieved only by the utilization of 665 m level waters, since most of the chlorides and sulfates (about 84%) originate from this mine level.

The estimated volume of waters, which might be deposited in the mines with power station ashes, is 500 m^3/d, which is about 6-times lower than the amount of water which should be utilized. Moreover, utilization of 465 m level waters, with their 15.1% of the total salts charge, should be also considered. Therefore the reduction of these waters volume by its concentration is necessary. The feasibility of twig tower evaporative concentration of 665 m level waters was examined at "Wesola" demonstration plant [5]. The yearly average power consumption was equal to 4.22 kWh per 1 m^3 of distillate (the energy required for brine pumping and recirculation) while the unit cost of evaporation was estimated to be ca \$0.75/m^3. It was however found that the twig power productivity decreases with salt concentration and is limited to ca 9–10 % of total salinity. This limitation is the result of low vapor pressure over $CaCl_2$ and $MgCl_2$ containing saline waters: the relative humidity of NaCl saturated solution is equal to 75 % (at 25 °C) while the relative humidity of $CaCl_2$ and $MgCl_2$ solutions are equal to, respectively, 29 and 33 % only [6]. The ability of up to 2-fold concentration (from ca 5 % to 10 %) only in the "Wesola" twig tower demonstration plant was then proved thus further evaporation is necessary. The performance of the twig tower might be also improved by prior saline water pre-treatment (softening).

Table 1
The quantities of mine wastewaters and their salinity predicted for 2005–2015 period

Mine level (m)	Amount (m^3/d)	Concentration (g/L)		Charge of Cl^-&SO_4^{2-}	
		Cl^-	SO_4^{2-}	t/year	fraction (%)
230	3600	0.100	0.300	525.6	1.1
465	7100	2.25	0.524	7,188.8	15.1
665	3050	35.5	0.408	39,974.6	83.8
Total	13750	—	—	47,689.0	100.0