Circular Economy Approach in the coal mine sector: Innovative technologies for clean water and high purity salt recovery from coal mine brine

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Introduction

Coal mine wastewater is a very saline effluent, and it is sometimes characterized by salinity even higher than that of seawater. Its discharge in the environment results in the salinization of soil and water bodies, the disruption of the aquatic ecosystem, and the hindering of water utilization in the agricultural, municipal and industrial sectors (Belmer et al., 2014). The current method of treatment is its purification through sedimentation in technical lagoons. However, it appears that this treatment is not effective, as the salinization of soil and water bodies in nearby areas has been recorded. The project demonstration system has been designed and constructed for the desalination of coal mine effluents, with direct recovery of high-purity water for industrial and irrigation purposes and valuable salts.

Materials and methods

The Brine-Mining demonstration system comprises membrane, precipitation, and thermal technologies to remove ions of sodium (Na), chloride (Cl), calcium (Ca), magnesium (Mg), and sulfates (SO_4) for the purification of coal mine wastewater. Three Precipitation Reactors were used for the recovery of magnesium, calcium ions and sulfates ($Mg(OH)_2$, $CaCO_3$, $CaSO_4$), while three membrane technologies (Nanofiltration, Electrodialysis, and Reverse Osmosis) were utilized to recover water and further concentrate the saline solution. Thermal units (MED evaporator, Crystallizer, Dryer) turned concentrate saline solution into valuable NaCl salt and high-purity water. The pilot system, with a potential capacity of 0.8 m^3/h of brine, was installed in the Ziemowit mine, in South Poland, and operated for 18 months, treating a saline effluent with 8% total dissolved solids content (TDS) (Figure 1).

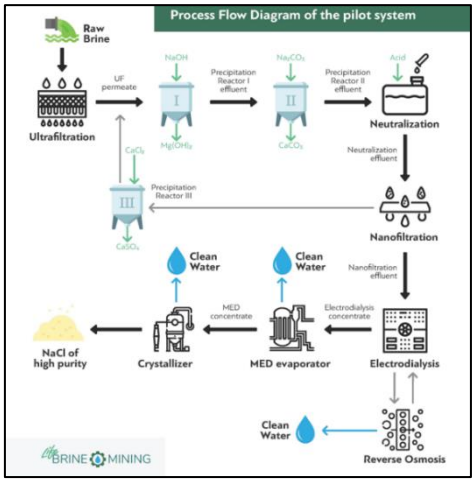

Figure 1: The process flow diagram of the Brine-Mining pilot system, treating coal mine wastewater

Results and discussion

The results of the analysis showcased that the quality of the water recovered from the pilot system matches the quality standards of potable water exhibiting comparable levels of conductivity, as well as concentrations of the various ions (Table 1). However, since this water comes from mining activities, its use can be restricted in agriculture and industry. From the three Precipitation Reactors and the

Crystallizer, salts of high-quality were recovered. Table 2 demonstrates the quantities of salts recovered per hour, while Table 3 demonstrates the recovery of ions from the project pilot system.

Table 2: Water quality analysis from the three units of the pilot system that recover water: RO, MED evaporator, and Crystallizer, compared to the EU drinking water standards

Quality of the recovered water from the BM pilot system

	Reverse Osmosis	**MED Evaporator**	**Crystallizer**	**Overall water quality from the BM pilot system**	**Drinking water standards (Council Directive 2020/2184)**
Ions	Concentration (mg/L)	Concentration (mg/L)	Concentration (mg/L)	Concentration (mg/L)	Concentration (mg/L)
Na	135.1	22.5	62.9	90	200
K	1.5	0.10	0.1	0.75	12
Mg	0.2	3.69	5.1	2.64	-
Ca	0.3	3.50	4.3	2.37	-
Cl	244.9	49.4	116.5	165.37	250
SO_4	3.3	2.00	3.0	2.98	250
B	0.03	-	0.0	0.02	1.5
Si	0.02	-	0.0	0.01	-
TDS	385	81.2	192.0	264.1	-
Cond. (µS/cm)	601.9	130	300.0	420	2,500

Table 2: Salts production in the Brine-Mining plant

Salts production		
$Mg(OH)_2$	3.79	kg/h
$CaCO_3$	4.63	kg/h
$CaSO_4$	3.08	kg/h
NaCl	72.08	kg/h
Total	**83.58**	kg/h

Table 3: Recovery of ions in the Brine-Mining plant

% Recovery of ions in the plant	
Mg^{+2}	83.8 %
Ca^{+2}	90 %
SO_4^{-2}	41.5 %
Na^{+}	99.9 %
Cl^{-}	99.9 %

Conclusion

Brine-Mining directly addresses the EU goal of transitioning to a circular economy model. By recovering high-purity water and valuable salts from coal mine wastewater, the project promotes a closed-loop material cycle. The project pilot system recovered 83.58 kg/h salts and 776.85 L/h high-purity water. From a wastewater with no use, Brine-Mining succeeded in recovering clean water suitable for irrigation or industrial use, or for internal use, and marketable salts that can be exploited by other industries. This way, the mine has the chance to close the loop in coal mine wastewater management and also increase its revenues from the exploitation of the valuable salts it recovers.

References

Belmer, N., Tippler, C., Davies, P. J., & Wright, I. A. (2014). Impact of a coal mine waste discharge on water quality and aquatic ecosystems in the Blue Mountains World Heritage area. *Authors Names*, *2014*, 1–7.