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Short Communication

Potential mining of lithium, beryllium and strontium from oilfield wastewater after enrichment in constructed wetlands and ponds

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HIGHLIGHTS

- Produced water of oil industry is a source for rare earth elements.
- Wetlands can be used for mining of rare earth elements.
- A considerable monetary worth can be gained by use of the proposed technique.

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ABSTRACT

Shortages of resources (chemical elements) used by growing industrial activities require new techniques for their acquisition. A suitable technique could be the use of wetlands for the enrichment of elements from produced water of the oil industry. Oil industries produce very high amounts of water in the course of oil mining. These waters may contain high amounts of rare elements. To our best knowledge nothing is known about the economic potential regarding rare element mining from produced water. Therefore, we estimated the amount of harvestable rare elements remaining in the effluent of a constructed wetland-pond system which is being used to treat and evaporate vast quantities of produced waters. The examined wetland system is located in the desert of the south-eastern Arabian Peninsula. This system manages 95,000 m^3 per day within 350 ha of surface flow wetlands and 350 ha of evaporation ponds and is designed to be used for at least 20 years. We found a strong enrichment of some chemical elements in the water pathway of the system (e.g. lithium up to 896 $\mu g\ L^{-1}$ and beryllium up to 139 $\mu g\ L^{-1}$). For this wetland, lithium and beryllium are the elements with the highest economic potential resulting from a high price and load. It is calculated that after 20 years retention period 131 t of lithium and 57 t of beryllium could be harvested. This technique may also be useful for acquisition of rare earth elements. Other elements (e.g. strontium) with a high calculated load of 4500 tons in 20 years are not efficiently harvestable due to a relatively low market value. In conclusion, wetland treated waters from the oil industry offer a promising new acquisition technique for elements like lithium and beryllium.

1. Introduction

The problem of shortages in metals, metalloids and especially rare earth elements for commercial products is increasing worldwide (Feltrin and Freundlich, 2008; Hong, 2006). At the same time more and more alternative techniques are used to exploit the required elements. In the course of oil drilling and extraction very high amounts of water are lifted to the earth surface (Cheryan and Rajagopalan, 1998). After oil separation, the remaining wastewater is known in the oil industry as "produced water". These waters often contain high amounts of chemical elements such as metals, metalloids and rare earth elements (Afkhami et al., 2013; Fiedler et al., 2009). There are several techniques for managing these waters e.g. ultrafiltration (Asatekin and Mayes, 2009). One of them is deep well disposal or re-injection in which the produced water is pumped back to the oil reservoirs or deep aquifers, consuming high amounts of energy which in turn results in high costs and high CO_2 emission (Din et al., 2009). Alternative commonly used techniques for water treatment in general are precipitation, co-precipitation or pH manipulation (Fu and Wang, 2011).

Another technique known for its low operating costs is the use of constructed wetlands. Such an approach was implemented by BAUER in 2010 in the desert of the south-eastern Arabian Peninsula. The Produced Water Treatment Plant (PWTP) uses 350 ha of surface flow wetlands to degrade residual hydrocarbons after oil separation and reduce the water volume through evapotranspiration, followed by a 350 ha series of evaporation ponds to evaporate the treated water that is not reused, with salt being the final residue at the end of the system. This wetland treatment plant is designed to operate for a minimum of

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20 years and treats 95,000 $m^3\ d^{-1}$ of produced water and functions primary as a zero liquid discharge system (i.e. no outflow). Nothing is currently known about the possible elemental harvest from such a water treatment plant to our best knowledge. However, resulting from moderate to high element concentrations in the water and vast quantity of received water, a high element accumulation within this system is expected. Consequently, we tried to determine the potential harvest sites and conducted a screening trial to identify elements present in potentially harvestable quantities over a 20 year operating period at the water treatment plant. Our hypothesis is that a high amount of rare elements can be potentially harvested from the evaporation ponds of the water treatment plant.

2. Material and methods

2.1. The Produced Water Treatment Plant

The oilfield is located in the south eastern part of the Arabian Peninsula and the oil deposit is found at a depth of about 3000 m. The water is traditionally managed after oil separation by deep well disposal underground. 95,000 $m^3\ d^{-1}$ is treated at the PWTP. The system was commissioned in early 2011 and run by BAUER. The PWTP is primarily designed as a zero-discharge system and consists of a constructed wetland which enhances the evapotranspiration by using plants with a high transpiration rate (e.g. common reed, *Phragmites australis* Cav. (Trin.) ex Steud.). The influent of produced water (PW) is treated by an oil separator and afterwards flows into an inlet distribution and buffering pond (BP) (Fig. 1). In the next step the water flows from the buffer pond into a 350 ha surface flow wetland (SFW) system divided into nine parallel streams, each with four wetland cells in series. Each SFW cell has a size of 9.75 ha. From the SFW the water enters a collection channel (CC) from where some water is extracted and reused for purposes such as irrigation and drilling water. Thereafter, the water flows into a 350 ha series of evaporation ponds (EP) where the remaining water is evaporated with salt being the final residue (Fig. 1). The whole system covers an area of more than 700 ha. The substrate layer used for the system is the onsite predominating laterite soil.

Conductivity and temperature (95 Lf, Fa WTW) as well as pH value (Electrode: Mettler Toledo INLAB 414, unit: Delta 320, Germany) was measured directly (DIN-EN-27888, 1993) in the outlets of each reed bed/buffer pond/collecting channel or within the evaporation ponds. The produced water entering this wetland has a conductivity of about 11 mS cm^{-1} and a pH of 7.9. pH values increased within the system to more than 9. Dissolved oxygen measured by Oxi-320 (WTW, Weilheim, Germany) at the inflow is low (0.4 mg L^{-1}) and increases within the system up to 10 mg L^{-1}. The conductivity increased along the whole

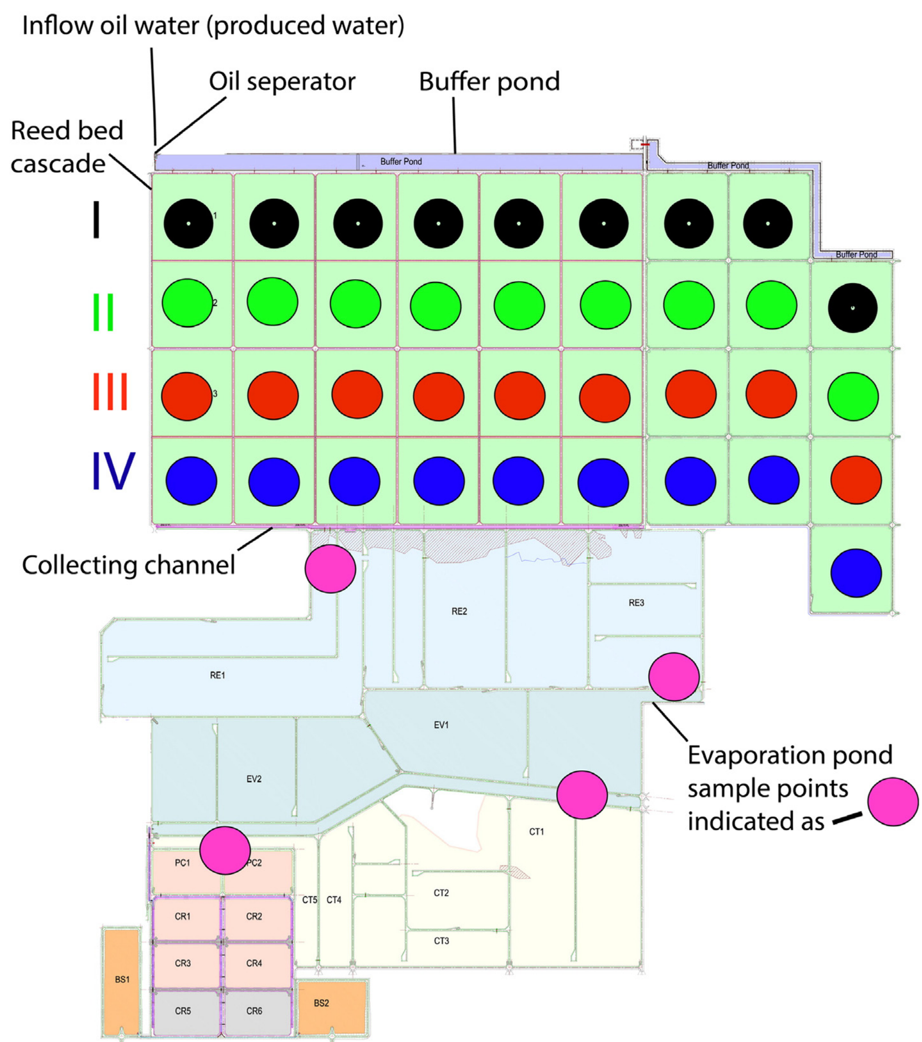

Fig. 1. Overview of Produced Water Treatment Plant and locations of water sampling within the reed bed, buffer pond and collecting channel samples, and evaporation ponds. Sampling points are figured as dots of different color. The water flow within the evaporation ponds is from RE1 to RE3, followed by EV1 and EV2, CT1 to CT5, PC1 and PC2 to the last ponds (CR1–CR6) where the elements can be harvested.