Membrane processes including reverse osmosis (RO) have been widely adopted for water treatment and reuse [4] and it has been employed to purify condensates across various industries, including ammonium nitrate production [5], pharmaceuticals [6], beverages [7, 8], and others.

Purification of Acidic Condensate Using Reverse Osmosis Test Unit

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INTRODUCTION

Many industrial processes generate contaminated liquid streams that must be treated before sewage discharge to remove pollutants in order to meet sustainability standards, protect public health and the environment.

Due to advances in membrane technology, reverse osmosis (RO) has become a cost-effective method for water treatment, widely used in various industries, such as fertilizer, pharmaceuticals, and beverage.

This study, being part of the EU Horizon 2020 iWAYS project ("Innovative WAter recoverY Solutions"), focuses on purifying diluted but still highly acidic condensate (pH ≈ 2.2) formed during the condensation of simulated humid industrial gas at 200–250 °C in the economizer. The HCl-containing condensate was collected using a corrosion-resistant condensing economizer made of alloys 400, 904L and stainless steel 304L.

METHODS AND MATERIALS

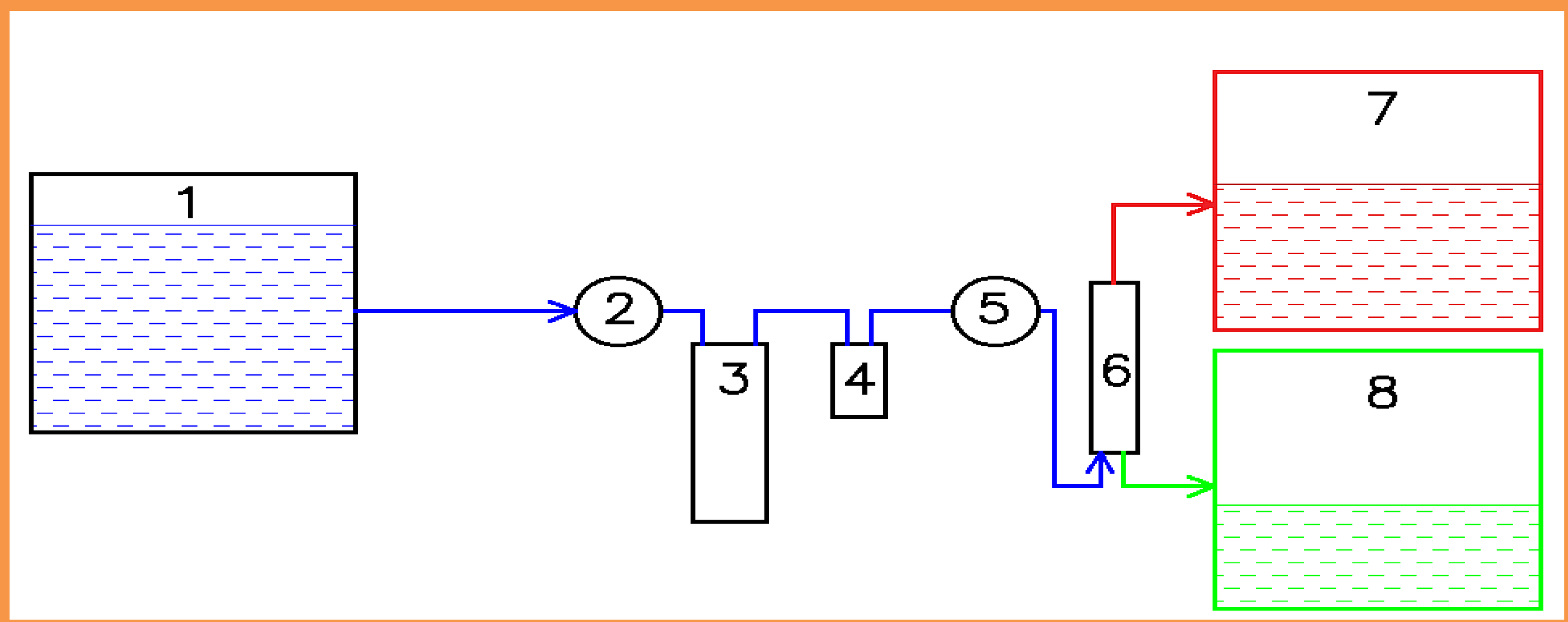

Figure 2. Scheme of the reverse osmosis test unit: 1) tank with diluted condensate, 2) feed pump, 3) quartz filter, 4) mechanical filter, 5) high-pressure pump, 6) RO membrane, 7) tank for concentrate, 8) tank for permeate

The HCl-containing condensate, along with corrosion products from the economizer piping, was treated using a lab-scale multi-stage filtration test unit with a reverse osmosis (RO) membrane (see Fig.1).

This process generated two streams: concentrate and permeate. The pH, electrical conductivity (EC), and metal concentrations of the feed (i.e. diluted condesate), concentrate, and permeate were measured during this study.

pH was measured with a Hanna HI98191 meter (range: -2 to 20, accuracy: ±0.002 pH). A refillable glass electrode was used for the acidic conditions.

EC was measured with a Thermo Orion™ Star A222 meter (range: 0.001 µS/cm to 3000 mS/cm, accuracy: 0.5%).

Metal concentrations were analyzed using a PerkinElmer Optima 7000 DV ICP-OES system.

RESULTS AND DISCUSSION

Samples of the diluted condensate (before RO treatment), as well as the resulting permeate and concentrate (after RO treatment), were collected to measure pH, electrical conductivity (EC) and dissolved metal concentrations from the economizer's internal surfaces.

Results before RO treatment (diluted condensate):

- pH ≈ 2.20;
- EC = 5.59 mS/cm.

Results after RO treatment:

- Concentrate: pH ≈ 2.15, EC ≈ 3.49 mS/cm;
- Permeate: pH = 2.82, EC = 0.67 mS/cm.

Comparison of pH values shows a slight decrease in the concentrate pH, while the permeate pH increased more noticeably—from 2.20 to 2.82—indicating reduced acidity, though it still remained acidic. This change suggests that some acidic components were retained in the concentrate, while the permeate has became slightly less aggressive.

Before the treatment, the EC of the diluted condensate was 5.59 mS/cm. After the treatment, the EC in the concentrate decreased by about 1.6 times, while in the permeate it dropped approximately six times.

Metal concentrations (in ppm) before and after treatment are shown in Fig. 2. Notably, Fe, Ni, Cr and Cu were present in higher amounts before the treatment, suggesting these metals were leaching from the economizer pipes' surfaces.

After the treatment, metal concentrations in the concentrate increased by about 5–15% compared to the original diluted condensate, with the most notable rise in Ni, Fe, Cr and Cu (Fig. 2a). In contrast, the permeate (Fig. 2b) showed a sharp decrease in metal concentrations for all metals until the values between 0.03 and 0.05 ppm.

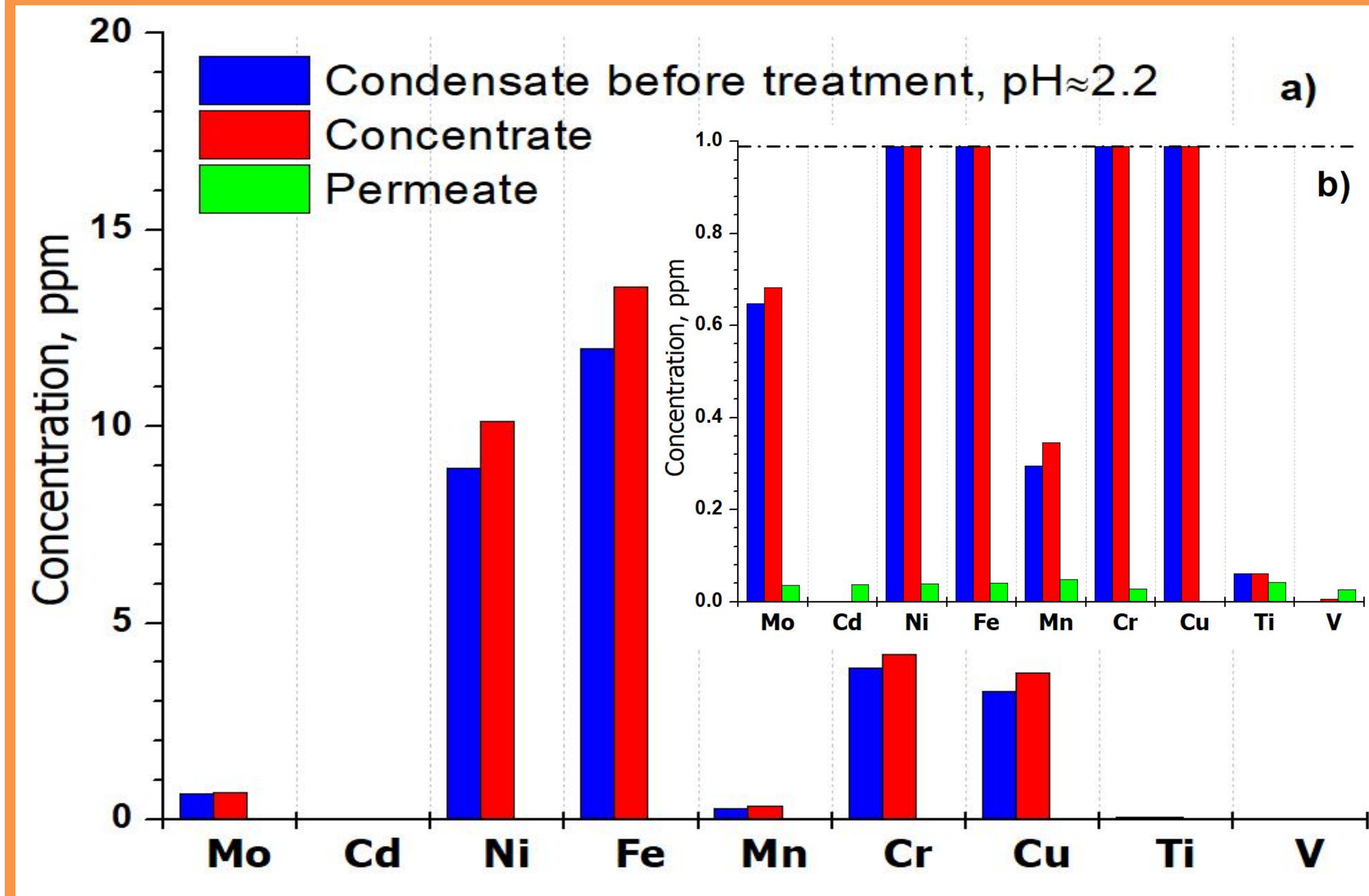

Figure 2. Concentrations of metals in the case of diluted condensate with pH ≈ 2.2 before and after treatment with the RO test unit. Small scale (a), large scale (b)

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