

18. Production of Mineral Water at Various High Concentrations from Deep Sea Water by Flexible Operating Freeze Concentration Apparatus

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This research was presented last year. However, the presentation content was unclear. Accordingly, we have reviewed this research.

1. Introduction

1.1 Concentration of DSW

Deep Sea Water (DSW) has abundant nutrients and good water quality that is stable and pathogen-free. Also, seawater including DSW contains all major and micro essential minerals necessary for humans, and its minerals balance is close to that of humans. Therefore, seawater could be the best supply-source for natural essential minerals. However, in order to promote the use of DSW, existing technologies for concentrating DSW are non-flexible operating apparatuses, and cannot easily and quickly obtain various (high) concentration solutions for applications or transportation.

Further, the existing technologies have the following problems:

- Markedly decreases Ca-mineral ion concentration for crystalizing CaSO₄, e.g., evaporation.
- Cannot concentrate to high concentrations, e.g., membranes.
- Changes the relative proportions of each mineral-ion, e.g., membranes and evaporation.
- Consumes large amounts of energy, e.g., evaporation.
- Has High initial costs, e.g., using high-cost corrosion-resistant materials.

1.2 Properties of freeze concentration

Freeze concentration of seawater has the following properties:

- Increases Ca-ion concentration during the concentration: Umano et al. (1958) indicated that the concentration of seawater (salinity: 3.5wt%, Ca-ion concentration: 0.042wt%) by freezing crystallizes Na₂SO₄ from salinity (9.8wt%), Ca-ion concentration (0.17wt%) and freezing point (-6°C), and Moreover with decreasing temperature and increasing salinity, the Na₂SO₄ crystals increase and CaSO₄ crystals do not appear, and therefore the Ca-ion concentration increases.
- Does not change the relative proportions of each mineral-ion during the concentration.

- Is an energy saving technology which the latent heat of solidification is about 1/7 that of evaporation. However, existing freeze-concentration apparatuses for high concentrations have complicated structures and operations, and therefore cannot flexibly operate and have very high initial costs.

2. Freeze Concentration Apparatus of this Research

This research apparatus comprises a cooled-rotating cylindrical ice generator and a scraping-blade centrifuge separator (Jpn Pat App. 2017-255358). The ice generator produces an ice-concentrate mixture and the separator separates the ice and concentrate.

This apparatus has the following properties:

- Enables flexible operation, and can easily and quickly obtain arbitrary concentrations and operate intermittently.
- Concentrates to high concentrations.
- Has a low initial cost.

Through experiments of this research apparatus, concentrate salinities of 8.9 to 15.9wt% were obtained from mother seawater salinities of 3.1 to 5.4wt%. In addition, a solute recovery rate of 86% was obtained.

Further, this apparatus can obtain concentrate salinities of 20wt% (Ca-ion concentration: 0.24wt%) or more by additional treatments of the concentrates under different operating conditions, for example the cooling temperature of the ice generator.

3. Use of this Apparatus at DSW Companies

DSW companies have reverse-osmosis (RO) and electric-dialysis (ED) membrane-equipment. Combining the RO equipment with this research apparatus can enable the use of the DSW-concentrate waste (salinities < 6wt%) from the RO equipment, saving the production energy of mineral concentrates. On the other hand, combining the ED equipment with this research apparatus can produce mineral concentrates of Ca/Mg ratio = 1 - 2, which is excellent for the regular use of humans.