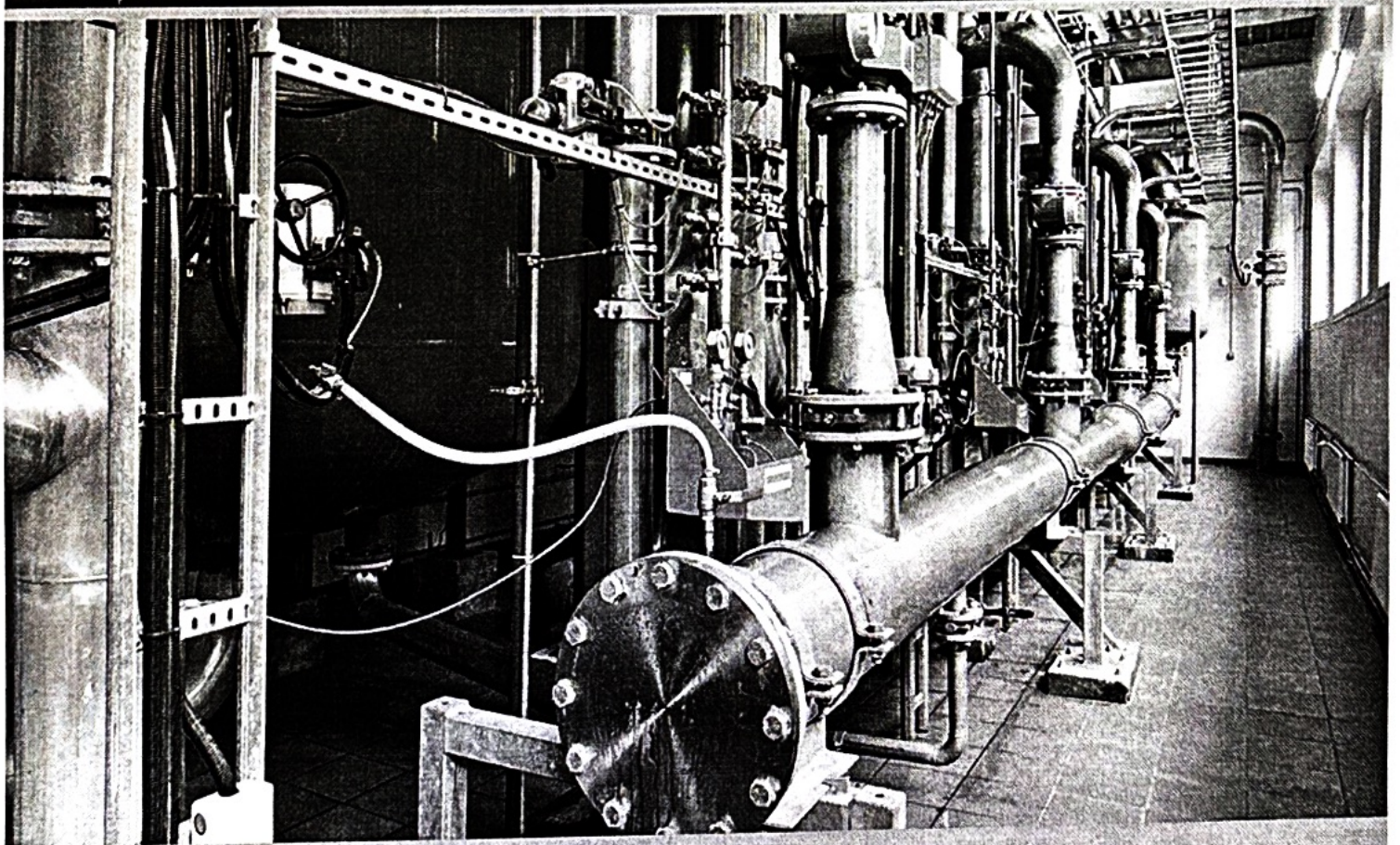


# Resource Recovery in INDUSTRIAL WASTE WATERS



*Edited by* Mika Sillanpää, Ali Khadir, Khum Gurung



# Resource Recovery in Industrial Waste Waters

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# Vanadium in industrial wastewater: a study on methods implicated for their removal and recovery

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## Abbreviations

|                                    |                                    |
|------------------------------------|------------------------------------|
| °C                                 | degree Celsius                     |
| BrF <sub>3</sub>                   | bromine trifluoride                |
| BW                                 | bodyweight                         |
| CaCl <sub>2</sub> -HCl             | calcium chloride–hydrochloric acid |
| Cl <sup>-</sup>                    | chloride                           |
| Cr <sup>3+</sup>                   | chromium                           |
| DNA                                | deoxyribonucleic acid              |
| DW                                 | dry weight                         |
| g                                  | gram                               |
| gm/cm <sup>3</sup>                 | gram per cubic centimeter          |
| GPa                                | gigapascal                         |
| H <sub>2</sub> O                   | water                              |
| J kg <sup>-1</sup> K <sup>-1</sup> | joule per kilogram per kelvin      |
| L                                  | liter                              |
| M                                  | molar                              |
| Mg/Al                              | magnesium/aluminum                 |
| mg/g                               | milligram per gram                 |
| mg/L                               | milligram per liter                |
| mg/L · d                           | milligram per liter in a day       |
| mL                                 | milliliter                         |
| mm                                 | millimeter                         |

\* Both authors have contributed equally to this work.

|                      |  |
|----------------------|--|
| <b>N<sub>2</sub></b> | nitrogen                                 |
| <b>NaOH</b>          | sodium hydroxide                         |
| <b>pm</b>            | picometer                                |
| <b>RNA</b>           | ribonucleic acid                         |
| <b>rpm</b>           | revolutions per minute                   |
| <b>V(II)</b>         | Vanadium with oxidation state in bracket |
| <b>µg/L</b>          | microgram per liter                      |

## 23.1 Introduction

Vanadium, a greyish metallic element with atomic number 23, is placed at period 4, block d in group 5 of the periodic table. Vanadium comes from the name “Vanadis,” the name of the Scandinavian goddess “Freyja” known for beauty, love, and fertility. Vanadium in metallic state possesses an electronic configuration of [Ar]3d<sup>3</sup> 4s<sup>2</sup>, with V(II), V(III), V(IV), and V(V) as their most usual oxidation states. Vanadium is abundantly present in soil, water, and atmosphere, with an abundance of nearly 0.019%. It is considered to be the 5th in abundant transition element existing in soil and the second most abundant transition metal in the ocean (Awan et al., 2021). The potable water has vanadium concentration of around 10 nM at the volcanic zones. The concentration of vanadium in the human body remains the same with continuous vanadium consumed and excreted on daily basis. Vanadium is present in various marine microalgae at the active site of haloperoxidase enzyme and is also found in medicinal plants like wild thyme. The geochemical properties of vanadium depend on its oxidation state and its pH. Vanadium was first discovered by Andrés Manuel del Río (Escamilla-Gonzalez and Morelos-Rodriguez, 2020), but at that time the French Chemical Society considered it as impure chromium. Later, vanadium was identified in 1830 by Sefstrom in Tabrez mines, Sweden.

Vanadium does not exhibit particular risk to human health in pure metal or alloy form. On the other hand, it violently reacts with certain materials like chlorine, lithium, BrF<sub>3</sub>, and with few strong acids. Powdered form of vanadium has a moderate risk of fire, certain vanadium compounds are found to cause mucosae irritation, and the continuous long exposure may lead to pulmonary-level complications. The daily intake of vanadium for human is between 0.01 and 0.02 mg (Rehder, 2020). The vanadium intake within a safe range via water or nutrient absorption is beneficial while excessive vanadium intake through breathing or other activity is supposed to be toxic. The occupational-determined exposure limit to vanadium gases and dusts is 0.05 mg/m<sup>3</sup> per 8-h shift, decided by the National Institute for Occupational Safety and Health (NIOSH, 2019) and the American Conference of Governmental Industrial Hygienists (OSHA, 2011). Transferrin and albumin are the transporters of vanadium oxide ions in the bloodstream (Rehder, 2020).

According to Pearson’s theory, vanadium ions during the natural evolution process are incorporated in living systems, serve in multiple biological processes at the physiological level, and are thus considered as a biological interest. Vanadium is present in the active site of haloperoxidase and nitrogenase enzymes and also acts as a counterion in RNA and DNA