学 位 論 文 審 査 の 要 旨

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Development of Absorbents for Removal of Pollutants from Hydrosphere
（水圏からの汚染物質除去のための吸着材料の開発）

This thesis comprises 116 pages, 28 figures, 5 tables, and 6 chapters, with 2 reference literatures.

Shuang Li developed the new absorbents and applied them for the removal of pollutants from hydrosphere. The concept of combination of electrochemical driving force and the composited absorbent is totally new idea. However, the effect of the electrochemical driving force onto the absorption process was not known. Here, she needed to devise the evaluation method of absorbent ability. She attempted to modify the basic kinetic concept, Langmuir isotherm, and calculated the theoretical maximum absorption capacity and the affinity constant between the target ion and the absorbent. And then, she proved that her theoretical values were coincided to the experimental results. From this result, she concluded that the electrochemical driving force could not improve the affinity constant but the maximum absorption capacity. This conclusion was different from the initial model that the electrochemical driving force could promote the affinity constant. However, it was reasonable model if the target ions were incorporated into the inside of absorbent. This new evaluation method based on kinetics will be a useful way to develop the absorbent in the fields of academia and industry.

In Chapter 1, these challenges of Global Food Resources are introduced. Public pollution of radioactive substance, heavy metals, and arsenic was described. To solve these challenges, the current technologies were also written. Subsequently, the natural recovery mechanism is depicted. In nature, the pollutants were absorbed into plants. For example, it was known that some seaweeds absorb radioactive substances. The surface of seaweed is coated with sticky material, alginate. The sequence of alginate consisting of mannuronate and guluronate is adjusted to capture the radioactive substance by enzyme of bacteria. As a result, the “eggbox” structure is formed in the sequence of alginate. The capacity of storage of radioactive substances is not so high. Therefore, it is necessary to find a way to improve the capacity for practical application. As well, it is known that some reeds also absorb the heavy metals and arsenic substances. Amylose of stem of reed can incorporate heavy metals by electrostatic interaction. Carboxylate group in sugar sequence associates to these pollutants. This mechanism is used for removing heavy metals from hydrosphere. It is known as the lagoon treatment. In this chapter, she explain the basic concepts of electrochemical deriving force and the kinetics.

In Chapter 2, the experimental methods and the basic concepts of instruments used in this research are described.

In Chapter 3, the selective removal of strontium from seawater by using alginate doped TiO_2 porous carbon electrode was introduced. Fukushima nuclear power plant disaster released the radioactive substance into the Pacific Ocean. It damaged on these marine livings. So, the seafood in Fukushima became hazardous, and not eatable. Among radioactive substances, only strontium is still remained as the problematic material. However, the RO membrane could not remove strontium fully, and the discharged water of Fukushima nuclear power plant needs to be stored in tank. The life time of tank is 10 years. Therefore the removal method is absolutely urgent issue. The Japanese government decided to release this discharged water into the Pacific Ocean after dilution. She collaborated with Hitachi-GE Co., and developed the method of combination of electrochemical driving force and alginate-TiO_2 doped porous carbon electrode. Finally, it was noticed that strontium could be fully removed from seawater by this absorption system. This result was handled to the patent section of Hitachi. She waits for an agreement from the company to submit the manuscript.

In Chapter 4, the new absorbent, amylose-graphite composite electrode was used for removal of heavy metals. Lead, cupper, cadmium, and chromium were chosen to be examined, because those four species were representative pollutants in hydrosphere. Since the evaluation method of absorption ability was not established, the quantitative mechanism was not clarified. The proposed concept was applied to analyze the absorption mechanism. Thus it was proved that the maximum absorption capacity was improved by electrochemical driving force. In other words, the kinetic analysis showed evidence that the concept of combination of electrochemical driving force and the absorbent was useful.

In Chapter 5, arsenic pollution in Bangladesh were reported. In addition, the removal method was proposed. She found that rice and drinking water contained approximately 1,000 times higher concentration than the standard of WHO. She also proposed use of the amylose-TiO_2 doped graphite electrode for removal of arsenic from water. Unfortunately, COVID-19 disaster interrupted the practical application in Bangladesh.

In Chapter 6, she described the conclusion, and mentioned the effort to the global food resources.

Based on the diploma policy of the Graduate School of Global Food Resources, her eligibility for doctoral degree of Food Resources could be explained as follow.

She lead the students of University of Rajshahi, and investigated the arsenic pollution in Bangladesh with world-class communication skills, the ability to take actions and be aware as a leader.

She innovated the new kinetic theory and proved the concept by three practical applications i.e., insights and the analytic ability to grasp problems precisely, broad knowledge and deep understandings of the complicated global food resources problems, an ability to build strategies to solve problems and to promote research.

Above these reasons, it is considered that the diploma policy was satisfied. Therefore, we acknowledge that Shuang Li is qualified to be granted the Degree of Doctor of Philosophy in Food Resources from Hokkaido University.