MOVEMENT OF MICROPLASTICS IN THE WASTEWATER DISCHARGED FROM THE ANTARCTIC RESEARCH STATION

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INTRODUCTION

As a large number of microplastics (MPs) have been found around the Antarctic research stations, the wastewater from the station is presumed to be a local source of MPs pollution (Waller et al., 2017). In addition, more than half of stations in Antarctica have no adequate sewage treatment systems (Gröndahl et al., 2009). The present study collected MPs in Marian Cove, West Antarctica. In this bay, the King Sejong Station, which is a Korea station, is located, and other research stations are located around. And, we actually found a significant amount of MPs in the seawater and wastewater of the station. So, we assumed that this research station can be a local source in this cove.

To investigate how the MPs discharged from the stations are transported and accumulated, it is necessary to understand the movement of MPs. However, it is quite difficult, since their size, density, and shape are too various, which determine their vertical movements. In addition, oceanographic variables such as waves and tides determine the hydrodynamic properties of the bay (Kim et al., 2018a), and therefore can affect the movement of particulate matter floating in the bay (Kim et al., 2018b). Thus, these variables should be considered

Accordingly, we need to consider these variables to accurately track MPs discharged into Marian Cove.

This study investigated the movement of MPs discharged from the research station through numerical simulation to elucidate the transport mechanism of MPs. And, the Lagrangian particle tracking method was coupled with the numerical simulation to track the trajectories of MPs. The present study finally suggested an optimal wastewater discharge method by simulating MPs according to waves, tidal cycles, and discharge locations.

METHODOLOGY

To elucidate the local source effects of MPs pollution, we first reproduced the seawater flow in Marian Cove using a hydrodynamic model, Delft3D-FLOW. And, when considering wave effects on MPs, the wave model, Delft3D-WAVE, was coupled online with the flow model. Then, the particles were released into the surface layer, just as the wastewater of station was discharged into the surface layer. The trajectories of MPs were determined by calculating the advection, diffusion, and the particle's vertical velocity as Equation (1).

$$\mathbf{X}(t+\Delta t)=\mathbf{X}(t)+\mathbf{U}(x,y,z,t)\Delta t+R\sqrt{2\mathbf{K}\Delta t}+\mathbf{w_s}(t)\Delta t \qquad (1)$$

In Equation (1), $\mathbf{X}$ is the particle location and $\mathbf{U}$ is the Eulerian velocity field of the hydrodynamic model. R is a random number with a mean of zero and a standard deviation of one. $\mathbf{K}$ is the eddy diffusivity coefficient vector, and $\mathbf{w_s}$ is the vertical velocity of particle.

As suggested by Chubarenko et al (2018), the particle tracking was simulated by categorizing MPs into two groups: rising particles (RPs) and falling particles (FPs). In the real seas, the particles with a lower density than seawaters can sink owing to biofouling, and the particles with a higher density than seawaters can rise owing to degradation. However, it is too difficult to parameterize these processes for simulation. In addition, since the goal of this study is to reveal the transport mechanism of MPs in the wastewater, MPs were divided into two groups and simulated.

In order to describe the motion of particles, especially in the vertical direction, a dimensionless number, the HK angle, was proposed by this study as Equation (2).

$$\theta_{HK}=\arctan\left(\frac{w_s}{W}\right) \qquad (2)$$

This number was determined by the particle vertical velocity (w_s) to the flow vertical velocity (W), and thus it can help explain the trajectories of MPs as it decides the forces that govern the motion of MPs (Figure 1). The HK angles were calculated for the surface, middle, and bottom layer. Consequentially, the trajectories of the simulated MPs were analyzed using this HK angle.

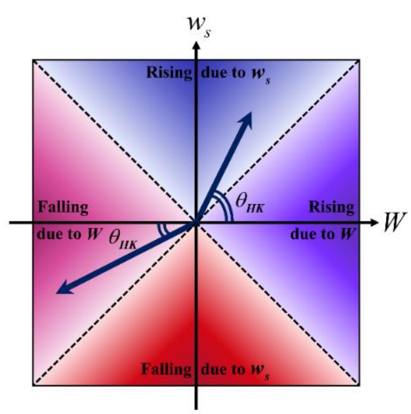

Figure 1 – Dominant force on MPs according to the HK angle.

RESULTS

Before tracking MPs, the HK angles that can account for the transport of MPs were calculated for each layer. The HK angles of RPs and FPs for the surface layer are shown in Figure 2.

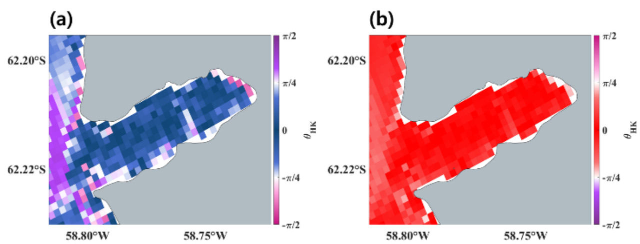

Figure 2 – The HK angles of (a) RPs and (b) FPs for the surface layer.

The MPs' tracking was first performed according to the wave effects. When the flow-wave model was used to track MPs, it increased the travel distances of RPs and FPs by 75% and 45%, respectively, and reduced the travel time by more than half. RPs were mainly transported along with the surface currents owing to their buoyancy. In the case of FPs, they sank to the intermediate layer just after release owing to their falling velocity, as implied by the HK angles. As a results, at the end of the simulation, about 80% of RPs landed on the coastline, and more than half of FPs were deposited on the seabed.

And next, the particles were released according to the tidal cycle to investigate the effect of release time on the accumulation of MPs. When particles were released during the ebb time rather than the flood time, the amount of MPs remained in Marian Cove was reduced by more than twice. However, when discharged from the current location of the discharge port, MPs tended to be greatly disturbed by the shoreline and landed on the shoreline immediately after discharge regardless of their type.

Accordingly, we traced the MPs by changing the releasing location so that the MPs do not accumulate immediately after release, as shown in Figure 3. If the particles were released from the surface layer a little farther from the coastline in the ebb time, MPs could leave Marian Cove without being disturbed by the coastline, thereby reducing MPs pollution in the cove.

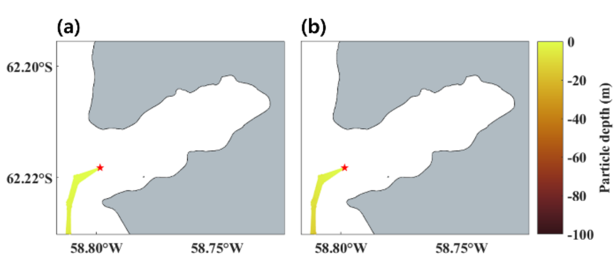

Figure 3 – Trajectories of (a) RPs and (b) FPs discharged from the surface far from the coastline.

CONCLUSIONS

The present study performed the tracking of MPs to investigate how MPs released from the research station are transported in the cove. MPs were classified into two groups according to their original properties, and we used the HK angles to describe the movement of MPs. The buoyant particles were transported with the surface layer, whereas the negatively buoyant particles sank into the intermediate layer after release. As a result of simulating MPs tracking according to waves, the wave conditions should be considered when tracking MPs accurately. In addition, when discharging wastewater from the research station located on the coastline within the cove, such as the King Sejong Station, it is the best way to reduce pollution in the cove to discharge it for ebb time away from the shoreline.

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