Simulation of micro plastic filtration for existing filters

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Abstract. This paper uses DPM model in Fluent to divide the mesh and conduct fluid analysis for the existing family filter, by using the Rosin - Rammler distribution simulated reality of different diameter of the plastic particles’ distribution in the water. Secondly, using particle tracking algorithm to calculate the distribution of particle diameter of the export, so as to check the existing household filter’s ability for the different plastic particle diameter.

1. Introduction
Mass production of plastics began in the 1940s, since then, the production and consumption of plastics around the world have increased dramatically.

Global plastic production reached about 300 million tons in 2013 [1]. According to the United Nations Environment Community, there are about 18,000 plastic pollutants per square kilometre floating on the surface of the world's oceans. If take the mostly polluted sea area into account, the pollution value can reach 38,000 plastic pollutants per square kilometre [2]. Plastic pollutants cause damage to global Marine ecosystems, causing economic losses of more than $13 billion a year, and the trend is increasing year by year.

According to statistics, most of the micro plastics existing on sea surface are between 400 and 600µm, with the minimum diameter up to 0.7µm [3]. Because of the water flow, the plastic particles in the ocean gradually go deeper into inland lakes and rivers, the pollution of some inland lakes has greatly affected the safety of human drinking water and the health of human [4].

This paper mainly studies the filtration performance of household filters on plastic particles in water, and explores the lower limit of filtration diameter, so as to provide reference for the research and treatment of plastic particles in the world.
2. Filter principle
Particle filtration is traditionally a separation process in which microplastics are filtered at the micron scale. The basic principle of particle filtration is to make the fluid-particle suspension flow through the filter bed. As the suspension flows through the filter bed, some particles in the suspension deposit on the surface of the filter bed. The way the particles deposit on the surface of the filter bed is different, so the filtration mechanism is different. The main mechanisms of particle filtration are inertial collision, interception, and gravity and Brownian diffusion. Since the diffusion and gravitational action are only for particles with \( d < 1.0 \mu m \), and the microplastics are mostly distributed in the range greater than 1 \( \mu m \), this paper only discusses inertial collisions and interception.

Single-stage filter of the internal flow model for particle removal rate is defined as a single stage filter filtration efficiency of \( \eta_s \), which is defined as the deposition rate from entry to filter bed direction on the total number of particles. After periodization, the efficiency of single-stage filter is

\[
\eta_s = \frac{4N}{U_s C_0 \pi D_g^2}
\]

Where \( N \) is the deposition rate of particles on the filter bed, \( C_0 \) is the inlet concentration of particles, \( U_s \) is the surface velocity of the fluid, and \( D_g \) is the filter diameter.

Single-stage filter filtration efficiency and the whole efficiency of granular bed \( \eta \) are related. Single-stage filter efficiency can be related to the entire granular bed efficiency \( \eta \) through a mass balance for a packed bed filter composed of spherical collectors, this relation is

\[
\eta_s = \frac{-2D_g \ln(1 - \eta)}{3 \varepsilon_s L}
\]

Where \( \varepsilon_s \) is granule volume fraction, \( L \) is the length of the granular bed, \( D_g \) is the granule diameter.

3. Simulated analysis

3.1. Settlement of condition
In this paper, it is assumed that the plastic particles and the filter bed are in a unidirectional coupling state, that is, the fluid can only affect the momentum and kinetic energy of DPM particles, but the movement of DPM particles will not affect the flow field of the continuous phase around them.

As for the diameter distribution of plastic particles, since the diameter of plastic particles is generally distributed between 400\( \mu m \) and 600\( \mu m \), the Rosin-Rammler distribution is adopted in this paper to make the particle distribution closer to the reality.
3.2. Simulation result
The Fluent module was used to simulate the particle trajectories of micro plastics flowing through the filter bed, and the simulation results are shown in the figure.2 below.

![Particle trajectories](image)

**Figure 2.** Particle trajectories

As shown in the figure, the motion state of the plastic particles in the filter bed is relatively complex, and the speed of the plastic particles in the near-wall area drops sharply. As the particles flow through the filter bed, their velocity decreases with the increase of the flow depth, and a circulation is formed in the filter bed, which is more conducive to the absorption of plastic particles in the filter bed and the reduction of the concentration of plastic particles at the outlet.

In order to explore the filtration capacity of the existing widely used filters on plastic particles, the particle diameter distribution set by the reference r-r model was introduced at the inlet of this paper, and the filtration capacity of the existing filters on plastic particles could be obtained by observing the proportion of particle diameter distribution at the outlet.

![Proportion of particle diameter distribution](image)

**Figure 3.** The proportion of particle diameter distribution at the outlet
As shown in the figure above, most of the particle diameters at the exit are distributed in the range of d<0.1mm, and the proportion of exit particles in the range of (0.1, 0.15) is greatly attenuated. When d<0.05mm, the proportion of particles is more than 50%.

3.3. Effect of particle orientation on flow curve of micro plastics in filter bed

At the beginning of the filter bed, the particles tend to be randomly distributed state of filter bed, after a period of time, the trend direction of particles in the filter bed is similar, and when plastic particles through the filter bed, at this time due to the sinuosity reduce particle trajectory, caused by the plastic particles and the decrease of the filter bed particle collision probability filtering effect becomes poor phenomenon, in the image below shows the plastic particles through the initial filter bed and use after a period of time of filter bed particle sinuosity

![Figure 4. Particle tortuosity](image)

As can be clearly seen from the figure above, when the plastic particles flowing through the particle zigzag of the filter bed with random distribution of particles (SC) is much higher than that of the filter bed with partial orientation of particles. Because the inertial particles are more likely to deviate from the relatively tortuous fluid flow line, the higher the fluid flow line curvature is, the more beneficial it is to filter particles
Figure 5. The proportion of particle diameter distribution at the outlet of used filter

As shown in the above, after a period of time the particle diameter distribution in the outlet of the filter bed has a big change compared with Figure 3, as due to the filtering performance is reduced, the increase of ratio of the exit of large diameter plastic particles, and because the diameter of particles of different than dropping phenomenon disappears, the filter can filter out the smallest particle diameter increased

4. Conclusion
Existing conventional filter without using, can filter plastic particles whose diameter d > 0.1, and after a period of using, due to the particle filtering bed area of synthetic plastic particles caused the faltering flow curve reduce, which makes its filtering effect backwards to d > 0.3 mm, cause the filter performance is reduce.

Thus to guarantee the security of human daily drinking water filter replaced periodically head is very necessary, otherwise, will cause human health problems.

Acknowledgments
This work was financially supported by National innovation and entrepreneurship training program for college students 201910497084.

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