(Micro)Plastics are known to be in our waterways.

How much is there and where do they come from?

As the prominence of plastic as an environmental pollutant grows, efforts on several facets of particulate plastic (nano- and microplastic particles and fibers) research has begun to intensify to better understand their sources, fate and transport, as well as biological uptake and effects. Municipal wastewater treatment plants (WWTP) are considered hubs between the urban and natural environments. As an analytical chemist in the field of environmental chemistry at Eawag, you are asked to evaluate the effectiveness of the WWTP in Zürich to remove microplastics from wastewater and assess the exposure of receiving waters to plastic. You want to assess the removal of plastic particles from a WWTP and therefore must assess the plastic coming in (influent) and the plastic released (in the effluent or the sludge).

You must keep in mind that the term plastic is inclusive of a wide range of polymers and additives which have different chemistries, densities, hardness, and other characteristics. Therefore, work on identifying plastic and understanding its likely source requires knowledge from the fields of materials science and chemical engineering. Along with the base plastic characteristics, microplastics have an array of sizes, shapes and surface characteristics.

One key consideration in establishing an analytical strategy for measuring particulate plastics is that two metrics are considered equally valuable when assessing exposure: 1) plastic mass (i.e. total plastic burden) and 2) particle size and number (since organisms may be more affected by smaller particles). Therefore, a combination of methods will likely be necessary to fully describe the characteristics of particles in the WWTP.

Questions:

1) There are different sources of wastewater which enter a treatment plant and these may carry different types of (micro)plastics. Wastewater from households may contain microbeads used as scrubbers in e.g. toothpaste and fibers from textiles. Additionally, road run-off is collected in combined treatment systems and there, tire wear, paint fragments, and fragmented plastic waste such as soda bottles will make their way to the WWTP. What different types of polymers or polymer mixtures are represented by these materials?
2) Wastewater is a complex mixture of organic substances and inorganic particles such as sand, as well as micropollutants, microplastics and other moieties at relatively low concentrations. As a first step, particles need to be extracted from the more complex matrix. Subsequently, plastic particles need to be chemically differentiated from other particles contained in the wastewater. What options exist for degrading the wastewater matrix and what analytical tools are available to chemically identify individual plastic particles? Will the suggested extraction or analytical technique be polymer dependent?

3) a) Just as large plastic items break down over time to form microplastics, it is expected that microplastics will continue to degrade to form nanoplastics. What is the smallest size particles which can be measured from the techniques suggested in response to question 2? What is the limiting factor(s) in this detection limit?
   b) Not all microplastics are the same shape. Are there some morphologies which have proven more difficult to analyze than others? Why?

4) Instead of measuring individual particles, one could alternatively measure the bulk concentration of microplastics in the sample. How does the sample preparation considerations and analysis differ from the techniques suitable for question 2? While you will lose information about particle number, what additional knowledge can you gain from this type of analysis about the plastics in your sample?

Prepare and present your answers in a 20 minute presentation.

Suggested Reading:

Information regarding municipal wastewater treatment

A standard layout for a municipal WWTP, as shown in the figure above. Generally, WWTPs consist of primary, secondary and tertiary treatment stages. The primary step, also known as the mechanical treatment stage, is the first purification step and removes solids and grease from the wastewater. This is done by screening, sedimentation in the sand trap and the primary clarifier, or by removing the floating grease in the grease removal tank. In the secondary treatment step, the organic load of the wastewater is transformed by heterogeneous carbon removal by the suspended biomass to CO₂. Nitrogen, predominantly present in the form of ammonium in the influent, is removed by nitrifying and denitrifying bacteria. In the secondary clarifier, the sludge is separated from the effluent. Since all parts of the secondary treatment step involve degradation of components of the wastewater by bacteria, it is also referred to as biological treatment stage. Depending on the composition of the wastewater, a secondary WWTP might not be sufficient to fulfill the statutory provisions to directly discharge the effluent into the receiving water. In this case, a tertiary treatment step can be applied. Depending on outstanding criteria to fulfill legal obligations, filtration, nutrient precipitation or disinfection can be used to further improve the effluent quality. Microplastics enter the WWTP along with the wastewater and can leave the system either along with the effluent or the sludge. In Switzerland, the sludge is incinerated but in other countries this sludge can be used as fertilizer for agricultural fields. Therefore, this may be another alternative path of microplastics into the environment.