Paper 03 / 2023 doi: 10.7795/320.202303

[JUNGE wissenschaft]

JungforscherInnen publizieren
online | *peer reviewed* | original

Verlag:
Physikalisch-
Technische
Bundesanstalt
PTB

Technik

Removing Microplastics from Water

Test of an Innovative Filtering Approach using Density Differences

Considering the indispensability of plastics worldwide, the impact of emerging microplastic on nature and additionally new findings on its existence in the human body, we need new approaches to remove it out of the potable water cycle. This paper investigates an innovative filtration approach using a new concept based on the well-known principles of density differences and phase separation of oil and water.

DIE JUNGFORSCHERIN

Antonia Lampke (2005),
Regenbogen-Gymnasium-Augustusburg

Eingang der Arbeit:
22.7.2022
Arbeit angenommen:
06.10.22

Removing Microplastics from Water

Test of an Innovative Filtering Approach using Density Differences

1. Introduction

For electronic devices, automotive, construction and, most importantly, the packaging industries, different types of plastic consisting mainly of synthetic polymers, are used in Europe (see Fig. 1).

Plastics are obtained from fossil raw materials such as coal, crude oils and natural gas [1]. They are built from very long, intertwined molecular chains which are composed of repeating basic units called monomers. Polymers are synthesized by polymerization. Inherent properties of plastics are water and shock resistance, high malleability, resistance to chemical reactions that otherwise degrade other common materials such as metals, inexpensive manufacturing and also being lightweight with a high strength-to-weight ratio. Plastic is a unique and desirable synthetic material being able to fulfill certain requirements for many specific applications [2].

Without plastic, technical progress and development would not have been possible. Our current living standard partly depends on polymers in advanced products like airplanes, high-end sports equipment, artificial limbs and other technical devices [3]. Unfortunately, these great advantages are also accompanied by human-made challenges as plastics are used in incomplete material cycles that lead to environmental pollution. It is proven that plastic waste accumulations with a surface area as large as Germany are drifting around in the sea. Experts say that one of the most powerful plastic waste flows, the Great Pacific Garbage Patch in the North Atlantic, contains up to 100 million tons of plastic and is still growing [4].

Since most polymers are chemically resistant, plastics are degraded mainly by mechanical processes, resulting in the formation of fragments smaller than 5 mm [5]. Not only plants and animals are impaired by these fragments called microplastic, as they are often mistaken as food, but the waste also enters the human food chain and contaminates drinking water. According to a WWF supported study by Newcastle University, people could be consuming about 5 grams of plastic each week, equivalent to the weight of a credit card [6].

Additionally, once microplastic enters the water cycle, it is nearly impossible to remove. It is an established fact that the potable water supply system contains microplastics and that the amount present is not healthy [7] as experts have already found microplastics in humans [8].

The idea presented below combats the presence of microplastic in potable water supply and introduces a new filtering approach. Subsequent laboratory tests reveal if special oil can be used as a filtering liquid due to its properties. In order to prove the filtering efficiency, several samples of the different plastics PET, PE, LD-PE, HD-PE and additionally two kinds of tire wear particles were produced. In the following, the methodical approach, preparation process, characterization of the samples used, detailed evaluation of the experimentation results as well as substantial conclusions are presented.

2. Impact of Microplastic and Requirement of Filtering

Why is microplastic so dangerous and destroys our nature? Microplastic is considered to be dangerous and to

doi: 10.7795/320.202303

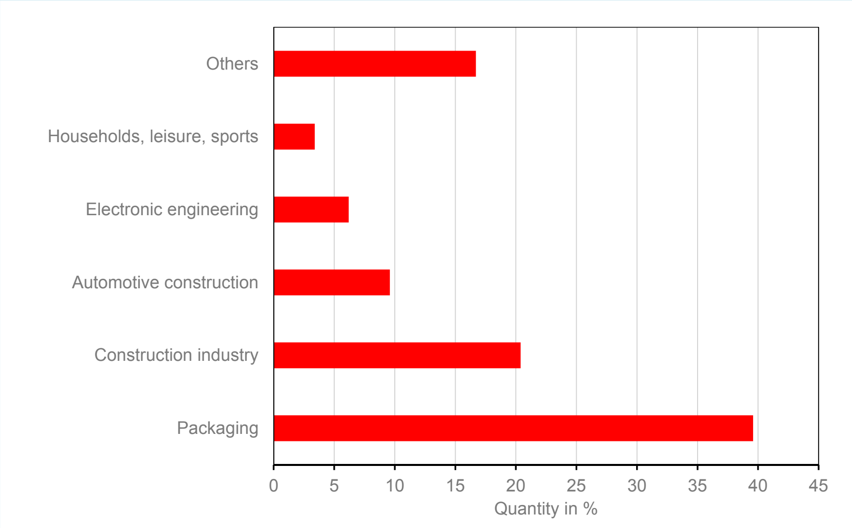


Fig. 1: Use of polymers in Europe in 2019 (adapted from VDI Nachrichten 42/2021, Source: Europäisches Patentamt)

destroy nature due to the main problem that it does not decompose. Fig. 2 shows the estimated decomposition rates of different plastic items.

Additionally, more and more plastics are being produced, used and afterwards badly disposed of. In 2018, the amount of plastic waste in Germany reached a new record. 18.9 million tons of packaging waste were being produced, meaning 227.5 kilograms per person, and these numbers only include packaging waste [11]. It is estimated that 12,000 megatons of plastic waste will be released into the environment by 2050 [12].

Chemical, biological and mechanical processes crush plastic into microplastic. For instance, waves or wind rub plastic bottles against rocks or heat and solar radiation degrade the plastic slowly [13]. The emerging microplastics are particles with a diameter smaller than 5 mm, i.e. 5,000 µm. If microplastic enters the water cycle, it is nearly unremovable due to its size and leads to subsequent problems with water filtration. Furthermore, there are no bacteria that can biodegrade plastic, including common plastics like PE, PP, PS, because they have not originated from nature and are new to the environment [14]. A meta study revealed that in the human body, microplastic smaller than 150 µm was found in the lymphatic system and particles smaller than 100 µm in the blood. Even some organs were contaminated by microplastic with a size smaller than 20 µm and the human brain with a size

Origin and Background of this Paper

In May 2021, the Social Studies (GRW) teacher at the Regenbogen-Gymnasium-Augustusburg gave a class the assignment of formulating a business use case including a business plan, financial, marketing and production aspects. This start-up project, which sought to develop a water filter for microplastic, was expanded by the author and a classmate. A detailed business plan was developed and market strategies, a business model, target groups, pricing, legal form of a company and much more was theoretically expanded upon. Furthermore, a prototype, a 3D-model, a 3D-animation and an advertisement video were produced by the group. The applications Blender, Fusion360 and MAGIX Video Deluxe were used for creating the digital representation. With support from the Chemnitz University of Technology (CUT) and the start-up network SAXEED, the printing of the 3D-model was completed without any complications. The main supporter was Joseph Stevens. An article was written about the cooperation between the two institutions [9].

Later, the school also published an article about a class competition, which was part of the start-up project. The winners of this competition were the author and the classmate [10].

Afterwards, the project got redesigned and refined for realistic applications and intensively worked on exclusively by the author. Therefore, a waiver to allow continued exclusive operation on a future joint project had to be signed by the classmate.

While working on this project, several innovation platforms offered support in product development and strategic planning. Through FutureSAX – the innovation platform of the Freistaat Sachsen, further progression and networking took place. Additionally, the platform Start Up Teens, the digital education platform for entrepreneurship and start-ups with the greatest reach in Germany, wanted to support and accompany the project. The above-mentioned filter against microplastic was presented at the START UP TEENS Challenge 2021 and prevailed against the participants to finish 5th place nationwide in the category Science & Health. In order to create a realistic and operating solution against microplastic, the presented system of the filter needed to be scientifically characterized and validated. For this purpose, the laboratories of CUT were used.

doi: 10.7795/320.202303

Fig. 2: Estimated decomposition rates [National Oceanic and Atmospheric Administration US, Woods Hole Sea Grant; US Graphic: Oliver Lüde, Museum für Gestaltung Zürich, ZHdK]

smaller than 0,1 µm [8]. These results make it more important for humankind to understand the behaviour, character and properties of microplastic as well as new approaches for removing it out of the potable water cycle.

A filtering approach that was designed for household systems works with different membranes [15]. Polycarbonate, cellulose acetate, and polytetrafluoroethylene membranes with a pore size of 5 µm were used to filter the plastics polyamide and polystyrene microparticles in the range of 20 µm to 300 µm. With this method, more than 94 g out of 100 g of microplastic were removed. However, particles with irregular shape or different degradation were able to either slip through the pores or break into even smaller pieces. Furthermore, membrane abrasion can occur as well as long-term wear and tear of the membrane. When choosing membrane properties, a trade-off would have to be made between the risk of producing a larger amount of nanoplastics, or allowing larger microplastic particles to pass through. It is not clear how such a filter system would respond to various microplastic accumulations and mixtures of contaminants [15].

Another filtering approach was created by the team of the non-profit initiative Water 3.0 [16]. Hybrid silica gel is added to water that rotates in a circular motion. The gel is based on quartz sand and acts like a chemical glue to the microplastic in the water. It consequently sticks together in larger clumps and can be easily removed. According to the researchers, the filter rate is approximately 95 percent. An analysis of the water to be filtered is necessary in order to provide the appropriate hybrid silica gel. This depends, among other things, on the type of plastic and the size [16]. Unfortunately, this system is yet not flexible enough to be used in households, because rotating motions in the water and an analysis are necessary.

Acoustic waves can also filter microplastic with the help of speakers [17]. The waves use their force to create a separation of the microplastic from the water by exerting pressure on a pipe with incoming water. The microplastic is forced into the center channel of three channels inside the pipe and the two outer channels release clean water. This method was tested with three different materials and achieved an efficiency of over 56 percent in pure

doi: 10.7795/320.202303

water and 58 percent in seawater. The acoustic frequency, distance between loudspeaker and pipe and water density can be used to influence the efficiency. A major drawback of the approach is potential harm to marine life from the acoustic waves. Therefore, and due to the comparatively low efficiency, the method is not yet mature. It is not sufficiently tested whether this method can also be used in households or industry [17].

These three chosen examples of filtering approaches describe current filtering concepts. However, all of them contain drawbacks and are yet not flexible, safe and mature enough to be widely used in households.

3. Development Needs and Research Hypothesis

Considering the impact of microplastic and the lack of practicable filtering solutions, it is obvious that there is a great need for filtration systems. As demonstrated above, despite several advantages, all currently available filtering concepts show restrictions, which have to be overcome. Therefore, research is required to find new innovative solutions [18]. The approach tested in this work is based on the ondina oil *Ondina909*, which is a medical, colourless, odourless and tasteless white oil. The special fluid fulfills the legal purity requirements that apply when handling food [19]. The filtering concept employs density differences and phase separation of oil and water.

Oil could act as a filtering liquid because plastic and oil are both nonpolar, meaning they are likely to stick together. As mentioned above, plastic waste tends to age due to chemical and mechanical processes which affects its polarity and influences the adhesion to the oil. Nevertheless, this effect is used in the scientific concept which reflects the following hypothesis: After the addition of oil and an emulsification process, the microplastic contained in the water attaches itself to the oil and can thus be safely separated from the water. To confirm this hypothesis, the microplastic (which normally settles in water due to its density greater than 1 g/cm^3) must bind to the oil and be able to separate from the water.

For this purpose, it is necessary to select relevant microplastic samples and examine them with regard to their characteristic features.

4. Practical Preparations and Applied Methods

4.1 Selection of Materials and Preparation of Microplastic Samples

For laboratory testing, samples needed to be prepared. The chosen plastics: polyethylene terephthalate (PET), polypropylene (PP), low-density polyethylene (LD-PE), high-density polyethylene (HD-PE) and additionally two different tire wear particle samples were selected according to important criteria like natural occurrence, relevance and hazard. Furthermore, these plastics are widely used in different processes and devices [20]. Tire wear is known to be ecotoxicological and is present in the air as well as in all environmental substrates and water. Its presence represents a potential risk to aquatic organisms and therefore also to humans [21].

In the work, a polystyrene (PS) sample was always used to first run through the methods for characterization and the filtration test. In this way, possible mismeasurements and errors with the main samples could be avoided. The authenticity of the measurement procedures was thus ensured. Therefore, the measurements with the PS sample are also evaluated and analysed in the work.

The production of the samples was carried out with a centrifugal mill at Chemnitz University of Technology, Faculty of Mechanical Engineering, Professorship of Plastics Engineering. Centrifugal mills are generally used for fast, fine comminution of materials. The size reduction can be adjusted by different rotors, ring sieves and cassette pans inside the machine. Fine size reduction is provided by an impact and shearing action between the rotor and the fixed ring screen. The added material is thrown outward by centrifugal acceleration and hits the rotating, wedge-shaped rotor teeth at high speed. Depending on the size of the sieve, the ground material is then further comminuted [22].

Plastics in the form of pellets were taken from the materials warehouse. One kilogram of each plastic was filled into a beaker and brought to the centrifugal mill. Before the production could be started, a detailed cleaning of the equipment had to be done with ethanol.

After each type of plastic was processed in the mill, the machine needed to be cleaned thoroughly with water and ethanol. Only one piece of plastic was added every five seconds to the running machine in order to prevent overheating and to create a safe workflow.

While processing polypropylene (PP), liquid nitrogen had to be used to make the material more brittle. For carrying liquid nitrogen containers made of styrofoam were used. On this account, polypropylene and presumably polystyrene came into contact which contaminated the sample. Therefore, the PP sample will later occur as a MIX sample. Over time, the sieve of the machine became contaminated and difficult to clean as melted plastic had settled into the small pores. Different ideas for removing the melted plastic were attempted, like cooling down to –26 °C, heating in an oven at 150 °C and physically removing it with a tin brush. Finally, the combination of a small gas burner and the tin brush made the removal possible. While producing the other samples, no further significant problems occurred.

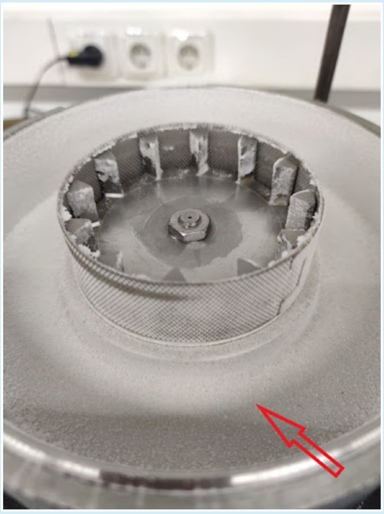


Fig. 3. Sample container with microplastic sample

The microplastic was gathered in the cassette pan (Fig. 3) and was collected with a small brush and filled into the sample container with help of a small funnel and labelled.

Finally, six microplastic samples were completed and weighted with a very accurate scale. The two additional samples of tire wear were gathered from a stock of Chemnitz University of Technology.

4.2 Methods for Characterization of Microplastic Samples

The different kinds of microplastic used in this work were characterized with three scientific analytic methods: infrared spectroscopy, particle size distribution and optical microscopy.

Previously, the analysed samples were irradiated with UV-light, in order to perform the characterization and laboratory tests as accurately and authentically as possible. Due to UV degradation, nanoparticles are formed from microplastic. UV radiation allows the particles to decompose into particles smaller than 100 nm, therefore representing the existing problems [23].

Furthermore, the samples were filtered with a sieve for the purpose of obtaining a size sample smaller than 500 µm. However, since the samples were already well produced, meaning very small, the existing sample of HD-PE only lost 0.6 percent of its particles through filtering.

Fourier transform infrared spectroscopy is one of the applications where quick and easy qualitative and quantitative analysis of samples can be performed. The wide range of analyses include: investigation of surface modification and functionalization, investigation of reaction kinetics and thermal effects, monitoring of additive concentrations and comonomer content, branching and tacticity.

Infrared spectroscopy can be used to identify, compare and classify the characteristic vibrations of functional groups in molecular structures. In the case of plastics or plastic mixtures, the infrared spectrum offers identification features for the nature of the polymer base materials. For example, polymer analysis also tests the functionality and concentration of specific additives that can change the properties of polymers [24]. For analysing the infrared spectra of the polymer samples, the FTIR-spectrometer Bruker Vertex 70 with a powder device was used.

The technique of static light scattering is generally used for characterization and investigation of microparticle systems. Although statistical inaccuracies can show up in very broad distributions, the method is important and widely used in many industries. Applications range from characterization of active pharmaceutical ingredients to cosmetic products, paints, polymers, metals, building materials and ceramic materials. There are various reasons for its success. Short measuring time, high reproducibility, wide measuring range and good automation capabilities are some of the main advantages of this method. In addition, there is a high degree of flexibility with regard to the sample feed method. Substances that are difficult to disperse in liquids, for example because they dissolve quickly or are difficult to distribute, can be measured in dry dispersion units with the aid of compressed air. There are also specific solutions for aerosols or very small sample quantities, depending on the measuring device [25]. With the laser particle size analyser, the particle size of the samples was measured in ethanol through static light scattering. For each sample, three measurements were carried out. This allowed the exact distribution of the particles to be measured and showed that all of the samples were authentic.

Optical microscopy remains central to modern biomedical science even though the technique is over 400 years old and is used for providing magnified images of samples. The optical magnification is reached by light that passes through magnification lenses. Specimens are illuminated or irradiated with light in the visible region of the spectrum or in the adjacent ultraviolet or near-infrared region of the spectrum. The results are

Fig. 4: Clarification of the phases

doi: 10.7795/320.202303

used in the biometrical science, but are also well suitable for the characterization and visualization of different samples [26]. The optical microscopy was performed on the sample HD-PE with the Nikon OPTIPHOT-2.

4.3 Implementation of Filtration Tests

In order to prove the filtering concept, a functioning experimental setup had to be determined. First, a separating funnel was selected as a reliable phase separator; in this case oil and water. For securing a clean process without any by-products, distilled water was used and prepared with a defined amount of microplastic samples. One problem was the tracking of the microplastic. In order to be able to indicate the retention in percent, the particles used had to be compared with the recovered particles. At first place, gravimetric methods were tested employed for counting the particles. However, this method turned out to be too inaccurate. Afterwards, particle recovery by centrifugation and drying of individually sampled phases was performed as an evaluation method. Work process and procedure were verified on the basis of preliminary tests with the plastic PS and recorded in a protocol.

The tests showed that the particles settled inside the separating funnel due to their density after UV irradiation. By adding oil and applying vigorous shaking, the particles passed into the upper oil phase and collected at the oil/water interface. After a clarification time of 10 to 30 minutes, the phases were separated. After the same time, a poorer collection of the particles at the interface was observed with rapeseed oil. Many particles stayed in the water phase. Thus, the rapeseed oil was not used for the filtration tests. After phase separation, the water was drained in a separate beaker and the oil into a previously weighed centrifuge tube. After centrifugation, the oil was dried and the separating funnel was repeatedly washed with isopropanol. This detergent was also filled into a centrifugal tube, which was dried, too.

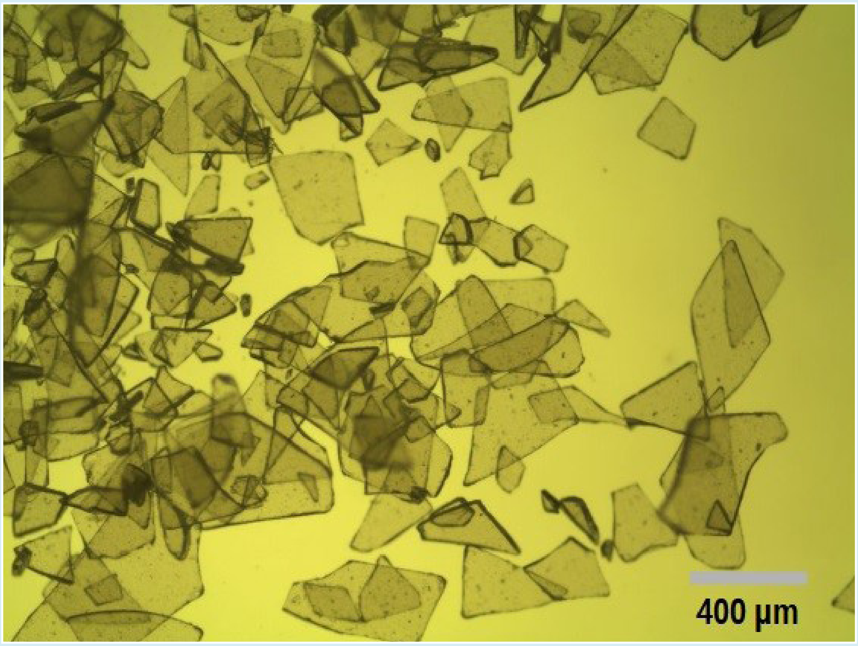


Fig. 5: Transillumination microscopy of HD-PE sample

The final process for quantitative validation was determined. Afterwards, the centrifuge tubes were dried in the drying oven overnight. The final efficiency and retention could be calculated by weighing the centrifuge tubes and retrieving the recovered plastic particles.

The total filtration procedure consists of the following steps:

1. Irradiation of the plastic particles with UV light (5 h);
2. Weighing of the particles (approx. 100 mg);
3. Shaking of the particles in 50 ml water in the separating funnel, „swelling time“ overnight, then assessing the sedimentation;
4. Addition of 10 ml oil *Ondina 909*, vigorous shaking;
5. Settling of the liquid phases, clarification (Fig. 4) time approx. 30 min;
6. Draining the water;
7. Draining the oil into weighed (!) centrifuge tube;
8. Centrifugation (approx. 5 min);
9. Drying of the oil;
10. Washing the separating funnel with 10 ml of isopropanol and detergent;
11. Draining the detergent into the centrifuge tube;
12. Washing the centrifuge tube;
13. Centrifugation (approx. 5 min);
14. Drying of the detergent;
15. Repeat washing of the funnel and centrifuge tube;
16. After drying of the wash residue, drying of the centrifuge tube in the drying oven (overnight);
17. Weighing of the empty centrifuge tube and determination of the recovered plastic particles

5. Results and Discussion

5.1 Optical Microscopy

The optical microscopy was exemplarily performed on the HD-PE sample and allows visualization of the sample and shows an overview of the actual structure and composition, which is not visible with the naked eye. Fig. 5 reveals that a sample consists of many particles with different sizes. The particles also

doi: 10.7795/320.202303

differ significantly in shape, which can cause complications in filtering up to their variation in geometry. The approach tested in this work avoids these complications by taking advantage of density differences instead of using membranes.

5.2 Infrared Spectroscopy

Fig. 6 represents the infrared spectra of the polymer samples measured by a FTIR-spectrometer Bruker Vertex 70 with a powder device. The samples were sorted according to similar compositions and features of their FTIR spectra for easy viewing and differentiation.

The absorption of medium wavelength infrared light is plotted in the Fig. 6a to c as a function of wavenumber and can be distinguished using the legend and the assigned colours of the samples.

Through measurement, it was found that the polyethylene polymers HD-PE and LD-PE in Fig. 6a as well as the MIX samples in Fig. 6b exhibit strong absorption bands at wave numbers around 2900 cm^{-1}. In the case of PS, several bands are seen at 3100, 2900, 1500, 1400 and 700 cm^{-1}. PET exhibits broad absorption bands at 1600, 1300, 1100 and 700 cm^{-1}. The measurements revealed that the samples Tire_1 and Tire_2 in Fig. 6c have the same underlying molecular structure with adsorption bands at 2900, 1600, 1400 and 1200 cm^{-1}.

5.3 Particle Size

Fig. 7 presents the measurements of the particle size using static light scattering. The uniform scale across samples enables visual comparison.

Depending on the composition and material characteristics, the comminution process by means of the centrifugal mill results in different particle size distributions of the samples.

Fig. 7g can shortly be discussed with a little more detail. It represents the distribution of the MIX sample, meaning PP and another unknown material – perhaps PS. It is remarkable that the distribution of the MIX sample is irregular compared to the other data. This indicates another material in the sample. It is likely that the additional material has a lower proportion but is smaller than the plastic PP.

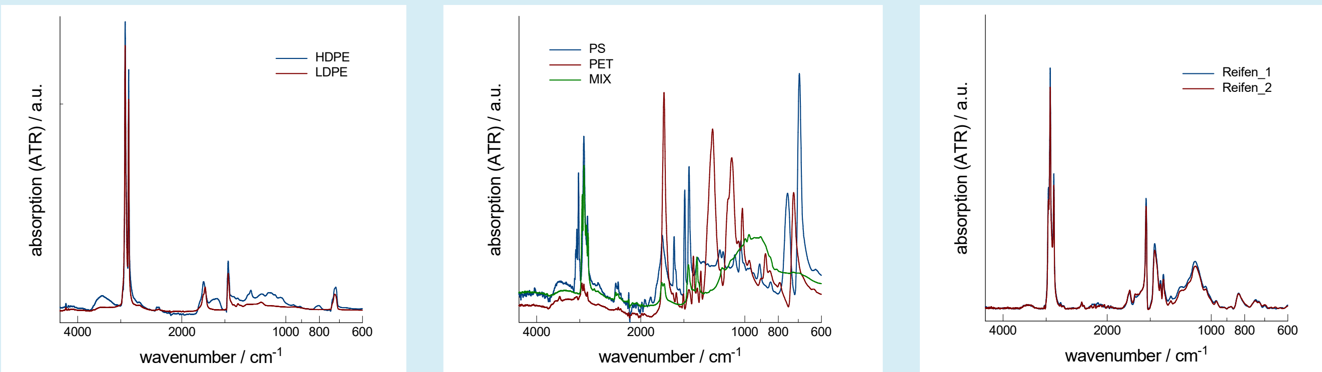
The numbers in the graphs clarify the authenticity of the samples and give an overview on the realistic size of microplastic in the environment.

Tab. 1 presents the diameter in µm of all samples at 10 %, 50 % and 90 %. Thus, the samples can be compared not only visually, but also on the basis of the concrete measured values.

5.4 Filtration Tests

Tab. 2 specifies the retention of each microplastic sample in percent with exact comparison data. In addition to a blank value (oil and water, no plastic particles), a comparison value (water and plastic particles, no oil) was determined by the same procedure. Its retention of 5 percent represents the recovered particles from the separating funnel after draining the water. This 5 percent of microplastic remains due to its adhesion to the glass surface. The retention rate of all samples is between 92 percent and 102 percent, an explanation for these values above 100 ercent is given below.

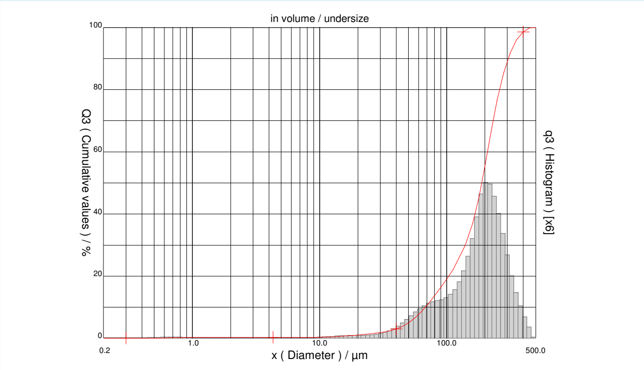
Due to its density, the plastic LD-PE did not settle in the separating funnel, which makes a filtering process based on density easier. This can be seen in the table by a high retention. One reason why Tire_2 has relatively lower retention is the smaller particle size (see Fig. 7d) and inhomogeneity. This can be detected with the static laser light scattering and shows that the filtering of smaller particles is more difficult than filtering larger particles. The sample of PS contains the largest particles and therefore has, among



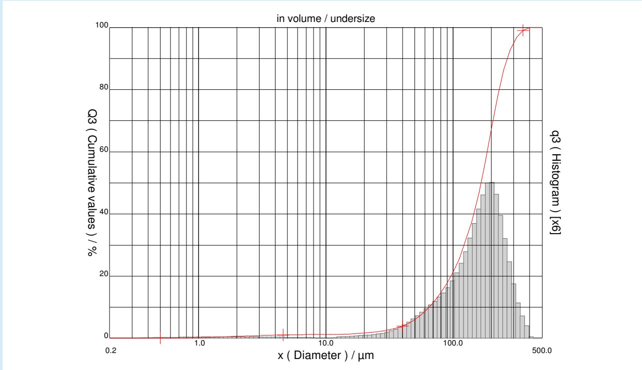
a) b) c)

Fig. 6: Experimentally determined infrared spectra of the plastic powder samples
a) HD-PE and LD-PE b) PS, PET and MIX c) Tire_1 and Tire_2

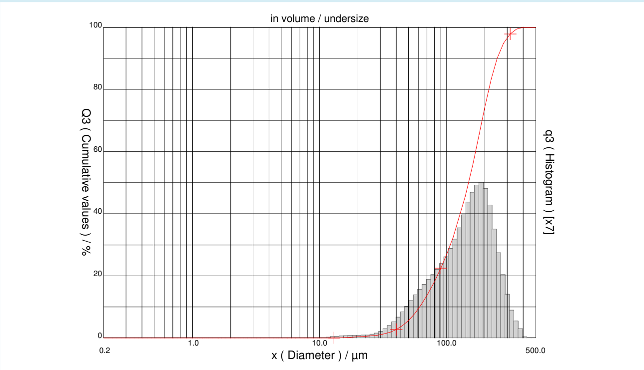
doi: 10.7795/320.202303



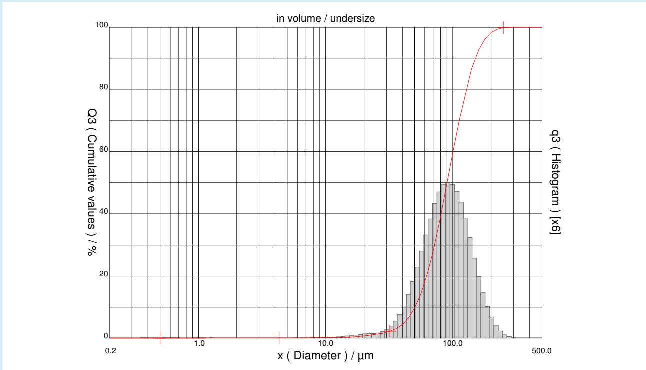
a) PS



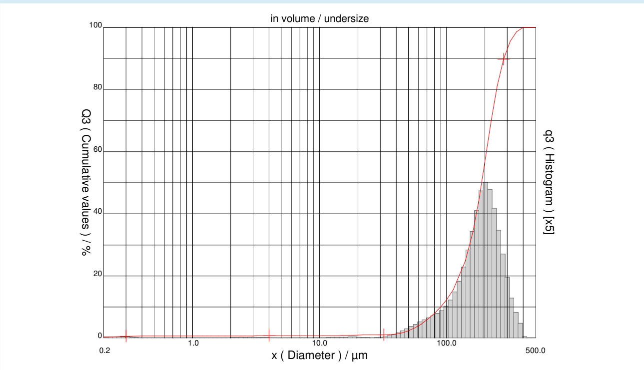
b) PET



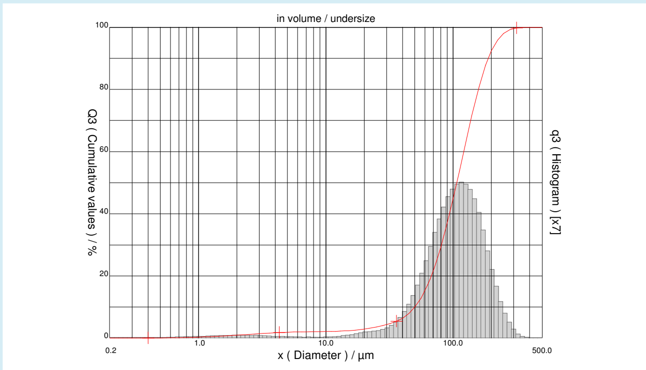
c) Tire_1



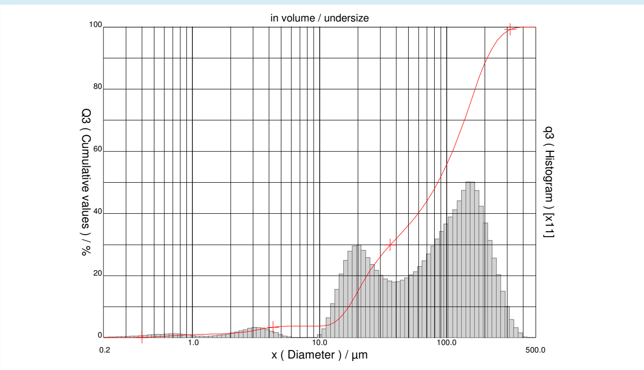
d) Tire_2



e) HD-PE



f) LD-PE



g) MIX

Fig. 7: Particle size distribution of the samples a) to g) in ethanol, but e) was measured in isopropyl alcohol. Both dispersants were appropriate for the measurements. Q3: cumulative value in % (red line); q3: population density

doi: 10.7795/320.202303

Tab. 1: Diameter of the samples at different cumulative value

	Diameter in µm						
Cumulative Value in %	PS	PET	Tire_1	Tire_2	HD-PE	LD_PE	MIX
10	67.71	64.71	58.36	50.33	89.29	50.04	16.91
50	188.61	165.80	144.72	90.08	188.31	106.80	85.22
90	305.29	267.32	248.03	150.94	281.83	189.37	208.35

other characteristics, the highest retention. Another reason why Tire_2 has relatively lower retention could be the surface charge of the tire particles which tend to adhere to the water. Therefore, their tendency to bind to the nonpolar oil might be lower.

It was striking during the tests that the plastic particles adhere strongly to the glass surface. When draining water and oil, almost all plastic particles remain in the separating funnel, which can be seen as a positive effect. The usual problem of plastic sticking easily to material can be used as a positive feature.

Furthermore, there is an explanation for the retention of more than 100 percent for some of the samples, which is theoretically impossible. The materials absorb water or the solvent during swelling in the separating funnel and the subsequent washing process. Possibly, the following drying conditions before the back weighting were not strong enough. This results in a small weight difference which causes a higher final weight and a retention of more than 100 percent. Still, the data can be considered as reliable.

A negative impact, after the positive recognition that the filtered water is nearly freed from microplastic, is a new contamination of the water. During the filtering process, parts of the oil become a single phase with the whole amount of filtered water. A subsequent split of the liquids with the centrifuge is not possible. Another oil, like rapeseed oil, could not be used even though the separation from water is better, because the microplastic does not stick to it as much. A compromise had to be made. But it is important to mention that the tests need to be laboratory-friendly and not too time-consuming. It is possible that a highly scaled-up technical implementation could separate the phases more efficiently. Other oils could also be used, since the mechanical support provided by a rotor or a continuous centrifuge favours the separation processes in terms of energy. One can see that the described fundamental tests required conditions set up as easy as possible in order to prove the basic concept. Now, the adaptation to practice could start.

6. Conclusion and Outlook

This paper aimed to develop a new approach to remove microplastic (MP) – including two kinds of tire wear – from water and demonstrate its functionality. The approach tested is based on ondina oil and employs density differences and phase separation of oil and water. Additionally, the non-polarity of microplastic and oil is being used.

The following hypothesis was formulated: After the addition of oil and an emulsification process, the microplastic contained in the water attaches itself to the oil and can thus be safely separated from the water.

First, plastic materials had to be identified, crushed into microplastic by means of a centrifugal mill and irradiated with UV light in order to create realistic and representative samples. The successfully used methods for the characterization of the different samples proved their authenticity and clarified relevance and texture. Microplastic particles have been found to have different properties and vary greatly in size and shape within one material. These irregularities complicate current filtering methods, which confirms that current concepts are yet not flexible, safe and mature enough to be used on a large scale.

The new filtering approach was shown to be successful with filtering retention above 92 percent. On the one hand, the oil acts well as a filtering liquid to which the microplastic particles bind. The property of microplastic to stick easily to glass was also detected and used as an amplifying feature in the filtering process. On the other hand, a part of the oil contaminates the purified water phase after the emulsification and cannot be separated again. This problem might be solved by a technical implementation in e.g. sewage treatment plants and the use of microorganisms. Using edible oils, to which the microplastic seems to bind less readily, the water could be purified completely and possibly made drinkable, despite the subsequent higher effort required for phase separation. A practical implementation in the sewage treatment plant could

Tab. 2: Experimental results on the retention of polymer particles dispersed in water by Ondina 909

Trial	Material	Sedimentation	Used particles in mg	Recovered particles in mg	Retention in %
Blank value	-	-	-	-0,8	-
Comparative value without oil	PS	yes	105.0	5.5	5
1	PS	yes	109.0	109.7	101
2	PS	yes	100.9	100.6	100
3	PS	yes	113.3	115.4	102
4	PET	yes	107.4	108.8	101
5	Tire_1	yes	108.5	107.4	99
6	Tire_2	yes	110.4	102.4	92
7	HD-PE	yes, slowly	111.4	111.0	100
8	LD-PE	no	103.7	104.5	101
9	MIX	yes	96.2	91.1	95

be taken as a preliminary stage, after which microorganisms clean the water contaminated by oil. Perhaps further tests using the presented filtering approach will uncover an even better filtering oil.

Finally, the positive results and findings of this paper point to a great potential for development and research that should be worked on.

Acknowledgements

This project would not have been possible without the support of Chemnitz University of Technology.

Many thanks to my adviser, Dr. Enrico Dietzsch, who introduced me to the laboratory of the Professorship of Chemical Technology and to the used measurement methods. He also supported me in the preparation and evaluation of the large amount of measurement data. His extensive contribution was of vital importance to me.

Prof. Dr. Michael Gehde and Marco Schmitt made it possible for me to prepare the microplastic samples in their laboratory. I am grateful to have had access to the centrifugal mill.

Finally, many thanks to my parents who endured this long process with me, always offering support and love.

References

[1] Nielsen, T., Hasselbalch, J., Holmberg, K., & Stripple, J. (2020). Politics and the plastic crisis: A review throughout the plastic life cycle. In (p. 18). WIREs Energy Environ. https://doi.org/10.1002/wene.360

[2] Osborne Industries. (2018, March 19). The Properties of Plastic: What Makes Them Unique? | Osborne. Osborne Industries. https://www.osborneindustries.com/news/plastic-properties/

[3] Muccio, E. A. (1991). Plastic Part Technology. ASM International. https://books.google.de/books?id=pBq4wljvD-EC&printsec=frontcover&hl=de#v=onepage&q&f=false

[4] Lohmann, D. (2013). Müllkippe Meer – ein Ökodesaster mit Langzeitfolgen. In N. Podbregar (Ed.), Im Fokus: Meereswelten: Reise in die unbekannten Tiefen der Ozeane (pp. 193-205). Springer Berlin Heidelberg.

[5] Singh, B., & Sharma, N. (2008). Mechanistic implications of plastic degradation. In Polymer Degradation and Stability (3rd ed., Vol. 93, pp. 561-584). Elsevier. https://doi.org/10.1016/j.polymdegradstab.2007.11.008

[6] University of Newcastle. (2019, June 12). Plastic ingestion by people could be equating to a credit card a week. https://www.newcastle.edu.au/newsroom/featured/plastic-ingestion-by-people-could-be-equating-to-a-credit-card-a-week.

[7] Haubensak, S., Schober, D., Sturm, M., & Schuhen, K. (2021). Den Kreislauf schließen Mikroplastik detektieren, entfernen und wiederverwerten. CITplus. https://onlinelibrary.wiley.com/doi/epdf/10.1002/citp.202100115

[8] Bach, A., Brüning, R., Heiss, C., & Quarks (Writers). (2021). Experiment Plastik: Wie schädlich ist Kunststoff für Körper und Umwelt? [TV series episode]. In Quarks. WDR. https://www.youtube.com/watch?v=cFoOluk4dAM

[9] Bornkampf, C. (2021). Rapid Prototyping verhilft zum Sieg bei Pitch-Wettbewerb zur Unternehmensgründung. SAXEED. https://www.saxeed.net/rapid-prototyping-verhilft-zum-sieg-bei-pitch-wettbewerb-zur-unternehmensgruendung

[10] Bornkampf, C., & Lindner, C. (2021). Wie gründe ich ein Unternehmen? DPFA-Regenbogen-Gymnasium Augustusburg. https://www.dpfa-augustusburg.de/organisatorisches/aktuelles/beitrag/wie-gruende-ich-ein-unternehmen-1264

[11] ZDFheute. (2020, October 27). Fast 228 Kilogramm pro Kopf: Rekord bei Verpackungsmüll. ZDF. https://www.umweltbundesamt.de/presse/pressemitteilungen/verpackungsverbrauch-2018-weiter-gestiegen

[12] Geyer, Roland, et al. (2017, July 19). Production, use, and fate of all plastics ever made. Science Advances. https://www.science.org/doi/10.1126/sciadv.1700782.

[13] Barrett, A. (2021, January 25). The Degradation of Plastics and Polymers (FREE). Bioplastics News. https://bioplasticsnews.com/2021/01/25/degradation-plastic/

[14] Wolchover, N. (2011). Why Doesn't Plastic Biodegrade? Live Science. https://www.livescience.com/33085-petroleum-derived-plastic-non-biodegradable.html

[15] Pizzichetti, A. R. P., Pablos, C., Álvarez-Fernández, C., Reynolds, K., Stanley, S., & Marugán, J. (2021). Evaluation of membranes performance for microplastic removal in a simple and low-cost filtration system (Vol. 3). Case Studies in Chemical and Environmental Engineering. https://doi.org/10.1016/j.cscee.2020.100075

[16] Hoferichter, A. (2021, April 15). Hybridkieselgel - Teilchenfänger für Mikroplastik im Wasser. Deutschlandfunk. https://www.deutschlandfunk.de/hybridkieselgel-teilchenfaenger-fuer-mikroplastik-im-wasser-100.html

[17] Institution of Engineering and Technology. (2021, November). Subjecting contaminated water to speaker system helps eliminate microplastics. E&T Magazine. https://eandt.theiet.org/content/articles/2021/11/subjecting-contaminated-water-to-speaker-system-helps-to-eliminate-microplastics

[18] Silva, A. L.P., Prata, J. C., Duarte, A. C., Soares, A. M. V. M., Barceló, D., & Rocha-Santos, T. (2021). Microplastics in landfill leachates: The need for reconnaissance studies and remediation technologies. In Case Studies in Chemical and Environmental Engineering (Vol. 3). Elsevier. https://doi.org/10.1016/j.cscee.2020.100072

[19] Albert Beck GmbH. (2006). Shell Ondina 909. Shell Schmierstoffe. https://www.schmierstoff-datenbank.de/shell-produkte-variant/shell-ondina-909

[20] Kutz, M. (Ed.). (2011). Applied Plastics Engineering Handbook: Processing and Materials. Elsevier Science. https://doi.org/10.1016/B978-1-4377-3514-7.10001-7

[21] Wik, A., & Dave, G. (2009). Occurrence and effects of tire wear particles in the environment – A critical review and an initial risk assessment. In Environmental Pollution (p. 356). Elsevier. https://doi.org/10.1016/j.envpol.2008.09.028

[22] Retsch GmbH. (n.d.). Ultra Zentrifugalmühle ZM 200 - leistungsstarke Zerkleinerung. Retsch. https://www.retsch.de/de/produkte/zerkleinern/rotormuehlen/zm-200/funktion-merkmale

[23] Gigault, J., Pedrono, B., Maxit, B., & Halle, A. T. (2016). Marine plastic litter: the unanalyzed nano-fraction. Environmental Science: Nano, 2, 350. https://doi.org/10.1039/C6EN00008H

[24] Agilent Technologies. (2020). FTIR-Anwendungen Polymeranalytik mit Fourier-Transform- Infrarotspektroskopie (FTIR).

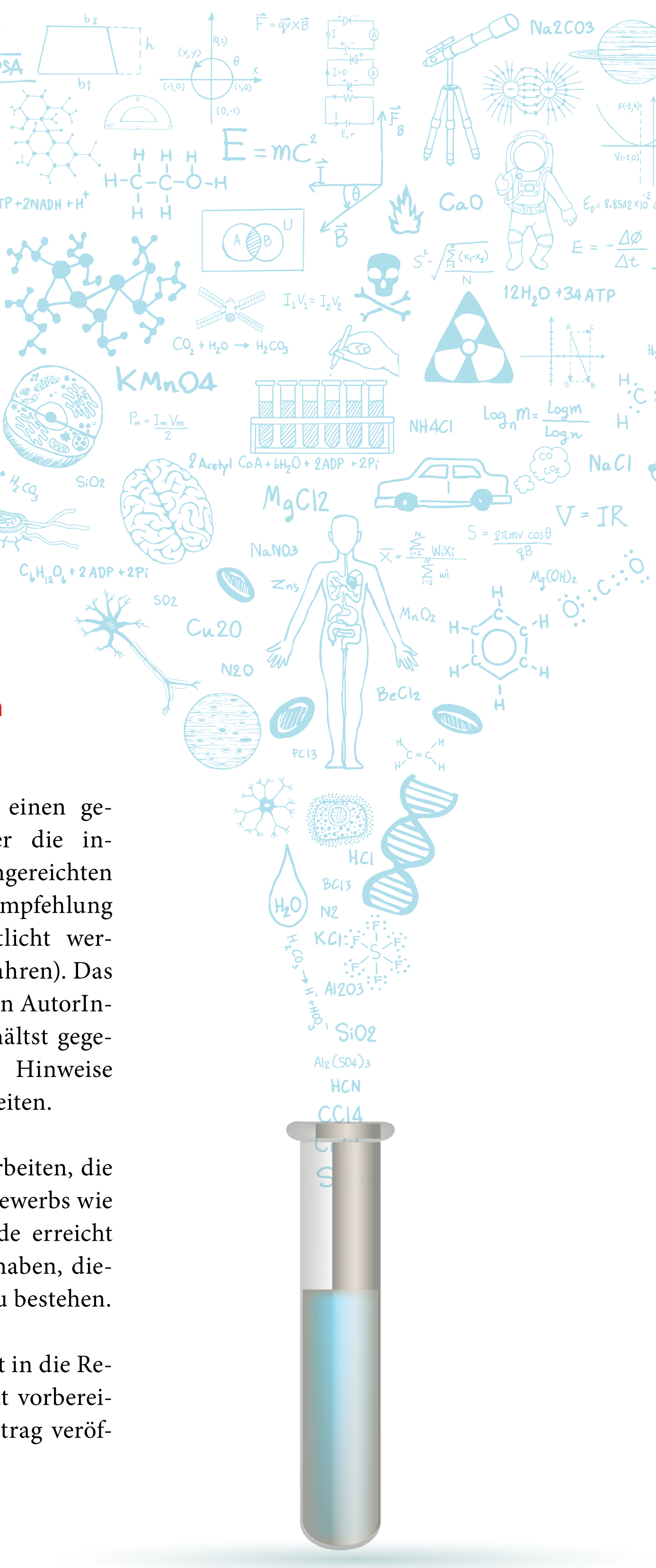
[25] Schleife, F., Klank, D., & Oetzel, C. (2018). Exact Particle Size and Shape Analysis in One Instrument: Combination of Static Light Scattering and Dynamic Image Analysis. In Chemie Ingenieur Technik (Vol. CIT-journal, pp. 419-426). Wiley-VCH GmbH. https://doi.org/10.1002/cite.201870413

[26] Hutmacher, D. W., Ng, M. M.-L., & Dokland, T. (2006). Techniques in Microscopy for Biomedical Applications. World Scientific. https://books.google.de/books?id=Ix3G9_Rr0EAC&dq=use+of+light+microscopy&lr=&hl=de&source=gbs_navlinks_s

doi: 10.7795/320.202303

JUNGE wissenschaft
Verlag: Physikalisch-Technische Bundesanstalt PTB

Publiziere auch Du hier!



Forschungsarbeiten von Schüler/Inne/n und Student/Inn/en

In der Jungen Wissenschaft werden Forschungsarbeiten von SchülerInnen, die selbstständig, z. B. in einer Schule oder einem Schülerforschungszentrum, durchgeführt wurden, veröffentlicht. Die Arbeiten können auf Deutsch oder Englisch geschrieben sein.

Wer kann einreichen?

SchülerInnen, AbiturientInnen und Studierende ohne Abschluss, die nicht älter als 23 Jahre sind.

Was musst Du beim Einreichen beachten?

Lies die Richtlinien für Beiträge. Sie enthalten Hinweise, wie Deine Arbeit aufgebaut sein soll, wie lang sie sein darf, wie die Bilder einzureichen sind und welche weiteren Informationen wir benötigen. Solltest Du Fragen haben, dann wende Dich gern schon vor dem Einreichen an die Chefredakteurin Sabine Walter.

Lade die Erstveröffentlichungserklärung herunter, drucke und fülle sie aus und unterschreibe sie.

Dann sende Deine Arbeit und die Erstveröffentlichungserklärung per Post an:

Chefredaktion Junge Wissenschaft
Dr.-Ing. Sabine Walter
Paul-Ducros-Straße 7
30952 Ronnenberg
Tel: 05109 / 561508
Mail: sabine.walter@verlag-jungewissenschaft.de

Wie geht es nach dem Einreichen weiter?

Die Chefredakteurin sucht einen geeigneten Fachgutachter, der die inhaltliche Richtigkeit der eingereichten Arbeit überprüft und eine Empfehlung ausspricht, ob sie veröffentlicht werden kann (Peer-Review-Verfahren). Das Gutachten wird den Euch, den AutorInnen zugeschickt und Du erhältst gegebenenfalls die Möglichkeit, Hinweise des Fachgutachters einzuarbeiten.

Die Erfahrung zeigt, dass Arbeiten, die z. B. im Rahmen eines Wettbewerbs wie **Jugend forscht** die Endrunde erreicht haben, die besten Chancen haben, dieses Peer-Review-Verfahren zu bestehen.

Schließlich kommt die Arbeit in die Redaktion, wird für das Layout vorbereitet und als Open-Access-Beitrag veröffentlicht.

Was ist Dein Benefit?

Deine Forschungsarbeit ist nun in einer Gutachterzeitschrift (Peer-Review-Journal) veröffentlicht worden, d. h. Du kannst die Veröffentlichung in Deine wissenschaftliche Literaturliste aufnehmen. Deine Arbeit erhält als Open-Access-Veröffentlichung einen DOI (Data Object Identifier) und kann von entsprechenden Suchmaschinen (z. B. BASE) gefunden werden.

Die Junge Wissenschaft wird zusätzlich in wissenschaftlichen Datenbanken gelistet, d. h. Deine Arbeit kann von Experten gefunden und sogar zitiert werden. Die Junge Wissenschaft wird Dich durch den Gesamtprozess des Erstellens einer wissenschaftlichen Arbeit begleiten – als gute Vorbereitung auf das, was Du im Studium benötigst.

doi: 10.7795/320.202303

Richtlinien für Beiträge

Für die meisten Autor/Inn/en ist dies die erste wissenschaftliche Veröffentlichung. Die Einhaltung der folgenden Richtlinien hilft allen – den Autor/innen/en und dem Redaktionsteam

Die Junge Wissenschaft veröffentlicht Originalbeiträge junger AutorInnen bis zum Alter von 23 Jahren.

- Die Beiträge können auf Deutsch oder Englisch verfasst sein und sollten nicht länger als 15 Seiten mit je 35 Zeilen sein. Hierbei sind Bilder, Grafiken und Tabellen mitgezählt. Anhänge werden nicht veröffentlicht. Deckblatt und Inhaltsverzeichnis zählen nicht mit.

- Formulieren Sie eine eingängige Überschrift, um bei der Leserschaft Interesse für Ihre Arbeit zu wecken, sowie eine wissenschaftliche Überschrift.

- Formulieren Sie eine kurze, leicht verständliche Zusammenfassung (maximal 400 Zeichen).

- Die Beiträge sollen in der üblichen Form gegliedert sein, d. h. Einleitung, Erläuterungen zur Durchführung der Arbeit sowie evtl. Überwindung von Schwierigkeiten, Ergebnisse, Schlussfolgerungen, Diskussion, Liste der zitierten Literatur. In der Einleitung sollte die Idee zu der Arbeit beschrieben und die Aufgabenstellung definiert werden. Außerdem sollte sie eine kurze Darstellung schon bekannter, ähnlicher Lösungsversuche enthalten (Stand der Literatur). Am Schluss des Beitrages kann ein Dank an Förderer der Arbeit, z. B. Lehrer und Sponsoren, mit vollständigem Namen angefügt werden. Für die Leser kann ein Glossar mit den wichtigsten Fachausdrücken hilfreich sein.

- Bitte reichen Sie alle Bilder, Grafiken und Tabellen nummeriert und zusätzlich als eigene Dateien ein. Bitte geben Sie bei nicht selbst erstellten Bildern, Tabellen, Zeichnungen, Grafiken etc. die genauen und korrekten Quellenangaben an (siehe auch Erstveröffentlichungserklärung). Senden Sie Ihre Bilder als Originaldateien oder mit einer Auflösung von mindestens 300 dpi bei einer Größe von 10 · 15 cm! Bei Grafiken, die mit Excel erstellt wurden, reichen Sie bitte ebenfalls die Originaldatei mit ein.

- Vermeiden Sie aufwendige und lange Zahlentabellen.

- Formelzeichen nach DIN, ggf. IUPAC oder IUPAP verwenden. Gleichungen sind stets als Größengleichungen zu schreiben.

- Die Literaturliste steht am Ende der Arbeit. Alle Stellen erhalten eine Nummer und werden in eckigen Klammern zitiert (Beispiel: Wie in [12] dargestellt …). Fußnoten sieht das Layout nicht vor.

- Reichen Sie Ihren Beitrag sowohl in ausgedruckter Form als auch als PDF ein. Für die weitere Bearbeitung und die Umsetzung in das Layout der Jungen Wissenschaft ist ein Word-Dokument mit möglichst wenig Formatierung erforderlich. (Sollte dies Schwierigkeiten bereiten, setzen Sie sich bitte mit uns in Verbindung, damit wir gemeinsam eine Lösung finden können.)

- Senden Sie mit dem Beitrag die Erstveröffentlichungserklärung ein. Diese beinhaltet im Wesentlichen, dass der Beitrag von dem/der angegebenen AutorIn stammt, keine Rechte Dritter verletzt werden und noch nicht an anderer Stelle veröffentlicht wurde (außer im Zusammenhang mit **Jugend forscht** oder einem vergleichbaren Wettbewerb). Ebenfalls ist zu versichern, dass alle von Ihnen verwendeten Bilder, Tabellen, Zeichnungen, Grafiken etc. von Ihnen veröffentlicht werden dürfen, also keine Rechte Dritter durch die Verwendung und Veröffentlichung verletzt werden. Entsprechendes Formular ist von der Homepage www.junge-wissenschaft.ptb.de herunterzuladen, auszudrucken, auszufüllen und dem gedruckten Beitrag unterschrieben beizulegen.

- Schließlich sind die genauen Anschriften der AutorInnen mit Telefonnummer und E-Mail-Adresse sowie Geburtsdaten und Fotografien (Auflösung 300 dpi bei einer Bildgröße von mindestens 10 · 15 cm) erforderlich.

- Neulingen im Publizieren werden als Vorbilder andere Publikationen, z. B. hier in der Jungen Wissenschaft, empfohlen.

doi: 10.7795/320.202303

Impressum

Junge Wissenschaft
c/o Physikalisch-Technische Bundesanstalt (PTB)
www.junge-wissenschaft.ptb.de

Redaktion
Dr. Sabine Walter, Chefredaktion
Junge Wissenschaft
Paul-Ducros-Str. 7
30952 Ronnenberg
E-Mail: sabine.walter@verlag-jungewissenschaft.de
Tel.: 05109 / 561 508

Verlag
Dr. Dr. Jens Simon,
Pressesprecher der PTB
Bundesallee 100
38116 Braunschweig
E-Mail: jens.simon@ptb.de
Tel.: 0531 / 592 3006
(Sekretariat der PTB-Pressestelle)

Design & Satz
Sebastian Baumeister
STILSICHER – Grafik & Werbung
E-Mail: baumeister@stilsicher.design
Tel.: 05142 / 98 77 89