Paper 05 / 2023 doi: 10.7795/320.202305

[JUNGE wissenschaft]

JungforscherInnen publizieren
online | *peer reviewed* | original

Verlag:
Physikalisch-
Technische
Bundesanstalt
PTB

Geo- & Raum-
wissenschaft

Tire Wear Particles in the Air

Measurement and Analysis of Particles
from Tire Abrasion in the Air

This research aims to investigate if plastic particles can spread through the air. The focus was on tire abrasion particles. The particles were collected at three separate locations at different distances from a road for five months and analysed by light microscopy. The conclusion is that tire abrasion particles spread through the air and that the weather influences the dispersion of the particles.

DIE JUNGFORSCHERIN

Géraldine Heuer (2001),
Kantonsschule Wattwil,
Kanton St.Gallen
Eingang der Arbeit:
06.09.2022
Arbeit angenommen:
19.11.2022

Tire Wear Particles in the Air

Measurement and Analysis of Particles from Tire Abrasion in the Air

1. Introduction

Plastic has simplified our lives in many ways; without it, many advances would never have been made. Today, countless products are made of plastic or involve plastic. Nevertheless, besides all the advantages, plastic also has its downside. Since disposal and recycling can be very time-consuming, costly, or not possible at all, a lot of plastic ends up in the environment. Plastics are polymer groups produced from petroleum in a long manufacturing process and may also contain toxic chemicals. Plastics in the environment can harm living organisms, for example, by injuring the gastrointestinal tract or causing poisoning.

Plastic parts smaller than 5 mm are called microplastics. Anything larger is called macroplastic and is usually visible. Microplastics are further subdivided into primary and secondary microplastics [1]: Primary microplastics are plastic particles that are deliberately manufactured and added to cosmetics and hygiene products, among others, to create a cleansing effect. Secondary microplastics are created during the use and disposal of plastic products, such as the abrasion of car tires, fiber abrasion during the washing of synthetic textiles or decomposition and weathering of macroplastics into microplastics. Exposure to sunlight and mechanical stress are the main reasons plastic parts in the environment can break down into smaller fragments.

That plastic can decompose into such small particles is a major problem. Small-sized plastic particles can be more easily taken up by animals and plants and enter the food cycle [1]. Further research is needed to determine whether (agricultural) plants can take up microplastics, how microplastics affect plants and soil fertility, and whether humans ingest microplastics by eating crops. However, it is already feared that food such as honey and mineral water are contaminated with these particles, and that plastic infiltrates our food chain. [1, 2, 3, 4, 5, 6].

In Switzerland, the main source of microplastics is tire wear [7, 1, 2, 8, 3, 9, 10, 11]. Tire wear can be transported through the atmosphere and enter the environment through dry deposition and precipitation. Tire abrasion is often referred to as micro-rubber, as tires are made from synthetic and natural rubber. However, the rubber itself is very friable, which is why fillers are added to the rubber mixture, such as carbon black, silica, carbon, and chalk, as well as large amounts of heavy metals such as zinc, lead and cadmium. However, with these fillers, the tire is again too hard, which is why softeners are added to the compound.

Approximately 60 % of tire wear consists of microplastics, 30 % of soot, and 10 % of inorganic substances [2, 8]. Many studies are being conducted on how particulate matter from roads endangers health [12]. Particulate matter (PM), or airborne dust, is solid or liquid matter suspended in the atmosphere (aerosols) that does not immediately sink to the ground but remains in the air for a certain time. Particulate matter is divided into fractions according to the size of the particles: The mass concentration of particles with an aerodynamic diameter of fewer than 10 µm is called PM10. Particles with an even smaller diameter are called PM2.5, i. e., their aerodynamic diameter is smaller than 2.5 µm. The size ranges from 2.5 µm to 10 µm and is referred to as the coarse fraction of fine dust [4].

doi: 10.7795/320.202305

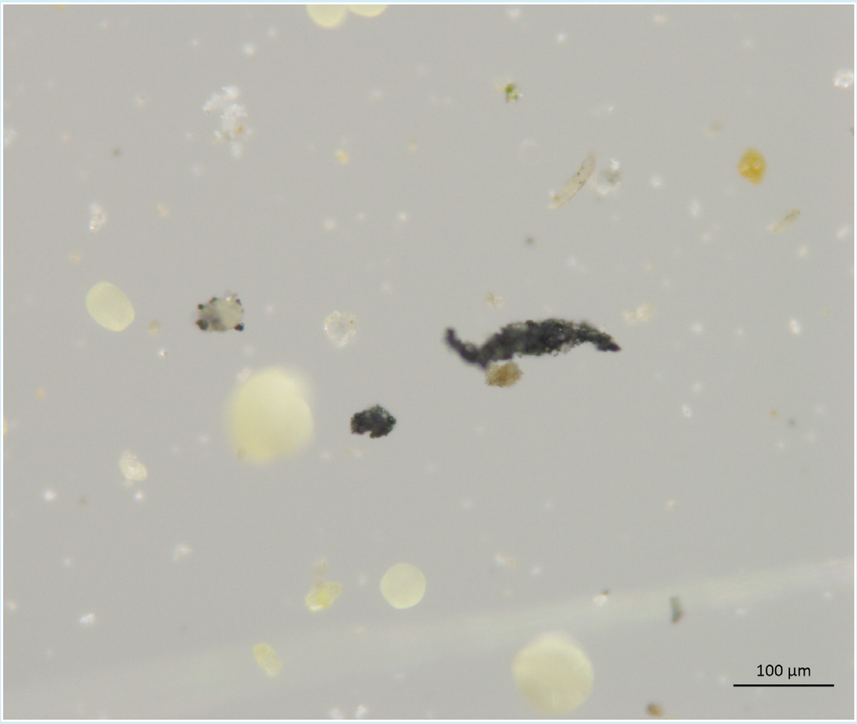


Fig. 1: Image of clear-greenish pollen particles and dark tire abrasion particles (Collector S6, April 11, 2020)

Fig. 2: Sigma-2 passive sampler

Coarse and fine dust can have negative consequences on human health. For example, an immediate health issue caused by stirred-up coarse dust (e.g., through wind) is the irritation of the eyes and the upper respiratory tract, and fine dust can even cause lung damage. Further, coarse and fine dust contain various allergens, such as pollen, fungal spores, or particles from tire wear [13] (see Fig. 1).

The idea for this research was inspired by the assumption that small plastic particles could be transported through the air the same way Saharan dust can be transported over long distances. This work is about the measurement and determination of tire wear in the air.

At the beginning of this research on tire wear, it became clear quickly that there is little knowledge on the topic. Thus, this research aims to answer some basic questions: a) is it possible to detect plastic particles, respectively tire wear in the air, b) how far can tire wear be transported away from roads and c) does the weather influence the dispersion of the particles? The measurements are also intended to determine how much tire wear enters the air compared to natural particles and how far the particles can be transported from the road. So far, it has been estimated that tire wear particles can be transported up to 50 meters [14]. The work also explores whether the weather influences the dispersion of the particles. We assume that fewer particles get into the air when it rains, but during periods with intense winds, the particles are distributed further due to the stirred-up air.

2. Materials and Methods

2.1 Sampler and Sample Collection

For the sampling, the Sigma-2 passive sampler was used (see Fig. 2). This sampler is designed to collect airborne particles with geometric diameters from 2.5 µm to 80 µm in an unpowered and cost-effective manner. The operator can choose the time interval for the sampler exposition. The acceptor area must contain enough particles after sampling to obtain a statistically relevant result. Originally, the collector was invented by the German Meteorological Service to check the air quality at German health resorts. The analytical procedure worked well, and the collector began to be used for other applications such as pollen monitoring to measure pollen from different crops, sampling to distinguish between natural and anthropogenic constituents in coarse dust and estimating particle pollution in urban environments. The data can then be used for further investigations, such as source attribution or linkage of the found particle load with health effects [13].

The collector works passively by sedimentation of particles on the acceptor surface. For example, the collector works as a coarse dust collector for particles from 2.5 µm to 80 µm, and natural air turbulence is used to get the particles into the collector. A 3 cm × 2 cm acceptor surface is placed in an exposure capsule (see Fig. 3). An adhesive foil is on the acceptor surface

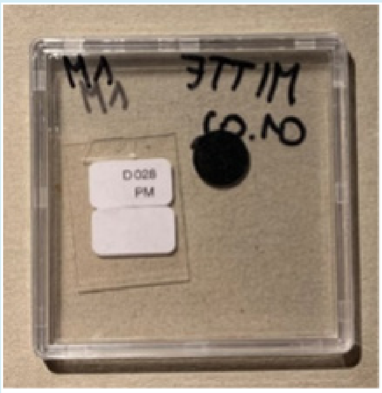


Fig. 3: An exposure capsule for a single sampling

allows for the collected particles to stick to the surface. The black dot is a Boron substrate which can be used for scanning electronic analysis, but it was not used for this work. The collector should be placed about 1.5 m and not more than 4 m above the ground and must not be moved during the measurement time. The coarse dust collector consists of a sedimentation cylinder with a protective cover diameter of 10.5 cm. At the lower end, it has a swing-out sampling plate for the placement of the acceptor surface for sample change, which is covered at the upper end by a fixed protective hood of 15.5 cm. In the upper part of the coarse dust collector and the protective hood, there are four air inlet windows, each at the same height with a size of 3.7 cm × 7.7 cm, which are radially offset 45° from each other. The design of the coarse dust collector ensures a highly wind-calming, low-turbulence air volume inside, which serves as a sedimentation path. At the bottom of the collector, the air velocity reaches only 5 % of the inflow velocity. Therefore, the outside air conditions are usually sufficient to ensure that the ambient air is exchanged [13].

Over five months, measurements were made at three selected locations in Rapperswil-Jona, Switzerland, using Sigma-2 passive samplers. The collectors were set up perpendicular to the main road and a railway track.

The three locations were labelled N (north), M (centre/middle) and S (south) (see Fig. 4).

- Location N was located about 3 m next to a railway track, 80 m away from the main road and was placed at a height of 2 m.
- Location M was placed above a garage driveway and was 1.7 m above the ground and 4.5 m above the driveway. The collector was 48 m from the main road.

Fig. 4: The three locations of the samplers [18]

- Location S was placed right next to the main road, about 3 m away and was installed at 1.9 m above the ground.

A time interval of two weeks was selected for replacing the acceptor surface located in the collector. Acceptor surfaces were replaced every Saturday beginning February 1, 2020, until June 20, 2020. A log was kept of the start date and time when the new acceptor surface was inserted and the end date and time when the acceptor surface was replaced again. In addition, specific weather changes were recorded during the two-week time intervals of the measurements later to determine correlations between collected particles and weather conditions. It was also noted if the area was very heavily covered with insects or if there were many cobwebs in the collector. The collector was usually cleaned before a new acceptor surface was inserted. Table 1 shows the corresponding key data.

For quality control, collectors at locations N and M were completely covered during series 10. Covering the inlets, it was checked whether particles enter the collector only from the outside air or whether particles are emitted from the collector itself. In the subsequent analysis, a few large particles were found, contaminating the sample when the acceptor surface was changed. Thus, the sampler should not be a source of contamination for this research.

2.2 Analysis

The samples were photographed using a light microscope AxioZoom V.16 (Zeiss, Germany). For imaging, the sample, an area of 3 mm × 3 mm (77-fold magnification), was selected, mostly in the centre of the acceptor surface (see Fig. 5). The light microscope images were then analysed with the associated measuring device from the Zen Software. The measuring device counts how many dark and clear particles are on the surface. Finally, the images were evaluated with a specially created Macro from the FUB AG for ImageJ and Excel software. The result of these analyses is the number of light and dark particles in the selected area. The measurements and analyses focus on the dark particles because this research assumes that the dark particles are anthropogenic and are tire wear particles. The typical size of all identified tire abrasion particles usually corresponds to a geometric diameter of 10 µm to 30 µm, so most particles are larger than PM10. However, the geometric diameter changes depending on the distance of the tire wear source.

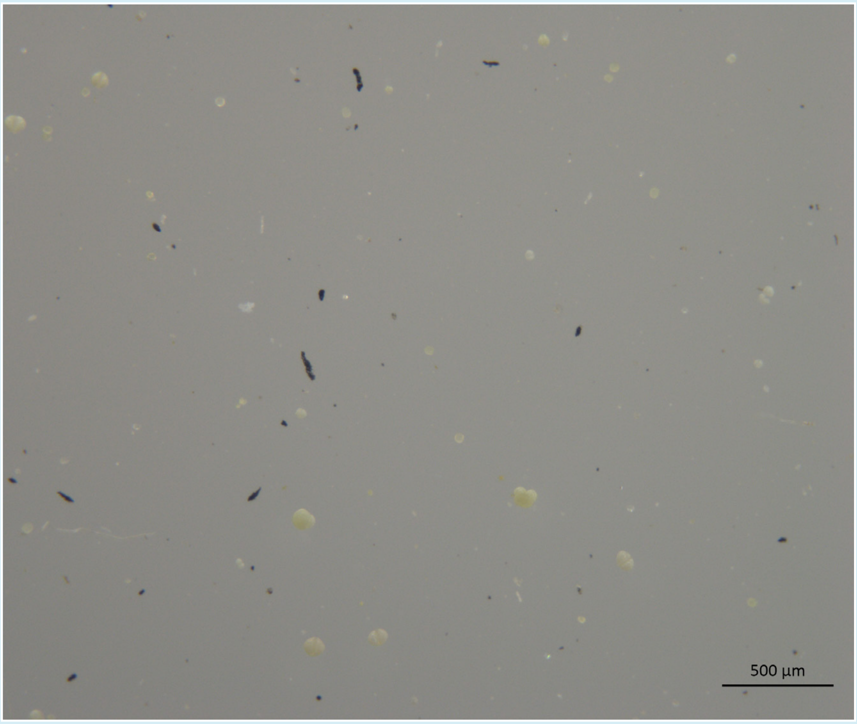


Fig. 5: Image of a partial area of acceptor surface S7 (April 25, 2020) with microscope AxioZoom V.16 by Zeiss

In Fig. 5 dark particles are visible, some of which are elongated. Abrasion is described in theory as black, rust-containing rubber fragments with a roundish, kidney-shaped to elongated form with a typical size of 10 µm to 30 µm [1]. Some of such described particles can be seen in the image, which is not surprising since the sampling site was next to the road. This research assumes that the clear particles are mostly from a natural source. Especially roundish, yellow-green particles indicate that it is mostly pollen and elongated fungal fibers (Fig. 5). For further interpretation of the microscopic images, the ZEN software measured all the particles in the image, and the areas of the particle silhouettes were projected onto the imaging plane. From the measured particle area, the equal-area circle diameter d is calculated as the geometric equivalent diameter [15].

For further evaluation of the results, the focus is on the deposition rate D_n and the mass concentration C_m. The deposition rate or number sedimentation rate shows how many particles are sedimented per area and time [13]:

$$D_n = \frac{n}{F \cdot t}$$

D_n sedimented particle count per area in $cm^{-2}s^{-1}$

n particle count on the evaluation area

F evaluation area

t exposition rate

doi: 10.7795/320.202305

Tab. 1: Log of the data series, their time frames and remarks

Location Code	Start date	Start time	End date	End time	Remarks
North 1	01.02.2020	13:45	15.02.2020	14:18	strong wind (storm), dead fly, cobweb around filter
North 2	15.02.2020	14:19	29.02.2020	17:33	strong storm
North 3	29.02.2020	17:33	14.03.2020	14:55	sunny weather
North 4	14.03.2020	14:55	28.03.2020	13:38	sunny weather
North 5	28.03.2020	13:38	11.04.2020	11:36	green dots on acceptor surface, sampler cleaned, sunny weather
North 6	11.04.2020	11:37	25.04.2020	20:39	heavy pollen count, no rain
North 7	25.04.2020	20:40	09.05.2020	20:04	a lot of rain
North 8	09.05.2020	20:05	23.05.2020	13:15	warm tempertures, sunny
North 9	23.05.2020	13:15	06.06.2020	17:58	sunny, many cobwebs
North 10	06.06.2020	18:02	20.06.2020	10:18	idle, rain
Middle 1	01.02.2020	13:42	15.02.2020	14:21	strong wind (storm)
Middle 2	15.02.2020	14:22	29.02.2020	17:35	strong storm
Middle 3	29.02.2020	17:35	14.03.2020	14:48	sunny weather
Middle 4	14.03.2020	14:48	28.03.2020	13:35	sunny weather
Middle 5	28.03.2020	13:35	11.04.2020	11:38	sampler cleaned, sunny weather
Middle 6	11.04.2020	11:41	25.04.2020	20:05	heavy pollen count, no rain
Middle 7	25.04.2020	20:06	09.05.2020	18:55	a lot of rain
Middle 8	09.05.2020	18:55	23.05.2020	13:18	sunny, warm temperatures
Middle 9	23.05.2020	13:18	06.06.2020	17:51	sunny, many cobwebs
Middle 10	06.06.2020	17:56	20.06.2020	10:23	idle, rain
South 1	01.02.2020	13:50	15.02.2020	14:25	strong wind (storm)
South 2	15.02.2020	14:26	29.02.2020	17:39	strong storm
South 3	29.02.2020	17:39	14.03.2020	15:02	sunny weather
South 4	14.03.2020	15:02	28.03.2020	14:42	sunny weather
South 5	28.03.2020	14:42	11.04.2020	11:45	sampler cleaned, sunny weather
South 6	11.04.2020	11:45	25.04.2020	20:40	dead mosquitoes, heavy pollen, no rain
South 7	25.04.2020	20:41	09.05.2020	19:00	a lot of rain
South 8	09.05.2020	19:00	23.05.2020	13:13	warm tempertures, sunny
South 9	23.05.2020	13:13	06.06.2020	18:07	sunny, many cobwebs
South 10	06.06.2020	18:08	20.06.2020	10:30	rain

doi: 10.7795/320.202305

The mass concentration can be calculated with the mass sedimentation rate D_m by sedimentation velocity, assuming it is the final sedimentation velocity v_{ts} [16]:

$$D_m = \sum_{i=1}^{n} \frac{m_i}{F \cdot t} = \sum_{i=1}^{n} \frac{V_i \cdot \rho_{p,i}}{F \cdot t} = \sum_{i=1}^{n} \frac{\pi \cdot d_{p,j}^3 \cdot \rho_{p,j}}{6 \cdot F \cdot t}$$

D_m total sedimented particulate mass per area and time

i running index

m_i particle mass of the i-th particle

V_i particle volume of the i-th particle

$\rho_{p,i}$ apparent density of the i-th particle of 1.0 g/cm³

$d_{P,i}$ diameter of the i-th particle

By sedimentation velocity, assuming it is the final sedimentation velocity v_{ts} [13]:

$$v_{ts} = \frac{C \cdot \rho_p \cdot g \cdot d_p^2}{18 \cdot \eta \cdot \chi \cdot k}$$

C Cunningham correction: Here, the assumption C = 1 is usually made.

ρ_p apparent density of 1.0 g/cm³

g acceleration due to gravity of 9.81 m/s²

χ aerodynamic shape factor of 1.3

k volume factor of 0.75

η dynamic viscosity of air of $1.813 \cdot 10^{-4}$ g/(cm s) at 20 °C

Based on this, the mass concentration is calculated as follows [13]:

$$C_m = \frac{D_m}{v_{ts}}$$

The calculated mass concentration and deposition rate express how many particles have settled in the sampling intervals, allowing comparisons between the different sites and whether external influences such as weather might have influenced the deposition of the particles. However, the mass concentration and deposition rate alone does not give information about the exact substance of the clear and dark particles. Therefore, all samples were analysed with the microscope manually by comparing the particle directly with the characteristics of tire abrasion or natural particles. The best example is sampled from location N, where the collector was located directly next to a railway track, in a place where the trains start to brake. Thus, at this location, we expected an increased number of smaller particles of 2.5 µm to 5.0 µm from the metallic abrasion of the train brakes, which should arise during the braking process.

3. Results and Evidence of Tire Abrasion in the Air

3.1 The Deposition Rate and Mass Concentration of the Collected Particles

The results indicate that black particles can spread through the air. The results in Fig. 6 only include the particles of the sizes between 2.5 µm and 40 µm since larger particles were rarely recorded. Fig. 6 compares the deposition rate of the different particle sizes per series and per location with a dot diagram.

The first observation is the high number of dark particles from 2.5 µm to 5.0 µm at location N, where twice as many particles were collected in the first six series compared to the other locations. Particles of size 2.5 µm to 5.0 µm were collected the most at all sampling sites. Also, if fewer particles were collected at one site in a series, it did not mean fewer particles were collected at another location in the same series. A good example is series 3. Only a slight drop of small particles is visible at locations N and S compared to location M. For particle sizes 5.0 µm to 10.0 µm, there was less variation between results.

Nevertheless, more particles were collected at location N than at other locations. That there are more smaller particles at location N than at the others can be attributed to location N being directly positioned next to the railway track. Some of the „break-ins" in the diagram can also be seen in different series. For example, a strong collapse, seen in series 7, could be attributed to the weather because it rained during this period. This means the particles fall faster to the ground due to the rain and could spread out poorer via the air. However, if you look at the next series M8, you can see that even fewer particles

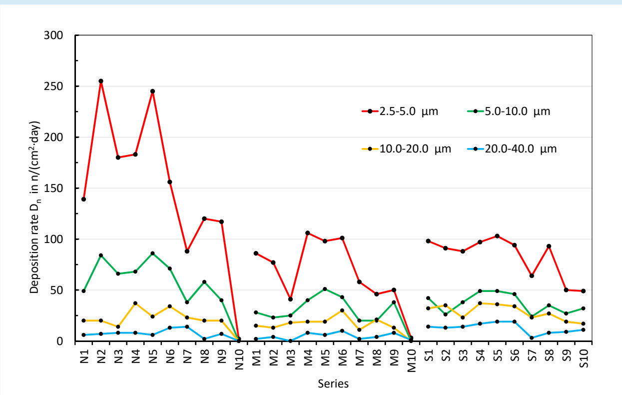


Fig. 6: Deposition rate of dark particles

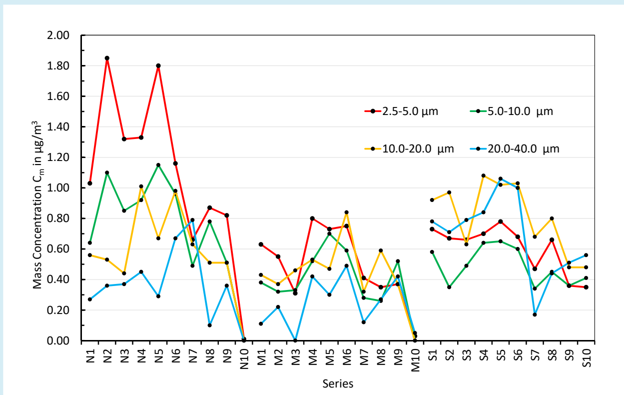


Fig. 7: Mass concentration of dark particles

doi: 10.7795/320.202305

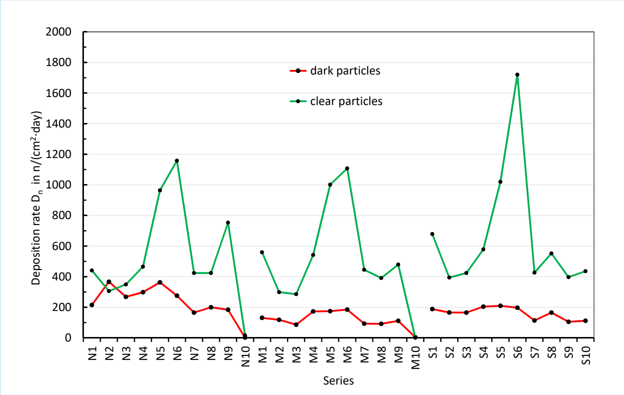


Fig. 8: Average deposition rate of clear and dark particles per series

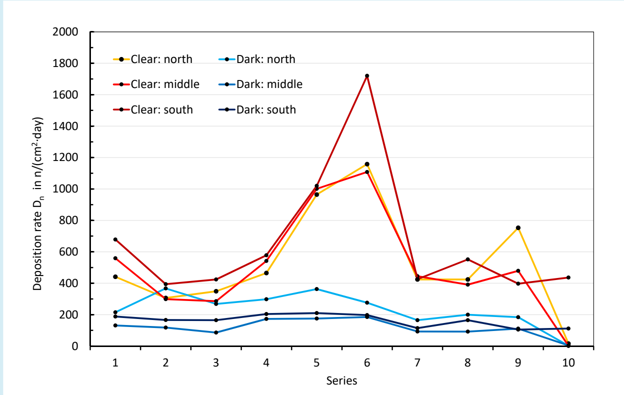


Fig. 9: Average deposition rate of clear and dark particles

were collected. This suggests that the rain was not the only reason why fewer particles were collected in M7.

Interestingly, strong wind does not cause more particles to be collected. The most particles per series were collected in the sunny periods. What may have influenced having fewer black particles in the air at all locations was the Covid-19 lockdown in Spring of 2020. This started in series 5. There is also a sudden visible drop in particle size 2.5 µm to 10.0 µm, which did not recover and cannot be attributed to weather. Since there was less traffic on the road during this time because fewer people were commuting but working at home, one could attribute this dip to this new situation on the road.

The mass concentration also shows a similar picture (see Fig. 7). The mass concentration is more concrete about how many particles of the sizes have settled in the collector. At location N, the mass concentration of particles between 2.5 µm and 5.0 µm exceeded the others. At location M, the mass concentration of particles was more regular, while at location S, particles between 10.0 µm and 40.0 µm were mainly found. According to theory, tire abrasion particles are mainly of size 10 µm to 30 µm. However, the large number of smaller, black particles could indicate that tire abrasion can also reach a smaller size during abrasion. However, it cannot be ruled out that the small particles could come from another anthropogenic source.

3.2 Comparison of the Average Deposition Rate of Clear and Dark Particles

If the deposition rate of the clear and dark particles is compared, it can be seen how the particles have proportionally settled and how large the difference was over the entire period. Fig. 8 shows that more clear particles were collected except for location N in series 2. In this series, more dark particles were collected than clear ones, which could be attributed to the fact that it was still very cold in this period and very windy. Therefore, fewer clear particles were able to propagate from natural sources. At the remaining locations and series, the ratio was at least 2:1 for clear to dark particles. The results show that a sudden decrease in the concentration of clear and dark particles during series 7 behaved very similarly at every location (see Fig. 8). If fewer clear particles were collected in a series, fewer dark particles were usually collected.

The measurements were carried out from February to July, and the collected clear particles indicated the different seasons. In series 5 and 6, there was a sudden increase in the deposition rate of clear particles. During these four weeks, spring began, and many plants started to bloom. Many pollen and fungal fibers were observed on the acceptor surfaces of these weeks, so the surface was almost too heavily loaded. At location S, right next to the road, more clearer particles were collected than at the other locations. Even in the case of the clear particles, it can be observed that the particles have moved through the air more strongly in sunny weather than in rainy or stormy periods. Thus, general statements about how different particles move through the air can be made.

Tab. 2: Average deposition rate at all three locations

Average deposition rate of total period in cm^{-2} day^{-1}	Location N	Location M	Location S
Dark particles	233.8	116.8	162.6
Clear particles	530.0	511.1	662.5

doi: 10.7795/320.202305

Table 2 shows the results numerically: we can see that the ratio is 2:1 to goes even up to 4:1 for the distribution of clear to dark particles.

In conclusion, this means that one-quarter to one-half of the particles in the air under consideration of the size range are dark particles and, therefore, most likely to be particles originating from an artificial source like tire wear abrasion. The locations were in a neighbourhood in Rapperswil-Jona, surrounded by nature and outside of the city. However, the level of dark particles is still remarkably high, either because of the road or the railroad track. For this research, it was impossible to make a chemical analysis of the particles, so the analysis of the particles is based only on their shape, colour, and possible place of origin. However, despite the lack of precise analysis, the particles are likely tire abrasion, as there is hardly any other source that could produce dark particles at these locations and in this amount.

4. Conclusion

For this work, only one environment was chosen to place the collectors. Therefore, the results are one-sided and can only be compared between the three locations. For further work, collectors could be placed at several locations further apart. For example, one could compare motorways and main roads or how tire abrasion spreads in comparison between cities and the countryside to make more precise statements about the spread of tire abrasion in the air.

The results show the dispersion of the dark and clear particles in the air. Comparison with the clear particles (Fig. 9) is important to make precise statements about weather influences and whether the dark particles are particles of anthropogenic origin. The results show that both assumptions can be verified. In contrast to the dark particles, the natural ones could be measured regularly at all three locations. This is an indicator of the natural origin because a large part of the clear particles come from plants, which depend on weather and season at all three locations.

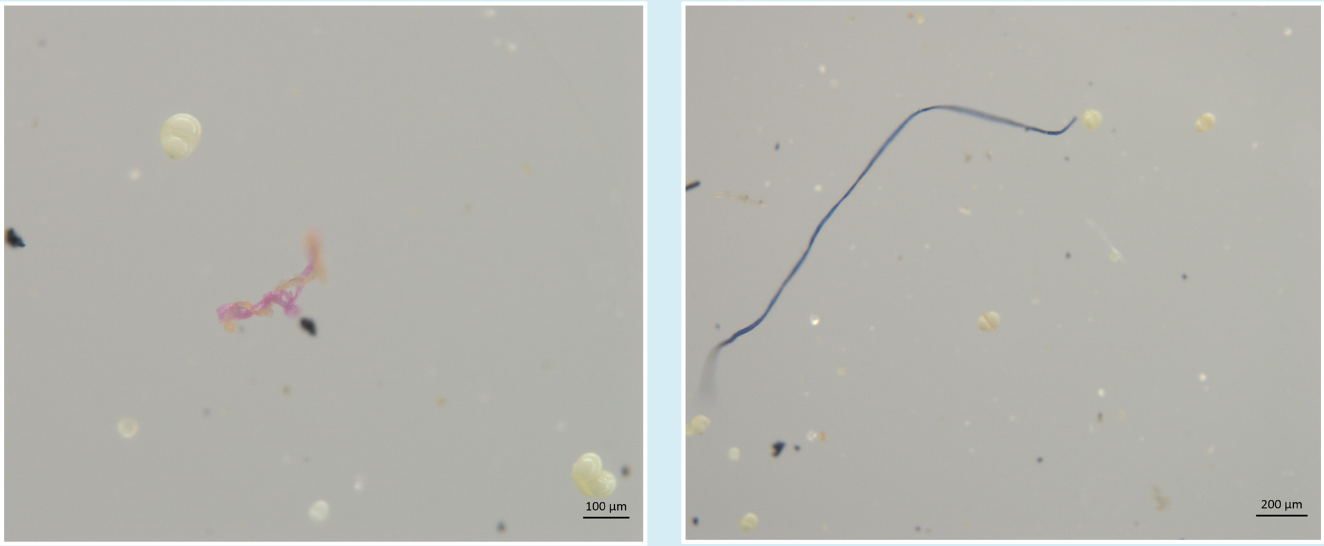
A good example is series 6, where clear particles had their peak (see Fig. 9). During this period, spring was in full bloom. It was a sunny week after some rain, so the plants started to spread their pollen. By analysing the samples by eye, it is possible to make assumptions about the origin of the particles because of form and colour. The dark particles had mostly the typical size and form of tire wear abrasion, so for a first conclusion, it is assumable that tire wear particles can spread through the air. Analysing each location individually, the following conclusions can be drawn.

Location N was right next to a railroad track, at a point where the train begins to brake. This could be why most dark particles of 2.5 µm to 5.0 µm were found there. However, at location N also the highest overall number of dark particles, with sizes up to 40.0 µm, was found. Looking at the particles on the measurement images and location N, most of the larger particles had the typical tire abrasion shape, although this location was the furthest away from the road, 80 meters to be exact. This would mean that tire abrasion can be deposited more than 50 meters away from the road [13]. Another factor was the constant air turbulence from passing trains, which resuspended the particles every 30 minutes. Some smaller particles will probably also be metallic abrasion from train traffic and the track. In a 2007 study, the emission from trains was examined. It was found that the abrasion from trains was around the PM10 range. However, it should be noted that modern trains are equipped with magnetic brakes, so there is less abrasion in rail traffic today. Passenger trains produce a smaller share of particle emissions than freight trains. At location N, passenger trains pass by, so their emissions should be lower. [16] This research means that without an in-depth analysis of the smaller particles from location N, it will be assumed that only a small number of particles originated from rail traffic.

At location M, a medium quantity of particles was collected compared to the other locations. At this location, the least dark particles were found, but only with a small difference to the locations N and S. The sampler was placed higher than at the other two locations, so this could be why fewer dark particles were collected. The collector at location M is the only one not directly next to traffic, which is why the air turbulence should have been quieter. This could explain why fewer particles were found.

The location S was directly next to a road. The expectation was to collect the highest number of dark particles at location S. Only a medium quantity, compared with the other locations, of dark particles were collected at location S. On the other hand, the highest number of clear particles were collected at S. The analysis revealed that the S sampler had collected many particles between 10.0 µm and 40.0 µm. Tire abrasion particles belong mostly in this size range, and with the image analysis, one could recognise increasingly quantity of dark particles, which had the typical tire abrasion form. Also worth mentioning is that only at collector S colourful plastic fibers have been found on the acceptor surface of S7 (April 25 to May 9, 2020). Location S is the nearest to daily human activities, so that these fibers will be highly likely from an anthropogenic source (see Fig. 10).

The assumption is that by the passing vehicles, the particles are stirred up more, so lighter particles are transported further. In contrast, the coloured plastic fibers, which have a larger and therefore heavier shape, directly drop next to the road. This assumption also explains why the large, dark particles of 20.0 µm to 40.0 µm were mostly collected in collector S and only a few small particles. Compared to the particle size at Location N, where the



a) b)

Fig. 10: Images of coloured plastic on S7 (April 25, 2020)

smallest particles have been found, it is possible to assume that the larger the tire wear particles are, the closer they are deposited to the source of origin, the road. Therefore, smaller particles can travel correspondingly greater distances. Nevertheless, it is important to note that in all three locations, dark particles of the typical size were found, with only a small difference to location S. Thus, there is no guarantee that the large tire wear particles will be deposited directly next to the road, which gives tire wear pollution a poorly assessable gravity.

From the deposition rate, it is identifiable that the weather played a role in the dispersion of the dark and clear particles. One could clearly detect fewer particles in the series with rainy periods than in sunny weeks. However, this does not mean that fewer dark particles were formed but that reached the ground more quickly and were washed away. Also, storms did not have such a big effect on the dispersion as assumed. The reason is mostly attributed to the collector being designed for normal air circulation and not for exceptionally intense winds.

What is difficult to conclude from the results is whether, due to the decrease in traffic on the road during the Covid 19 lockdown, less tire abrasion was produced. The lockdown began in Switzerland in mid-March 2020, so in series 5. At location N, a collapse is visible in the deposition rate of all particle sizes. At location M, the collapse was not as extreme but still noticeable. Only at location S, directly next to the road, were the values stable over almost the entire period. To conclude, one would have to collect even more particles with measurements of normal traffic on the road to make a comparison. Should the lockdown have influenced the formation and spread of the dark particles, this would further indicate that the dark particles are tire abrasion.

The current method of investigation is based only on the colour, size, and appearance of the black particles. For further research, the analysis method should be significantly improved and made more accurate to determine whether the black particles are tire abrasion particles and to determine their origin. The considerable number of black particles found, especially in a region and a country known for clean air, is very worrying. The particles should not yet affect human health with a size of 10 µm to 30 µm in the air. However, once the particles settle in the soil and decompose, they can enter our food chain and harm us. The overall damage of micro- or nanoplastics is still largely unexplored. However, as harmful particles can travel distances through the air, it adds a new dimension to the problem.

5. Reducing the Spreading of Tire Wear

In the case of tire wear, it is, fortunately, quite easy to say where the particles come from and how they are produced. To reduce tire wear, several things can be done by every driver: reduction of acceleration, speed reduction in curves and practice of economical and preventive driving style to prevent panic braking. A steady driving style and low driving speeds can also be helpful in avoiding resuspension. [17]

High-quality tires are also worthwhile, as they produce less tire wear and therefore do not need to be replaced quickly. In addition, winter tires should not be used in summer, as they are made of a harder rubber compound and produce more tire wear due to increased friction. In future, vehicle manufacturers could make sure that they produce lighter vehicles and use

doi: 10.7795/320.202305

narrower tires because if no tire-wear-friendly vehicles are sold on the market, there is not much that can be done against pollution.

Tire wear results from energy transfer via tires to the road surface. The lower the energy input, the less abrasion is produced. In summary, low vehicle weight, low speeds and smooth traffic can prevent abrasion and emission of tire wear particles and deposition of tire wear in the environment.

Acknowledgement

First, I would like to thank my chemistry teacher Gabriela Eugster who encouraged me to do this research for my Matura thesis and to carry out my ideas. Many thanks also to Mario Meier, the head of FUB – *Forschungsstelle* für *Umweltbeobachtung* AG, who provided me with the necessary material for the measurements, access to the light microscope and answered my questions and helped me with a lot of information about tire abrasion. My thanks also go to Christoph Hüglin of EMPA, who improved my competition work for Schweizer Jugend forscht (SJF) and answered all my questions about plastics.

References

[1] Dr. Anke Schäfer, Mikroplastik in der Umwelt, Infoblatt Juli 2015, Oekotoxzentrum, centre ecotox (Schweizerisches Zentrum für angewandte Ökotoxikologie, Eawag-EPFL) https://www.oekotoxzentrum.ch/media/2243/2015_mikroplastik_de.pdf Download: 15. Juni 2020, 18:00 Uhr

[2] Das passiert mit dem Abrieb von Autoreifen, 28. September 2018, Herausgeber Quarks, WDR https://www.quarks.de/technik/mobilitaet/das-passiert-mit-dem-abrieb-von-reifen/, Download: 28. September 2020, 17:00 Uhr

[3] Flüsse und Seen, Kunststoffe in der Umwelt, Faktenblatt Nr.1, 2020, Herausgeber Bundesamt für Umwelt https://www.bafu.admin.ch/content/dam/bafu/de/dokumente/abfall/fachinfo-daten/kunststoffe-1-fluesse-seen.pdf, Download: 18. Oktober 2020 10:50 Uhr

[4] Aktuelle Informationen zum Umgang mit Reifenabrieb und Mikroplastik, Juli 2019, Mall-Umwelt-Info Ausgabe 5, Herausgeber Mall Umweltsysteme https://www.mall.ch/fileadmin/user_upload/unternehmen/umwelt-info/umwelt-info-5-umgang-mit-reifenabrieb-und-mikroplastik.pdf, Download: 20. Juli 2020, 11:20 Uhr

[5] Joachim Wille, Mikroplastik auf den Feldern, 05. März 2018, Klimaretter.info, Frankfurt am Main http://www.klimaretter.info/umwelt/hintergrund/24343-mikroplastik-auf-den-feldern, Download: 05. März 2021, 18:30 Uhr (Link funktioniert nicht mehr)

[6] Christoph Barkewitz, „Zieht Mikroplastik schädliche Keime an?", 26. Februar 2018, Ärztezeitung https://www.aerztezeitung.de/Panorama/Zieht-Mikroplastik-schaedliche-Keime-an-224238.html

[7] Kunststoffe in der Umwelt, 15. Juli 2020 (Letzte Änderung), Herausgeber Bundesamt für Umwelt https://www.bafu.admin.ch/bafu/de/home/themen/abfall/fachinformationen/abfallpolitik-und-massnahmen/kunststoffe-in-umwelt.html

[8] Reifenabrieb, Kunststoff in der Umwelt, Faktenblatt Nr.6, 2020, Herausgeber Bundesamt für Umwelt https://www.bafu.admin.ch/content/dam/bafu/de/dokumente/abfall/fachinfo-daten/kunststoffe-6-reifenabrieb.pdf, Download: 18. Oktober 2020, 11:10 Uhr

[9] Muriel Jeisy, Matthias Schmid, 12'000 Tonnen Pneu-Teilchen auf Schweizer Strassen, 02. Mai 2015, SRF „Espresso Aha!" https://www.srf.ch/sendungen/kassensturz-espresso/services/interaktiv/espresso-aha/12-000-tonnen-pneu-teilchen-auf-schweizer-strassen, Download: 7. Oktober 2020, 10:30 Uhr

[10] Cornelia Zogg, Gummi in der Umwelt, Empa berechnet die Belastung mit Mikrogummi, 14. September 2019, Empa https://www.empa.ch/web/s604/mikrogummi?inheritRedirect=true, Download: 31. August 2020, 20:40 Uhr

[11] Luft, Kunststoff in der Umwelt, Faktenblatt Nr.3, 2020, Herausgeber Bundesamt für Umwelt https://www.bafu.admin.ch/content/dam/bafu/de/dokumente/abfall/fachinfo-daten/kunststoffe-3-luft.pdf Download: 18. Oktober 2020. 11:00 Uhr

[12] Leni, L.-E. Cassagnes, K.R. Daellenbach, I. El Haddad, A. Vlachou, G. Uzu, A.S.H. Prévôt, J.-L. Jaf-frezo, N. Baumlin, M. Salathe, U. Baltensperger, J. Dommen, M. Geiser, Oxidative stress induced inflammation in susceptible airways by anthropogenic aerosol. PLOS ONE, 18. November 2020; https://doi.org/10.1371/journal.pone.0233425, Download: 04. Dezember 2020, 15:50 Uhr

[13] Messen von Immissionen, Passive Probenahme mit einem Grobstaubsammler zur Charakterisierung von Einzelpartikeln und Berechnung der grössenfraktionierten Massenkonzentrationen, Oktober 2011, Verein Deutscher Ingenieure, VDI/DIN Handbuch Reinhaltung der Luft, Band 4: Analyse und Messverfahren I

[14] Messen von Immissionen, Passive Probenahme mit einem Grobstaubsammler zur Charakterisierung von Einzelpartikeln und Berechnung der grössenfraktionierten Massenkonzentrationen, Oktober 2011, Verein Deutscher Ingenieure, VDI/DIN Handbuch Reinhaltung der Luft, Band 4: Analyse und Messverfahren I

[15] Passive Probenahmen mit einem Grobstaubsammler zur Charakterisierung von Einzelpartikeln und Berechnung der grössenfraktionierten Massenkonzentration, Oktober 2011, Verein Deutscher Ingenieure, Beuth Verlag GmbH, 10772 Berlin

[16] Jürg Heldstab, Natascha Kljun, Infras, PM10-Emissionen Verkehr, Teil Schienenverkehr, Schlussbericht, 10. Januar 2007, Bern https://www.bafu.admin.ch/dam/bafu/de/dokumente/luft/fachinfo-daten/pm10-emissionen_schienenverkehr.pdf.download.pdf/pm10-emissionen_schienenverkehr.pdf Download: 7. März 2021, 17:56 Uhr

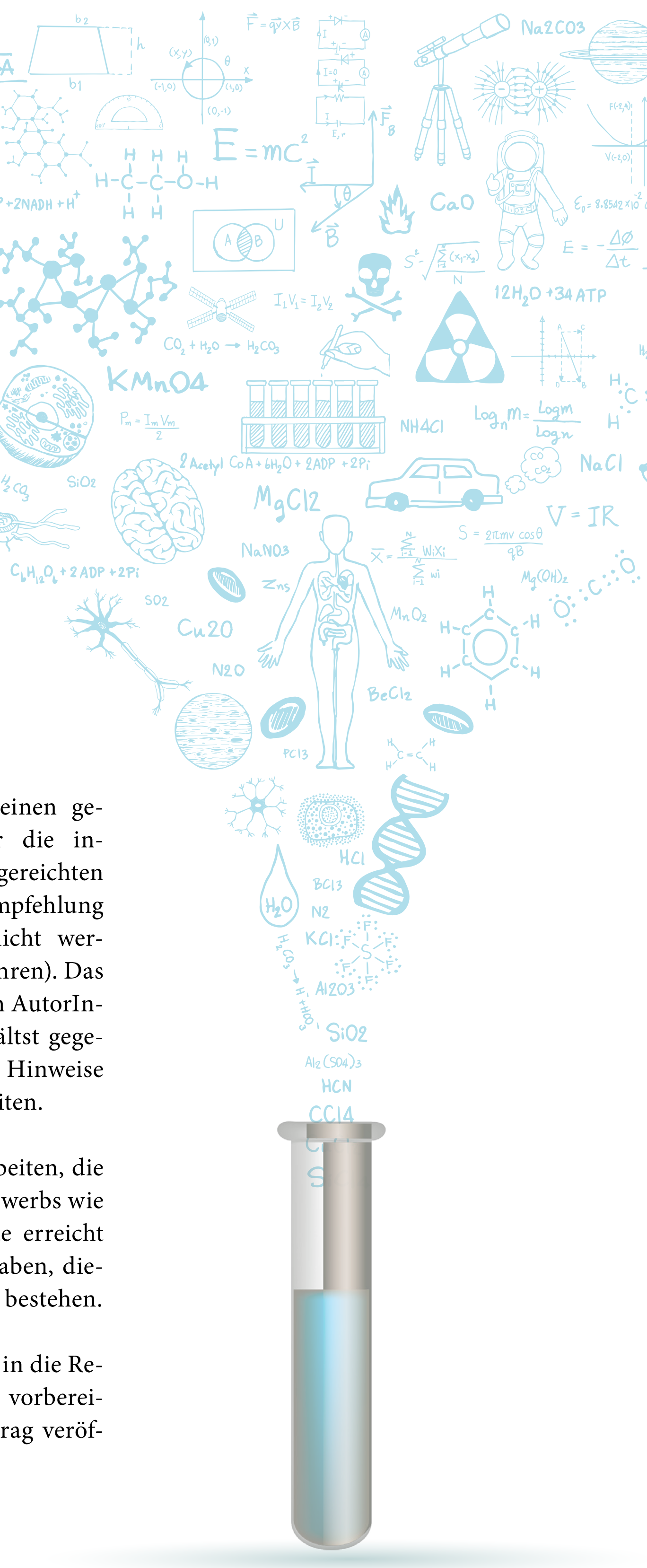
[17] Böden, Kunststoff in der Umwelt, Faktenblatt Nr.2, 2020, Herausgeber Bundesamt für Umwelt https://www.bafu.admin.ch/content/dam/bafu/de/dokumente/abfall/fachinfo-daten/kunststoffe-2-boeden.pdf, Download: 18. Oktober 2020

[18] Maps of the Swiss Confederation https://map.geo.admin.ch/?lang=de&topic=swisstopo&bgLayer=ch.swisstopo.pixelkarte-farbe&catalogNodes=1392&layers=ch.swisstopo.swissnames3d&lon=8.80751&lat=47.23717&elevation=635&heading=360.000&pitch=-40.000, zuletzt aufgerufen am 15.03.23

doi: 10.7795/320.202305

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: 10.7795/320.202305

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: 10.7795/320.202305

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