Supplement to

Microplastic detectives: a citizen-science project reveals large variation in meso- and microplastic pollution along German coastlines

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Text S1. Rationale for chosen sampling methodology and strategy to motivate and recruit citizen scientists

A lot of thought and discussion went into (1) the sampling methodology and (2) the strategy to motivate and recruit citizen scientists to participate in the sampling (see also Dittmann et al., 2023; Thiel et al., 2023). It is impossible to describe every detail of these thought processes, discussions and resulting decisions, but we will describe the main points with a special emphasis on those points which may be useful to consider during future similar citizen-science campaigns.

Text S1.1. The sampling methodology

There are so many permutations of how a sampling methodology could be set up for the specific purpose of citizen scientists sampling for meso- and microplastic (MM) particles that it would be impossible to cover them all. Therefore, we here explain only the major strategic decisions which we made to arrive at a sampling methodology to be used by the citizen scientists.

Our first *a priori* decision was to only sample sandy beaches because sampling sand is much easier to sample for MM than, e.g., sampling other coastal habitats, such as mudflats or saltwater marshes (indeed, some citizen scientists asked about sampling these habitats as well). Given the time and financial constraints of the project (20 months of salary for one senior scientists, namely BAW, and about 10000 Euros for equipment and other expenses), we decided that sampling sandy beaches was the best choice because (1) sand is easy to dry and sieve, (2) most sandy beaches have relatively easy access because they are used by tourists (which also means that access is not restricted as, e.g., for protected mudflats or saltwater marshes), and (3) many previous studies have sampled sandy beaches, so that there would be many studies to compare our results to.

Our second *a priori* decision was for the citizen scientists to actually take sand samples because there is also the alternative possibility of just using visual estimates (Figure S1). For example, citizen scientists employed visual estimates of pollution levels of macroplastic pollution around the entire coast of Taiwan (Yen et al., 2022). Naturally, MM pollution is much smaller than macroplastic pollution and thus less visible to the naked eye, but it may nevertheless be possible to establish three or four ranking categories (e.g., no pollution, 1-2 MM per m^2, 2-10 MM per m^2, and > 10 MM per m^2) which could be visually estimated without the need for actual sampling. We do not know of any study (with the exception of Lavers et al., 2016) which has tested or employed visual estimates of MM pollution levels which may be a worthwhile future study.

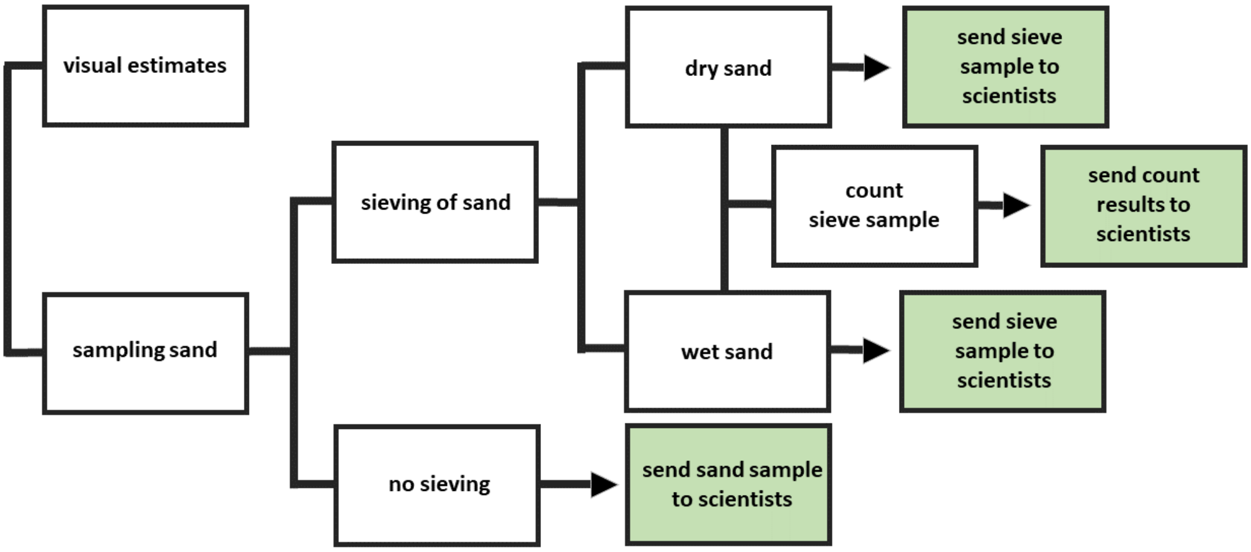

Figure S1. Flow diagram of possible permutations for a sampling methodology to sample meso- and microplastics on sandy beaches.

Our third *a priori* decision was that the citizen scientists should take sand samples (called bulk sampling, see Hanvey et al, 2017) but to not sieve these samples *in situ* to check for MM particles themselves (called volume-reduced sampling) (Figure S1). Rather, we decided that the citizen scientists should send the sand samples directly to the laboratory (as done in many studies conducted by scientists, e.g., Kunz et al., 2016; Korez et al., 2019). We decided on this strategy because we believed that the advantages of this method outweighed the disadvantages (Table S1). The most important considerations for this decision were our concerns about time spent on the beach, possible contamination or loss of the samples (e.g., during windy days), and financial costs.

However, first we need to clarify one more aspect. When we write above that "we decided" then this choice of words is actually not quite accurate. In the first few months of the project, BAW engaged in numerous one- to two-hour discussions with citizen scientists and other scientists (see list of people under "for comments and discussions" in the Acknowledgements) during which we discussed in detail many of the pros and cons of the various sampling methodologies and the alternatives as depicted in Figure S1. These discussions greatly informed the following discussions between BAW, LG and ML during which we made our decisions about which methodology to ultimately choose among the many alternatives.

Out of these discussions came three important realizations. The first one was that if we asked the citizen scientists to sieve the sampled sand (Figure S1), this would greatly increase the time spent on the beach. From our own trials at the beginning of the project as well as from experiences of other people, we realized that just sampling the sand by transferring it directly into 20 metal boxes (or sample containers) would take between 1.5 to 2.5 hours for one beach. However, sieving even of dry sand would increase the time spent on the beach by several hours. To illustrate, A Rocha International (2018) and Robert Slutka from A Rocha International (in litt. 2021) reported that it took 30-60 minutes to finish just one 50 cm x 50 cm quadrat on the beach despite using several people. Even worse, if the sand was wet, normal sieving would become impossible because wet sand simply does not pass through a 1-mm sieve. Sampling wet sand can be achieved by rinsing with water (e.g., A Rocha International, 2018; Haseler et al., 2018; 2019; Jones et al., 2022), but getting and then filtering water on a beach adds several further logistical obstacles and further time (e.g., no water present during low tide or a long walk to the low tide's edge, A Rocha International, 2018), so that the task becomes almost impossible to achieve with citizen scientists. Furthermore, there is the risk of "material gets lost over the edge of the sieve" (Haseler et al., 2018). Thus, sieving the sand would mean that citizen scientists would spend a minimum of three to four hours, possibly more, on the beach, which we simply considered to be too much time. Either citizen scientists would refuse to do this, or, if they did go to the beach, possibly give up during the sampling or just work inaccurately because of built-up frustration. Another serious problem with this method is that one cannot determine the mass and volume of the sand sample, but only the surface area sampled (e.g., Haseler et al., 2018; 2019; Jones et al., 2022) which report all results in only numbers per m^2).

The second realization was that even if the citizen scientists were to sieve the sand (dry or wet), they would need reliable, scientific sieves which are very expensive (> 100 Euros). To buy such sieves for more than 50 participating groups was thus much more expensive than to simply mail the sand samples (cost during 2022: transport cost for 50 kg **sand** = 5 times 8.50 Euros per 10 kg package = 42.50 Euros in total).

The third realization was that even with good prior training, sources of inaccuracy and bias (Walther and Moore, 2005) would still be considerably greater if the citizen scientists were to sieve the sand on the beaches (Table S1). The main reasons for this are:

(1) Despite training, different people will perform tasks differently, which automatically introduces variation in the results. In the laboratory, only one or two people were working at any time, thus reducing interpersonal variation.

(2) Environmental factors vary on the beaches and can thus introduce inaccuracies (e.g., wind blowing away light MM particles such as foam or Styrofoam/Styropor particles), despite the best efforts of the citizen scientists. To illustrate, this problem of wind blowing away light MM particles was repeatedly encountered during one study on Taiwanese beaches (Bancin et al., 2019) but not during another similar study when the sand was taken back to the laboratory (Kunz et al., 2016). Conceivably, wind could also blow light MM particles into the sieve leading to sample contamination, although the probability of that happening is much lower.

(3) A further logistical problem if citizen scientists were to sieve the sand on the beach is how to transfer the contents remaining on the sieve into a container for transport (e.g., a Ziploc plastic bag or a small metal box). It is very difficult and time-consuming to transfer every small particle from a sieve into a transport container (Fig. 2c in Haseler et al., 2018), especially if the particles stick to the sieve when the sieve is wet (M. Haseler, personal communication 2021, and our own observations during initial trials). This step was thus also fraught with (1) adding considerable working time and (2) introducing potential errors, such as dropping contents during the transfer process.

Some citizen scientists complained about the disadvantages which are also listed in Table S1, mostly about the cumbersome transport of approximately 50 kg of sand divided into 20 metal boxes, especially if they had to carry it through the sand a considerable distance back to the transport vehicle. Some solved this problem by using a hand-pulled transport wagon (often also called toy wagon or handcart, and sometimes called “Bollerwagen” in German). However, such complaints were only heard a handful of times, while the vast majority reported back impressions of “having had a great day on the beach” including sending photos of groups of smiling citizen scientists in front of their filled and sealed metal boxes (Figure S2). Furthermore, some citizen scientists complained about having to find appropriate packing material and to package 20 metal boxes in such a way that they would not get damaged during the transport back to the laboratory. Possibly out of that frustration or just out of inexperience, a few packages were not made well enough so that a few metal boxes arrived at the laboratory damaged in such a way that we could not use the sand samples inside anymore (see Tables S1 and S4).

Figure S2. A typical group photo showing the happy citizen scientists in front of their 20 filled and sealed metal boxes. Weserstrand in Bremerhaven, Germany, 14 May 2022 (photo by BAW, standing on the right).

In the end, we believe that our decision to not have the sand sieved by the citizen scientists (Figure S1) was the correct choice for the purposes of this citizen-science project because (1) it limited the time on the beach to a manageable two hours (not counting transport to and from the beach and time needed to package and post the samples), (2) it reduced the instructions to a manageable 18 pages (see Text S2.1) which is still a considerable amount of information to digest, (3) it was the cheaper solution, and (4) it reduced many potential errors. Given the overall success of the project (71 collections with around 300 participants in a time span of 16 months), we believe that our chosen sampling methodology was the correct one for the stated purposes of the project (Texts S5-S6). The other reason for the success of the project was our strategy to motivate and recruit citizen scientists to participate (see below).

Text S1.2. The strategy to motivate and recruit citizen scientists

The usual suspects. To provide some background information on the overall goals of the citizen-science project MICROPLASTIC DETECTIVES, BAW with input from ML wrote two documents: a short project summary and some background information (Texts S5-S6). These two motivational information documents could then be emailed to relevant people in conjunction with an invitation to discuss the project via email, telephone, or video call.

To recruit citizen scientists, our strategy could be called ‘the usual suspects’ followed by ‘snowball sampling’ or ‘snowball recruitment’. First, our invitation email (a short email text briefly introducing us and the project plus the two information documents) was sent in September-November 2021 to the usual suspects which we either knew personally or knew that certain non-governmental organizations (NGOs) were working on some aspect of plastic pollution. For example, everybody who knows something about environmental issues of the German coastline can name the relevant NGOs working on these topics: specifically, Bund für Umwelt und Naturschutz Deutschland (BUND), Bye Bye Plastik Sylt, EUCC - Die Küsten Union Deutschland, Küste gegen Plastik e.V., MeeresBürger-Netzwerk, Mellumrat, Naturschutzbund Deutschland (NABU), Schutzstation Wattenmeer, Verein Jordsand, und Weniger.Ist.Machbar (see Text S4). In addition, there are the various national park entities: e.g., Biosphärenreservatsamt Südost-Rügen, FÖJ Umweltbildung Nationalparkamt Vorpommern, Nationalpark Jasmund, Nationalpark-Haus Wittbülten Spiekeroog, Nationalpark-Schiff Feuerschiff Borkumriff, Nationalparkhaus Wittmund-Carolinensiel, Watt Welten, Besucherzentrum Norderney, or Wattenmeer-Besucherzentrum Cuxhaven. We also contacted those scientists who worked on plastic pollution topics, e.g., the scientists involved in the Plastic Pirates project at the Kieler Forschungswerkstatt (Kiessling et al., 2019; 2021) and the Leibniz-Institute for Baltic Sea Research (Haseler et al., 2018; 2019; 2020) (more relevant people are listed under “for comments and discussions” in the Acknowledgements).

Snowball recruitment. Some of these NGOs and people agreed to participate, while others suggested further contacts (thus beginning the snowball sampling which is a recruitment technique in which research participants are asked to assist researchers in identifying other potential subjects). For example, the BUND and NABU sent lists of local affiliated groups which, in turn, we then contacted directly. Others suggested to contact some schools and students with a known interest in environmental issues, which resulted in the collaboration with the schools of Grundschule Neuhaus, Stadtteilschule Wilhelmsburg, and Werner-Heisenberg-Gymnasium, and students of the Grüne Jugend Schleswig and Geomar Universität Kiel.

Through the snowball recruitment, we also got into contact with several interested but unaffiliated citizens as well as two organizations which would play a major role in the success of the project. The first contact was with the Lions Club which led to the acquaintance and later friendship with Thorsten Dahl (TD). The second one was with the Natureum Niederelbe which led to the acquaintance and later friendship with Rainer Himmighofen (RH), who then contributed to the rewriting of the sampling instructions (Text S2). When we wrote the sampling instructions, we (1) avoided scientific jargon as much as possible, (2) describe the methods as simple as possible but also very logically and precisely, explaining each step to be taken in detail with many pictures and background explanations.

As explained in Text S1.1, this sampling methodology was repeatedly revised in the first few months of the project due to discussions between BAW and other people as well as field trials of BAW and Tim Hinzmann. Nothing was set in stone, but could be changed and adapted if needed.

Once the final version of the sampling instructions had been written by BAW, MB, and RH, it was sent to all prospective participants together with the two motivational information documents mentioned above and a short publication about the project (Walther, 2021).

Personal relationships. At this point, we have to emphasize the value of personal interactions. People react to people, so personal conversations via telephone or video calls where essential to establish interest, motivation, and trust, and BAW spent a large amount of time on pursuing such personal communications and on building personal relationships through emails, phone and video calls, and face-to-face conversations. In several cases, this meant even meeting people at their homes or in bakeries or cafeterias, or to give personal presentations at local meetings (see below '*Returning favors and media presence*' and Table S2). The latter had the double benefit of building relationships as well as informing the public. To illustrate the importance of taking time to build such personal relationships, we here specifically describe how we came to collaborate with the Lions Club Schleswig-Holstein.

On 7 January 2022, BAW met with TD of the Lions Club in a bakery near Hamburg (Figure S3). While BAW spent some time explaining the MICROPLASTIC DETECTIVES project, most of the two-hour conversation was taken up by "chatting about God and the world" (literal translation of a common German expression "über Gott und die Welt reden" which means to talk about just about everything and anything, a wide-ranging, spontaneous discussion about many different topics).

Figure S3. The value of establishing personal relationships was exemplified by the meeting between Thorsten Dahl and BAW in in a bakery (Bäckerei-Konditorei Nitt - OXEN Café, Ochsenzoller Str. 103, Norderstedt) on 7 January 2022 (photo by BAW, sitting on the left).

Afterwards, TD was so enthusiastic about supporting the project that he exchanged around a hundred emails with BAW from 8 January to 30 March 2022 which resulted in the following achievements:

1. TD drew up an Excel-list of about 30 potential sampling locations in Schleswig-Holstein and connected them to local Lions groups or people who may be interested to take samples. This resulted in about 15 locations being sampled along the coastline of Schleswig-Holstein by Lions Club members.

2. The Lions Club donated 250 Euros to pay for the postage of the sand samples back to the laboratory.

3. Several short articles about the project appeared in the local Lions membership journal, and a 2-hour talk was presented about the results of the project to Lions Club members on 27 April 2023 (Table S2). During this talk, BAW emphasized that the Lions Club had thus actually contributed the lion's share of sampling locations for the MICROPLASTIC DETECTIVES project.

The point is not to write small talk in this description of the project, but to emphasize that engaging in 'small talk' with citizen scientists is actually one important aspect of establishing personal relationships (which, in the case of RH, TD and several other participants will likely outlast the project itself). Other studies previously pointed out the importance of establishing personal relationships between the scientists, project coordinators, and citizen scientists (Rotman et al., 2014; Phillips et al., 2019).

Other selling points. While establishing personal relationships was certainly one important part of motivating people to participate in the sampling, two other important aspects were that the topic was topical and that the actual activity was pleasant and interesting. Certainly, the problem of plastic pollution has entered the public consciousness during the last decade or so (Schnurr et al., 2018; da Costa et al., 2020; Tekman et al., 2022). Consequently, many participants were motivated to work on the project because it is a problem that they are acutely aware of and even one which they are actively raising awareness about and working on possible solutions. Our two motivational information documents may have further fostered this sense of urgency and importance of the topic. For example, it may be more difficult to motivate people to sample sand on beaches if the message was that geologists needed the samples in order to obtain a better distributional map of different sand types along the German coastlines. Plastic pollution is simply a popular topic in the public's mind right now.

Furthermore, the actual activity was an overwhelmingly pleasant one. In essence, the sampling involved a 'day on the beach'! The only difference to taking a walk along the beach or taking a sunbath or a swim was that the activity was a somewhat more challenging and interesting one of accessing a suitable beach, staking out a sampling grid, and then filling metal boxes with sand samples, labelling them, and trans porting them back to the cars. Given that the task could only be realistically achieved by smaller or larger groups, it also involved a social component of doing it together, which increases the memorable fun aspect of it. Many participants reported back to BAW that they had had fun, that the whole experience had been very enjoyable, and that they felt like they had done something useful, and often sent photos of groups of smiling citizen scientists in front of their filled and sealed metal boxes (Figure S2) or even of drinking their well-deserved beers together. For example, it may be more difficult to motivate people to sample different types of plastic debris on actual garbage dumps. Beaches are simply a popular destination to visit.

Constant availability and regular communication. Another important factor which helped to keep the momentum and motivation of the project was that the scientific coordinator BAW was almost 'always available'. The citizen scientists were able to contact BAW via email, WhatsApp, video calls, landline and mobile telephone at any reasonable time and any day, even weekends, and BAW made a point of answering all queries as soon as possible. Thus, any potential problems, necessary changes, or misunderstandings (e.g., with the sampling instructions) could quickly and easily be resolved. During such communications, BAW would also often use small talk to further engage people (see above), explain the project's progress, and would thank the participants repeatedly and profusely.

In order not to forget any participant or other interested party, an email list was made which included the relevant information (name, organization, address, telephone number, website, etc.), and this list was then used to regularly sent out informational emails and project reports (the latter especially in the later stages of the project, when results became available) which were always written in non-scientific, popular language. Further information was disseminated via the project's Facebook and Twitter pages (Table S2), and these social media sites were also used to inform readers about other scientific and policy developments concerning plastic pollution with no relation to MICROPLASTIC DETECTIVES.

Returning favors and media presence. We also made offers to participants and participating NGOs which they could receive in return for their participation: to give talks or guided tours of our institute, mention their NGOs on our own social media (Facebook and Twitter), and to help with writing press releases which went out to local media. Such activities further developed personal relationships and further heightened public awareness of the project. Some of these activities, especially press releases and talks, resulted in numerous articles in the local and even regional media, but many other articles and other media reports were the result of the participants themselves writing them or voluntarily working together with the local media, without any direct input from the scientific coordinator BAW. In the end, six public talks, one television report, five press releases, about 25 newspaper articles, about 30 website articles, and several other articles and publications resulted so far from these efforts to present MICROPLASTIC DETECTIVES in social and traditional media (see Table S2).

Involving children and students. Through the increasing public awareness of the project, the project was then approached by several school children and students who wanted to participate in the project, wanted help with their own research project, or to interview BAW as part of their project (Table S3). These interactions with school children and students were a completely unplanned but welcome further interaction with the public which further raised awareness of the project and the problem of plastic pollution. These unplanned interactions with school children and students could be interpreted as further evidence of the 'snowball effect' once the project had reached a certain visibility in the public domain.

Table S1. List of the advantages of only taking sand samples and not sieving the sand (Figure S1) on the sandy beach. Many of these advantages and disadvantages apply regardless of whether the sampling is carried out by scientists or citizen scientists, while some apply only to citizen scientists.

Advantages	Disadvantages
Much less training and supervision needed	Citizen scientists do not get to "see" and "experience" the pollution, do not conduct their own calculations; therefore, the experience is less educational
Much less variation in how the methods are actually applied (interpersonal variation) which means greater accuracy of results (Walther and Moore, 2005)	Cumbersome to transport heavy sand samples (range 3.7-72.4 kg, see Table S4) from beach to vehicle
Much less time on beach (about 1.5-2.5 hours, depending on number of people); sieving of sand would take much more time	Cumbersome to package sand samples so that they do not get damaged during transport
If sand is wet, sieving becomes impossible unless water is used to rinse the sieve, but water is not always easily available (e.g., low tide, cumbersome or dangerous to get) and would need to be filtered first to avoid contamination with MM floating in the water (however, unfiltered water can be used when a sieve is held carefully inside a bucket filled with water (A Rocha International, 2018; Haseler et al., 2018; 2019; Jones et al., 2022) but this method is very time-consuming and depends on water being available)	Despite efforts to package sand samples well, they may still be damaged during transport (see number of samples [N_1 minus N_2] lost or damaged during transport in Table S4)
Reliable, scientific sieves are very expensive, and cheap, home-made sieves are not reliable	Expensive to ship large amounts of sand, although still less expensive than to buy expensive sieves (20 containers cost 47.20 Euros, shipping them with sand cost about 42.50 Euros, and containers could be used several times)

Much less potential for contamination of samples or loss of samples (e.g., light MM blown away by wind)	
No problem of transferring contents of sieve to some transport container	
Much more accurate laboratory methods can be used to determine mass and volume of sand, e.g., with a digital scale; indeed, this method would allow even for microplastics < 1 mm to be identified if the proper methods are used (Hidalgo-Ruz et al., 2012; Korez et al., 2019; Primpke et al., 2020b)	

Table S2. List of public relation events in which the citizen-science project MICROPLASTIC DETECTIVES was presented in social and traditional media.

Date	Type	Title
1 September 2021 - now	Twitter page	MikroPlastikDetektive (Bergmann, 2022)
September 2021	press release (Watt Welten)	MikroPlastikDetektive. Watt Welten Besucherzentrum unterstützt das neue Citizen Science Projekt des Alfred-Wegener-Institutes
October 2021 – now	email reports	Mikroplastikdetektiv-Berichte
November 2021	newsletter article (BUND)	Werdet MikroPlastikDetektive! Bürger*innen und Wissenschaftler*innen sammeln gemeinsam Daten zur Mikroplastik-Belastung von Nord- und Ostsee
17 November 2021	talk with live audience (NABU)	Auswirkungen von Plastikverschmutzung auf Seevögel (in Bremerhaven)
25 November 2021	website article (Küste gegen Plastik)	Buddeln nach Mikroplastik (Anonymous, 2021a)
25 November 2021	newspaper article (Norderney Kurier)	Mikro-Plastik-Detektive: Watt Welten Besucherzentrum unterstützt Projekt des Alfred-Wegener-Institutes (Bers, 2021)
28 November 2021	newspaper article (Norderneyer Zeitung)	„MikroPlastikDetektive“: Watt Welten Besucherzentrum unterstützt das neue Citizen Science Projekt des Alfred-Wegener-Instituts (Anonymous, 2021b)
2022	website article (Ocean Summit)	Meeresklicks: Mitforschen – diese Projekte setzen auf Bürgerwissenschaftler*innen (Tetzlaff, 2022)
January 2022	journal publication	MikroPlastikDetektive – Citizen Science Projekt zum Thema Müll im Meer (Walther, 2021)
February 2022	journal article (Lions Club)	Dem Mikroplastik auf der Spur. Es werden helfende Hände gesucht (Dahl, 2022)
February 2022 - now	project website	Mikroplastikdetektive (Walther and Bergmann, 2022b)
3 February 2022 - now	Facebook page	Mikroplastikdetektive (Walther, 2022a)
21 February 2022	website article (Amrum News)	Ein Zentner Kniepsand für das Alfred-Wegener-Institut (von Komorski, 2022)
22 February 2022	press release and website article (Schutzstation Wattenmeer)	Mikroplastikdetektive. Wieviel Plastik ist im Sand am Strand? (Anonymous, 2022d)
22 February 2022	talk with live and online audience (BUND)	Mikroplastikdetektive – Ein Citizen Science Projekt für die deutschen Meeresküsten (in Bremerhaven)
23 February 2022	website article (der kleine delfin)	Mikroplastik-Detektive (Anonymous, 2022e)
24 February 2022	newspaper article (MOIN.DE)	Sylt: Was hier an den Strand gespült wurde, hat verheerende Folgen und macht Menschen traurig (Gesmati, 2022)
25 February 2022	talk online audience (BUND)	Mikroplastikdetektive – Ein Citizen Science Projekt für die deutschen Meeresküsten (in Bremerhaven)

31 March 2022	Youtube video	Mikroplastikdetektive Weidefelder Strand Kappeln (Mau, 2022)
April 2022	journal article (Lions Club)	Mikroplastikdetektive vom LC Flensburg von 1959 unterwegs an Ostseestränden (Saust, 2022)
9 April 2022	newspaper article (Ostsee-Zeitung)	Prerow: Daten sammeln zur Strandbelastung mit Mikroplastik
9 April 2022	newspaper article (Ostsee-Zeitung)	Darum wird am Prerower Strand geschippt (Anonymous, 2022i)
9 April 2022	website article (Nationalpark Vorpommersche Boddenlandschaft)	Junior-Ranger und Bänker werden zu Mikroplastikdetektiven (Anonymous, 2022j)
12 April 2022	Facebook article	Küstenputz und Müllbingo (Anonymous, 2022k)
5 May 2022	press release (BUND)	BUND Unterweser beteiligt sich am AWI-Projekt „Mikroplastikdetektive“ und sammelt Proben am Weser-Strandbad in Bremerhaven
9 May 2022	newspaper article (Nordsee-Zeitung)	Detektive im Strandbad unterwegs
14 May 2022	website article (BUND)	Mikroplastik im Weser-Strandbad? (BUND, 2022b)
15 May 2022	newspaper article (Nordsee-Zeitung)	Plastikdetektive fahnden am Weserstrand (Kikker, 2022b; 2022c)
16 May 2022	newspaper article (Nordsee-Zeitung)	Plastikdetektive am Weserstrand
17 May 2022	newspaper article (Nordwest-Zeitung)	Am Weserstrand viel Mikroplastik? Umweltdetektive unterwegs – Demnächst auch in Kleinensiel und Brake
19 May 2022	newspaper article (NORD 24)	Plastikdetektive prüfen Belastung am Weserstrand (Kikker, 2022a)
19 May 2022	website article (Stadtteilschule-Wilhelmsburg)	ScienceCafé Zirkel endet mit Besucherrekord (Anonymous, 2022a)
31 May 2022	newsletter article (Pagensand-Infobrief)	Projekt "Mikroplastikdetektive" des Alfred-Wegener-Instituts (AWI) (Mandelartz, 2022)
31 May 2022	report	Commerzbank Umweltpraktikum. Bericht von Anne Schäfer (Schäfer, 2022)
16 June 2022	website article (BUND)	Meso- und Mikroplastik im Wesersand (BUND, 2022a)
17 June 2022	newspaper article (Nordwest-Zeitung)	Im Wesersand liegt Mikroplastik. Proben aus Bremerhavener Strandbad belegen erste Vermutungen
20 June 2022	website article (Boyens Media)	Mikroplastikdetektive unterwegs (Stelljes, 2022b)
27 June 2022	newspaper article (Dithmarscher Landeszeitung)	Mikroplastikdetektive unterwegs (Stelljes, 2022a)
6 August 2022	website article (der reporter)	„Mikroplastik-Detektive“ (Anonymous, 2022c)
19 August 2022	website article (Küste gegen Plastik)	Dosen-Sand vom Sønderstrand (Anonymous, 2022b)
19 August 2022	website article (replaceplasticapp)	Rømø-Strand (Anonymous, 2022n)

19 August 2022	website article (Lions Club)	Lions Club Lübecker Bucht unterstützt Aktion „Mikroplastik-Detektive“ (Anonymous, 2022l)
30 August 2022	website article (Nordwest-Zeitung)	Projekt „Mikroplastikdetektive“ auf Harriersand (Anonymous, 2022m)
7 September 2022	website article (Weser-Kurier)	Mikroplastikdetektive unterwegs (Keller, 2022)
10 September 2022	video report (NDR)	Wie viel Mikro- und Mesoplastik verbirgt sich im Strandsand? (NDR, 2022)
11 September 2022 (online 12 Sep)	newspaper article (Weser-Kurier)	Suche nach dem Müll der kleinsten Form (Hildebrandt, 2022)
12 September 2022	newspaper article (MOIN.DE)	NDR: „Hallo Niedersachsen“ zeigt schlimme Entdeckungen an der Küste – „Besorgniserregend“ (Skowronek, 2022)
13 September 2022	newspaper article (Weser-Kurier)	Suche nach dem Müll der kleinsten Form (Hildebrandt, 2022)
17 September 2022	website article	Mikroplastikdetektive – Suche nach Mikroplastik an deutschen Küsten (Walther, 2022b)
26-27 September 2022	website article (Weniger. Ist. Machbar.)	Wie W.I.M. in Schillig MikroPlastik suchte (Ernst and Kuper, 2022)
4 November 2022	press release (BUND)	BUND Kreisgruppe Wesermarsch beteiligt sich am AWI-Projekt „Mikroplastikdetektive“ und sammelt Proben in Brake und Kleinensiel
13 November 2022	website article (BUND)	Auf der Suche nach Mikroplastik (Anonymous, 2022h)
14 November 2022	newspaper article (NORD 24)	Plastik-Detektive auf Spurensuche an zwei Weserstränden (Seeland, 2022a)
14 November 2022	newspaper article (Kreiszeitung Wesermarch)	Plastik-Detektive auf Spurensuche an zwei Weserstränden (Seeland, 2022b)
15 November 2022	newspaper article (Kreiszeitung Wesermarch, Nordwest-Zeitung)	Plastikdetektive am Strand
15 November 2022	newspaper article (Nordwest-Zeitung)	Mikroplastik in Brake. 40 Sandproben geben Aufschluss über Verschmutzung an der Weser (Seeland, 2022c)
17 November 2022	conference talk (online)	Microplastic detectives search for microplastic pollution along the German coastline (Walther and Bergmann, 2022a)
21 November 2022	press release (BUND)	Plastikmüll in den Ozeanen, BUND Wesermarsch lädt zu Vortrag in Brake (Unterweser) ein
21 November 2022	newspaper article (Kreiszeitung Wesermarch)	Bruno Walther spricht über Plastikmüll im Meer (Redaktion, 2022a)
29 November 2022	talk with live audience (BUND)	Plastikmüll in den Ozeanen (in Brake)
December 2022	journal article (Lions Club)	Mikroplastik Detektive unterwegs an der Ostsee (Stappert, 2022)
December 2022	website article (Lions Club)	Mikroplastikdetektive (Anonymous, 2022g)
6 December 2022	website article (EUCC)	Beprobung zur Erfassung von Mikroplastik an Stränden (Anonymous, 2022f)

6 December 2022	newspaper article (Nordwest-Zeitung)	Vortrag über Meeresverschmutzung im Braker Fischerhaus (Schlüter, 2022)
12 December 2022	newspaper article (Kreiszeitung Wesermarch)	Ozeane werden zu gigantischen Plastikmüllkippen (Redaktion, 2022b)
14 December 2022	newspaper article (Kreiszeitung Wesermarch)	Immer mehr Plastik im Wasser
2023	website article (Weniger. Ist. Machbar.)	Citizen Science mit Wasser: Spülsaum-Monitoring für das Alfred-Wegener-Institut (Anonymous, 2023b)
19 April 2023	website article (Mellumrat)	Online-Vortrag der Mikroplastikdetektive (Anonymous, 2023a)
27 April 2023	talk with live and online audience (Lions Club)	Plastikverschmutzung in den Meeren und Mikroplastikdetektive (in Itzehoe)
Juni 2022	journal article (Lions Club)	Vortrag bei den Itzehoer Lions über die Plastikverschmutzung der Meere und die Mikroplastikdetektive (Bohnsack, 2023)

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Table S3. List of projects involving school children and students who interacted with the citizen-science project MICROPLASTIC DETECTIVES.

Date of interaction	Institution	Title
Dec 2021	Gymnasium Geschwister Scholl, Bremerhaven	‘Jugend forscht’ project entitled “Kläranlagen- Die Lösung gegen den Feind, das Mikroplastik? (gained 2nd price)
23 Mar 2022	children of Grundschule Neuhaus, Neuhaus	collection of sand samples (see Table S4 and Text S3)
24 Apr 2022	students of GEOMAR Universität Kiel	collection of sand samples (see Table S4)
15 May 2022	members of environmental youth group „Grüne Jugend Schleswig”	collection of sand samples (see Table S4)
19 May 2022	children of Werner-Heisenberg-Gymnasium, Heide	collection of sand samples (see Table S4)
20 May 2022	children of Werner-Heisenberg-Gymnasium, Heide	collection of sand samples (see Table S4)
28 Jun 2022	children of Stadtteilschule Wilhelmsburg, Hamburg	collection of sand samples (see Table S4)
Sep 2022-Sep 2023	Bertolt Brecht-Gymnasium, Dresden	compulsory technical report for 11th grade entitled „Plastikverschmutzung der Ozeane“
Oct-Dec 2022	two 12-year old pupils	‘Jugend forscht’ project
Dec 2022-Jan 2023	Carl von Ossietzky Schule, Bremerhaven	profile course work report for 11th grade
Jan-Apr 2023	Schiller-Gymnasium, Bautzen, Sachsen	compulsory technical report for 10th grade entitled “Mikroplastik: Entstehung, Auswirkung, Beseitigung und Vermeidung”
Jan 2023	Konrad-Adenauer Gymnasium, Langenfeld	enrichment course in 6th grade: topic microplastics presented with poster and talk

Text S2.1. Original German instructions for taking sand samples on sandy beaches by citizen scientists, written by BAW with some input from Rainer Himmighofen (followed by the English translation of these German instructions). All photos by BAW.

MIKRO PLASTIK DETEKTIVE

Anleitung zur Beprobung von Meso- und Mikroplastik an Stränden

Vorbemerkungen

Wir danken euch für euer Interesse, beim Forschungsprojekt Mikroplastikdetektive mitzuwirken. Mit diesem Projekt möchte wir herausfinden, wieviele Mesoplastikteile (5-25 Millimeter) und Mikroplastikteilchen (1-5 Millimeter) es an der deutschen Küste gibt. Dabei könnt ihr helfen, indem ihr dieser einfachen Sammlungsanleitung folgt. Dabei lernt ihr gleichzeitig etwas über dieses ernste Umweltproblem.

Plastik ist ein nützliches Material, weil es sich in vielen Formen, Farben, Härten und Biegsamkeiten herstellen lässt und weil es leicht, billig und haltbar ist. Aber genau die Haltbarkeit ist auch ein Problem, denn wenn das Plastik in die Umwelt gelangt, zersetzt es sich sehr langsam.

Wenn jemand ein Stück Papier ins Meer oder in den Wald wirft, dann ist das praktisch Futter für die Pflanzen und Tiere. Bakterien und Pilze können die Grundbausteine zersetzen, und dadurch werden Nährstoffe frei, die für die Pflanzen und Tiere im Meer oder Wald wichtig sind. Mit Plastik können die Bakterien und Pilze jedoch nichts anfangen, es sammelt sich an und wird dadurch zu einem immer grösser werdenden Problem.

Mit am schlimmsten ist es, wenn sich Meerestiere (zum Beispiel Delfine, Schildkröten, Seehunde, Wale) in Plastikteilen verheddern und sich dadurch verletzen oder qualvoll sterben. Viele andere Meerestiere werden krank oder sterben, weil sie Plastikteile essen und dadurch ihren Magen verstopfen oder verletzen und glauben sie wären satt. Pflanzen und Korallen werden durch größere Plastikteile verletzt oder durch Bedeckung von der Nahrung und anderen wichtigen Stoffen abgeschnitten. Außerdem enthält Plastik Chemikalien, die für Mensch und Tier gesundheitsschädlich sein können.

Hinweise zur sachgemäßen Anwendung

Damit ihr die Sammlung der Sandproben erfolgreich durchführen könnt, solltet ihr diese Anleitungen sorgfältig durchlesen. Zunächst einige allgemeine Hinweise:

1. Mit das Wichtigste ist dabei, dass Zufallsprinzip zu berücksichtigen. Das heißt, dass nicht ihr auswählt, an welchem Ort des Sandstrandes die Proben genommen werden, sondern dass der Ort durch eine Zufallszahl entschieden wird. Denn sonst sucht ihr euch vielleicht einen Ort aus, der besonders verschmutzt ist, was wir aber nicht wollen: wir wollen die Proben von einem zufällig ausgewählten Ort. Das spiegelt ein realistischeres Bild der Verschmutzung wider.
2. Eine Sammlung sollte nicht durchgeführt werden, wenn das Wetter zu schlecht ist. Insbesondere starker Regen oder Wind machen das Sammeln der Proben schwierig und unangenehm.
3. Natürlich solltet ihr auch immer auf eure Sicherheit und Gesundheit achten: Tragt bitte Kleidung, die dem Wetter angemessen ist. Dazu gehört es auch, angemessene Schuhe zu tragen, denn am Strand kann es spitze oder scharfe Gegenstände geben und nass sein. Auf keinen Fall solltet ihr unbeaufsichtigt ins Watt laufen, insbesondere wenn die Flut kommt. Manchmal können auch an einem Sandstrand plötzlich hohe Wellen auftreten, zum Beispiel wenn ein großes Schiff vorbeifährt. Bei viel Wind oder Sonne solltet ihr eine Kopfbedeckung tragen, Sonnencreme benutzen, ausreichend Wasser trinken und euch nicht überhitzen. Falls ihr euch verletzt oder nicht gut fühlt, solltet ihr sofort einer Aufsichtsperson Bescheid geben.
4. Fragen oder Bedenken besprecht ihr entweder mit der Lehrerin/dem Lehrer oder dem Projektleiter (Bruno Walther, Email: bwalther@awi.de).

Material und Ausrüstung vom Alfred-Wegener-Institut (AWI)

- Anleitungen, Blatt mit Zufallsnummern 1-100, Datenerfassungsblatt ORT
- Wasserfeste Stifte, Klemmbrett, breiter Tesafilm
- Maßband
- Haken (Zeltheringe) zum Markieren der Sammellinie und des Sammelrahmens
- Sammelrahmen
- Metallschaufel und Handfeger
- Metallbehälter für Sand
- Tüten mit Druckverschluss
- Paketmarken für den Versand ans AWI

Benötigte eigene Ausrüstung

- Mobiltelefon für Fotos, Filme und GPS-Koordinaten
- Münze
- Schere für Tesafilm
- Taschen, Kisten o.ä. für Ausrüstung und Proben
- Kartons für den Versand der Sandproben (Porto wird übernommen)

① Ort auswählen

Den Ort der Probennahme könnt ihr frei auswählen, aber mit dem Projektleiter Bruno Walther vorher abstimmen, um mehrfache Beprobungen desselben Ortes zu verhindern. Es sollte ein Sandstrand an der Nordsee oder Ostsee sein oder an einer ins Meer führenden Flussmündung, wo Ebbe und Flut noch spürbar sind. Der Strand sollte für die Beprobung gut zugänglich sein, denn sonst muss man das Material weit tragen.

Wir empfehlen einen Strandabschnitt auszuwählen, der 10 – 100 Meter breit ist. Wichtig ist, dass ihr einen Bereich mit sandigem Untergrund wählt; im Schlick ist die Probennahme nicht möglich. Achtung: Zu starker Regen oder Wind kann die Probennahme behindern bzw. unmöglich machen. Wenn möglich, beginnt mit der Probennahme bei ablaufendem Wasser, also einsetzender Ebbe, um gefährliches Arbeiten bei steigender Flut zu verhindern.

Füllt bitte das Datenerfassungsblatt „Ort“ vor Beginn der Probennahme aus (siehe hier ein nicht ganz ernst zu nehmendes Beispiel):

Dieses Datenerfassungsblatt, wenn möglich, bitte auch fotografieren als SICHERUNGSKOPIE!

***Bitte Einträge mit Sternchen unbedingt ausfüllen, alle anderen Einträge sind nicht obligatorisch.**

***Ort:** DUHNEN STRAND, CUXHAVEN

***Breite des Strandes an der Sammellinie 0 (siehe Abbildung 1 in der Anleitung):** 56 **Meter**

Ortsbeschreibung (kurze Beschreibung des Sammelortes, Art des Strandes, etc.):
Sauberer Sandstrand, kaum größerer Müll sichtbar, sehr wenige Steine, untere Kante ist Wattboden, obere Kante ist Dünenbewuchs.

GPS Koordinaten: 53° 53' 15" N, 8° 38' 46" E

***Datum:** 24. 12. 2021

***Name der Kontaktperson:** Bruno WALTHER

Anzahl der Teilnehmer: 4

Namen anderer Teilnehmer: Andreas WALTHER, Klaus MEINE, Otto WAALKES

Zeitdauer der Sammlung: von 10 **Uhr bis** 12 **Uhr**

***Anzahl der Sammellinien (mit 4 Sammelpunkten pro Sammellinie):** 5

Bemerkungen, z.B., über Probleme, Verbesserungsvorschläge, … Kommentare können natürlich auch direkt an Bruno Walther unter bwalther@awi.de geschickt werden (kann auch auf der Rückseite weiter geschrieben werden):
Kann man die Anweisungen in Plattdeutsch haben?

Die GPS-Koordinaten könnt ihr mit dem Smartphone ermitteln oder mit Google Earth (genaue Anweisungen stehen in Anhang 1).

Bitte fotografiert das ausgefüllte Datenerfassungsblatt „Ort“ als Sicherungskopie.

Bitte macht weitere Fotos und Video Clips, zum Beispiel (1) vom Strand in die verschiedenen Himmelsrichtungen, damit man einen Eindruck von der Umgebung bekommt oder (2) interessante Fundstücke, zum Beispiel ein altes Plastikmüllstück (Verfallsdatum erkennbar?).

Inhalt des Datenerfassungsblatt

Dieses Datenerfassungsblatt, wenn möglich, bitte auch fotografieren als SICHERUNGSKOPIE!

***Bitte Einträge mit Sternchen unbedingt ausfüllen, alle anderen Einträge sind nicht obligatorisch.**

***Ort:**
***Breite des Strandes an der Sammellinie 0 (siehe Abbildung 1 in der Anleitung): _____ Meter**
Ortsbeschreibung (kurze Beschreibung des Sammelortes, Art des Strandes, etc.):

GPS Koordinaten:
***Datum:**
***Name der Kontaktperson:**
Anzahl der Teilnehmer:
Namen anderer Teilnehmer:
Zeitdauer der Sammlung: von ______ Uhr bis ______ Uhr
***Anzahl der Sammellinien (mit 4 Sammelpunkten pro Sammellinie):**
Bemerkungen, z.B., über Probleme, Verbesserungsvorschläge, … Kommentare können natürlich auch direkt an Bruno Walther unter bwalther@awi.de geschickt werden (kann auch auf der Rückseite weiter geschrieben werden):

Zufallsnummern 1-100

67 68 29 1 36 58 5 82 70 60 99 52 79 29 33 49 93 80 93 73 68 31 100 55 49 55 45 97 39 24 19 20 90 15 50 70 31 65 45 93 22 5 26 54 100 34 48 3 9 76 37 27 67 14 13 98 91 43 26 76 3 18 50 74 33 87 34 93 25 71 68 60 87 10 3 76 25 54 54 76 13 24 42 41 3 90 10 64 52 72 4 35 72 3 63 44 66 90 37 44 61 56 98 92 71 80 61 80 62 46 52 54 99 85 79 44 36 31 64 70 42 16 85 95 50 80 5 57 96 2 83 3 19 53 47 31 63 57 44 11 71 63 18 21 39 52 92 94 10 79 88 20 40 18 79 47 11 5 84 19 17 95 100 96 64 93 79 65 60 76 88 78 90 85 38 37 86 86 6 69 83 56 59 36 86 63 33 92 3 14 74 31 27 79 4 42 86 25 42 1 84 57 22 73 36 24 11 50 77 11 55 22 18 20 4 12 55 7 24 49 21 76 10 42 3 22 71 16 80 59 94 35 40 6 58 63 48 70 73 74 70 6 39 87 93 60 5 99 62 3 42 1 78 77 95 83 57 93 33 10 92 89 24 79 64 5 87 89 95 21 44 56 83 95 15 99 15 21 52 14 7 12 78 17 59 72 3 40 45 12 79 2 30 40 42 15 66 18 72 44 11 3 36 56 36 37 26 55 98 45 24 55 66 40

Foto-Dokumentation

Die Foto-Dokumentation ist sehr nützlich, um die Strände zu kategorisieren, eine Vorstellung vom Sammlungsort zu bekommen und als Sicherungskopie des Datenerfassungsblatt ORT (die Fotos sind allerdings nicht absolut notwendig, aber sie wären halt sehr hilfreich). Folgende Fotos wären sinnvoll:

1. Foto von dem ausgefüllten Datenerfassungsblatt ORT (als Sicherungskopie).
2. Je ein Landschaftsfoto entlang der beiden Richtungen der Sammellinie 0, also ein Foto zum Wasser hin und ein Foto in Richtung Düne, Strandwall oder sonstigem Ende des Strandes. Dann zwei weitere Landschaftsfotos rechtwinklig zur Sammellinie; also insgesamt vier Fotos im rechten Winkel zueinander. Weitere Fotos vom Strand, um den Strand gut kategorisieren zu können, sind auch nützlich.
3. Weitere Fotos können die Sammlung dokumentieren: Fotos der beteiligten Personen bei der Arbeit für die sozialen Medien, des gesammelten und kategorisierten Makromülls (falls das auch Teil der Aktion ist), Fotos von besonders interessanten Fundstücken (sehr altes Fundstück, von sehr weit her, verstrickt oder bewachsen mit Tieren), usw.
4. Namen der Fotograf*innen werden benötigt und Erlaubnis zur weiteren Verwendung wird dann vorausgesetzt.

② Die „Sammellinie 0“ bestimmen

Wenn ihr am Strand ankommt, entscheidet ihr zufällig per „Münzwurf“, ob die Sammellinie links oder rechts von euch angelegt wird. Dabei schaut ihr zur Wasserkante (siehe Foto).

Dann wählt ihr eine Zufallsnummer vom Blatt aus:

Zufallsnummern 1-100

67 68 29 1 36 58 5 82 70 60 99 52 79 29 33 49
93 80 93 73 68 31 100 55 49 55 45 97 39 24 19
20 90 15 50 70 31 65 45 93 22 5 26 54 100 34
48 3 9 76 37 27 67 14 13 98 91 43 26 76 3 18
50 74 33 87 34 93 25 71 68 60 87 10 3 76 25 54
54 76 13 24 42 41 3 90 10 64 52 72 4 35 72 3
63 44 66 90 37 44 61 56 98 92 71 80 61 80 62
46 52 54 99 85 79 44 36 31 64 70 42 16 85 95
50 80 5 57 96 2 83 3 19 53 47 31 63 57 44 11
71 63 18 21 39 52 92 94 10 79 88 20 40 18 79
47 11 5 84 19 17 95 100 96 64 93 79 65 60 76
88 78 90 85 38 37 86 86 6 69 83 56 59 36 86 63
33 92 3 14 74 31 27 79 4 42 86 25 42 1 84 57
22 73 36 24 11 50 77 11 55 22 18 20 4 12 55
24 49 21 76 10 42 3 22 71 16 80 59 94 35 40 6
58 63 48 70 73 74 70 6 39 87 93 60 5 99 62 3
42 1 78 77 95 83 57 93 33 10 92 89 24 79 64 5
87 89 95 21 44 56 83 95 15 99 15 21 52 14 7 12
78 17 59 72 3 40 45 12 79 2 30 40 42 15 66 18
72 44 11 3 36 56 36 37 26 55 98 45 24 55 66 40

Augen zu und zufällig auf eine Nummer tippen.

Hier zum Beispiel die 57.

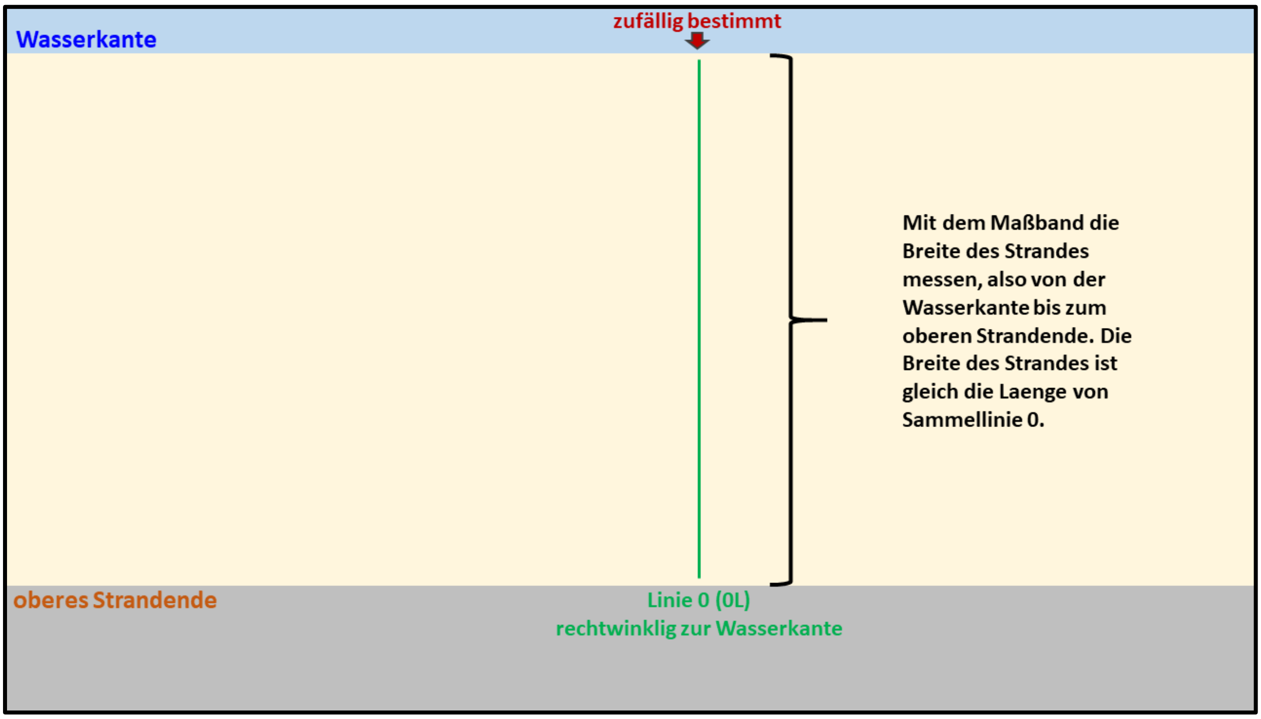
Die Nummer entspricht der Distanz in Metern entlang des Strandes. Wenn ihr also links und 57 Meter durch Zufall bestimmt habt, dann messt von eurem Ankunftspunkt, wo ihr die Münze geworfen habt, 57 Meter mit dem Maßband ab, parallel zur Wasserkante und in die linke Richtung.

Als zweites Beispiel: Hättet ihr aber zum Beispiel rechts und 26 Meter durch Zufall bestimmt, dann messt von eurem Ankunftspunkt (wo ihr die Münze geworfen habt) 26 Meter mit dem Maßband ab, parallel zur Wasserkante und in die rechte Richtung.

Damit habt ihr den Startpunkt für die Bestimmung der „Sammellinie 0“ gefunden. Diesen Startpunkt mit Hilfe eines Hakens (oder etwas anderem, zum Beispiel einem Stock oder Rucksack) markieren.

③ Strandbreite messen

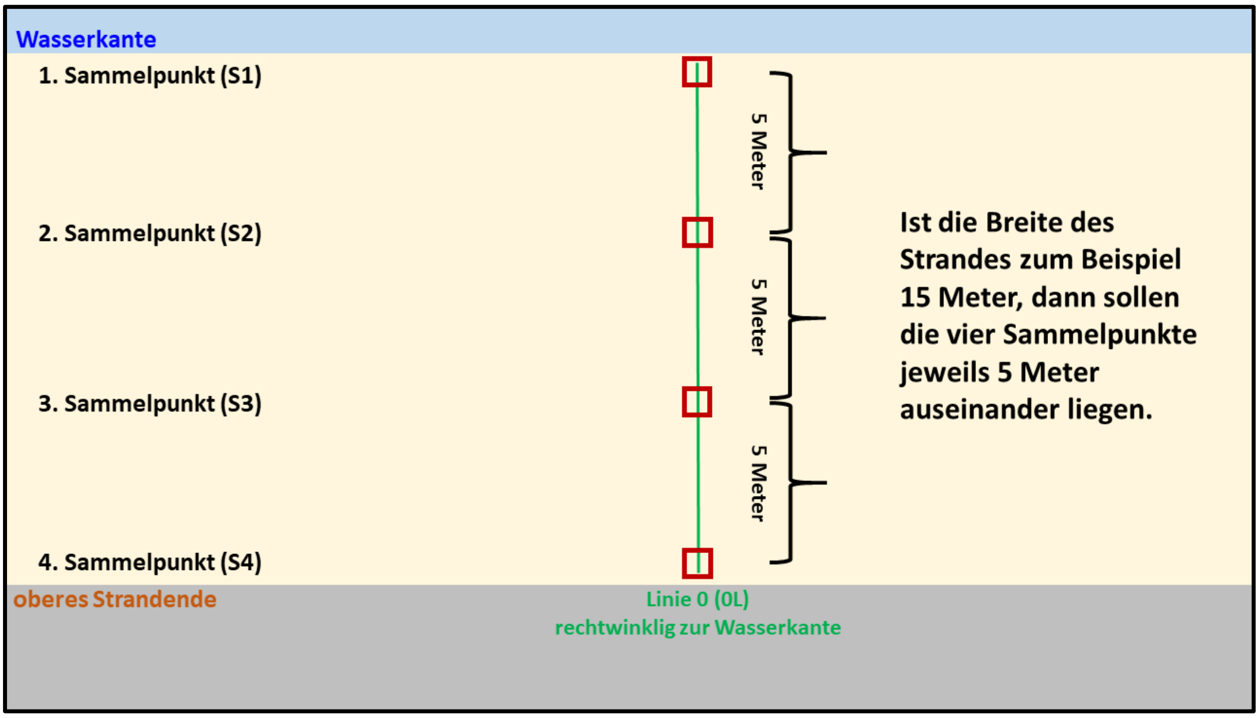
Nun messt ihr ausgehend von diesem Startpunkt (also der mit einem Haken markierten Sammellinie 0) rechtwinklig die Entfernung zwischen der Wasserkante und dem oberen Strandende.



Die Wasserkante und das obere Strandende müsst ihr selber bestimmen. Bei Flut ist die Wasserkante natürlich da, wo das Wasser anfängt, aber bei Ebbe müsst ihr schätzen, wo das Wasser normalerweise bei Flut ist. Das obere Strandende erkennt ihr meist an einer harten Kante, zum Beispiel an einer Steinmauer oder einer bewachsenen Düne. Unten sind zwei Beispiele dargestellt.

④ Sammelpunkte anlegen

Auf jeder der Sammellinien liegen 4 Sammelpunkte. Darum teilt ihr die gemessene Distanz durch „3“. Wenn zum Beispiel der Strand 15 Meter breit ist, dann werden die Sammelpunkte in jeweils 5 Meter Abstand angelegt. Beispiel: 15 : 3 = 5 → Sammelpunkte bei 0, 5, 10, 15 Metern.



Hier noch zwei weitere Beispiele: Wäre der Strand aber 90 Meter breit, dann würden die Sammelpunkte in jeweils 30 Meter Abstand angelegt werden. Und wäre der Strand 59 Meter breit, dann würden die Sammelpunkte in jeweils 19.67 Meter Abstand angelegt werden, und so weiter.
Wichtig: Der Punkt, der als nächster zur Wasserkante liegt, wird als „Sammelpunkt 1" bezeichnet usw. Die vier Sammelpunkte entlang der Sammelline 0 messt ihr mit Hilfe des Maßbandes und markiert jeden Sammelpunkt mit einem Haken.

⑤ Sand entnehmen

Nun könnt ihr auch schon mithilfe des Sammelrahmens die Sandproben entnehmen. Zuerst den Sammelrahmen in den Sand drücken, wo der Sammelhaken ist. Alle Makromüllteile (> 25 mm) innerhalb des Sammelrahmens entfernen und im Datenerfassungsblatt unter Bemerkungen eintragen. Andere große Teile (> 25 mm), die nicht Müll sind (z.B. Holz, Muscheln, usw.) auch zuerst entfernen.

Dann tragt ihr mit der Metallschaufel die oberen Zentimeter gleichmäßig innerhalb des Sammelrahmens ab und deponiert sie in einem Metallbehälter („Probenbehälter“).

Sand gleichmäßig von der Oberfläche abtragen

Ihr seid mit dem Sammelpunkt fertig, wenn der Probenbehälter ganz voll ist. Den Probenbehälter

verschließen und mit breitem Tesafilm zukleben.

Nun drei weitere Behälter an den drei verbleibenden Sammelpunkten entlang der Sammellinie mit Sand füllen, verschließen und zukleben.

Wichtig: Nach jeder Probennahme den Sammelrahmen und die Schaufel mit dem Handfeger reinigen, um eine Kontamination mit Sand zu vermeiden, der nicht von dem Sammelpunkt stammt!

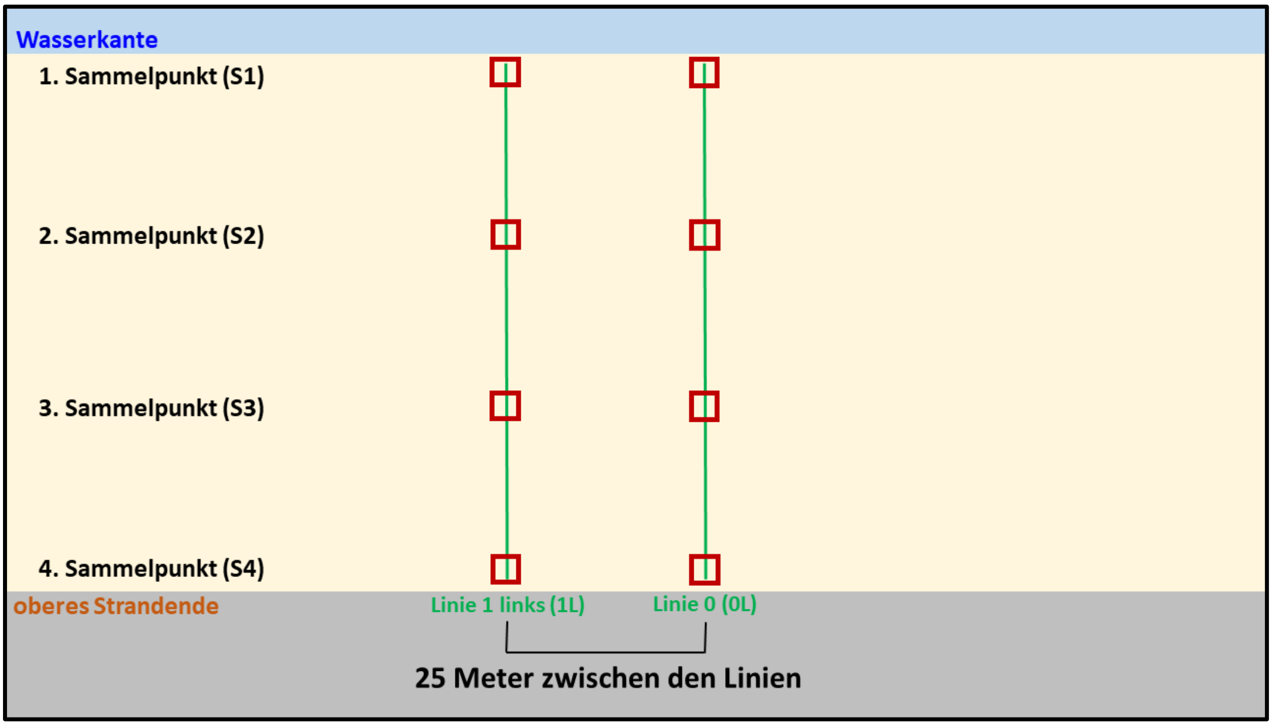
⑥ Weitere Sammellinien anlegen

Bitte schaut euch die beiden folgenden Abbildungen genau an. Die Sammellinie 0 (die ihr per Zufall bestimmt habt) liegt in der Mitte.

Sammelpunkt 1 ist **immer** an der Wasserkante und Sammelpunkt 4 **immer** an dem oberen Strandende.

Die Sammellinien **1 links** und **2 links** sind links von der Sammellinie 0, wenn man zum Wasser hinschaut!

Und die Sammellinien **1 rechts** und **2 rechts** sind rechts von der Sammellinie 0, wenn man zum Wasser hinschaut!



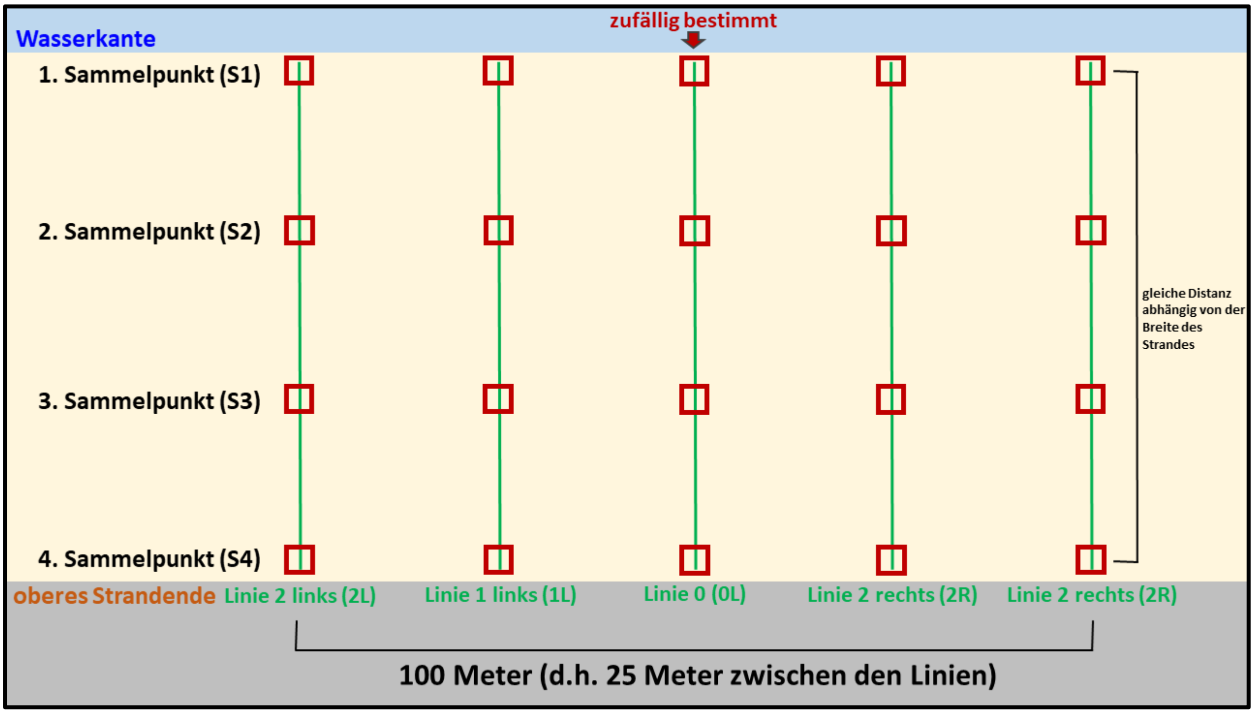
In der Grafik oben wird die zweite Sammellinie angelegt, die links von der Sammellinie 0 liegt, wenn man zum Wasser hinschaut.

Der Abstand zwischen zwei Sammellinien soll **immer** 25 Meter sein (bitte mit dem Maßband genau abmessen), es sei denn, der Strand ist weniger als 100 Meter lang (dann können auch kürzere Entfernungen genutzt werden).

Die Sammelpunkte sollen auf allen Sammellinien im gleichen Abstand zueinander sein, in unserem Beispiel wären es wieder 5 m. Und genauso wie für die „Sammellinie 0“ füllt ihr wieder jeweils einen Probenbehälter für jeden Sammelpunkt, also insgesamt vier Probenbehälter für jede Sammellinie.

Insgesamt sollen fünf Sammellinien angelegt werden (aber es können auch weniger sein, wenn nicht genügend Zeit zur Verfügung steht oder andere Umstände vorliegen), jede im gleichen Abstand von 25 m von der nächsten entfernt. Für jede Sammellinie werden 4 Behälter gefüllt. Insgesamt ergibt das:

5 Sammellinien × 4 Probenbehälter = 20 Probenbehälter (= 20 rote Quadrate in der Abbildung unten).



⑦ Behälter richtig beschriften

Es ist sehr wichtig, dass jeder Behälter mit den folgenden drei Angaben versehen wird (siehe Beispiel):

1. Sammelort und Datum

2. Sammellinie

3. Sammelpunkt

⑧ Proben verschicken

Alle Behälter und Datenerfassungsblätter werden per Post ans AWI geschickt. Hier könnt ihr die beigefügten Adressenaufkleber (als PDF-Datei) verwenden.

Inhalt: Wissenschaftliche Proben

An Bruno Walther
Deep Sea Ecology and Technology
Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
D-27570 Bremerhaven

Die Pakete werden mit der Paketmarke frankiert, die euch vom AWI zugeschickt wird. Bitte kontrolliert, dass euer Paket nicht über 10 kg wiegt.
Bitte schickt eure Fotos und zusätzliche Informationen per Email an Bruno Walther unter bwalther@awi.de

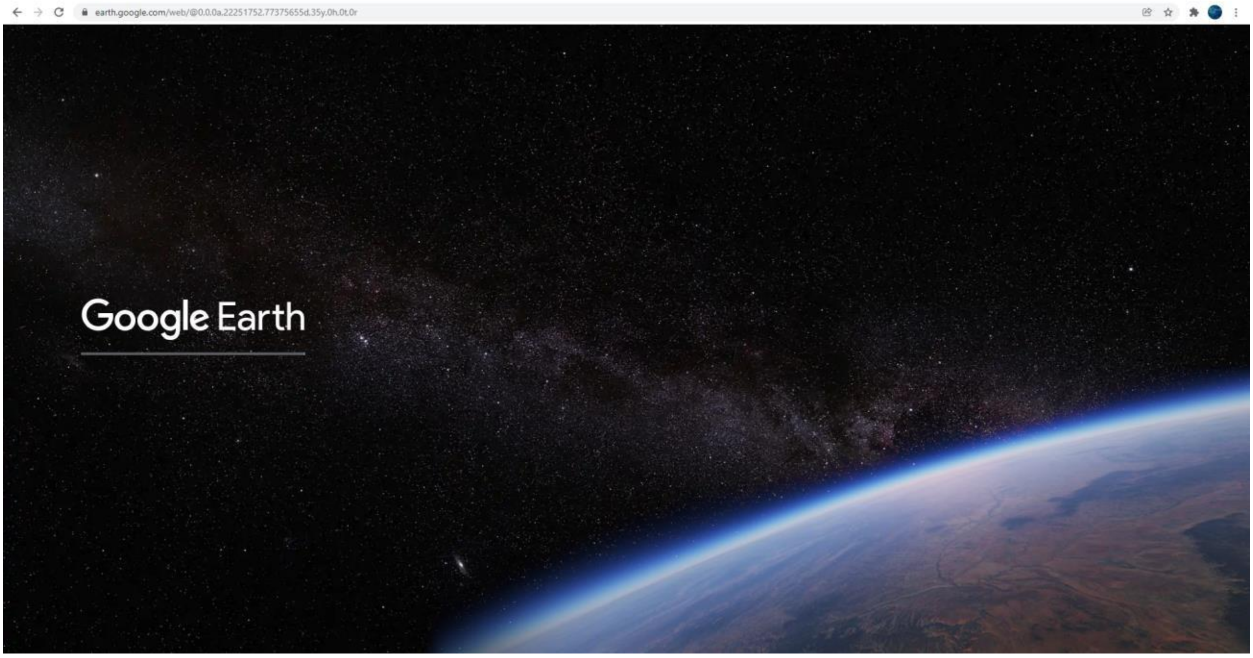
Anhang 1: Wie kann ich geographische Koordinaten ermitteln?

Natürlich kann man heutzutage mit einem Mobiltelefon sehr leicht die geographischen Koordinaten bestimmen. Weil aber die Funktionen bei jedem Mobiltelefon etwas anders ist, wird hier die einfachste Möglichkeit im Internet erklärt.

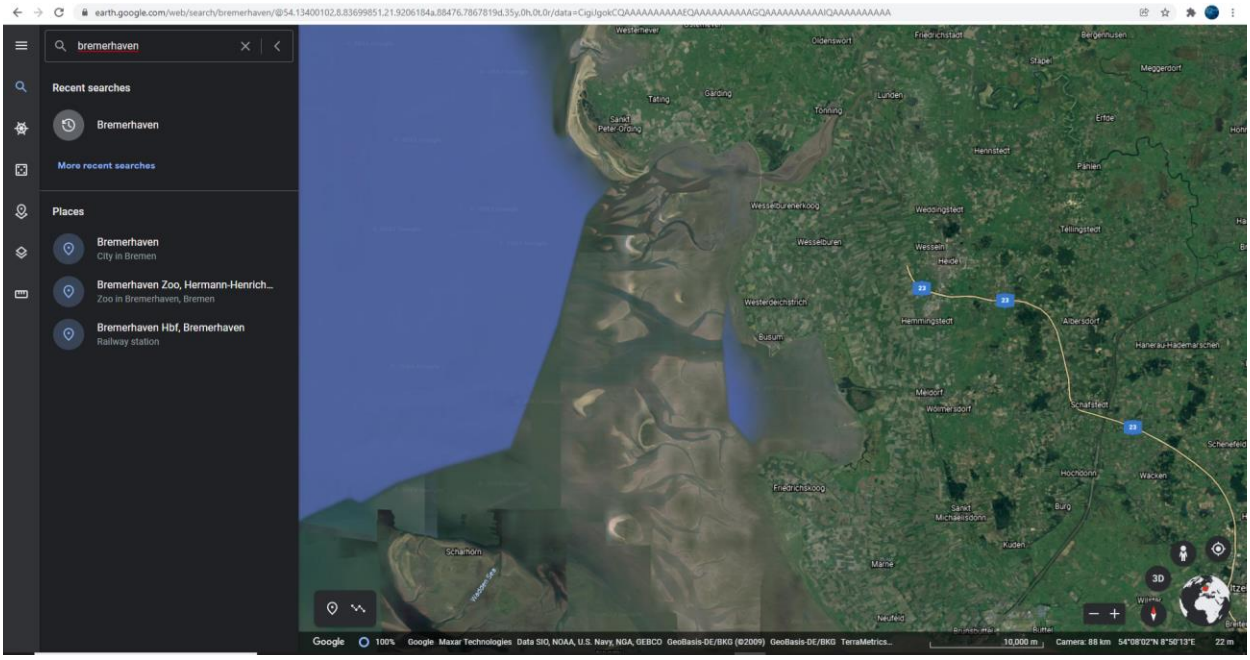
Benutze **Google Earth**

https://earth.google.com/

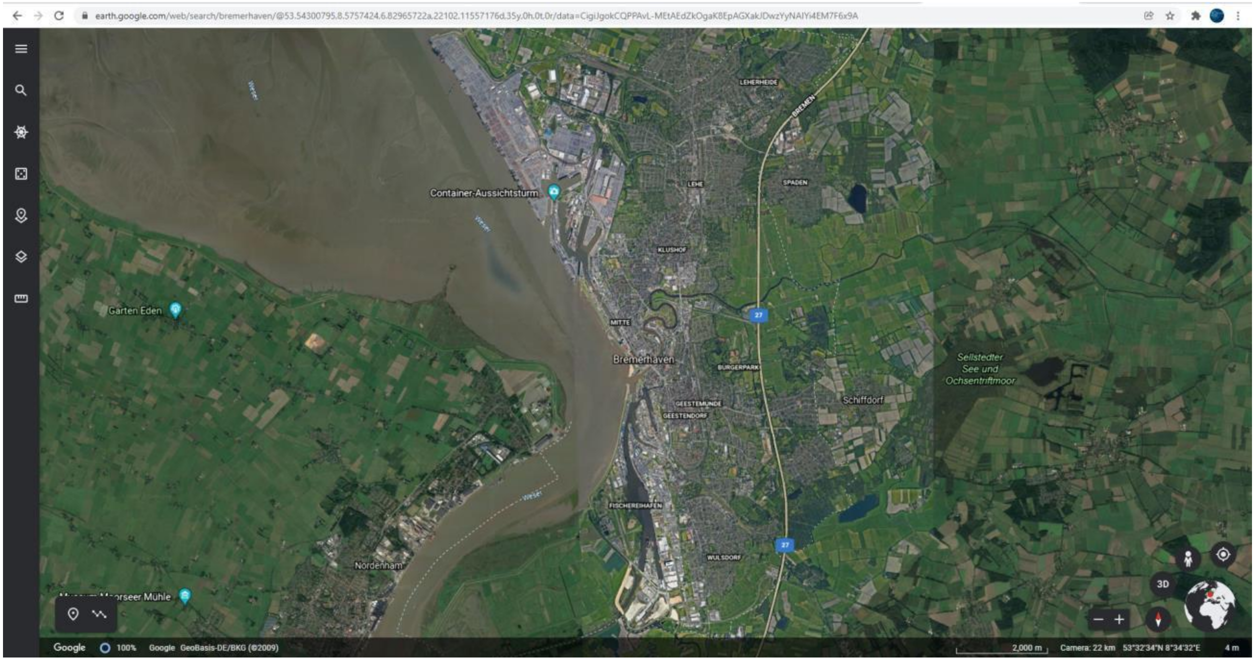
Zuerst sollte dieses Bild zu sehen sein.



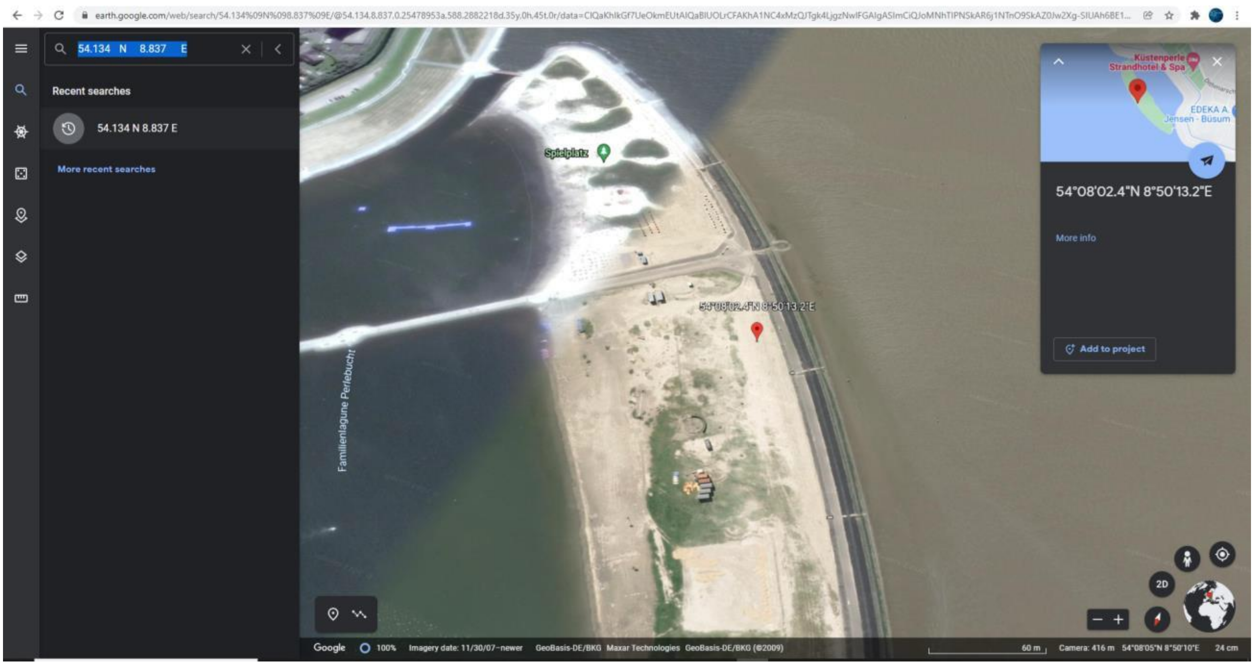
Dann kann man auf das Lupenfeld links oben klicken. In das erscheinende Suchfeld kannst Du dann einen Ort eintippen.



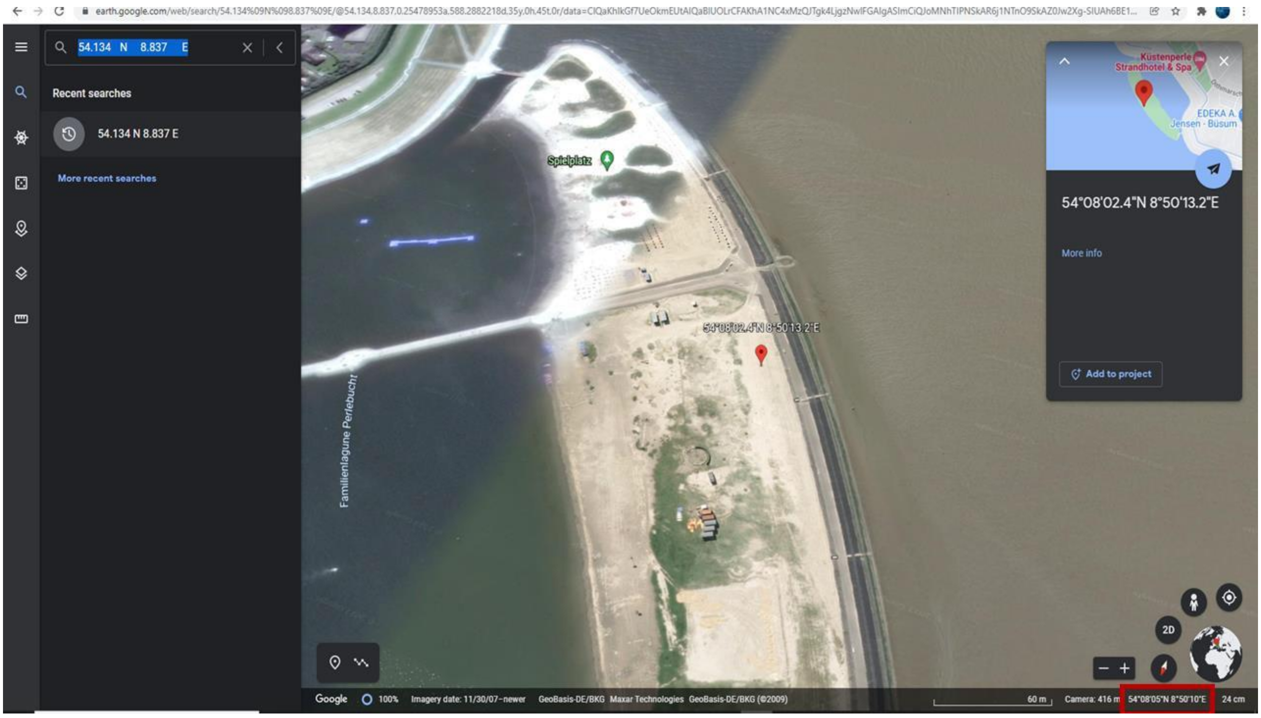
Drückst Du dann die Entertaste, fliegst Du virtuell zu dem ausgesuchten Ort, z.B. Bremerhaven.



Du kannst in das gleiche Suchfeld auch Koordinaten eingeben, zum Beispiel „54.134 N 8.837 E“ und dann fliegst Du dorthin.



Sobald Du in Google Earth bist, sind die geographischen Koordinaten immer da, wo sich die Maus gerade auf der Karte befindet (siehe dunkelrot umrandetes Feld unten rechts).



So kannst Du immer die Koordinaten eines Ortes sehr einfach am Computer bestimmen.
Google Earth kann man auch auf das Mobiltelefon runterladen. Dann muss man mit dem Finger nur solange auf eine Stelle tippen, bis ein roter Nadelkopf (oder Pin) erscheint – dieser gibt einem dann auch die geographischen Koordinaten des Ortes an.

Text S2.2. English translation of the German instructions above.

Guidance on sampling of meso- and microplastics on beaches

Preliminary remarks

Thank you for your interest in participating in the Microplastic Detectives research project. With this project, we would like to find out how many mesoplastic (5-25 millimeters) and microplastic particles (1-5 millimeters) there are on the German coastline. You can help by following these simple sampling instructions. At the same time, you will learn something about this serious environmental problem.
Plastic is a useful material because it can be made into many shapes, colours, hardnesses and flexibilities, and because it is light, cheap and durable. However, it is precisely the durability that is also a problem, because if the plastic gets into the environment, it decomposes very slowly.
If someone throws a piece of paper into the sea or into the forest, it is practically food for the plants and animals. Bacteria and fungi can decompose the basic building blocks, and this releases nutrients that are important for the plants and animals in the sea or forest. However, the bacteria and fungi cannot do anything with plastic, and it thus accumulates and becomes an ever-growing problem.
One of the worst effects is when marine animals (for example dolphins, turtles, seals, whales) get entangled in plastic debris (e.g., discarded nets) and die in agony. Many other marine animals get sick or die because they eat plastic parts and thus block or injure their stomachs and think that they are full. Plants and corals are injured by larger pieces of plastic or cut off from food and other essential materials by being covered by plastic. Plastic also contains chemicals that can be harmful to humans and animals.

Notes on proper use

In order for you to successfully collect the sand samples, you should read these instructions carefully. First of all, some general advice:
1. One of the most important things to consider is the random principle. This means that it is not you who chooses where on the sandy beach the samples are taken, but that the location is decided by a random number. Because otherwise you might choose a place that is particularly polluted, which is not what we want: we want the samples from a randomly chosen place. This reflects a more realistic picture of the pollution.
2. A collection should not be done if the weather is too bad. Especially heavy rain or wind make collecting the samples difficult and unpleasant.
3. Of course you should always take care of your health and safety: Please wear clothes that are appropriate for the weather. This includes wearing appropriate footwear, as there can be sharp or pointed objects on the beach, and it can become wet. Under no circumstances should you walk into the mudflats unsupervised, especially when the tide is coming in. Sometimes high waves can suddenly appear on a

sandy beach, for example when a large ship passes by. If there is a lot of wind or sun, wear headgear, use sunscreen, drink plenty of water and don't overheat. If you are injured or not feeling well, tell a supervisor immediately.

4. Discuss any questions or concerns with either the teacher or the project leader (Bruno Walther, email: bwalther@awi.de).

Material and equipment provided by the Alfred Wegener Institute (AWI)

- Instructions, sheet with random numbers 1-100, data collection sheet LOCATION
- Waterproof pens, clipboard, wide scotch tape
- Tape measure
- Hooks (tent pegs) for marking the collection line and the collection frame
- Collection frame
- Metal shovel and hand brush
- Metal boxes for sand
- Ziploc plastic bags
- Parcel stamps for shipping to AWI

Own equipment needed

- Mobile phone for photos, films and GPS coordinates
- Coin
- Scissors for scotch tape
- Bags, boxes or similar for equipment and samples
- Boxes for shipping the sand samples (parcel stamps for postage will be provided)

① Select location

You are free to choose the sampling site, but you must check it beforehand with the project leader Bruno Walther to avoid multiple sampling of the same site. It should be a sandy beach on the North Sea or Baltic Sea, or at a river mouth leading into the sea, where the tides are still noticeable. The beach should be easily accessible for sampling, otherwise you will have to carry the material a long way back.

We recommend choosing a stretch of beach that is 10 - 100 meters wide. It is important that you choose an area with a sandy ground; sampling is not possible in silt. Caution: Excessive rain or wind can hinder sampling or make it impossible. If possible, start sampling when the water is running out, i.e. when the ebb tide is going out, to prevent dangerous work when the flood tide is rising.

Please fill in the data collection sheet "Location" before you start sampling (see example):

Dieses Datenerfassungsblatt, wenn möglich, bitte auch fotografieren als SICHERUNGSKOPIE!

***Bitte Einträge mit Sternchen unbedingt ausfüllen, alle anderen Einträge sind nicht obligatorisch.**

***Ort:** DUHNEN STRAND, CUXHAVEN

***Breite des Strandes an der Sammellinie 0 (siehe Abbildung 1 in der Anleitung):** 56 **Meter**

Ortsbeschreibung (kurze Beschreibung des Sammelortes, Art des Strandes, etc.):
Sauberer Sandstrand, kaum größerer Müll sichtbar, sehr wenige Steine, untere Kante ist Wattboden, obere Kante ist Dünenbewuchs.

GPS Koordinaten: 53° 53' 15" N, 8° 38' 46" E

***Datum:** 24. 12. 2021

***Name der Kontaktperson:** Bruno WALTHER

Anzahl der Teilnehmer: 4

Namen anderer Teilnehmer: Andreas WALTHER, Klaus MEINE, Otto WAALKES

Zeitdauer der Sammlung: von 10 **Uhr bis** 12 **Uhr**

***Anzahl der Sammellinien (mit 4 Sammelpunkten pro Sammellinie):** 5

Bemerkungen, z.B., über Probleme, Verbesserungsvorschläge, ... Kommentare können natürlich auch direkt an Bruno Walther unter bwalther@awi.de geschickt werden (kann auch auf der Rückseite weiter geschrieben werden):
Kann man die Anweisungen in Plattdeutsch haben?

You can find the GPS coordinates using your smartphone or Google Earth (see Appendix 1 for detailed instructions).

Please take a photo of the completed data collection sheet "Location" as a backup copy.

Please take more photos and video clips, for example (1) of the beach in the different directions to get an impression of the surroundings or (2) interesting finds, for example an old piece of plastic rubbish (expiry date recognisable?).

Contents of the data collection sheet

If possible, please also photograph this data collection sheet as a BACKUP COPY!

***Please fill in entries with asterisks, all other entries are not obligatory.**

***Place:**

***Width of beach at collection line 0 (see figure in the instructions): _____ meters**

Description of location (brief description of the collection site, type of beach, etc.):

GPS coordinates:

***Date:**

***Name of contact person:**

Number of participants:

Names of other participants:

Duration of collection: from ______ hrs to ______ hrs

***Number of collection lines (with 4 sampling points per collection line):**

Comments, e.g., about problems, suggestions for improvement, ... Comments can of course also be sent directly to Bruno Walther at bwalther@awi.de (can also be written on the back):

Random numbers 1-100

67 68 29 1 36 58 5 82 70 60 99 52 79 29 33 49 93 80 93 73 68 31 100 55 49 55 45 97 39 24 19 20 90 15
50 70 31 65 45 93 22 5 26 54 100 34 48 3 9 76 37 27 67 14 13 98 91 43 26 76 3 18 50 74 33 87 34 93
25 71 68 60 87 10 3 76 25 54 54 76 13 24 42 41 3 90 10 64 52 72 4 35 72 3 63 44 66 90 37 44 61 56 98
92 71 80 61 80 62 46 52 54 99 85 79 44 36 31 64 70 42 16 85 95 50 80 5 57 96 2 83 3 19 53 47 31 63
57 44 11 71 63 18 21 39 52 92 94 10 79 88 20 40 18 79 47 11 5 84 19 17 95 100 96 64 93 79 65 60 76
88 78 90 85 38 37 86 86 6 69 83 56 59 36 86 63 33 92 3 14 74 31 27 79 4 42 86 25 42 1 84 57 22 73 36
24 11 50 77 11 55 22 18 20 4 12 55 7 24 49 21 76 10 42 3 22 71 16 80 59 94 35 40 6 58 63 48 70 73 74
70 6 39 87 93 60 5 99 62 3 42 1 78 77 95 83 57 93 33 10 92 89 24 79 64 5 87 89 95 21 44 56 83 95 15
99 15 21 52 14 7 12 78 17 59 72 3 40 45 12 79 2 30 40 42 15 66 18 72 44 11 3 36 56 36 37 26 55 98 45
24 55 66 40

Photo documentation

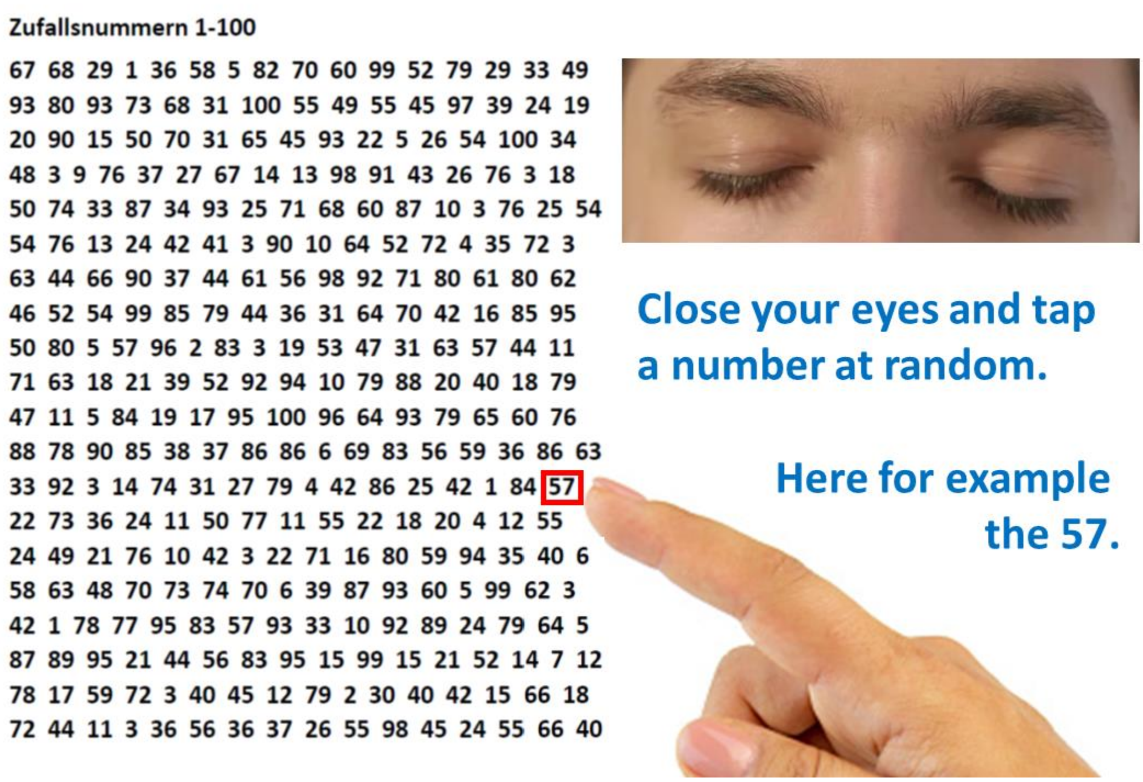
The photo documentation is very useful to categorise the beaches, to get an idea of the collection site and as a backup copy of the data collection sheet LOCATION (however, the photos are not absolutely necessary, but they would just be very helpful). The following photos would be useful:

1. Photo of the completed data collection sheet LOCATION (as a backup copy).
2. One landscape photo along each of the two directions of the zero collection line , i.e. one photo towards the water and one photo towards the dune, beach wall or other upper boundary of the beach. Then two more landscape photos at right angles to the collection line; thus, a total of four photos at right angles to each other. More photos of the beach to categorize the beach well are also useful.
3. More photos can document the collection: Photos of the people involved for use in social media, of the macro litter collected and categorized (if that is also part of the action), photos of particularly interesting finds (very old piece of debris, from very far away, entangled or overgrown with animals), etc.
4. Names of the photographers are required and permission for further use is then assumed.

② **Determine the „zero collection line“**

When you arrive at the beach, you decide randomly by "coin toss" whether the collection line will be placed on your left or right. Look towards the water's edge (see photo).

Then you choose a random number from the sheet:



Zufallsnummern 1-100

67	68	29	1	36	58	5	82	70	60	99	52	79	29	33	49
93	80	93	73	68	31	100	55	49	55	45	97	39	24	19	
20	90	15	50	70	31	65	45	93	22	5	26	54	100	34	
48	3	9	76	37	27	67	14	13	98	91	43	26	76	3	18
50	74	33	87	34	93	25	71	68	60	87	10	3	76	25	54
54	76	13	24	42	41	3	90	10	64	52	72	4	35	72	3
63	44	66	90	37	44	61	56	98	92	71	80	61	80	62	
46	52	54	99	85	79	44	36	31	64	70	42	16	85	95	
50	80	5	57	96	2	83	3	19	53	47	31	63	57	44	11
71	63	18	21	39	52	92	94	10	79	88	20	40	18	79	
47	11	5	84	19	17	95	100	96	64	93	79	65	60	76	
88	78	90	85	38	37	86	86	6	69	83	56	59	36	86	63
33	92	3	14	74	31	27	79	4	42	86	25	42	1	84	57
22	73	36	24	11	50	77	11	55	22	18	20	4	12	55	
24	49	21	76	10	42	3	22	71	16	80	59	94	35	40	6
58	63	48	70	73	74	70	6	39	87	93	60	5	99	62	3
42	1	78	77	95	83	57	93	33	10	92	89	24	79	64	5
87	89	95	21	44	56	83	95	15	99	15	21	52	14	7	12
78	17	59	72	3	40	45	12	79	2	30	40	42	15	66	18
72	44	11	3	36	56	36	37	26	55	98	45	24	55	66	40

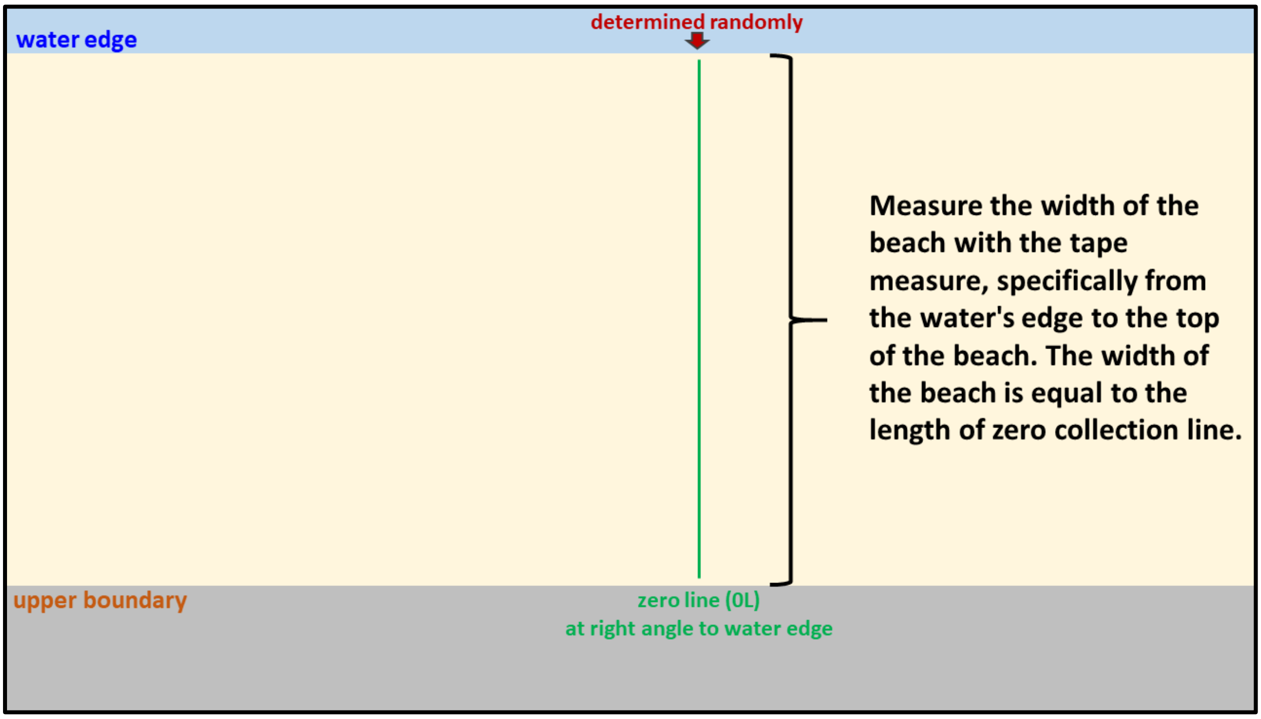
The number corresponds to the distance in meters along the beach. So if you have determined left and 57 meters by chance, then measure 57 meters from your arrival point where you tossed the coin, parallel to the water's edge and in the left direction with the tape measure.

As a second example: If, however, you had determined, for example, to the right and 26 meters by chance, then measure 26 meters from your point of arrival (where you threw the coin) with the tape measure, parallel to the water's edge and in the right direction.

This way, you have now determined the starting point for determining the „zero collection line“. Mark this starting point with the help of a hook (or something else, for example a stick or backpack).

③ Measure the width of the beach

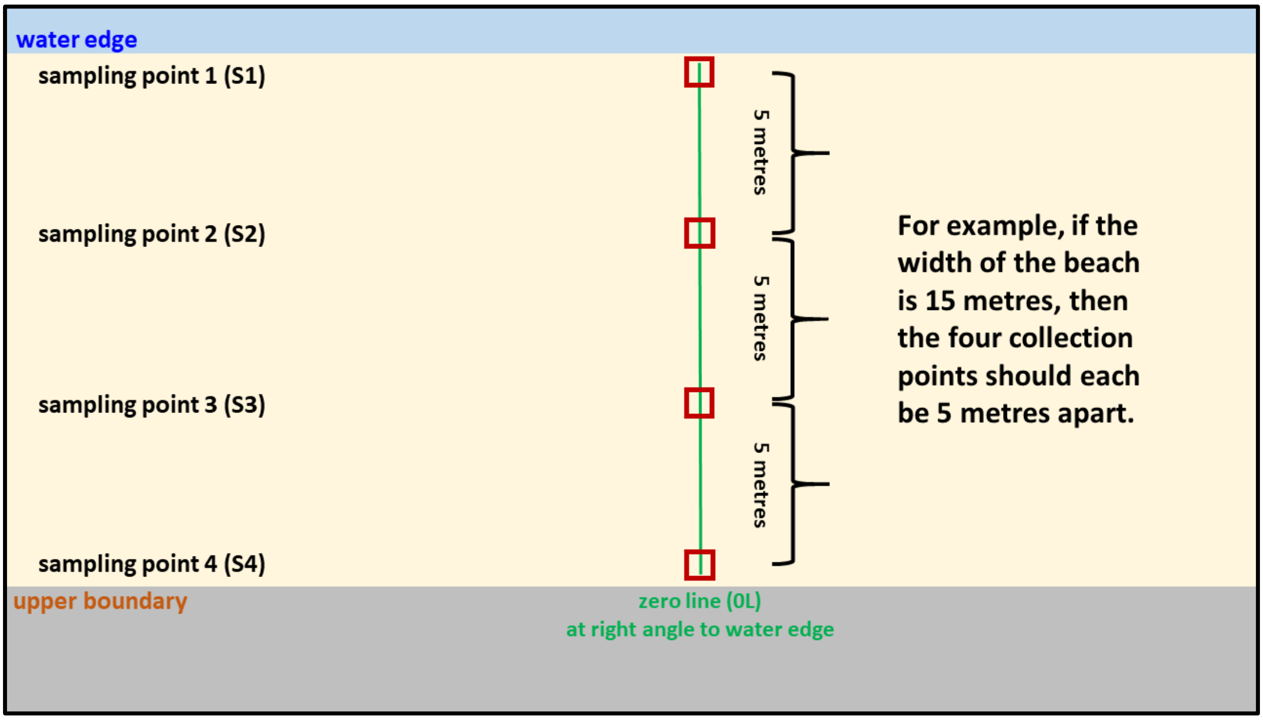
Now measure the distance between the water's edge and the upper end of the beach, traversing the starting point (i.e. the „zero collection line“ marked with a hook).



You have to determine the water's edge and the upper end of the beach yourself. At high tide, the water's edge is of course where the water starts, but at low tide you have to estimate where the water normally is at high tide. The upper end of the beach can usually be recognised by a hard edge, for example a stone wall or an overgrown dune. Below are two examples.

④ Determine sampling points

Every collection line has four sampling points. Therefore, you divide the measured distance by three. For example, if the beach is 15 meters wide, the collection points are placed at 5 meter intervals. Example: 15 : 3 = 5 → sampling points at 0, 5, 10, 15 meters.



Here are two more examples: If the beach were 90 meters wide, then the collection points would be placed 30 meters apart. And if the beach were 59 meters wide, then the collection points would be placed at a distance of 19.67 meters, and so on.
Important: The sampling point closest to the water's edge is called "collection point 1", etc.

Measure the four sampling points along the zero collection line with the tape measure and mark each collection point with a hook.

⑤ Taking sand sample

Now you can take the sand samples with the help of the collecting frame. First press the collection frame into the sand where the collection hook is. Remove all pieces of macro debris (> 25 mm) inside the collection frame and enter them in the data collection sheet under “Comments”. Other large parts (> 25 mm) that are not litter (e.g. wood, shells, etc.) should also be removed first.

Then evenly remove the top centimeters of sand inside the collection frame with the metal shovel and deposit them in a metal box ("sample container").

Remove sand evenly from the surface

You are finished with the sampling point when the sample container is completely full. Close the sample

container and tape it shut with wide adhesive tape.

Now fill three more containers with sand at the three remaining collection points along the collection line, close them and tape them shut.

Important: After taking each sample, clean the collection frame and the shovel with the hand brush to avoid contamination with sand not from the sampling point!

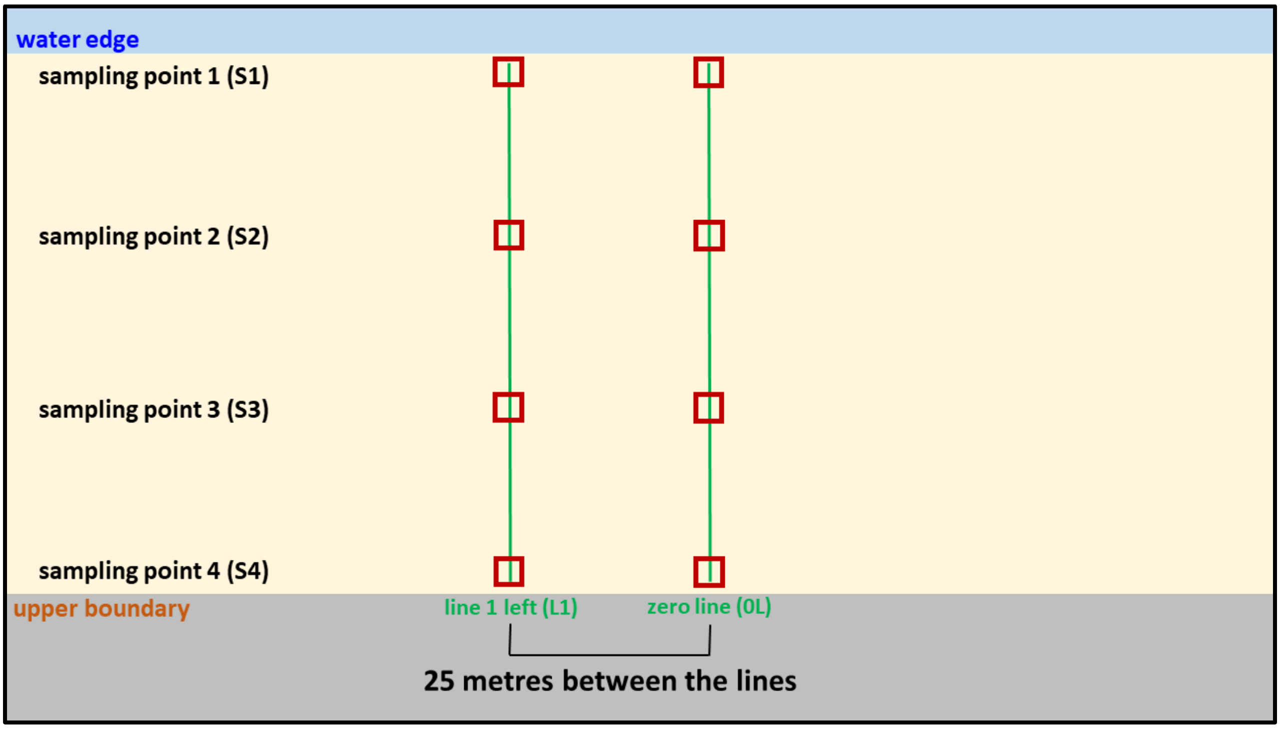
⑥ Determine further collection lines

Please take a close look at the following two illustrations. The zero collection line (which you have determined at random) is in the middle.

Sampling point 1 is **always** at the water's edge and sampling point 4 **always** at the upper end of the beach.

The collection lines **1 left** and **2 left** are to the left of the zero collection line, when you look towards the water!

And the collection lines **1 right** and **2 right** are to the right of the zero collection line, when you look towards the water!



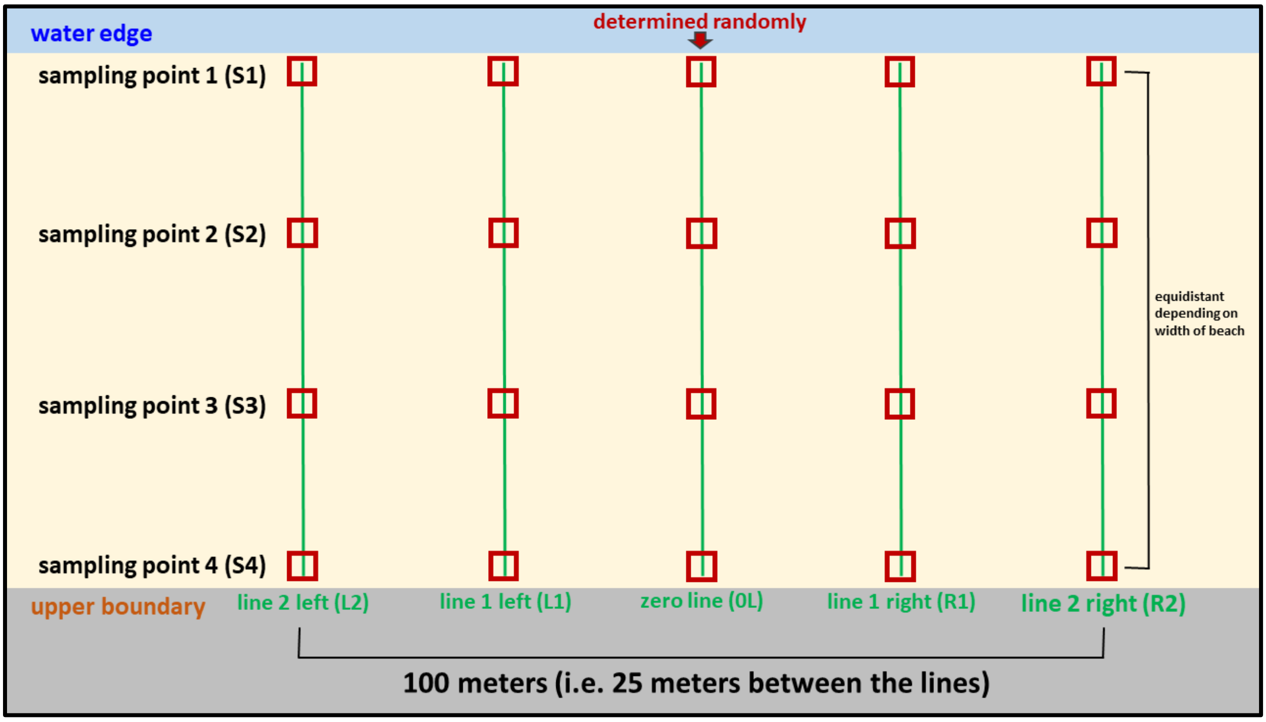
In the above illustration, the second collection line is created, which lies to the right of collection line 0 when looking towards the water.

The distance between two collection lines should **always** be 25 meters (please measure exactly with the tape measure) unless the beach is less than 100 meters long (then shorter distances can be used).

The sampling points should be at the same distance from each other on all collection lines, in our example it would be 5 m again. And just like for the zero collection line, you fill one sample container for each sampling point, i.e. a total of four sample containers for each collection line.

A total of five collection lines are to be created (but it can also be less if there is not enough time or because of other circumstances), each at an equal distance of 25 m from the next. For each collection line, 4 containers are filled. In total, this results in:

5 collection lines × 4 sample containers = 20 sample containers (= 20 red squares in the figure below).



⑦ Label containers correctly

It is very important that each container is labelled with the following information (see example):

4. Location and date

5. Collection line

6. Sampling point

⑧ Mail samples

All containers and data collection sheets are sent to the AWI by post. You can use this address label (also provided as a PDF file).

Contents: Scientific samples

To Bruno Walther
Deep Sea Ecology and Technology
Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
D-27570 Bremerhaven

The parcels will be paid with the parcel stamp sent to you by the AWI. Please check that your package does not weigh more than 10 kg.

Please send your photos and additional information by email to Bruno Walther at bwalther@awi.de

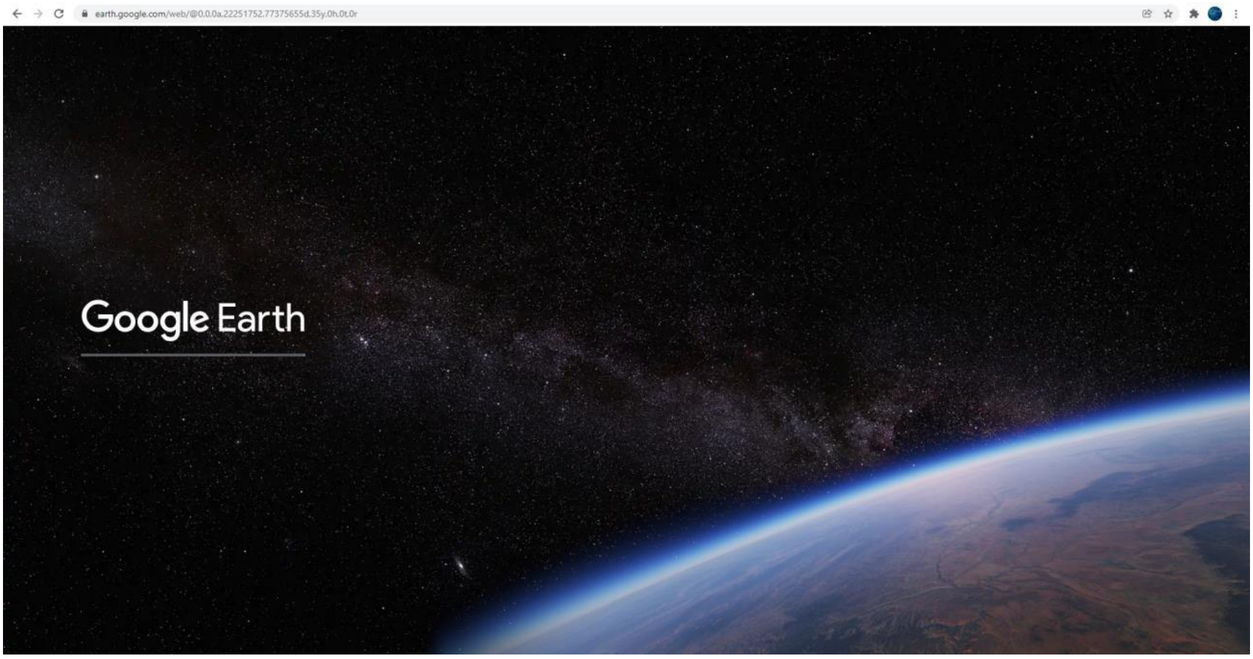
Appendix 1: How can I determine geographical coordinates?

Of course, nowadays it is very easy to determine the geographical coordinates with a mobile phone. However, because the functions of each mobile phone are somewhat different, the simplest possibility on the Internet is explained here.

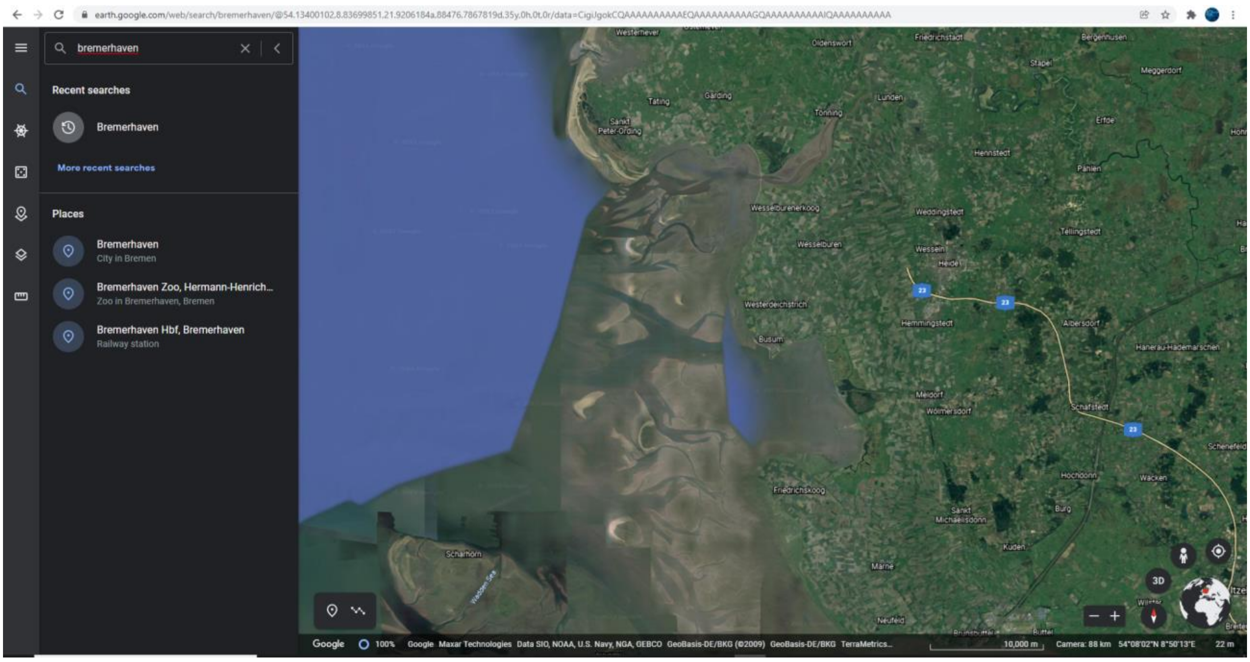
Use **Google Earth**

https://earth.google.com/

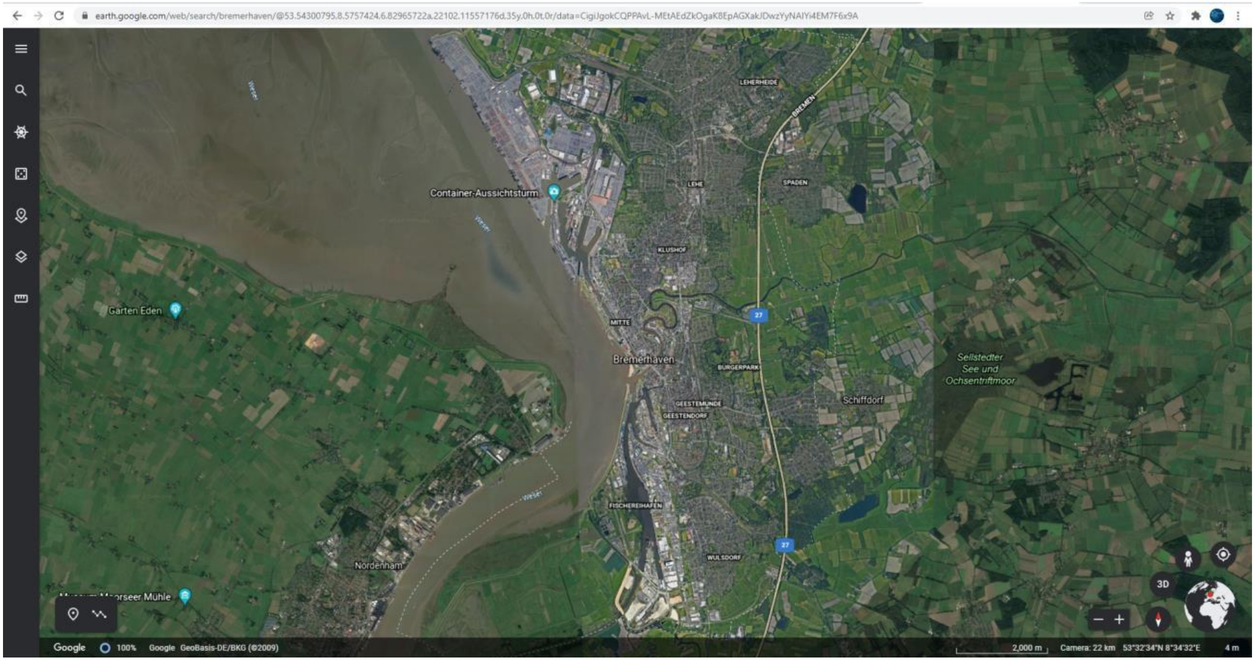
First you should see this picture.



Then you can click on the magnifying glass in the top left-hand corner. You can then type a location into the search field that appears.

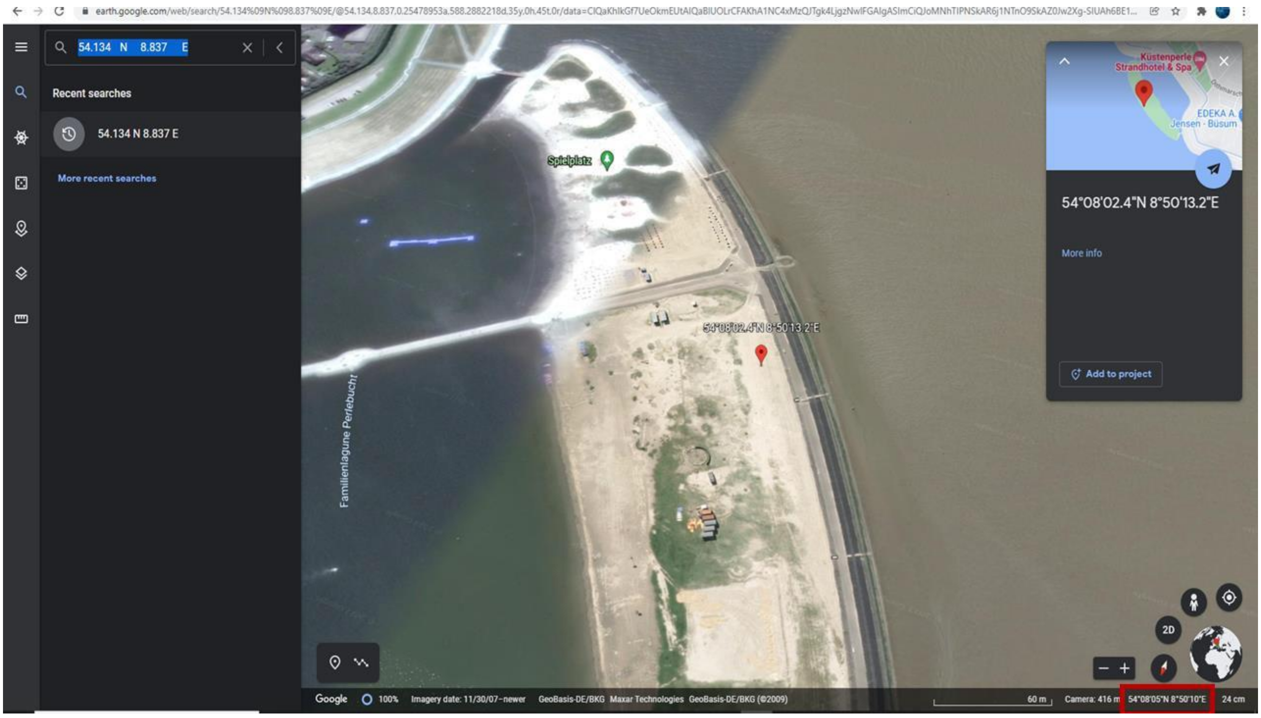


If you then press the Enter key, you fly virtually to the selected location, e.g., Bremerhaven.



You can also enter coordinates in the same search field, for example "54.134 N 8.837 E" and then fly there.

As soon as you are in Google Earth, the geographic coordinates are always where the mouse is currently located on the map (see dark red bordered field at the bottom right).



This way you can always determine the coordinates of a place very easily on your computer.

You can also download Google Earth to your mobile phone. Then you just have to tap on a place with your finger until a red pinhead (or pin) appears - this then also gives you the geographical coordinates of the place.

Text S3.1. Unpublished report written by BAW about the collection of sand samples with school children of the Grundschule Neuhaus on 23 March 2022 (followed by the English translation of this German report). All photos by BAW.

Sand buddeln mit der Grundschule Neuhaus für das Forschungsprojekt Mikroplastikdetektive

Es gibt so Momente, da denkt man sich: dafür hat sich der ganze Aufwand gelohnt!
Mit acht Schülerinnen und Schülern der Grundschule Neuhaus und ihrer Lehrerin Doris Henningson trafen wir uns am Wattenmeer-Besucherzentrum Cuxhaven am 23. März 2022. Das Wetter war strahlend schön, 100% blauer Himmel, man konnte die Neuwerker Türme gut erkennen, aber heutzutage kann man das auch nicht mehr uneingeschränkt genießen ob des Wissens, daß es eigentlich viel zu warm und trocken für diese Jahreszeit war. Der Klimawandel lässt grüßen!
Zusammen mit Rainer Himmighofen (abgeordnete BNE-Lehrkraft am Natureum Niederelbe) hatte ich alle Sammelmaterialien mitgebracht, und die Klasse hatte schlauerweise auch einen Bollerwagen dabei, der den ganzen Transport an den Strand so viel leichter machte. Und so machten wir uns nach der ersten Brotzeit gleich auf zum Strand. Eine kurze Einleitung folgte, wo ich kurz erklärte, was Wissenschaftler denn überhaupt so machen, und wie das Plastik ins Meer und an den Strand kommt, und warum es in immer kleinere Stücke zerfällt.
Aber die Schüler:innen waren viel erpichter darauf, gleich loszulegen, also fingen wir mit der Strandvermessung an. Zuerst wurde die erste Zufallslinie angelegt, dann die Breite des Strandes ermittelt, und dann wurden schon die ersten vier Sammelpunkte bestimmt. Und los ging's: Sammelpunkt

entlang vom Band, Sammelrahmen in den Sand, dann die Schaufel in die Hand, und im Nuh verschwand der Sand im Metalldosenverband (okay, der letzte Reim ist ein bisschen erzwungen, aber wenn jemand einen besseren weiß, bitte melden).
Die Schüler:innen waren einfach prima dabei. Kleine Gruppen bildeten sich selber, einige konzentrierten sich aufs Vermessen, andere aufs Sand schaufeln, und andere trugen die gefüllten Dosen zurück zum Anfangspunkt. Rainer klebte sie dann alle schön zu, und in weniger als zwei Stunden konnten wir dann schon alle 20 Dosen schön arrangieren und unser abschliessendes Erfolgsfoto schießen.

Fleissige Sandsammelbienen.

Daraufhin wurde auch noch ein bisschen Müll gesammelt und das Wattenmeer etwas erkundet. Und natürlich mit dem Sand gespielt, Füsse eingraben, und so was. Fun at the beach!
Und so ging die Zeit auch viel zu schnell vorbei, und nach zwei anstrengenden Touren mit dem nun schwer beladenen Bollerwagen durch den weichen Sand waren alle Proben in meinem Auto verstaut.
Vielen Dank, Bürgerwissenschaftler:innen der Grundschule Neuhaus! Ich hoffe, ihr hattet Spaß und habt auch etwas gelernt dabei.

Text und Fotos: Bruno Walther

Hurra, es ist geschafft!

Das Ziel des Forschungsprojekts MIKROPLASTIKDETEKTIVE ist die großräumig vergleichbare Erfassung von Mikro- und Mesoplastik an den deutschen Küsten durch Bürgerwissenschaftler:innen.

Kontaktperson

Bruno Walther

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, 27570 Bremerhaven, Tel: 0471-4831-1727, bwalther@awi.de

Facebook

https://www.facebook.com/groups/5080291445411517

Twitter

https://twitter.com/MP_Detektiv

Mikroplastikdetektive Webseite

https://tinyurl.com/awimpd

Text S3.2. English translation of the unpublished German report above.

Digging sand with the Neuhaus primary school for the research project Microplastic Detectives

There are such moments when you think to yourself: this was worth all the effort!

On 23 March 2022, we met with eight pupils from the Neuhaus primary school and their teacher Doris Henningson at the Wadden Sea Visitor Centre in Cuxhaven. The weather was brilliant, 100% blue sky, one could clearly see the towers on the island of Neuwerk. However, nowadays one cannot unreservedly enjoy such weather because of the knowledge that it was actually far too warm and dry for this time of year. Climate change sends its regards!

Together with Rainer Himmighofen (seconded teacher from the Natureum Niederelbe), I had brought all the collection materials, and the class had cleverly also brought a handcart, which made all the transport to the beach so much easier. And so, after the first snack, we immediately set off for the beach. A short introduction followed, during which I briefly explained what scientists actually do, how plastic gets into the sea and onto the beach, and why it breaks down into smaller and smaller pieces.

However, the students were much more eager to get started, so we began the beach survey. First, the first random line was drawn, then the width of the beach was determined, and then the first four sampling points were determined. And off we went: sampling point along the tape, collection frame in the sand, then the shovel in the hand, and within seconds the sand disappeared in the metal container (okay, the last rhyme is a bit forced, but if someone knows a better one, please let me know).

The pupils were just great about it. Small groups formed themselves, with some concentrating on measuring, others on shoveling the sand, and others carrying the filled containers back to the starting point. Rainer then taped them all shut, and in less than two hours we were able to nicely arrange all 20 containers and take our final success photo.

Busy sand collecting bees.

After that, we collected some rubbish and explored the Wadden Sea a bit. And of course play with the sand, dig in feet, and so on. Fun at the beach! And thus time went by much too quickly, and after two strenuous tours with the now heavily loaded handcart through the soft sand, all the samples were stowed in my car.

Thank you very much, citizen scientists from the Neuhaus primary school!

I hope you had fun and learned something.

Text and photos: Bruno Walther

Hooray, it's done!

The aim of the research project MIKROPLASTIC DETECTIVES is the large-scale comparable sampling of micro- and mesoplastics along the German coastline by citizen scientists.

Contact person

Bruno Walther

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, 27570 Bremerhaven, Tel: 0471-4831-1727, bwalther@awi.de

Facebook

https://www.facebook.com/groups/5080291445411517

Twitter

https://twitter.com/MP_Detektiv

Mikroplastikdetektive website

https://tinyurl.com/awimpd

Text S4. Participating citizen scientists and organizations

The following 30 organizations participated in the 71 collections: Biosphärenreservatsamt Südost-Rügen; Bund für Umwelt und Naturschutz Deutschland (BUND); Bye Bye Plastik Sylt; ElbeCamp; EUCC - Die Küsten Union Deutschland; FÖJ Umweltbildung Nationalparkamt Vorpommern; Förderverein Nationalpark Boddenlandschaft; Geomar Universität Kiel; Grundschule Neuhaus an der Oste; Grüne Jugend Schleswig; Kieler Forschungswerkstatt – MikroplastikPiraten (or Plastic Pirates); Küste gegen Plastik e.V.; Leibniz-Institute for Baltic Sea Research; Lions Club; MeeresBürger-Netzwerk; Mellumrat; Naturschutzbund Deutschland (NABU); Nationalpark Jasmund; Nationalpark-Haus Wittbülten Spiekeroog; Nationalpark-Schiff Feuerschiff Borkumriff; Nationalparkhaus Wittmund-Carolinensiel; Natureum Niederelbe; Stadtteilschule Wilhelmsburg, Hamburg; Schutzstation Wattenmeer; Verein Jordsand; Watt Welten, Besucherzentrum Norderney; Wattenmeer-Besucherzentrum Cuxhaven; Weniger.Ist.Machbar; Werner-Heisenberg-Gymnasium, Heide. In addition, many citizens unaffiliated with these organizations also organized or participated in collections. In total, around 300 participants took part, but the exact number cannot be ascertained because not all groups reported accurate numbers. We sincerely thank all participants for making this citizen-science project a reality.

Text S5.1. Short project summary for the citizen-science project MICROPLASTIC DETECTIVES which was provided to potentially interested citizen scientists, such as members of environmental organizations and authorities, school groups, and other citizens (followed by the English translation of this German project summary). All photos by BAW.

MIKROPLASTIKDETEKTIVE –
Pilotprojekt zur Erfassung von Meso- und Mikroplastik an deutschen Stränden durch Bürgerforschung

• **Ziel:** Quantifizierung der Mikro-und Mesoplastikverschmutzung deutscher Strände
• **Zielgruppen:** Umweltverbände und -behörden, Bürger*innen, Schulgruppen
• **Aktivitäten:** Probennahmen z.B. bei planmäßigen Strandsäuberungsaktionen und Analysen durch professionelle Wissenschaftler*innen
• **Verantwortlich:** Bruno Walther & Melanie Bergmann (bwalther@awi.de; Melanie.Bergmann@awi.de)
• **Förderung:** Dr. Ernst Weiße-Stiftung. Wegen der kurzen Projektdauer (01. 09. 2021 – 30. 4. 2023) soll MIKROPLASTIKDETEKTIVE als Pilotprojekt verstanden werden. Eine Verlängerung durch Akquise weiterer Förderungsmittel ist angestrebt.

Kurzbeschreibung. Durch die wachsenden Kunststoffproduktion und den unsachgemäßen Umgang mit Plastikprodukten hat sich die Verschmutzung der Umwelt mit Plastikmüll zu einem Problem globalen Ausmaßes entwickelt. Forschungsarbeiten dazu werden überwiegend von professionellen Wissenschaftler*innen durchgeführt. So untersuchen Forschende des Alfred-Wegener-Instituts (AWI) seit 2004 die Auswirkungen und Verbreitung von Kunststoffmüll in der Nordsee, im Pazifik, Atlantik und der Arktis. Seit 2011 entwickelt das AWI Verfahren zur Analyse von Mikroplastik, um die Verschmutzung durch Klärwerke, von Flüssen, Meer und die Auswirkungen auf Tiere zu erfassen.

Bürgerforschende leisten weltweit einen wichtigen Beitrag zur großräumigen und regelmäßigen Erfassung der Plastikverschmutzung. So haben sie z.B. in einer Pilotstudie mit dem AWI den Müll an sechs verschiedenen Stränden in der Arktis quantifiziert. Bislang beschränken sich diese Aktivitäten auf größeren Plastikmüll.

Mit der Zeit zerfallen Kunststoffe jedoch in immer kleinere Teilchen: Mesoplastik (5 – 25 mm) und Mikroplastik (kleiner als 5 mm). Dieser Bereich wird von der Bürgerforschung bisher kaum abgedeckt, weil ein Konzept zur verlässlichen Erfassung dieser Teilchen durch Bürgerforschende noch fehlt.

Das Projekt MIKROPLASTIKDETEKTIVE soll diese Lücke schließen, um großflächig vergleichbare Daten zur Meso- und Mikroplastik-Verschmutzung deutscher Küsten zu erheben. Zunächst wird durch Dialog und gemeinsame erste Probennahmen mit Umweltverbänden ein realistisches Konzept entwickelt. Ein Diskussionsvorschlag, wie das Projekt strukturiert sein könnte, wird in der Tabelle (s. unten) vorgestellt. In Zusammenarbeit mit Umweltverbänden und Bürgerforschenden werden dann z.B. bestehende Initiativen zur Strandmüllerfassung um den Faktor Mikroplastik-Probennahme erweitert. Alle Proben werden ans AWI geschickt und dort analysiert. Das Projekt bindet Bürgerforschende in die Erhebung wissenschaftlicher Daten zu einem aktuellen globalen Umweltproblem ein und wird durch Öffentlichkeitsarbeit über soziale und traditionelle Medien begleitet.

Neben dem wissenschaftlichen Erkenntnisgewinn spielt der Aspekt der Umweltbildung von Bürger*innen und Förderung von Wissenschaftsverständnis eine zentrale Rolle, da dies ein nachhaltigeres Verhalten begünstigt. Die Ergebnisse liefern ferner einen wichtigen Beitrag zur europäischen Überwachung der Verschmutzung deutscher Küsten mit Mikroplastik, denn im Moment ist der aktuelle Wissensstand noch ziemlich fragmentarisch.

Beiträge der Bürgerforschenden / NGOs	**Beiträge des AWIs**
Öffentlichkeitsarbeit: Verbände weisen bei bestehenden Kampagnen auf MIKROPLASTIKDETEKTIVE hin und schärfen ihr öffentliches Profil durch Zusammenarbeit mit dem AWI; Verbände nutzen AWI Info-Material, um Teilnehmende zu informieren und für Bürgerforschung zu begeistern	**Öffentlichkeitsarbeit:** regelmäßige Kurzberichte und Informationen, die von NGOs und Bürgerforschenden verwendet werden können; Jahresberichte, Veröffentlichungen und Kampagnen werden medial durch Pressemitteilungen und -kontakte begleitet

Finanzen: Keine zusätzlichen Auslagen über bestehenden Kampagnen hinaus	**Finanzen:** Materialien zur Probennahme, z.B. Sammelrahmen, Maßband, Behälter, Porto von Probenversand
Feldarbeit: Verbände organisieren Veranstaltungen, bei denen Mikroplastik gesammelt wird, z.B. bei Strandmüllsammlungen, aber auch unabhängig davon	**Feldarbeit:** das AWI stellt Materialien (s. oben) zur Verfügung, sowie Instruktionen und Formulare zur Datenerfassung
-	**Labor-Messungen**
Wissenschaftliche Publikationen: Verbände können Publikationen vor der Einreichung lesen, kommentieren & für Öffentlichkeitsarbeit nutzen	**Wissenschaftliche Publikationen:** open access, begleitende Presseaktivitäten (Wissenstransfer fördern)

[The actual visualization of this project summary and an English translation are given below.]

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Meso- und Mikroplastik am Strand

Mit der Zeit zerfallen Kunststoffe jedoch in immer kleinere Teilchen: Mesoplastik (5 – 25 mm) und Mikroplastik (kleiner als 5 mm). Dieser Bereich wird von der Bürgerforschung bisher kaum abgedeckt, weil ein Konzept zur verlässlichen Erfassung dieser Teilchen durch Bürgerforschende noch fehlt.

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Text S5.2. English translation of the German project summary above.

MICROPLASTIC DETECTIVES –
Pilot project to record meso- and microplastics on German beaches through citizen research

• **Goal:** Quantification of micro- and mesoplastic pollution of German beaches
• **Target groups:** Environmental organizations and authorities, school groups, and other citizens
• **Activities:** Sampling, e.g., during scheduled beach clean-ups, and analyses by professional scientists
• **Responsible:** Bruno Walther & Melanie Bergmann (bwalther@awi.de; Melanie.Bergmann@awi.de)
• **Funding:** Dr. Ernst Weiße-Stiftung. Because of the short project period (1 Sep. 2021 – 30 Apr 2023), MICROPLASTIC DETECTIVES should be understood as a pilot project. An extension through the acquisition of further funding is intended.

Short description. Because of the growing plastic production and the improper handling of plastic products, the pollution of the environment with plastic waste has become a problem of global proportions. Research on this issue is mainly carried out by professional scientists. For example, researchers at the Alfred Wegener Institute (AWI) have been studying the effects and distribution of plastic waste in the North Sea, the Pacific, the Atlantic and the Arctic since 2004. Since 2011, the AWI has been developing methods for analyzing microplastics in order to record pollution from sewage treatment plants, rivers, the sea and the effects on animals.

Citizen researchers are making an important contribution worldwide to the large-scale and regular recording of plastic pollution. For example, in a pilot study with the AWI, they have quantified litter on six different beaches in the Arctic. So far, these activities have been limited to larger plastic litter.

Over time, however, plastics break down into smaller and smaller particles: Mesoplastics (5 - 25 mm) and microplastics (smaller than 5 mm). This scientific area has hardly been covered by citizen-science so far because a concept for the reliable detection of these particles by citizen scientists is still missing.

The project MICROPLASTIC DETECTIVES aims to close this gap in order to collect comparable data on meso- and microplastic pollution of German coasts over a large area. Initially, a realistic concept will be developed through dialogue and joint initial sampling with environmental associations. A discussion proposal on how the project could be structured is presented in the table (see below). In cooperation with NGOs and citizen scientists, existing beach monitoring initiatives, for example, will then be expanded to include the sampling of microplastics. All samples will be sent to the AWI and analyzed there. The project involves citizen scientists in the collection of scientific data on a current global environmental problem and is accompanied by public relations work via social and traditional media.

In addition to gaining scientific knowledge, the aspect of environmental education of citizens and the promotion of scientific understanding play a central role, as this promotes more sustainable behavior. The results also provide an important contribution to the European monitoring of microplastic pollution of German coastlines, as the current state of knowledge is still rather fragmentary.

Contributions of citizen scientists / NGOs	**Contributions of AWI**
Public relations: NGOs draw attention to MICROPLASTIC DETECTIVES in existing campaigns and raise their public profile through cooperation with AWI; associations use AWI information material to inform participants and inspire them to engage in citizen-science research	**Public relations:** regular short reports and information that can be used by NGOs and citizen researchers; annual reports, publications and campaigns are accompanied by media through press releases and contacts
Financing: no additional outlays beyond existing campaigns	**Financing:** materials for collections, e.g. collection frame, measuring tape, metal boxes, postage of sample shipment
Field work: NGOs organize events where microplastics are collected, e.g. during beach litter collections, but also independently of these events	**Field work:** AWI provides materials (see above), as well as instructions and forms for data collection
-	**Laboratory measurements**
Scientific publications: NGOs can read, comment & use publications for public relations before submission	**Scientific publications:** open access, accompanying press activities (to promote knowledge transfer)

Text S6.1. Original German background information written for the participants of the citizen-science project called Mikroplastikdetektive written by BAW (followed by the English translation of this German background information).

Hintergrundinformation zum Projekt MIKROPLASTIKDETEKTIVE

Plastikverschmutzung ist ein exponentiell wachsendes Umweltproblem

Seit dem Ende des 2. Weltkrieges ist die Plastikproduktion exponentiell gewachsen. Im Jahr 1950 wurden ungefähr 2 Millionen Tonnen Plastik hergestellt, im Jahr 2015 schon 320 Millionen Tonnen. Zwischen dem Beginn der industriellen Plastikproduktion und dem Jahr 2015 wurden schätzungsweise 8300 Millionen Tonnen Plastik hergestellt.

Von dieser Gesamtmenge sind ungefähr 2% (oder 150 Millionen Tonnen) bisher in die Ozeane gelangt. Wenn sich nichts ändert an den aktuellen Produktions- und Emissionstrends, werden bis 2050 viele hunderte von Millionen Tonnen Plastikmüll in den Weltmeeren enden.

Selbst sehr optimische Szenarien, die den weltweiten Einsatz von verbessertem Abfallmanagement und –recycling und stark reduzierten Plastikverbrauch bis 2050 prognostizieren, würden trotzdem in einer weiteren Verschmutzung der Ozeane mit einigen hundert Millionen Tonnen Plastikmüll resultieren, wenn der Verbrauch, wie prognostiziert, weiter steigen sollte.

Plastikverschmutzung kommt in vielen Größen, Farben und Formen vor

Durch die wachsende Kunststoffproduktion und den unsachgemäßen Umgang mit Plastikprodukten hat sich die Verschmutzung der Flüsse, Meere und Ozeane mit Plastikmüll zu einem Problem globalen Ausmaßes entwickelt.

Weil Plastikprodukte so verschieden sind, ist auch die Plastikverschmutzung extrem heterogen. Sie reicht von sehr großen Müllteilen (z. B., Bootsrümpfen) bis zu Nanopartikeln*. Weil Plastikprodukte in allen Farben hergestellt werden, sind Plastikfragmente genauso farbenreich. Die Vielzahl der Plastikpolymere und Additive (z. B., Farbmittel, Flammschutzmittel, Weichmacher, usw.) spiegelt sich auch in den gefundenen Plastikfragmenten wieder.

Und weil Plastikmüll oft die Größe, Farbe und Form von Nahrungsteilchen hat, wird Plastikmüll auch von Tausenden von marinen Tierarten aufgenommen. Besonders tragische Beispiele sind z. B. Delfine, Wale und Schildkröten, die durch die Einnahme von Plastikmüll ihr Verdauungssystem verstopfen und dann elendiglich verhungern.

* 1-100 Nanometer, oder 0.000001-0.0001 Millimeter

Plastikverschmutzung ist ungleich verteilt

Forschungsergebnisse aus verschiedenen Regionen, Habitaten, und Meerestiefen bestätigen immer wieder, daß Plastikverschmutzung sehr ungleich verteilt ist. D. h., an vielen Orten ist die Verschmutzung vergleichweise gering, an einigen Orten durchschnittlich, und an wenigen Orten extrem hoch (‘hotspots’). Solche Hotspots sind z. B. die ozeanischen Strömungswirbel, Küstenbereiche in der Nähe von Emissionsquellen, oder Meeressenkungen.

Diese ungleiche Verteilung erfordert, daß viele Proben genommen werden müssen, um einen einigermaßen repräsentativen Überblick über die Umweltverschmutzung zu bekommen. Ist z. B. die Zahl der Proben zu klein, kann es bei der Errechnung des Durchschnitts zu systematischen Abweichungen kommen. Darum ist es wichtig, möglichst viele Proben von vielen verschiedenen Standorten zu bekommen.

Die Verteilung der Verschmutzung kann außerdem Hinweise geben auf potentielle Verschmutzungsquellen oder Verbreitungswege, z. B. durch Wind und Wellen.

Definition von Mesoplastik und Mikroplastik

Um die verschiedenen Größen des Plastikmülls zu kategorisieren, wurden die folgenden Größenintervalle definiert:

Megaplastik: > 100 Zentimeter
Makroplastik: 2.5 – 100 Zentimeter
Mesoplastik: 5 – 25 Millimeter
Mikroplastik: 0.0001 – 5 Millimeter
Nanoplastik: 1 – 100 Nanometer, oder 0.000001 – 0.0001 Millimeter

Allerdings werden leider auch viele andere Größenintervalle benutzt, was dann zu Verwirrung bei den Definitionen führt*. Für das Projekt MIKROPLASTIKDETEKTIVE werden wir aber die obigen Definitionen verwenden. Und aus praktischen Gründen werden wir unser Augenmerk auf größeres Mikroplastik (1 – 5 Millimeter) und Mesoplastik (5 – 25 Millimeter) fokussieren.

*(1) Bharagava. 2019. Environmental contaminants: Ecological implications and management. Springer. (2) Thushari & Senevirathna. 2020. Heliyon 6:e04709. (3) Hartmann et al. 2019. Environmental Science & Technology 53:1039-1047.

Herkunft von Mesoplastik und Mikroplastik

Plastik kommt über verschiedene Quellen in die Ozeane. Laut der derzeitigen Forschung sind die wichtigsten: Flüsse, küstennahe Verschmutzung, Schiffsabfälle, und, für kleinere Teilchen, Windeintrag. Die Plastikverschmutzung an deutschen Stränden ist demzufolge auch eine Kombination von terrestrischen Quellen (z. B., Touristen) und marinen Quellen (z. B. durch Wind und Wellen), wobei Windeintrag wahrscheinlich eine Nebenrolle spielt.

Meso- und Mikroplastik stammen entweder direkt aus der Plastikproduktion (Primärplastik) oder entstehen durch den Zerfall der Plastikprodukte (Sekundärplastik). Ein typisches Beispiel für ein Primärplastikprodukt sind die sogenannten "Pellets" (im Englischen auch Nurdles genannt), die 5 Millimeter oder kleiner sind. Diese Pellets werden um die ganze Welt transportiert, und aus ihnen werden dann die größeren Plastikprodukte produziert.

Durch mechanische Einwirkung, Lichteinstrahlung oder biologische Prozesse zerfallen primäre Kunststoffprodukte mit der Zeit in immer kleinere Teilchen. Diese Bruchstücke sind dann die sekundären Meso- und Mikroplastikfragmente.

Mesoplastik und Mikroplastik beeinflussen marine Ökosysteme

Die Auswirkungen von Makroplastik auf marine Pflanzen und Tiere sind eindeutig: Pflanzengemeinschaften werden durch Plastikbeschattung erstickt, und Tiere verenden in verlorengegangenen Netzen, verheddern sich in Plastikmüll, oder verhungern durch die Einnahme von größeren Plastikteilen.

Die Auswirkungen von Meso- und Mikroplastik auf marine Pflanzen, Tiere und Ökosysteme ist im Moment ein wichtiger und wachsender Forschungsbereich, aber trotzdem gibt es noch keinen eindeutigen Konsensus, was die negativen Auswirkungen betrifft. Z. B. wurden in vielen Laborversuchen negative

Auswirkungen auf Pflanzen und Tiere gefunden, aber oft waren diese nur bei sehr hohen Konzentrationen bemerkbar.

Solche hohen Konzentrationen treten in der Natur im Moment nur an einigen wenigen Stellen auf, könnten aber durch die rasante Verschmutzung der Weltmeere bald in größeren Bereichen relevant werden.

Mesoplastik und Mikroplastik beeinflussen marine Ökosysteme

Trotzdem sind folgende negative Einflüsse von Meso- und Mikroplastik schon dokumentiert worden:

1. Während Makroplastik zum Teil entfernt werden kann durch Strandsäuberungen oder Netzfang, kann die Verschmutzung mit Meso- und Mikroplastik derzeit nicht entfernt werden und stellt dadurch ein Bedrohung dar, weil durch weitere Fragmentierung eine zukünftige und immer größer werdende Belastung durch noch kleineres Mikro- und Nanoplastik entstehen wird.
2. Bei mittelgroßen Tieren (z. B. Seevögeln) und kleineren Tieren (z. B. Muscheln oder Korallen) können Meso- und Mikroplastikpartikel die Verdauungsorgane genauso verstopfen wie Makroplastikteile dies bei größeren Tieren tun. Zahlreiche Todesfälle sind für Seevögel schon dokumentiert worden.
3. Kleinere Mikroplastikpartikel und Nanoplastikpartikel können von den Verdauungsorganen in andere Bereiche des Körpers (und auch des menschlichen Körpers) gelangen, z. B. in das Gehirn und die Gebärmutter.

Plastikverschmutzung ist ein zusätzlicher Stressfaktor für marine Ökosysteme

Die zahlreichen negativen Auswirkungen von Plastikverschmutzung müssen unbedingt im Zusammenhang mit den anderen Stressfaktoren betrachtet werden:

marine Ökosysteme leiden schon gewaltig unter Klimawandel und Hitzewellen, Übersäuerung des Meereswassers durch gelöstes Kohlendioxid, durch Überfischung und Lebensraumzerstörung, durch invasive Arten, und durch Vergiftung mit Düngemitteln, Pestiziden, Schwermetallen, und den gelösten Inhaltsstoffen von Plastikprodukten (z. B., Bisphenol A und Phthalaten). Die rasant anwachsende Plastikverschmutzung muß darum unbedingt im Zusammenhang mit dieser ganzen Palette von anderen Stressfaktoren betrachtet werden. Selbst wenn Plastikverschmutzung allein nicht zu negativen Auswirkungen führt (z. B. in Laborversuchen, wo Plastikverschmutzung der einzige Stressfaktor ist), kann Plastikverschmutzung in Zusammenspiel mit all den anderen Stressfaktoren der Tropfen sein, der das Fass zum Überlaufen bringt. Sprich: der das Ökosystem unwiderbringlich beschädigt oder gar zerstört.

Makromüll wird seit Jahrzehnten an deutschen Küsten erfasst – aber Meso- und Mikroplastik nicht

Bürgerwissenschaftler*innen leisten weltweit einen wichtigen Beitrag zur großräumigen und regelmäßigen Erfassung der Plastikverschmutzung. Z. B. wird seit Jahrzehnten der Makromüll an deutschen Stränden u. a. durch das OSPAR-Monitoring erfasst. Kleinere Müllteilchen, insbesondere Meso- und Mikroplastik, werden aber bisher nicht erfasst, und es gibt nur wenige wissenschaftlich erhobene Daten zu deren Menge in der Nordsee und Ostsee.

Diese Lücke soll mit dem Projekt MIKROPLASTIKDETEKTIVE geschlossen werden. Die Bürgerwissenschaftler*innen können durch ihre Beteiligung helfen, großflächig vergleichbare Daten zur Meso- und Mikroplastik-Verschmutzung deutscher Küsten zu erheben. Durch das Projekt MIKROPLASTIKDETEKTIVE soll das Bewusstsein für dieses Umweltproblem gestärkt werden, das Wissenschaftsverständnis von Bürger*innen verbessert werden, und ein Datensatz zur Meso- und Mikroplastikverschmutzung der deutschen Küsten erhoben werden, der dann als Grundlinie (baseline) für weitere Forschung und Monitoring dienen kann.

Forschungsbedarf besteht – und Bürgerwissenschaftler*innen können helfen

Wir hoffen mit dem Projekt MIKROPLASTIKDETEKTIVE die Wissenslücke über Meso- und Mikroplastikverschmutzung der deutschen Küsten zu schliessen. Durch das zur Verfügung stellen von Sammelmaterialien und einfachen Anleitungen können Bürgerwissenschaftler*innen Proben entnehmen, die dann am Alfred-Wegener-Institut (AWI) auf Meso- und Mikroplastik hin untersucht werden.

Umweltverbände, Schulgruppen und engagierte Bürger*innen können alle teilnehmen. Zunächst soll durch erste Probennahmen von Bürgerwissenschaftler*innen und anschliessender Diskussion ein realistisches Konzept entwickelt werden, wie die Probennahmen optimiert werden kann (Herbst 2021 – Frühjahr 2022). Dann sollen weitere Teilnehmer*innen angeworben werden durch Medienarbeit, soziale Netzwerke und persönliche Kontakte (2022). Die Ergebnisse werden durch Berichte, Pressemitteilungen und wissenschaftliche Publikationen an die Öffentlichkeit vermittelt werden (Herbst 2022 – Frühjahr 2023).

Was macht das AWI mit den Proben?

Alle Proben werden ans AWI geschickt und dort analysiert.

Zuerst werden die Plastikteile durch Sieben und Dichtetrennung vom Sand und biologischem Material getrennt.

Jedes potentielle Plastikteil wird dann mit einem Fourier-Transformations-Infrarotspektrometer untersucht, um festzustellen, ob es sich wirklich um ein Plastikteil handelt, und wenn ja, um welchen Polymertypen (z. B. Polyethylen, Polypropylen, Styropor, usw.) es sich handelt.

Jedes erkannte Plastikteil wird fotografiert und in eine Datenbank eingegeben, die dann letztendlich die Grundlage für die wissenschaftlichen Berichte sein wird. Diese Datenbank wird dann auch der Öffentlichkeit und anderen Wissenschaftlern zugängig gemacht.

Wie kann das Projekt MIKROPLASTIKDETEKTIVE helfen, Wissenstransfer zu fördern?

Wir wollen den Wissenstransfer an Bürger*innen fördern durch:

1. Das Vermitteln von Hintergrundinformationen (wobei diese kurze Zusammenfassung hoffentlich auch diesem Zweck dient).

2. Durch Pressearbeit, wobei wir vor allen Dingen die Lokalpresse motivieren wollen, über Sammelaktionen zu berichten.

3. Durch regelmäßige Konsultation und Diskussion mit Teilnehmer*innen und Umweltorganizationen.

4. Durch die Veröffentlichung von begleitenden Berichten, die die Ergebnisse der wissenschaftlichen Veröffentlichungen dem breiteren Publikum verständlich vermitteln.

5. Durch das Veröffentlichen der Daten, die dann von anderen Wissenschaftlern oder von Umweltorganizationen genutzt werden können.

Wie kann das Projekt MIKROPLASTIKDETEKTIVE helfen, Umweltbewusstsein und Umweltpolitk zu fördern?

Das Projekt bindet Bürgerforschende in die Erhebung wissenschaftlicher Daten zu einem aktuellen globalen Umweltproblem ein und wird durch Öffentlichkeitsarbeit über soziale und traditionelle Medien begleitet.

Neben dem wissenschaftlichen Erkenntnisgewinn spielt der Aspekt der Umweltbildung von Bürger*innen und Förderung von Wissenschaftsverständnis eine zentrale Rolle, da dieser Wissenstransfer ein nachhaltigeres Verhalten begünstigt. Zusammen mit den Umweltorganizationen sollen Informationen vermittelt werden, wie Plastikverschmutzung vermindert werden kann.

Die Ergebnisse liefern ferner einen wichtigen Beitrag zur europäischen Überwachung der Verschmutzung der Küsten mit Mikroplastik. Die Meeresstrategie-Rahmenrichtlinie der Europäischen Union besagt, daß „Trends von Mengen, Verteilung und möglichst Zusammensetzung von Mikropartikeln (insbesondere Mikroplastik)" untersucht werden sollen. Das Projekt MIKROPLASTIKDETEKTIVE unterstützt genau dieses Ziel.

Text S6.2. English translation of the German background information above.

Background information for the project MICROPLASTIC DETECTIVES

Plastic pollution is an exponentially growing environmental problem

Since the end of World War II, plastic production has grown exponentially. In 1950, about 2 million tons of plastic were produced, in 2015 already 320 million tons. Between the beginning of industrial plastic production and 2015, an estimated 8300 million tons of plastic were produced.

Of this total, about 2% (or 150 million tons) have so far ended up in the oceans. If nothing changes in current production and emission trends, many hundreds of millions of tons of plastic waste will end up in the world's oceans by 2050.

Even very optimistic scenarios projecting global use of improved waste management and recycling and greatly reduced plastic consumption by 2050 would still result in further pollution of the oceans with several hundred million tons of plastic waste if consumption continues to rise as projected.

Plastic pollution comes in many sizes, colours and shapes

Due to the growing production of plastic and the improper handling of plastic products, the pollution of rivers, seas and oceans with plastic waste has become a problem of global proportions.

Because plastic products are so diverse, plastic pollution is also extremely heterogeneous. It ranges from very large pieces of waste (e.g. boat hulls) to nanoparticles*. Because plastic products are made in all colours, plastic fragments are just as colourful. The variety of plastic polymers and additives (e.g., colourants, flame retardants, plasticizers, etc.) is also reflected in the plastic fragments found.

And because plastic waste often has the size, colour and shape of food particles, plastic waste is also ingested by thousands of marine species. Particularly tragic examples include dolphins, whales and turtles, which clog their digestive systems by ingesting plastic waste and then starve to death.

* 1-100 nanometers, or 0.000001-0.0001 millimeters

Plastic pollution is unequally distributed

Research results from different regions, habitats and ocean depths repeatedly confirm that plastic pollution is very unevenly distributed. In other words, in many places the pollution is comparatively low, in some places average, and in a few places extremely high ('hotspots'). Such hotspots are, for example, the oceanic gyres, coastal areas near emission sources, or marine depressions.

This uneven distribution means that many samples have to be taken to get a reasonably representative overview of pollution. If, for example, the number of samples is too small, systematic deviations may occur when calculating the average. Therefore, it is important to get as many samples as possible from many different locations.

The distribution of pollution can also give indications of potential sources of pollution or routes of dispersal, e.g., by wind and waves.

Definition of mesoplastic and microplastic

In order to categorize the different sizes of plastic waste, the following size intervals were defined:

Megaplastics: > 100 centimeters
Macroplastics: 2.5 – 100 centimeters
Mesoplastics: 5 – 25 millimeters
Microplastics: 0.0001 – 5 millimeters
Nanoplastics: 1 – 100 nanometers, or 0.000001 – 0.0001 millimeters

However, unfortunately many other size intervals are also used, which then leads to confusion in the definitions*. For the MICROPLASTICS DETECTIVE project, however, we will use the above definitions. And for practical reasons we will focus our attention on larger microplastics (1 - 5 millimeters) and mesoplastics (5 - 25 millimeters).

*(1) Bharagava. 2019. Environmental contaminants: Ecological implications and management. Springer. (2) Thushari & Senevirathna. 2020. Heliyon 6:e04709. (3) Hartmann et al. 2019. Environmental Science & Technology 53:1039-1047.

Origin of mesoplastic and microplastic

Plastic enters the oceans through various sources. According to current research, the most important are: rivers, coastal pollution, ship debris, and, for smaller particles, wind input. Plastic pollution on German beaches is therefore also a combination of terrestrial sources (e.g., tourists) and marine sources (e.g., wind and waves), with wind input probably playing a minor role.

Meso- and microplastics either originate directly from plastic production (primary plastics) or are created through the decay of plastic products (secondary plastics). A typical example of a primary plastic product are the so-called "pellets" (also called nurdles in English), which are 5 millimeters or smaller. These pellets are transported around the world, and the larger plastic products are then produced from them.

Through mechanical action, exposure to light or biological processes, primary plastic products break down over time into smaller and smaller particles. These fragments are then the secondary meso- and microplastic fragments.

Mesoplastic and microplastic influence marine ecosystems

The impacts of macroplastics on marine plants and animals are clear: plant communities are suffocated by plastic shading, and animals die in lost nets (also called ghost nets), become entangled in plastic waste, or starve to death from ingesting larger pieces of plastic.

The impact of meso- and microplastics on marine plants, animals and ecosystems is an important and growing area of research at the moment, but despite this, there is still no clear consensus on the negative impacts. For example, negative effects on plants and animals have been found in many laboratory experiments, but these were often only noticeable at very high concentrations.

Such high concentrations only occur in a few places in nature at the moment, but could soon become relevant in larger areas due to the rapid pollution of the world's oceans.

Mesoplastic and microplastic influence marine ecosystems

Nevertheless, the following negative impacts of meso- and microplastics have already been documented:

1. While macroplastics can be partially removed by beach clean-ups or netting, meso- and microplastic pollution cannot be removed at present and thus poses a threat because further fragmentation will result in a future and ever-increasing burden of even smaller micro- and nanoplastics.

2. Meso- and microplastic particles can clog the digestive organs of medium-sized animals (e.g. seabirds) and smaller animals (e.g. mussels or corals) in the same way as macroplastics do in larger animals. Numerous deaths have already been documented for seabirds.

3. Smaller microplastic particles and nanoplastic particles can pass from the digestive organs to other parts of the body (including the human body), e.g., the brain and the uterus.

Plastic pollution is an additional stressor for marine ecosystems

The many negative impacts of plastic pollution must be considered in the context of other stressors: marine ecosystems are already suffering tremendously from climate change and heat waves, acidification of ocean waters from dissolved carbon dioxide, overfishing and habitat destruction, invasive species, and poisoning from fertilisers, pesticides, heavy metals, and the dissolved ingredients of plastic products (e.g., bisphenol A and phthalates). Rapidly increasing plastic pollution must therefore be considered in the context of this whole range of other stressors. Even if plastic pollution alone does not lead to negative effects (e.g., in laboratory experiments where plastic pollution is the only stressor), plastic pollution in combination with all the other stressors can be the straw that breaks the camel's back. In other words: that irretrievably damages or even destroys the ecosystem.

Macro litter has been recorded on German coasts for decades - but meso- and microplastics have not

Citizen scientists worldwide make an important contribution to the large-scale and regular recording of plastic pollution. For example, macro litter on German beaches has been recorded for decades by OSPAR monitoring, among others. However, smaller debris particles, especially meso- and microplastics, have not been recorded so far, and there are only few scientifically collected data on their quantity in the North Sea and Baltic Sea.

This gap is to be closed with the project MICROPLASTICS DETECTIVE. Through their participation, the citizen scientists can help to collect comparable data on meso- and microplastic pollution of the German coastline over a large area. The project MICROPLASTICS DETECTIVE aims to raise awareness of this environmental problem, to improve citizens' understanding of science, and to collect a data set on meso- and microplastic pollution of the German coastline, which can then serve as a baseline for further research and monitoring.

Research is needed - and citizen scientists can help

With the project MICROPLASTICS DETECTIVE we hope to close the knowledge gap about meso- and microplastic pollution of the German coastline. By providing collection materials and simple instructions, citizen scientists can take samples that will then be analyzed for meso- and microplastics at the Alfred Wegener Institute (AWI).

Environmental organizations, school groups and committed citizens can all participate. The first step will be to develop a realistic concept for optimizing sampling through initial sampling by citizen scientists and subsequent discussion (autumn 2021 - spring 2022). Then, further participants will be recruited through media work, social networks and personal contacts (2022). The results will be communicated to the public through reports, press releases and scientific publications (autumn 2022 - spring 2023).

What does the AWI do with the samples?

All samples are sent to the AWI and analyzed there.

First, the plastic pieces are separated from the sand and biological material by sieving and density separation.

Each putative plastic piece is then analyzed with a Fourier transform infrared spectrometer to determine if it is indeed a plastic piece, and if so, what type of polymer (e.g. polyethylene, polypropylene, Styrofoam, etc.) it is.

Each identified plastic piece will be photographed and entered into a database, which will eventually be the basis for the scientific reports. This database will then also be made available to the public and other scientists.

How can the MICROPLASTICS DETECTIVE project help to promote knowledge transfer?

We want to promote the transfer of knowledge to citizens through:

1. Providing background information (hopefully this short summary will also serve this purpose).

2. Through media work, where we especially want to motivate the local press to report about collections.

3. Through regular consultation and discussion with participants and environmental organizations.

4. By publishing accompanying reports that communicate the results of the scientific publications to the wider public in a comprehensible way.

5. By publishing the data, which can then be used by other scientists or environmental organizations.

How can the MICROPLASTICS DETECTIVE project help to promote environmental awareness and policy?

The project involves citizen researchers in the collection of scientific data on a current global environmental problem and is accompanied by media work via social and traditional media.

In addition to gaining scientific knowledge, the aspect of environmental education of citizens and promotion of scientific understanding plays a central role, as this knowledge transfer promotes more sustainable behavior. Together with the environmental organizations, information on how to reduce plastic pollution is to be conveyed.

The results also provide an important contribution to the European monitoring of coastal microplastic pollution. The European Union's Marine Strategy Framework Directive states that "trends in quantities, distribution and, where possible, composition of microparticles (in particular microplastics)" should be studied. The MICROPLASTICS DETECTIVE project supports precisely this objective.

Text S7. Laboratory workflow written by BAW (with input from Melanie Bergmann, Tabea Hepfner, Špela Korez Lupše, Sarah Lorenzana, and Franco Pasolini) for the processing of sand samples upon arrival at the laboratory of the Alfred Wegener Institute. All photos by BAW.

Drying the samples

Step 1. The correct labelling of the containers was checked (Figure S4). If mistakes happened, they could at times be rectified by communication with the citizen scientists.

Step 2. The tape which held the containers closed was removed and the lids were opened. The open containers were immediately placed into a drying oven in which they dried at 50°C for 1-3 days until they were dry.

Step 3. Once the samples were dried, the containers were removed from the drying oven and immediately closed and labelled ‘trocken’ (dry) and then transported to the laboratory for processing (Figure S4).

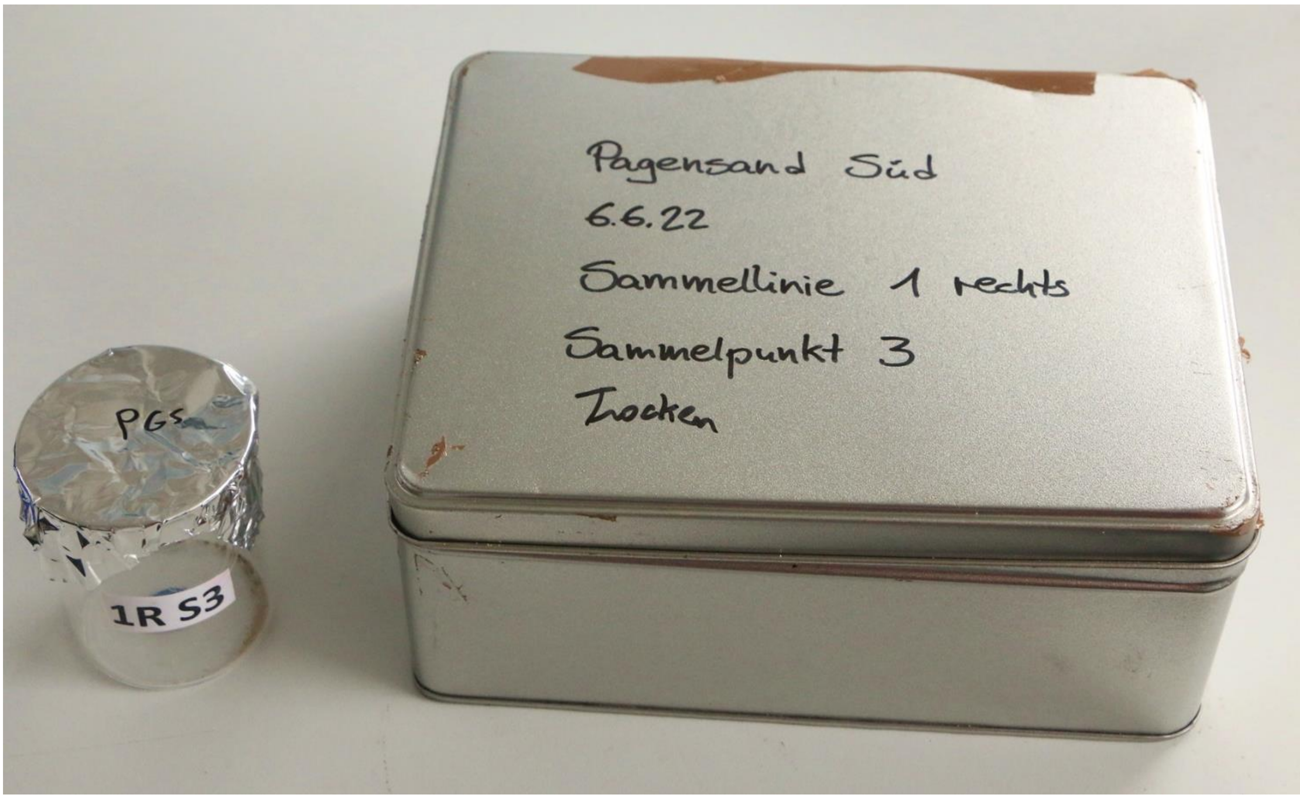


Figure S4. A correctly labelled metal container containing one sand sample (from top to bottom: location, date, line ID, sample ID, drying status). If the metal container was not damaged, it would be cleaned and mailed to another citizen-science group for sampling another location. The sieved contents of this sand sample were then transferred into a labelled glass beaker with the line ID and sample ID on a fixed label and the unique location identifier on the aluminium lid (see also Figure S10).

Processing the samples in the laboratory

To avoid contamination as well as to prevent fine dust from entering the airways, we always wore face masks (required due to Covid restrictions anyway) and white laboratory coats (which are made of non-plastic material) during all laboratory work. To further minimize contamination of the samples with airborne microplastics, a high-performance air purifier (DustBox 1000 VSC Hochleistungs-Luftreiniger H14) ran continuously along with the laboratory ventilation system, which also removed dust continuously during working hours.

Step 4. In the laboratory, we prepared one aluminium cup for a 50 g sand subsample. This was a standard aluminium cup for baking cupcakes. It was filled with approximately 50 g of sand from only one container taken randomly from the entire set of containers which originated from one sampling location. The aluminium cup was then sealed with an aluminium top and labelled (Figure S5). This sand subsample can later be used to measure sand grain sizes.

Figure S5. Sealing and labelling the aluminium cup containing the 50 g subsample for the sand grain size analysis.

The following steps 5-13 were repeated for each sample (i.e., the entire contents of one metal container).

Step 5. We cleaned the all the required glass containers and metal funnel and prepared one aluminium cup for the contents of the sieve.

Step 6. For *only* the first sample from one sampling location, we placed a 50 g sand subsample in the aluminium cup for sand grain size analysis (see step 4 above).

Step 7. We weighed the dried sample together with the closed metal container on an electronic scale (Kompakt Waagen Kern EMB-Serie 6000-1, accurate to 0.1 g).

Step 8. The sand was poured through a metal funnel into a glass volume beaker (Figure S6). The volume of the sand was recorded to the nearest 10 ml.

Figure S6. The contents from one sampling container were poured into a volume glass beaker through a metal funnel. The volume glass beaker was held in place by a specially built holder so that the glass beaker could not fall over.

Step 9. The empty metal container was weighed. Subtracting this weight from the weight recorded in step 7 gave us the mass of the sand sample.

Step 10. The sand was sieved with a 5-mm steel sieve on the top and a 1-mm steel sieve at the bottom into a big grey plastic box (Figure S7). Anything passing both sieves was later discarded. When the sand was very fine, we only used the 1-mm sieve (Figure S8).

Figure S7. Pouring the sand sample from the volume beaker through the 5-mm sieve on the top and the 1-mm sieve at the bottom with any material passing both sieves caught in a large box.

Figure S8. Pouring the sand from the volume beaker through the 1-mm sieve with any passing material caught in a large box. The red DustBox is visible in the background.

Step 11. We removed any large pieces which were obviously not plastic particles from the 5-mm sieve (e.g., rocks, large organic materials, etc.) but checking that these pieces did not have plastic particles stuck to them.

Step 12. All remaining contents of the 5-mm sieve were transferred to a smaller glass beaker (Figure S9) which was immediately covered with a piece of aluminium foil and labelled.

Step 13. All remaining contents of the 1-mm sieve were transferred to a smaller glass beaker which was immediately covered with a piece of aluminium foil and labelled. If the contents ended up being a lot of coarser sand, then a funnel would be used to transfer the contents from the sieve into the glass beaker (or several if needed, see Figure S9). If the contents of the 5-mm sieve and the 1-mm sieve were very little, then both contents would just be placed in one smaller glass beaker together (Figure S10).

Figure S9. Transferring the contents from the 1-mm sieve through the metal funnel into a labelled small glass beaker.

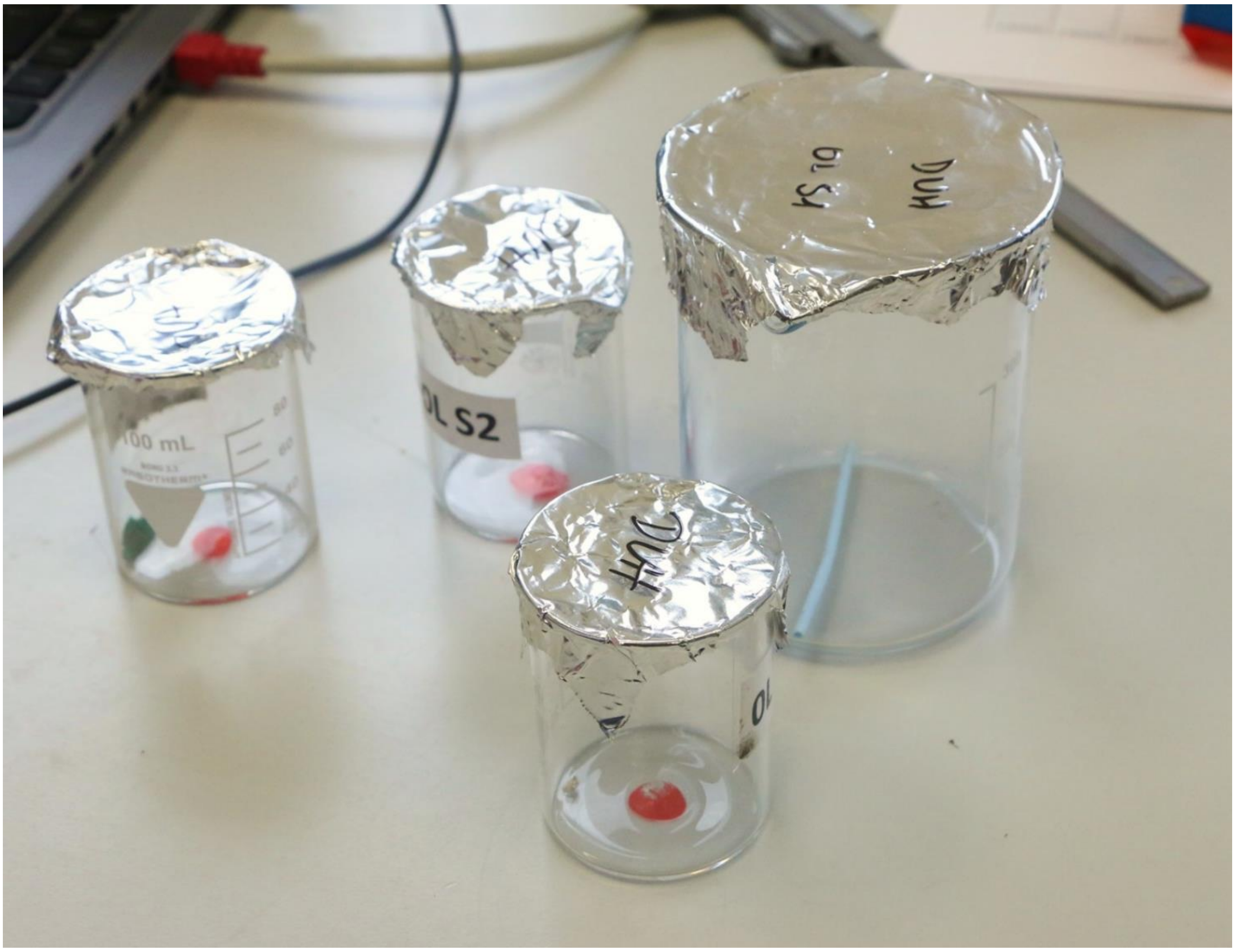


Figure S10. Glass beakers used to transport the contents of the sieves from the laboratory to the binocular microscope and the ATR-FTIR for further analysis. Glass beakers already had fixed labels containing the line ID and sample ID (see Methods and Table S7) so that we only had to write the unique location identifier onto the aluminium lid. If the sand was very fine, just a few items would end up in the glass beakers. However, if the sand was coarser, a lot of sand would end up in the glass beakers which then needed to be visually examined under the binocular microscope for putative plastic particles.

Step 14: We turned off the Dustbox and the laboratory ventilation system and cleaned the table and the equipment.

Step 15: We then visually checked all particles transferred to the labelled glass beakers under the binocular microscope. At this stage, only particles which clearly were not plastic were removed; e.g., see Norén (2008) for how to distinguish organic materials. If the sample only contained a few putative plastic particles, we then moved to step 17.

Step 16: If the sample still contained a lot of sand and organic material (e.g., broken pieces of shells), we would carefully pour a subsample into a glass Petri dish for visual examination (see Figure S11). Any putative plastic particle was placed with tweezers into a clean glass beaker for later Fourier transform infrared spectroscopy (ATR-FTIR) analysis (step 17).

Figure S11. For visual inspection under the binocular microscope, we transferred a subsample onto a glass Petri dish and spread it in such a way that the particles formed a single particle layer with no particles lying on top of each other obscuring the view of particles below (see Figures S13-S14).

Figure S12. Our photo setup consisted of a binocular microscope with 2x or 5x magnification with an Olympus digital camera placed on top. The camera took photos (e.g., Figures S13-S14) via a computer using the OM capture software (https://app.olympus-imaging.com/olympuscapture/).

Figure S13. A typical example of a single particle layer for visual inspection under the binocular microscope. Typically, > 99.9% of particles were either sand grains or organic material (e.g., broken pieces of shells).

Figure S14. A typical example of a single particle layer for visual inspection under the binocular microscope, but in this case containing a blue plastic fibre (WASLE_2R_S2_MP1, see Table S4). We checked many particles which perhaps could have been plastic, even many which did not look like plastic at all. However, in almost every case, the plastic particles could be easily visually distinguished from the other non-plastic particles, as in this case. Therefore, careful visual inspection of particles > 1 mm under a binocular microscope (Figure S12) can almost invariably distinguish plastic from non-plastic particles, but ATR-FTIR analysis is still needed to confirm the visual identification and to determine the polymer type (see Text S8).

Step 17. All putative plastic particles were checked with the ATR-FTIR. The use of our particular ATR-FTIR device (ALPHA Basis Modul A250/DII, Bruker Optics) in combination with the installed OPUS spectroscopy software and the freeware siMPle software is explained in detail in the Methods and our self-written manual (Text S8).

Step 18. If a particle was determined to be a plastic particle with the ATR-FTIR, then the following data for that particular particle were recorded (see Methods for definitions and details):

A. Shape (fragment, pellet, fibre, etc.)
B. Maximum length (in mm)
C. Colour
D. Polymer type (the OPUS-generated spectrum will be saved, the output of matching types and their matching scores from siMPle will be saved)
E. Photo (e.g., Figure S14)
F. A container was labelled with a unique identifier (see G below) into which the particle was then placed.
G. Particle ID: Unique identifier of the plastic particle, which was made up as follows:

unique location identifier (ID)_line ID_sample ID_consecutive unique number x given as MPx

For example, the identifier of the blue plastic fibre (Figure S14) was

WASLE_2R_S2_MP1

which refers to the collection at Wassersleben on 26 April 2022 (Tables S1-S2), collection line 2R, sampling point 2, and first microplastic (MP) identified from that particular sand sample. Thus, every plastic particle received its unique identifier (Table S4).

Step 19. Each confirmed plastic particle was placed inside a container (e.g., usually a small labelled Eppendorf tube, but sometimes a larger container, e.g., a plastic bag, depending on the particle's size) and kept in storage at the Alfred Wegener Institute for reference.

Text S8.1. Manual written by BAW (with input from Melanie Bergmann, Tabea Hepfner, Sarah Lorenzana, Franco Pasolini, and Sebastian Primpke) for the determination of polymer types with the software programs OPUS and siMPle. All photos by BAW.

Use of this manual

This manual was specifically written for our setup of our particular ATR-FTIR device (ALPHA Basis Modul A250/DII, Bruker Optics) in combination with the installed OPUS spectroscopy software and the freeware siMPle software written by Sebastian Primpke (Primpke et al., 2020a). Therefore, any information contained in this manual may not pertain to any other setup. Furthermore, there are of course manuals written specifically for the ALPHA Basis Modul A250/DII by Bruker Optics and the two software programs which users should also refer to. We suggest to use this manual in combination with other manuals. Finally, we are sorry that we had to use the German version of the OPUS software, but if you are using an English version, it should be relatively straightforward to find the English commands or to translate the German text in https://www.deepl.com/
or another translation program.
This manual contains a lot of information which is not needed during the normal analysis of particles. Therefore, at the end of this manual, we include a distilled and much shorter version of this manual (Text S8.2) for routine use which details how the measurement of a spectrum of each putative plastic particle and the determination of the polymer type.

Maintenance of ATR-FTIR

The ATR-FTIR should be checked by Bruker service every two years. The product number of the infrared source (which is a ceramic cylinder) is: Q328/D. It has a guarantee of five years, but it is prudent to order another one in case the one in the ATR-FTIR burns out, and ordering a new one might take some time.
The product number of the silica gel bags is 5119/D. They can apparently be dried (‘regenerated’) at 130 degrees Celsius within 20 minutes, but we also had good results at 70 degrees Celsius and several hours.

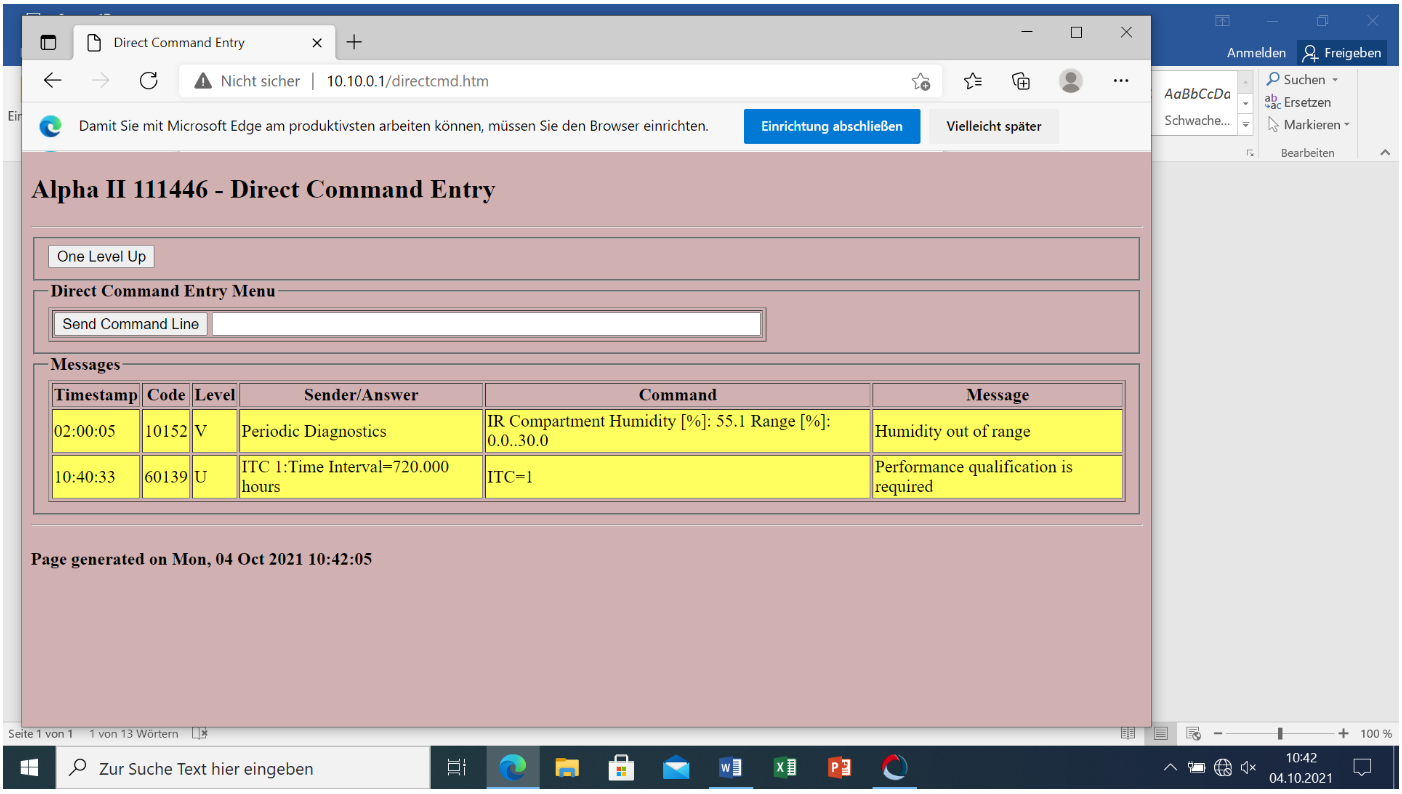
Running the ATR-FTIR

The ATR-FTIR should be plugged in and kept on as much as possible, and turned on and off as little as possible, because turning it on and off damages the light source, and keeping it on also dries

out the ATR-FTIR. So only turn it off for maintenance, transport, or when it will not be used for several weeks at least.
Before measurements, the ATR-FTIR should be on for an absolute minimum of 10 minutes, but better 1-2 hours or even longer.
When the ATR-FTIR is in good working condition, the light on the upper panel should shine in green colour. When the light shines in yellow colour, it can mean that the humidity inside the ATR-FTIR is too high. Other reasons for the light being yellow are detailed on page 37 in the booklet called “Alpha II Installationsanleitung”. A red light means that something is defect, and the Bruker service should be called.
Another way to decrease humidity (besides keeping the ATR-FTIR continuously on and in a good environment) is to exchange or dry the silica gel packages in the back of the ATR-FTIR. To remove them, the four large screws in the back plate of the ATR-FTIR need to be unscrewed and the silica gel packages removed, dried and replaced.
HOWEVER, the back plate should only be removed when the ATR-FTIR is unplugged!

Getting messages from the ATR-FTIR

If you want to see specific messages about the ATR-FTIR, open an internet program (e.g., Mozilla Firefox, Internet Explorer) and type into the search bar the following address
10.10.0.1
Then you can see different messages about the status of the ATR-FTIR, e.g.:



If you cannot see this page, but get a message that the computer cannot see (= is not connected to) the ATR-FTIR, three things may need to be done.

1. Check that the Ethernet cable connection is plugged in well in both the computer and the ATR-FTIR.

2. The computer and the ATR-FTIR are not in the same IP-Net. For example, the computer was set up to use the Dynamic Host Configuration Protocol (DHCP) which automatically assigns IP addresses and other communication parameters to devices connected to the network, but the ATR-FTIR uses a fixed (or manual) IP address. To fix this, the computer needs to be set up to have a fixed IP address, too. For example, since the ATR-FTIR has the address

10.10.0.1

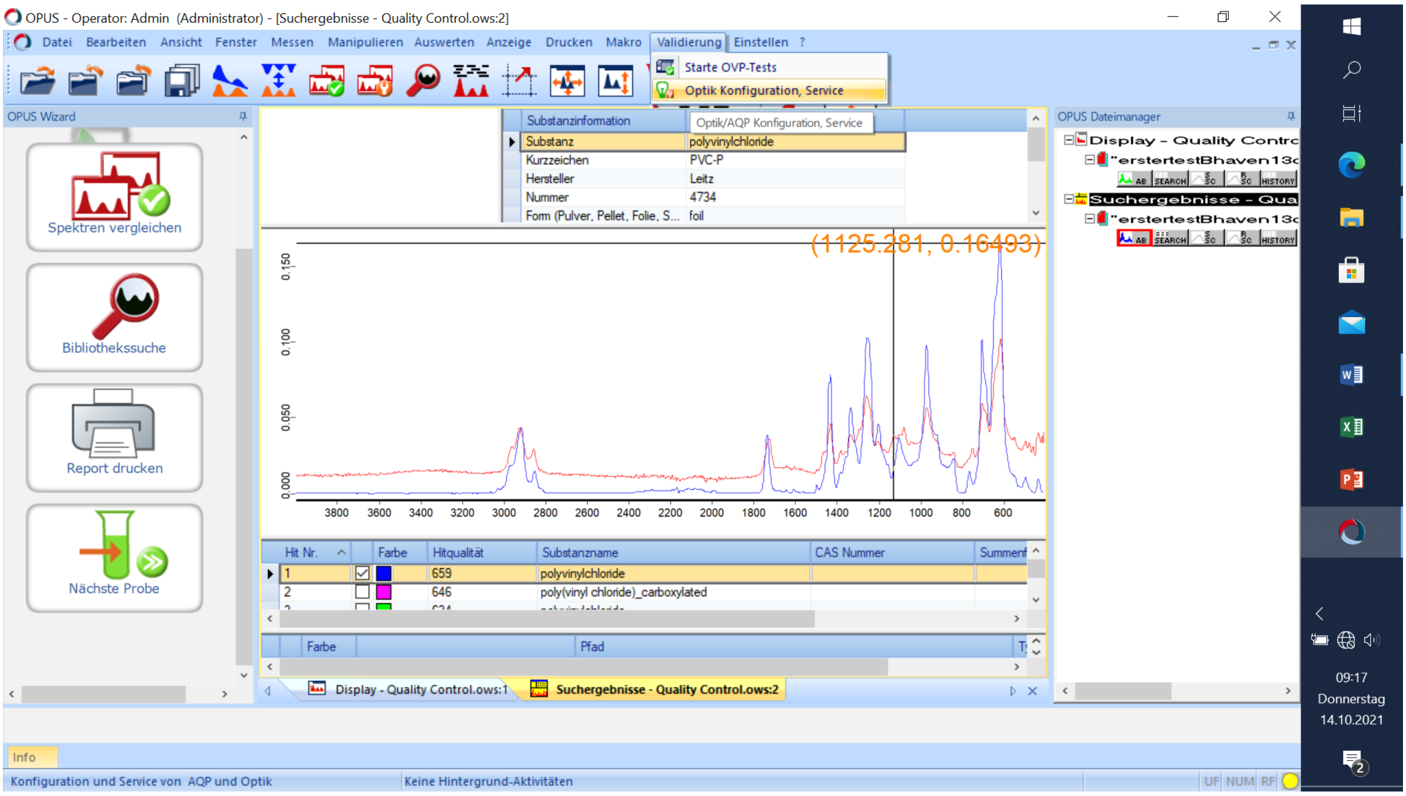
the computer can be set to

10.10.0.2

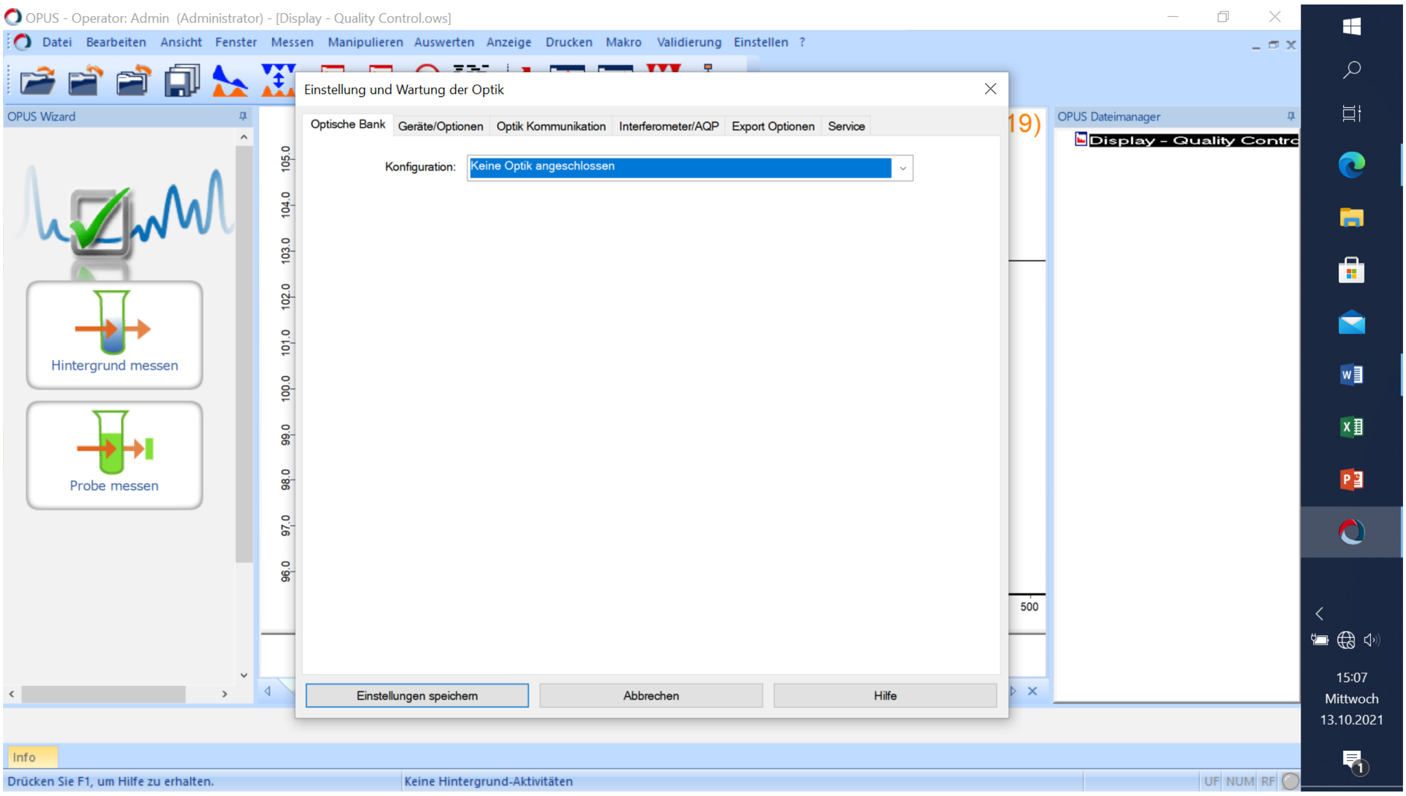
or another different address.

Most importantly, the two IP addresses may not be the same!

3. Another reason why the computer and the ATR-FTIR are not connected (which can be seen when typing 10.10.0.1 into an internet program, see above) can be the following. In OPUS, go to "Validierung" -> "Optik Konfiguration, Service".



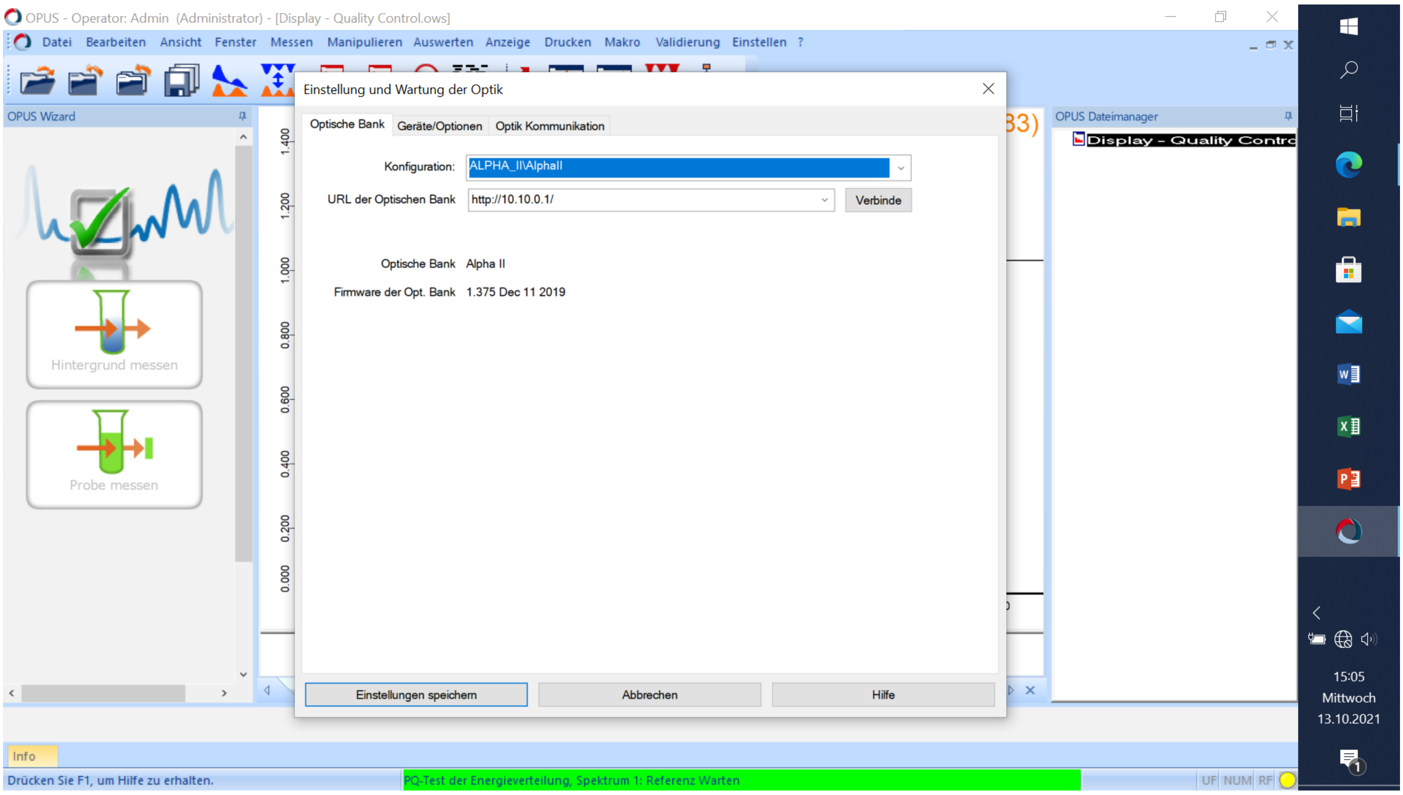
This opens the "Einstellung und Wartung der Optik" menu. Choose the "Optische Bank" tab and change the configuration from "Keine Optik angeschlossen"



to “Alpha_II\AlphaII”. Click on “Einstellungen speichern”.

Running the PQ-Test regularly

If the computer and the ATR-FTIR are properly connected and have not been connected for a while, then a “PQ-Test der Energieverteilung” (click on yellow circle at bottom right, click below picture of ATR-DIAMOND, let PG-test run, you should see the green bar below) should be run first. For the test to run properly, nothing should be touching the diamond sensor (meaning no sample should be on the ATR-FTIR). This test can happen automatically (or it can also be chosen by clicking the appropriate button in the left panel). Wait until this test has finished (the green bar disappears). Another way to run the “PQ-Test der Energieverteilung” is to click on the circle, then on the field which says “ATR-DIAMOND FAILED”, and then to choose the option to run the tests (“Starte tests”).



Use of the OPUS software to determine polymer types

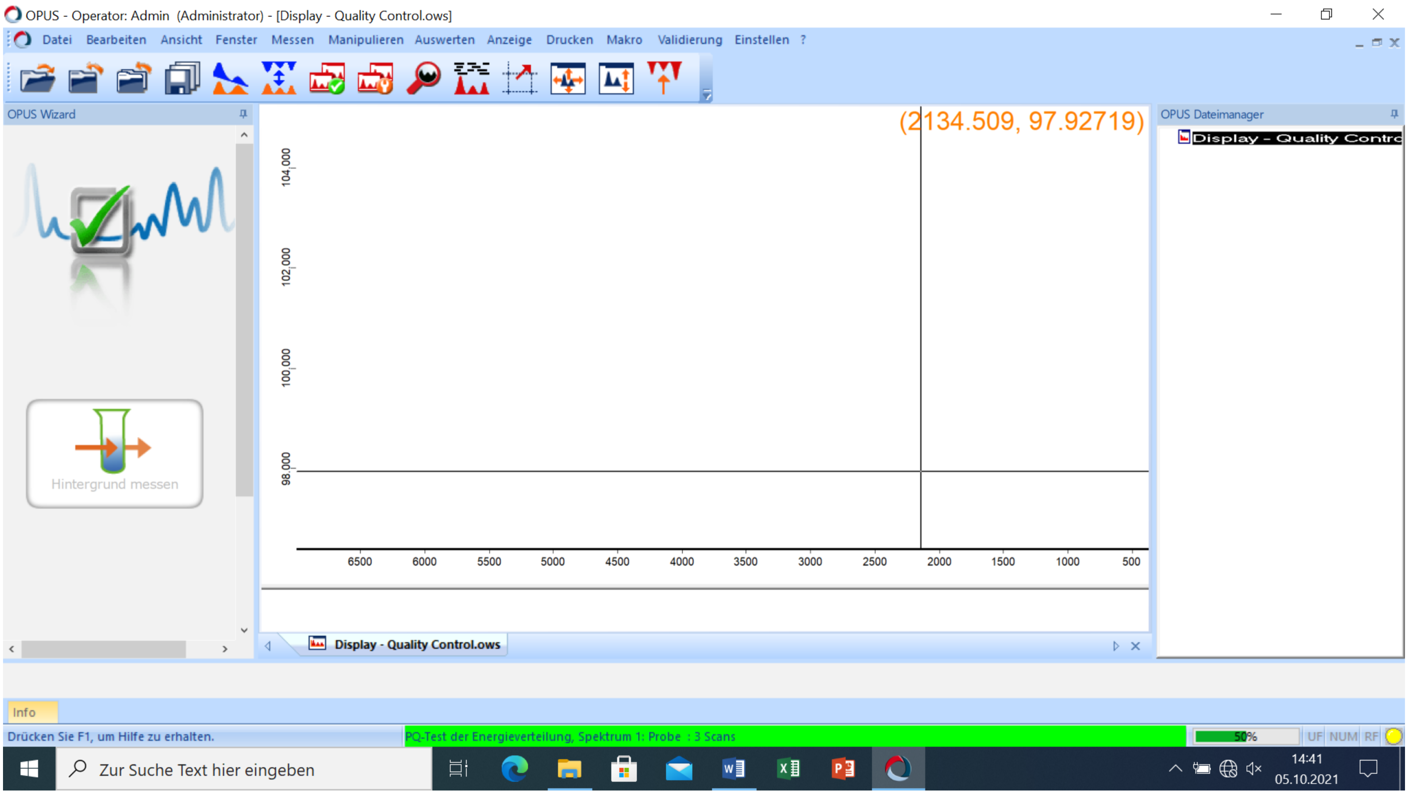
To begin measurements with the OPUS software, double-click on the OPUS (2) icon.

Enter password (in all capital letters): [whatever your password is]

Benutzererkennung should be on “admin”.

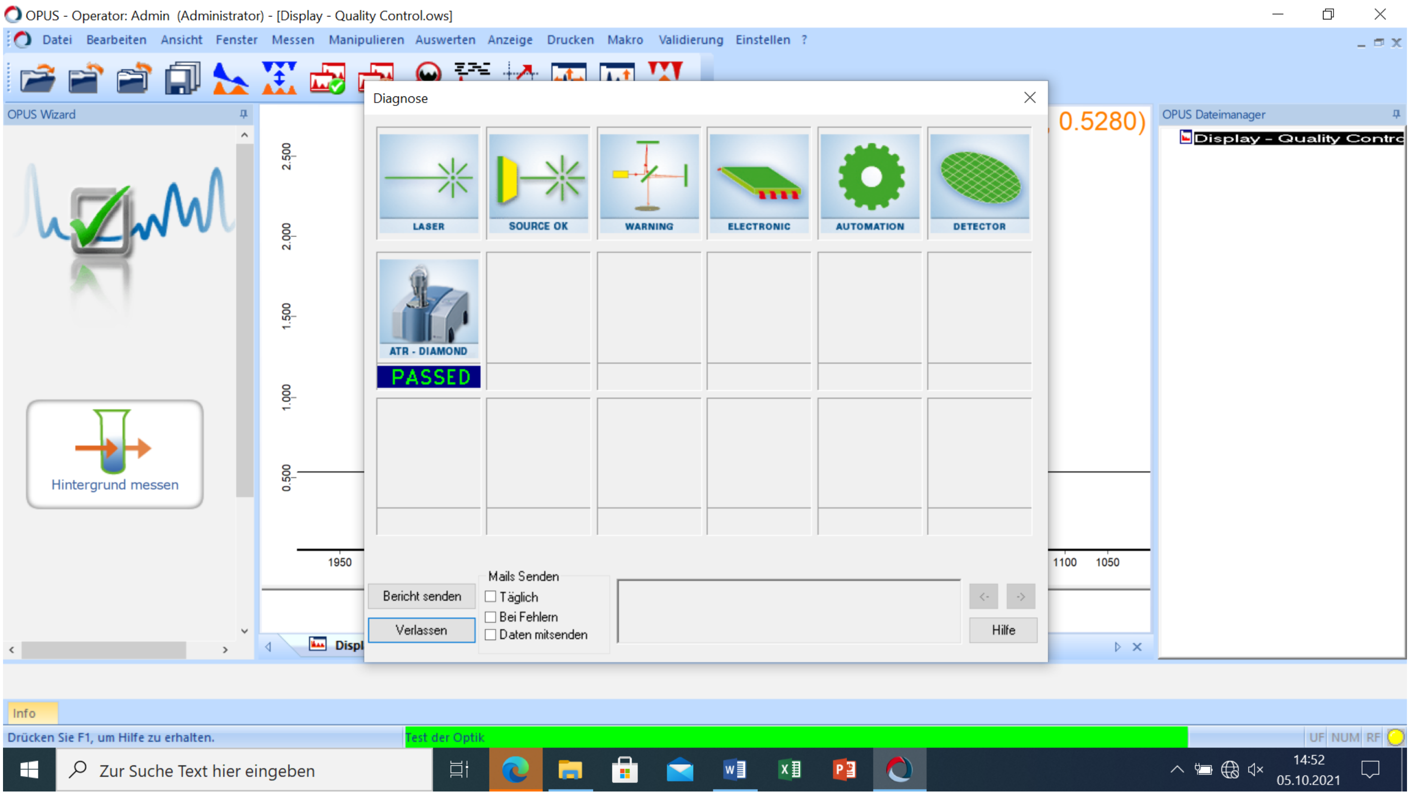
Click on “login”, then click on “ok”.

You should see the following window.

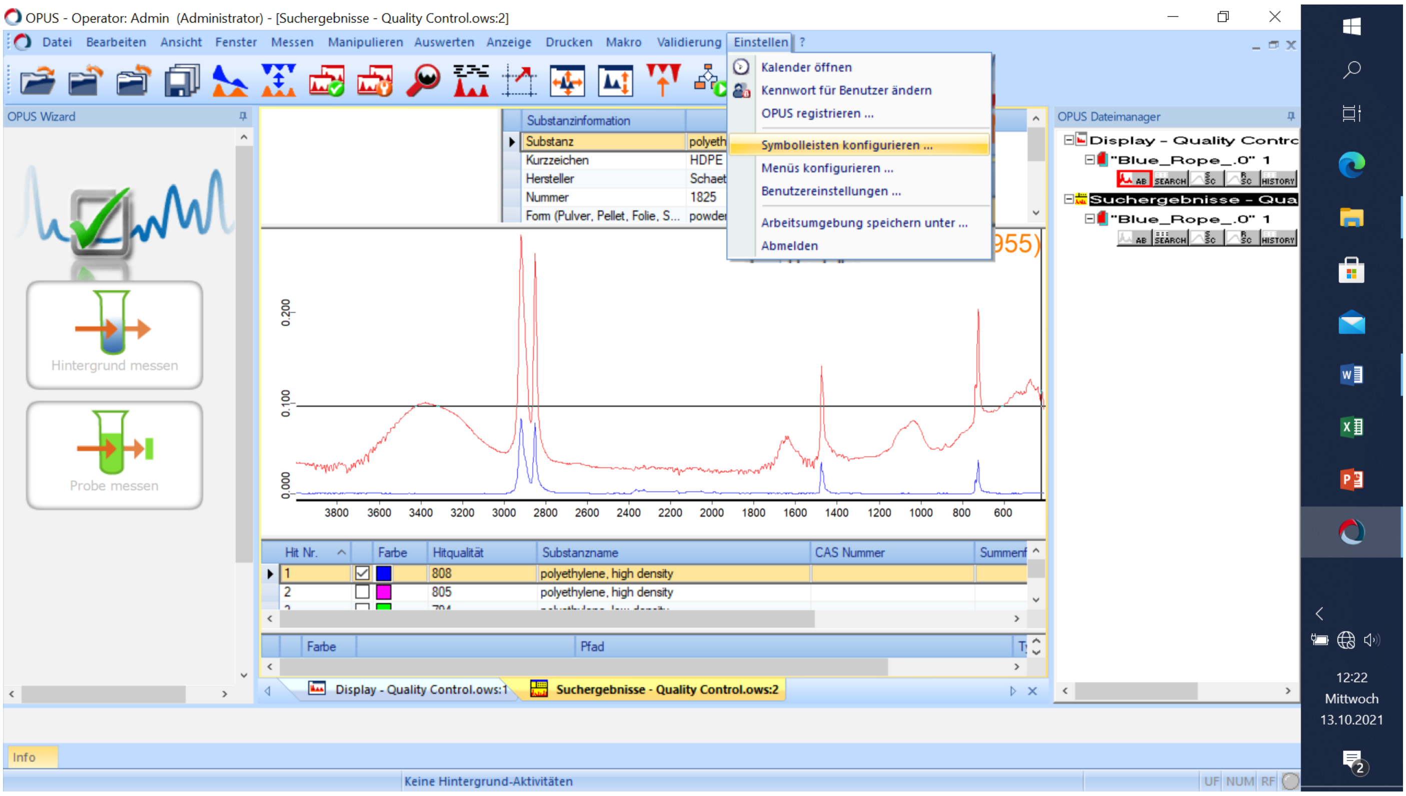


If below the button called "Hintergrund messen", there is another button asking for the PQ-test run ("PQ-Test der Energieverteilung"), click on that button first and let the test run proceed (see the green bar at the bottom of the picture above). This test should be run at least once a month. For the test to run properly, nothing should be touching the diamond sensor (meaning no sample should be on the ATR-FTIR; see also explanation above).

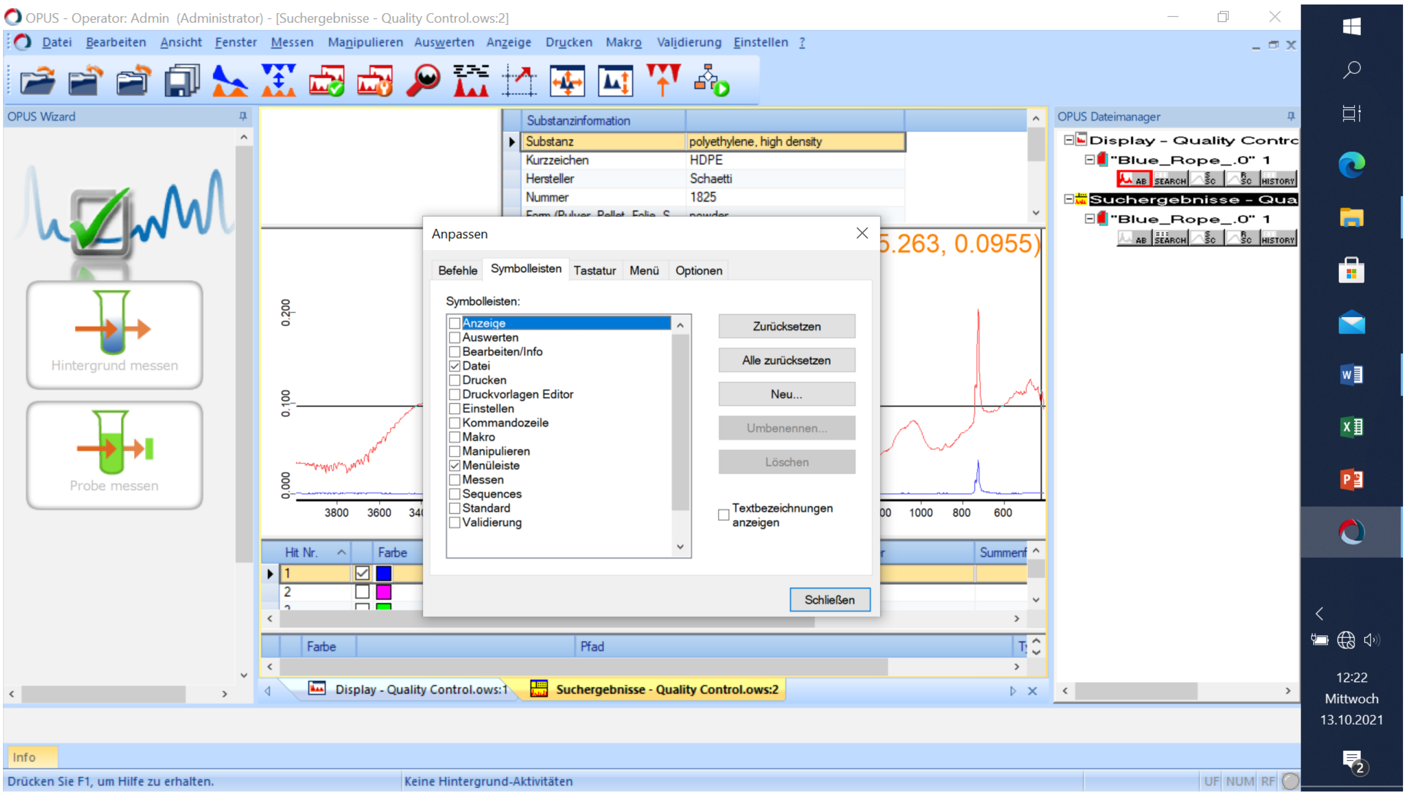
To look at diagnostics ("Diagnose"), click on the small round circle at the bottom right of the screen and you will see this picture. The circle can have the colour green (test passed) or yellow (test needs to be done) or red (test was not passed).



To configure the symbol boards, go to “Einstellen” -> “Symbolleisten konfigurieren”.



This window will appear, which allows you to select the symbol boards.



Before measuring a sample, click on the button called "Hintergrund messen" on the left panel and let the ATR-FTIR measure the background (e.g., with a standard 32 scans). For the measurement to run properly, nothing should be touching the diamond sensor (meaning no sample should be on the ATR-FTIR). See also these OPUS instructions:

"Für die Probenmessung plazieren Sie die Probe in der Messposition im Spektrometer. Für die Hintergrundmessung stellen Sie sicher, dass sich keine Probe in der Messposition im Spektrometer befindet."

Measuring the background should happen when

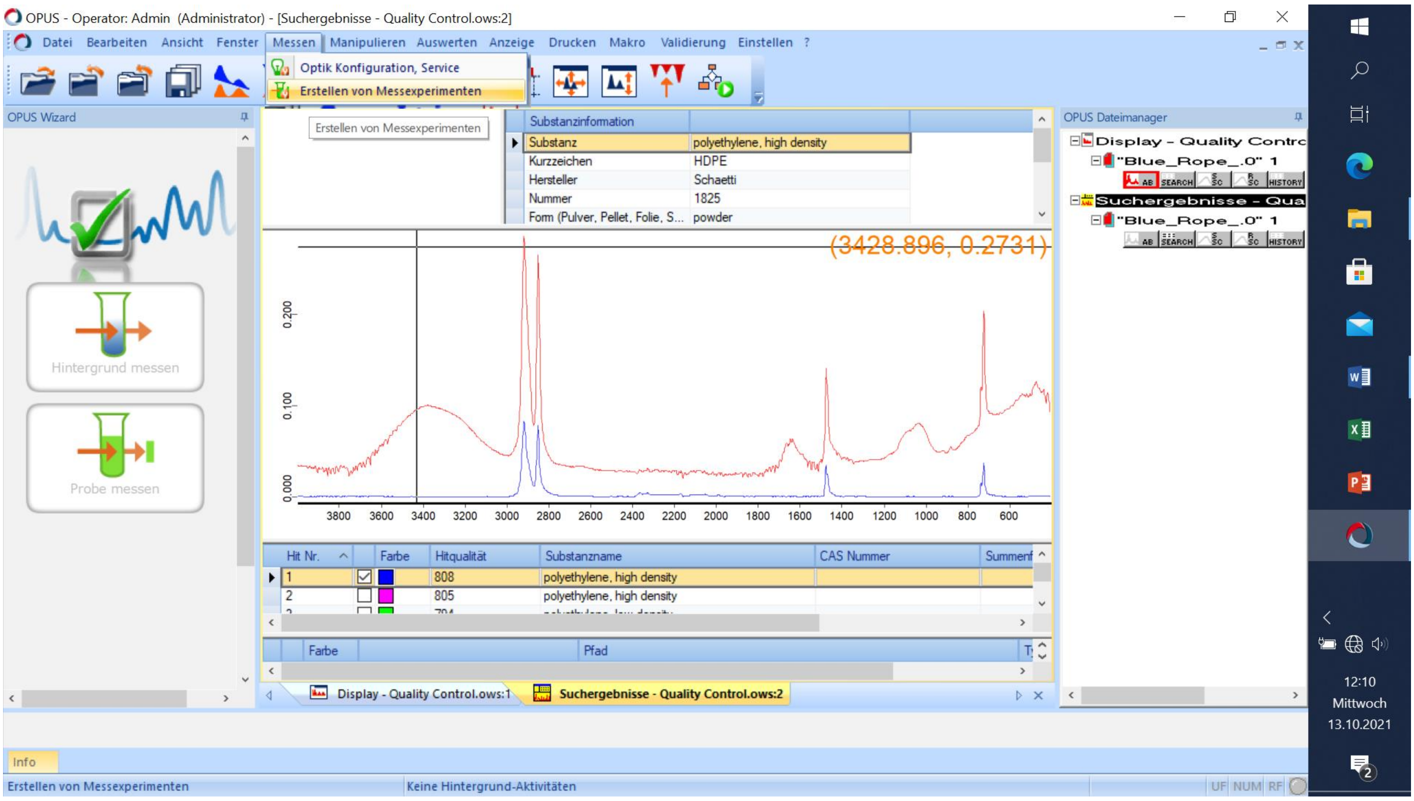
1. the spectra indicate that too much noise is being measured, or
2. at least every 1-2 hours.

The following peaks indicate noise from the following sources:

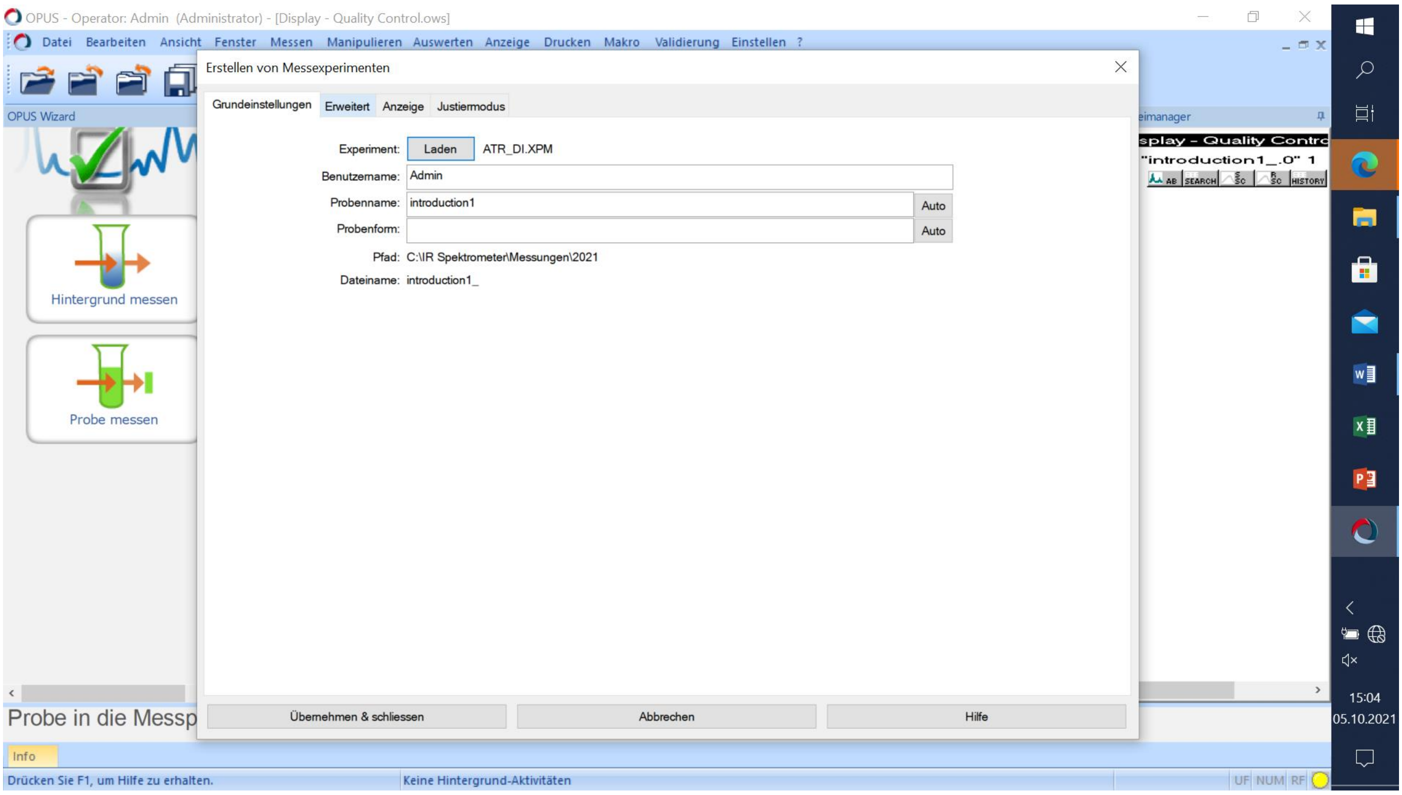
1. One or several peaks at 3500-4000 units indicates water vapor (the unit is wavenumbers/cm).
2. Peak at 2350 units indicates carbondioxide (CO_2).
3. Peaks at 1900-2500 indicate the self-absorption of the diamond in the ATR-FTIR.
4. Negative peaks (= negative absorbance, or below the x-axis) also indicate impurities (e.g., from the diamond).

To then measure a sample, place it on top of the diamond window (which should be regularly cleaned with cleaning alcohol) of the ATR-FTIR and secure it with the screw top. For good practice, every sample should be measured in three different places.

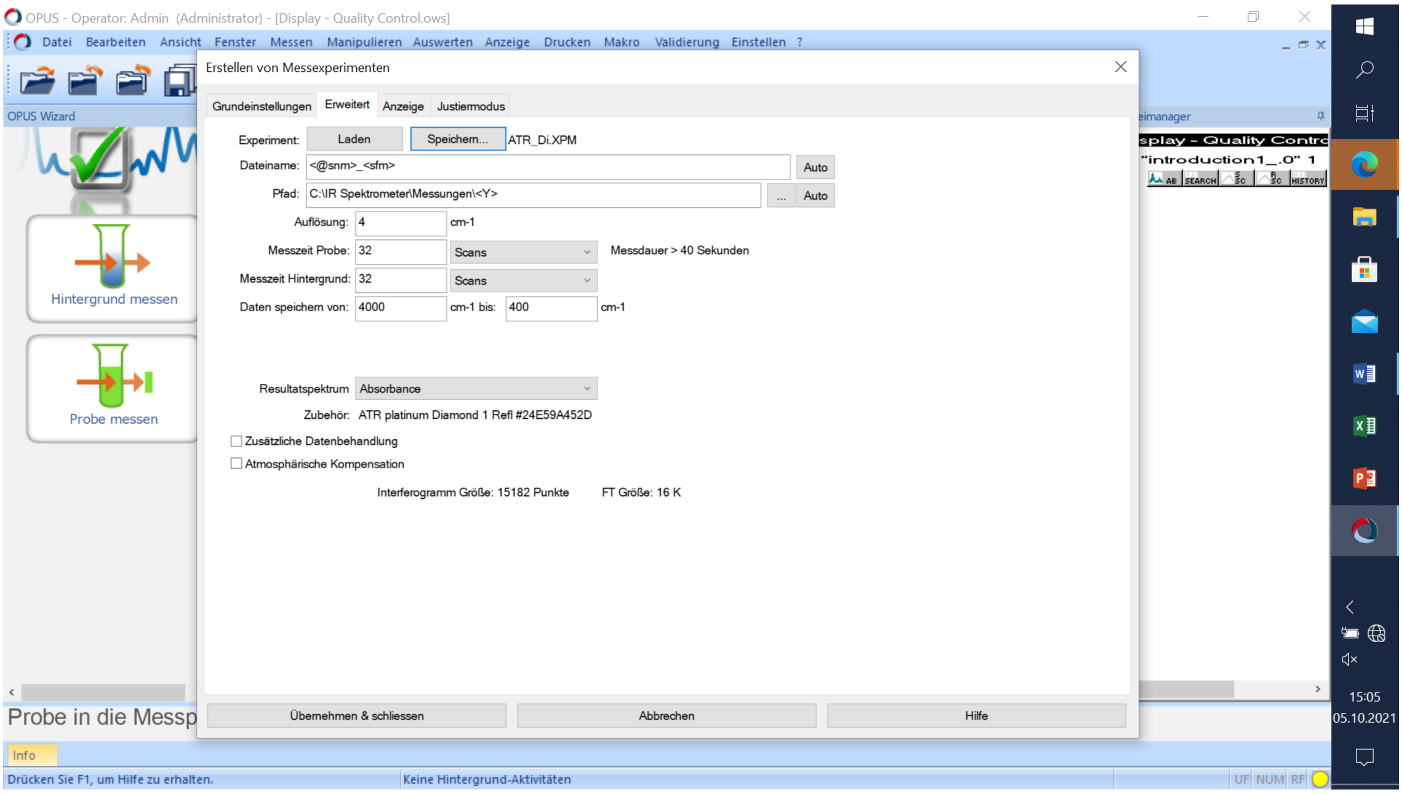
You then need to go to “Messen” -> “Erstellen von Messexperimenten”.



Enter the name (“Probenname” in the “Grundeinstellungen” tab) of the measurement.

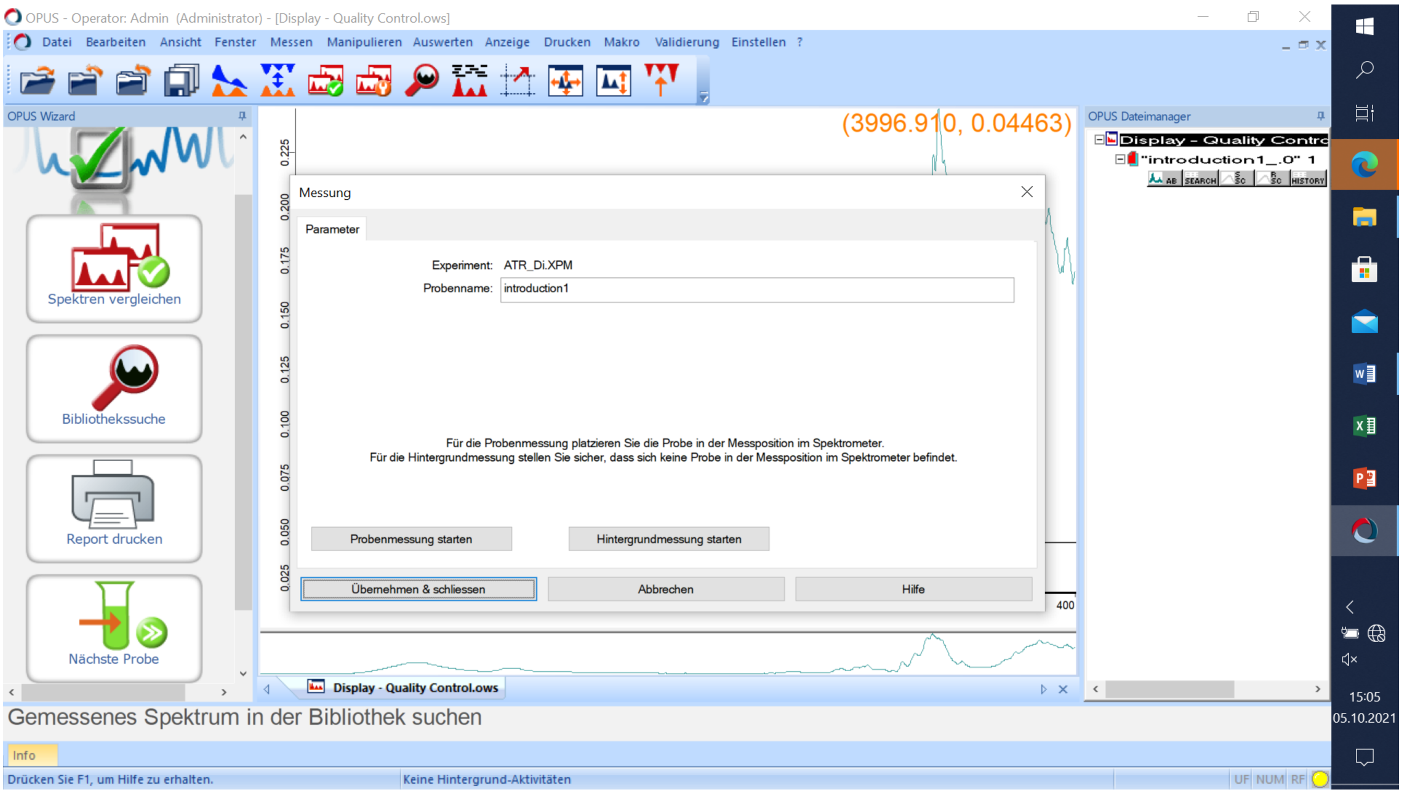


In the “Erweitert” tab, you can specify the path (“Pfad”) for the target folder where the data shall be placed, the number of scans, etc.

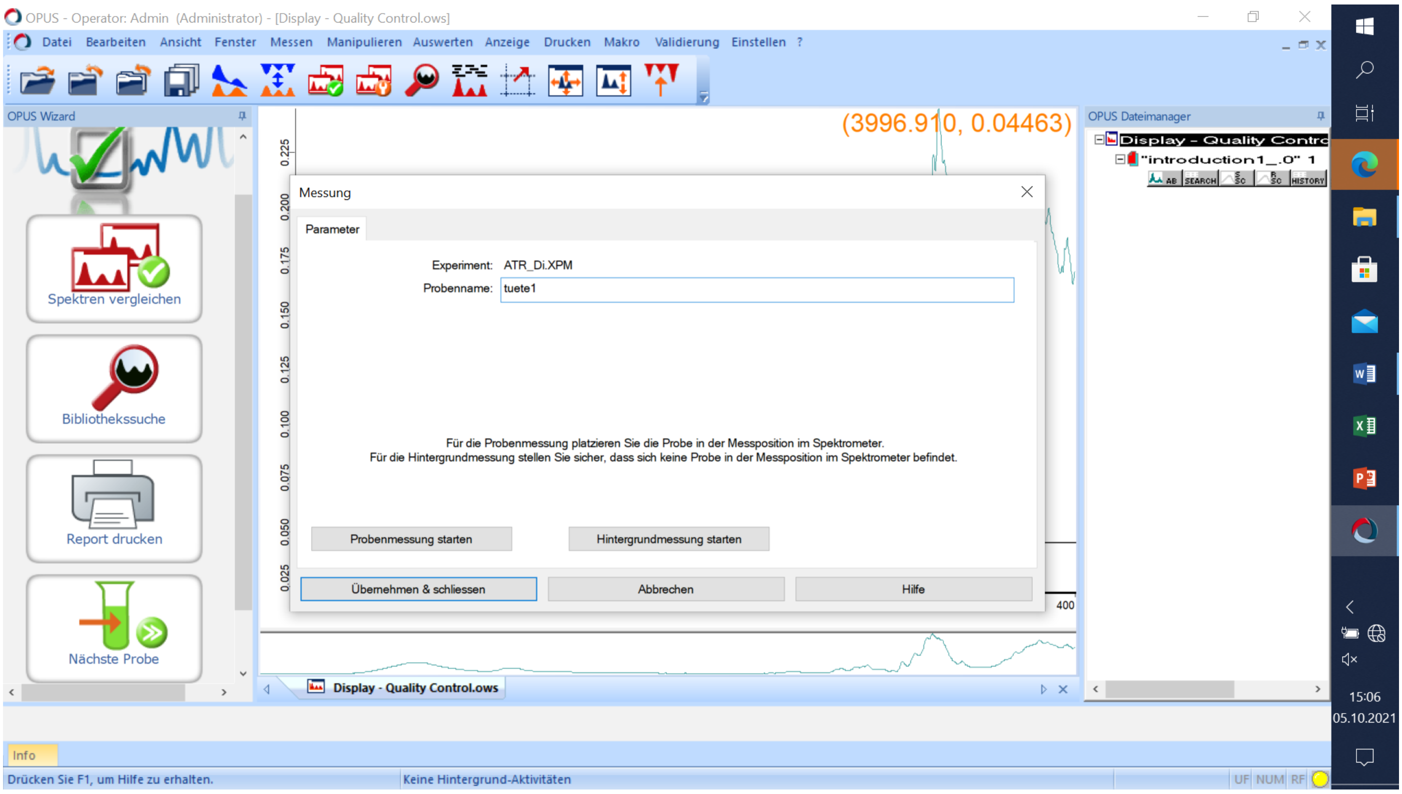


To save the specific entries, you first need to click on “Übernehmen & schliessen”.

To do the actual measurement, now place the sample onto the diamond sensor and secure it with the screw top. Then click on the button “Probe messen” (or for later measurements “Nächste Probe”) in the left panel and this window appears.

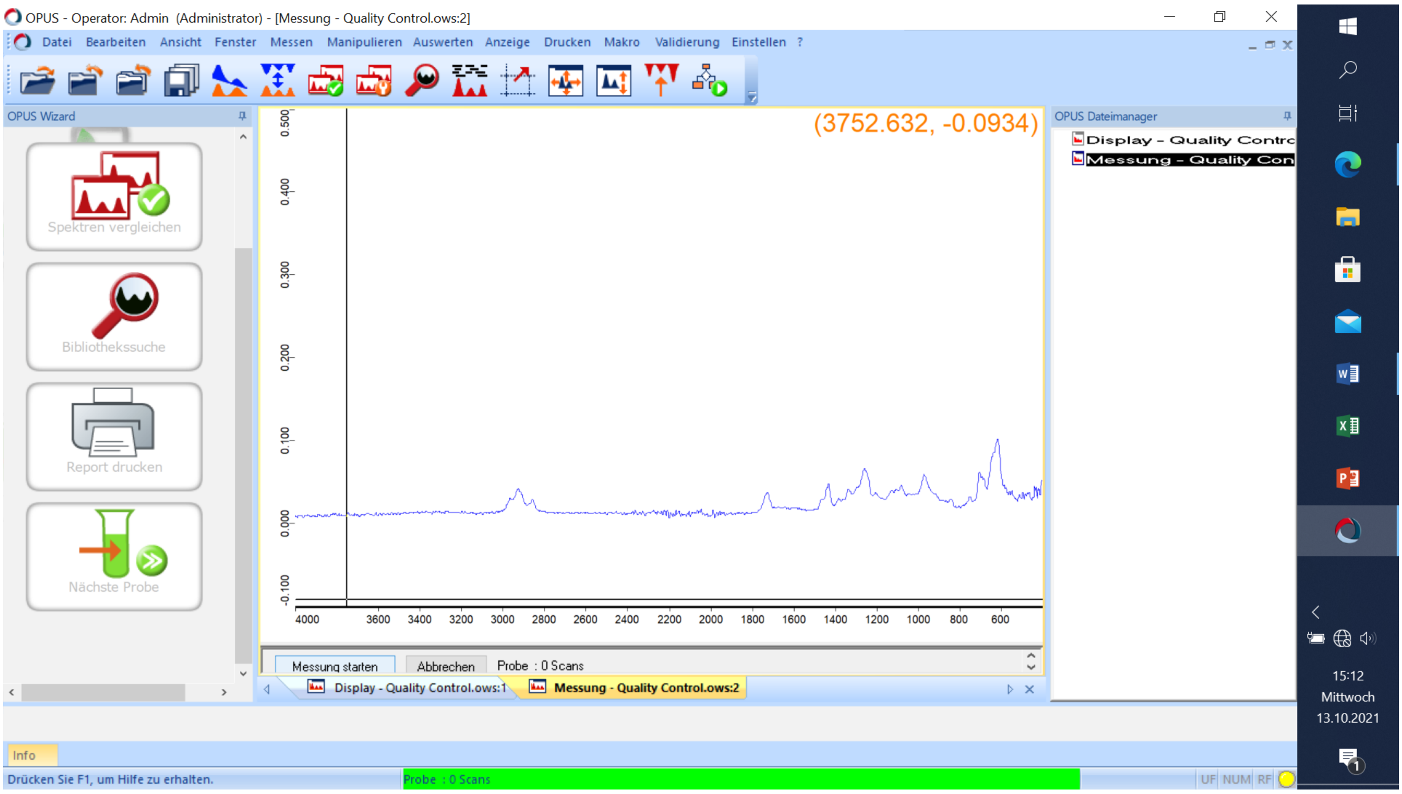


Enter the name of the measurement (e.g., tuete1) in the field called “Probenname”.

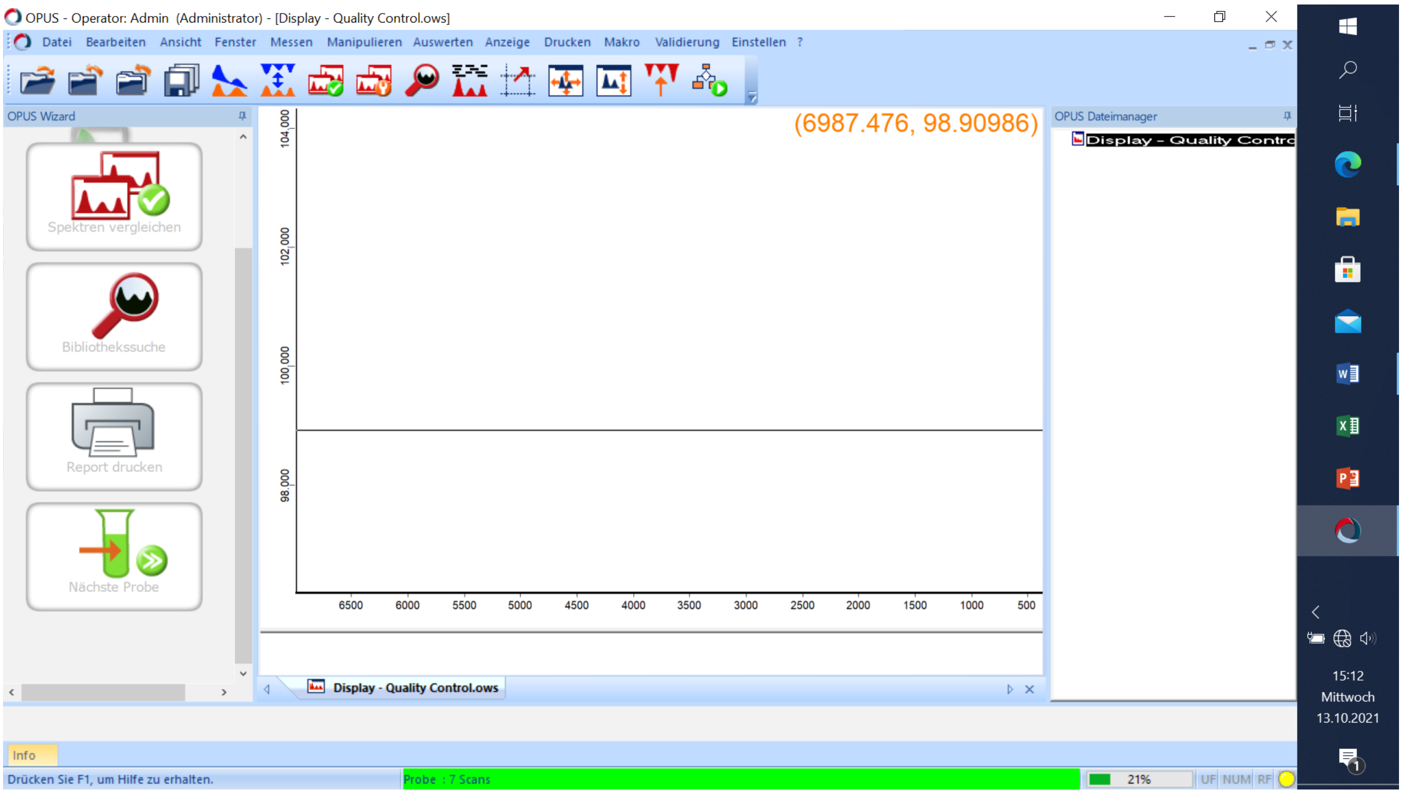


Then click on “Probemessung starten” (not “Übernehmen & schliessen”).

The software will then do one scan and show it for quality control (as shown below).

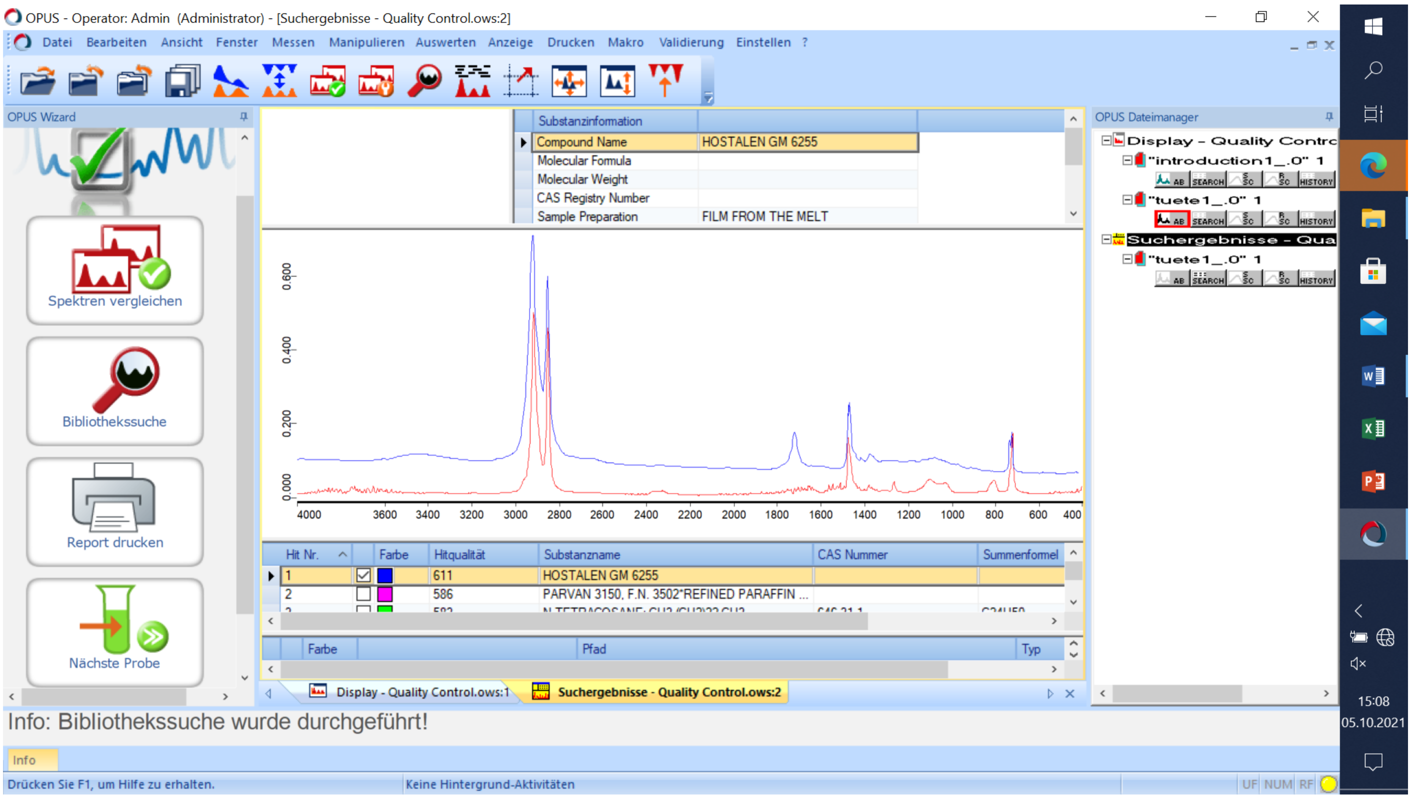


If the scan is satisfactory, then click on the button called “Messung starten” on the left below the scan. The software will then measure the sample with the predetermined number of scans (e.g., 32 scans).

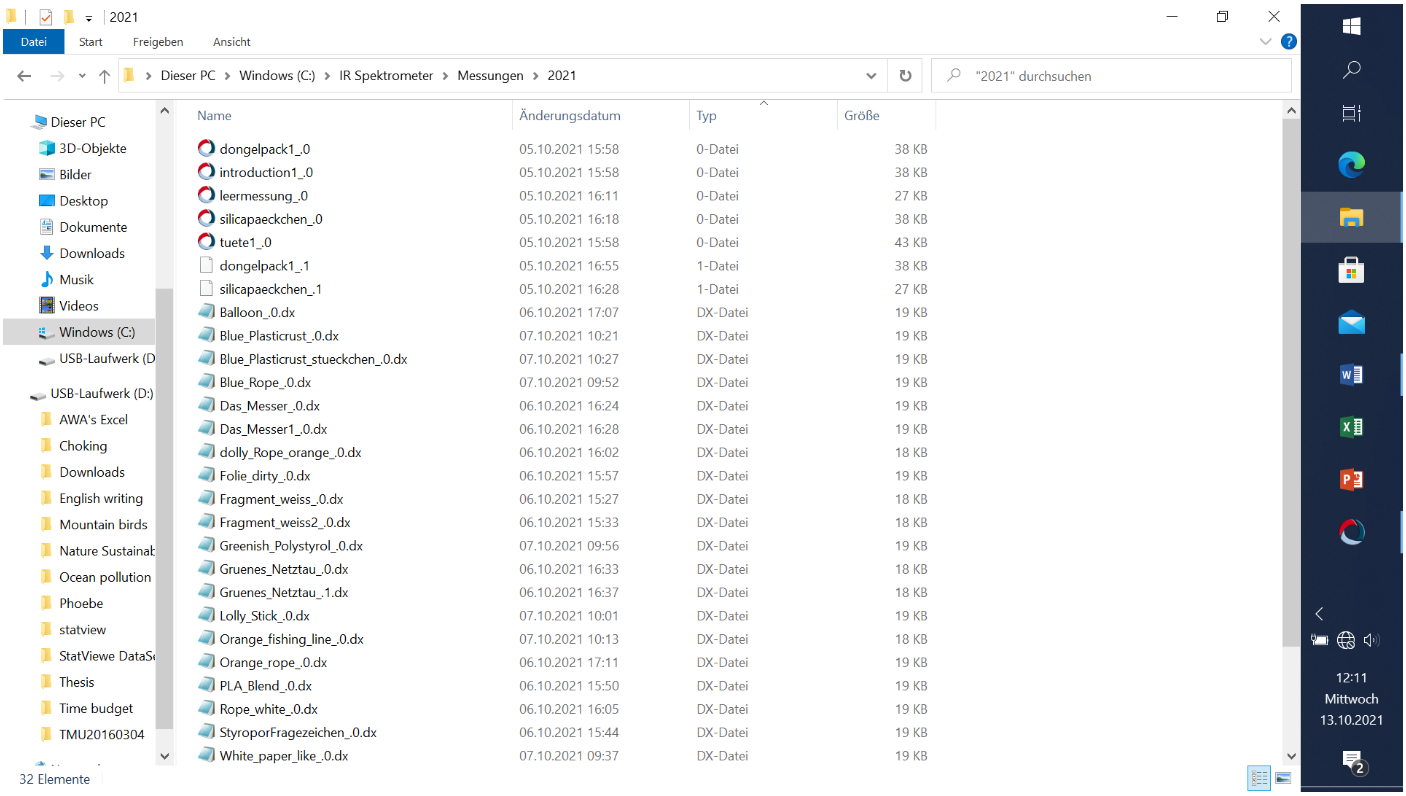


Here the program is on the 7th of 32 scans (see green bar).

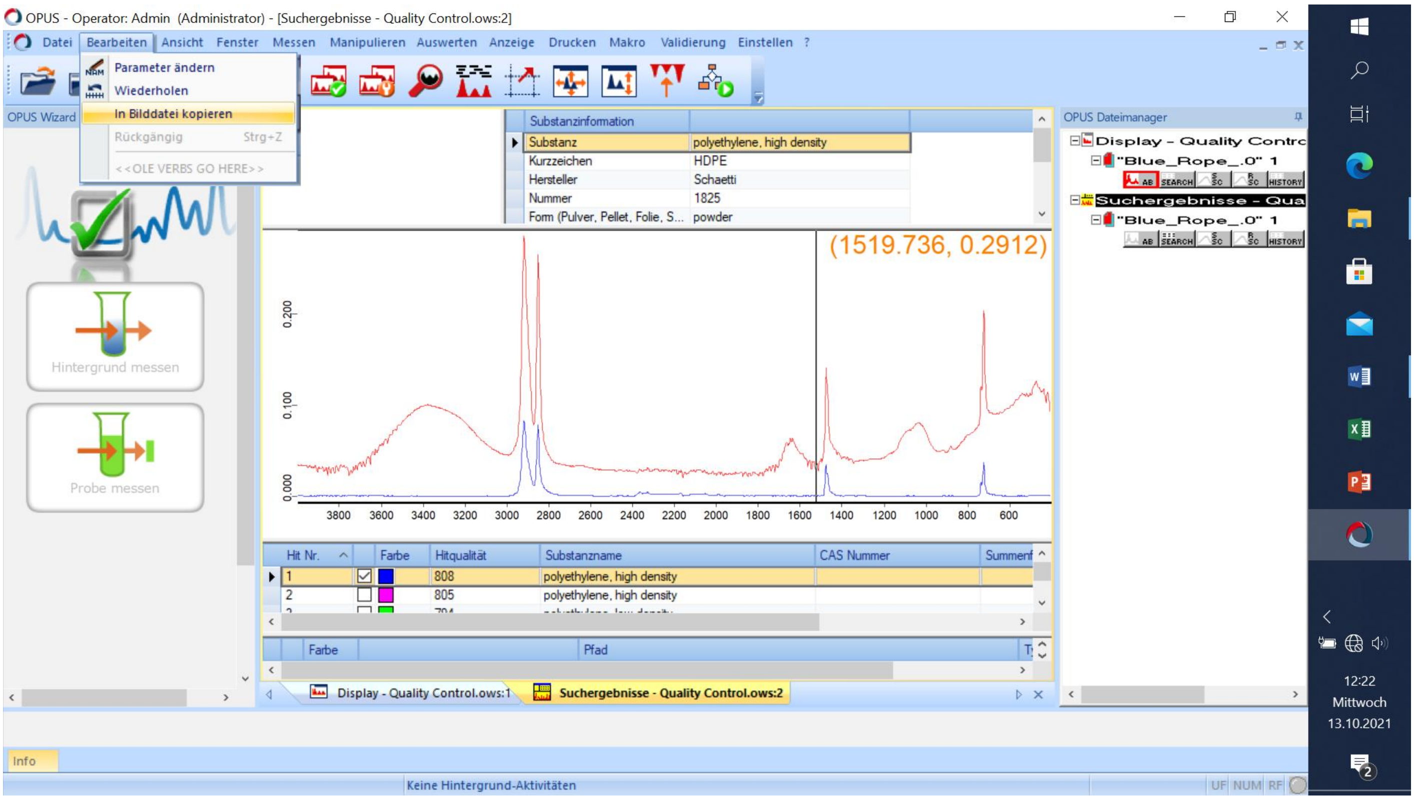
After the measurement scans have been completed, the resulting spectra will be shown in the window, with each measurement being assigned a row with the name and several small boxes in the right panel called “OPUS Dateimanager”. The active spectrum is the one where the small rectangle has a red frame (e.g., the second spectrum from the top in the picture below).



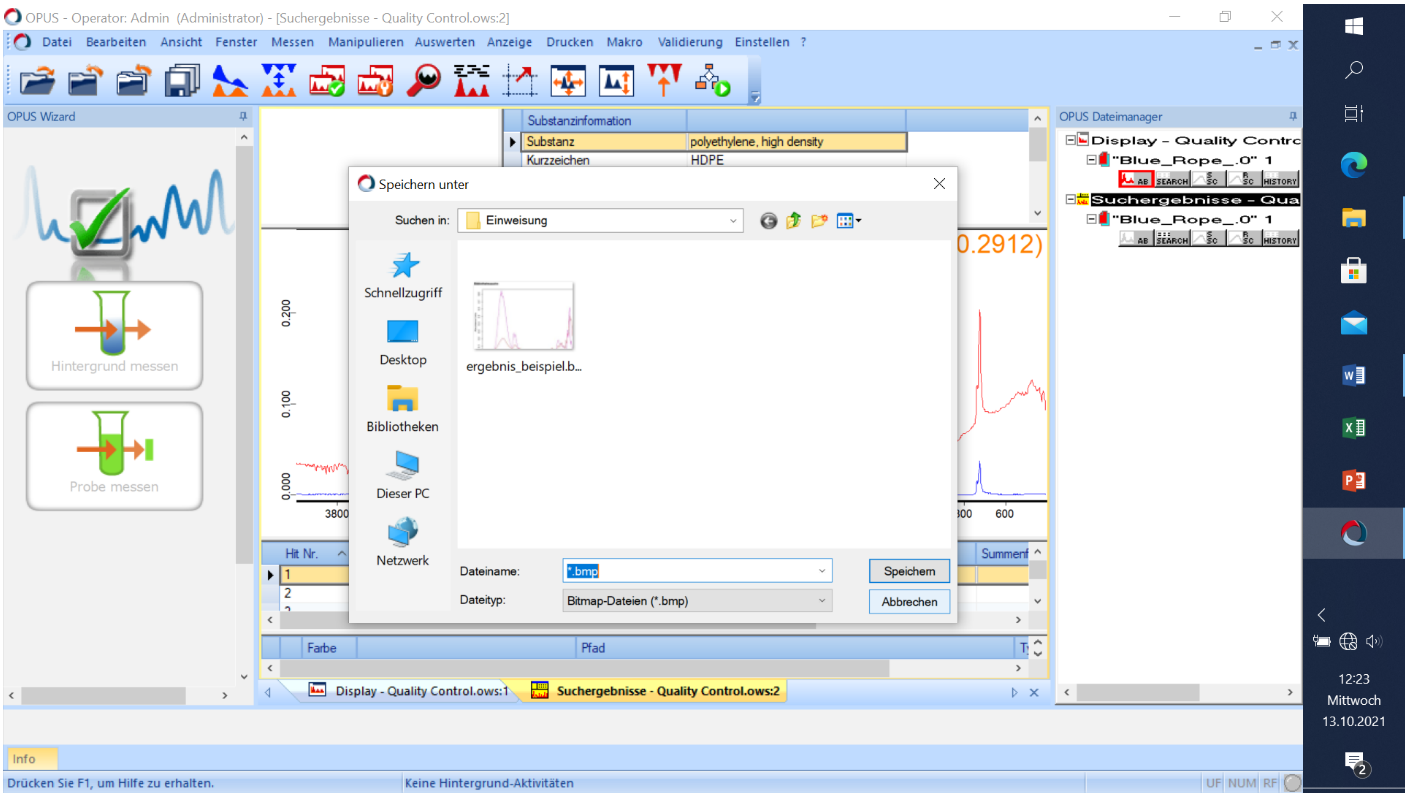
For each measurement, OPUS automatically generates a so-called “0-Datei” and sometimes also “1-Datei”, “2-Datei”, and so on (see examples below) and places them into the target folder.



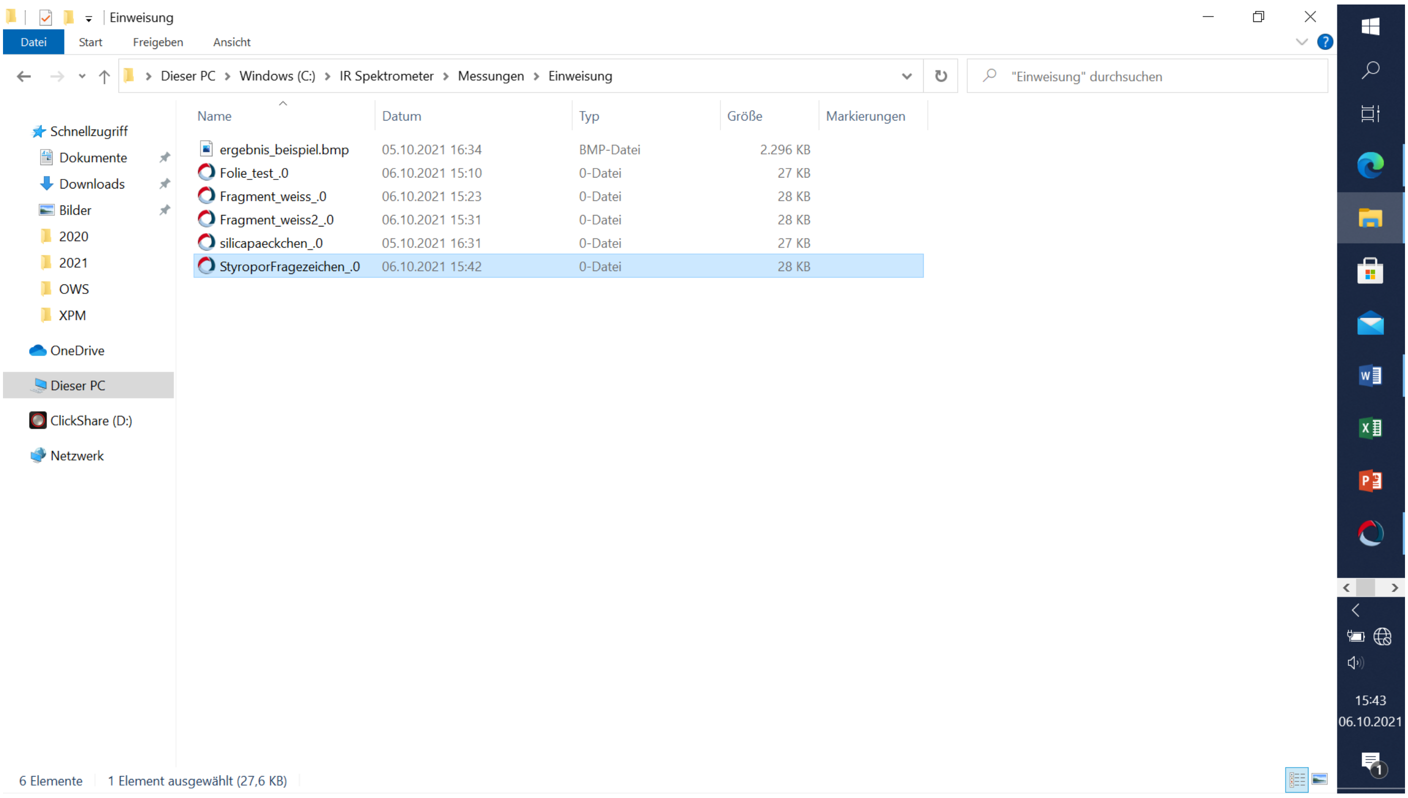
For a picture (not the raw data) of the spectrum, go to “Bearbeiten” -> “In Bilddatei kopieren”.



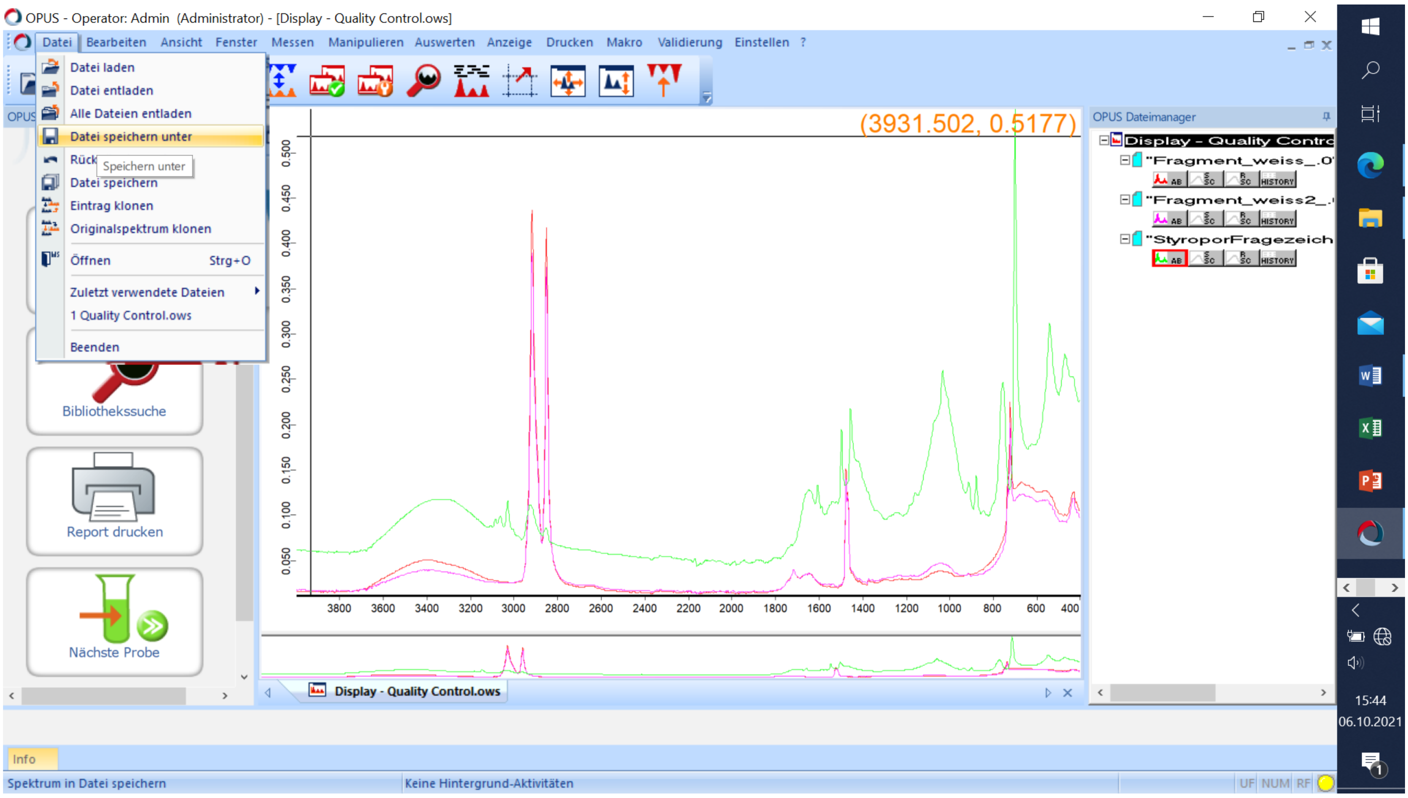
Save the active spectrum as, e.g., a bitmap (*.bmp) file.



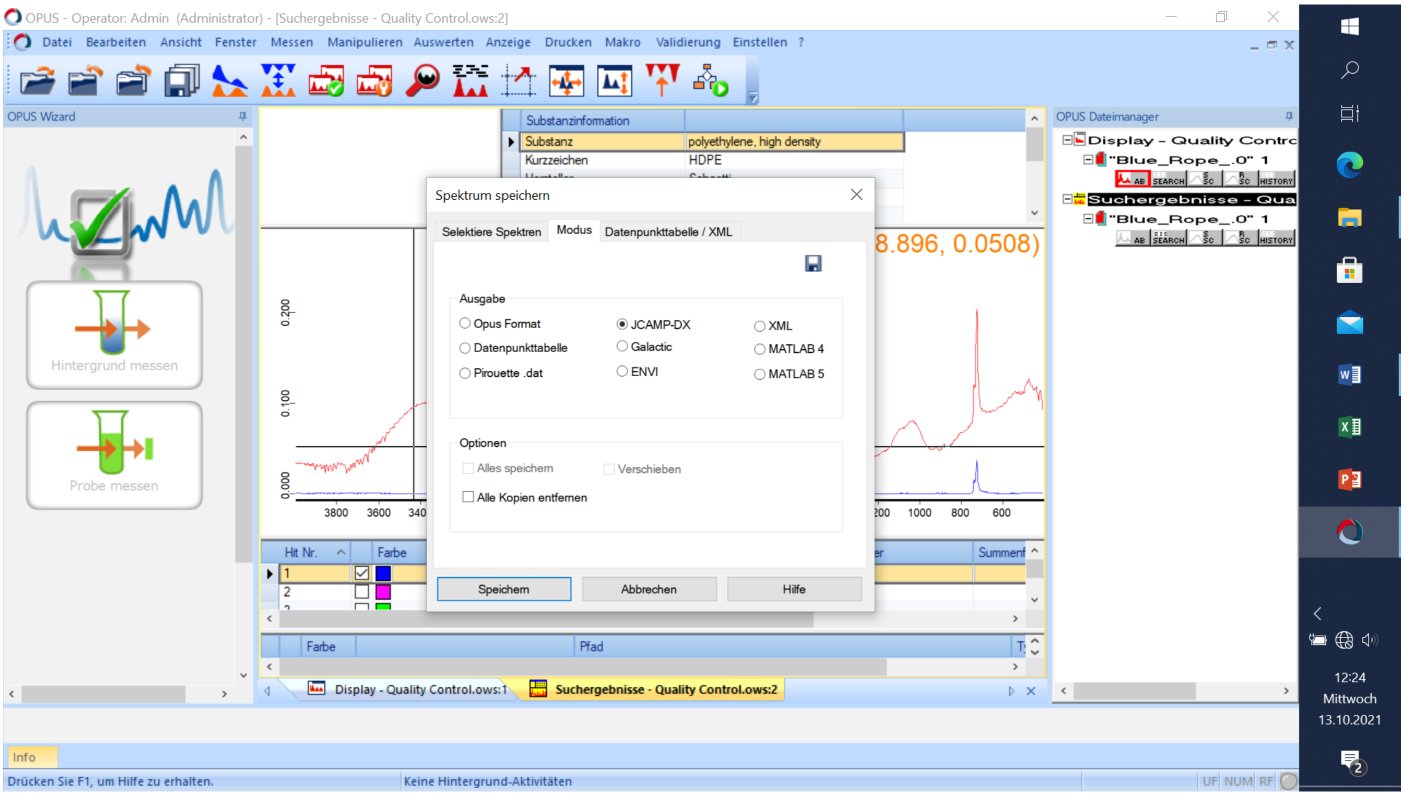
For analysis with the program siMPle, these files need to be converted into DX-Dateien.



For the conversion, go to “Datei” -> “Datei speichern unter” after having chosen the spectrum by making it active (red frame on rectangle, e.g., here StyroporFragezeichen_.0, whose location is shown in the picture above).

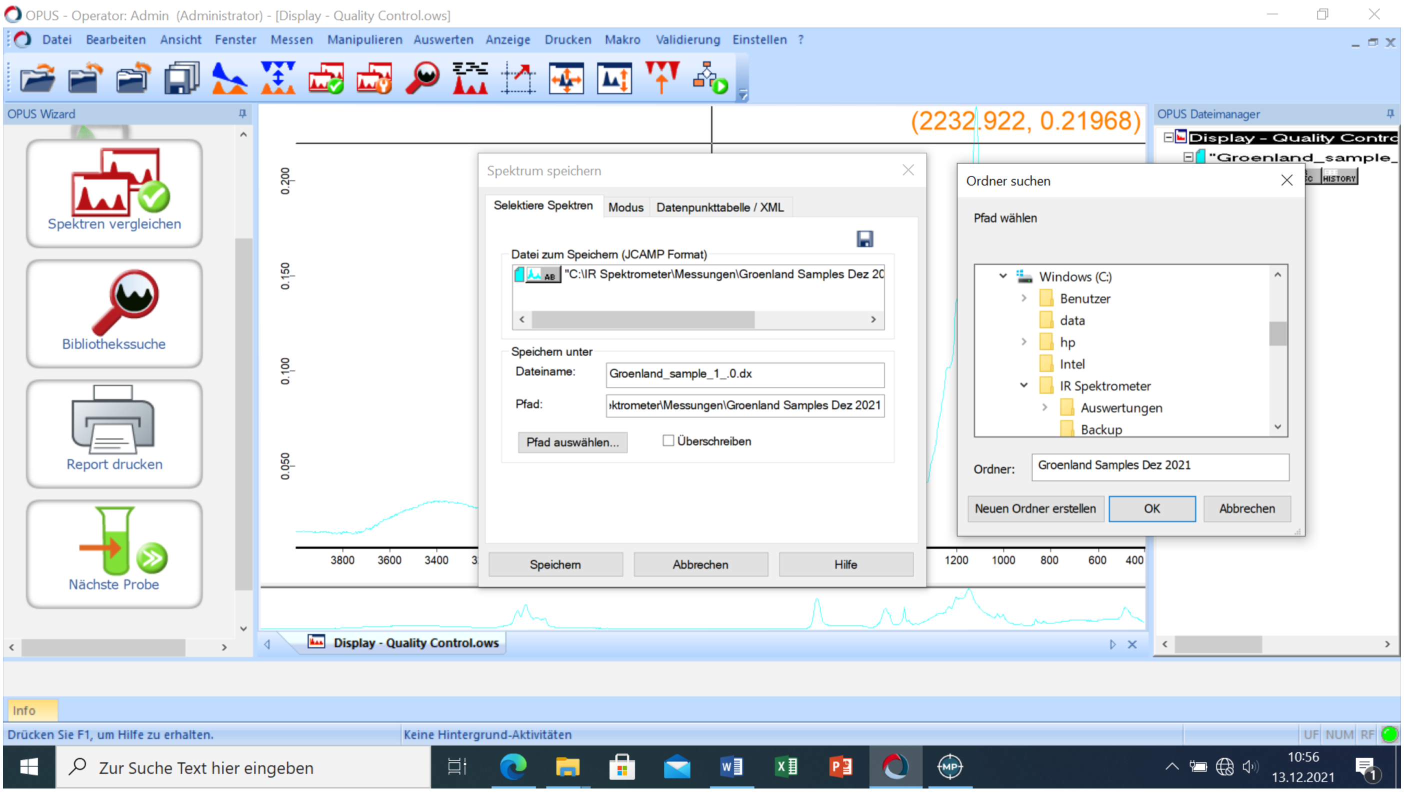


Usually, the format under which files are saved within OPUS is the Opus Format, which results in the "0-Datei". In order to analyze the data in the program siMPle, the data need to be translated into the JCAMP-DX format (*.dx) and not the Datenpunkttabelle (*.dpt) (see below).

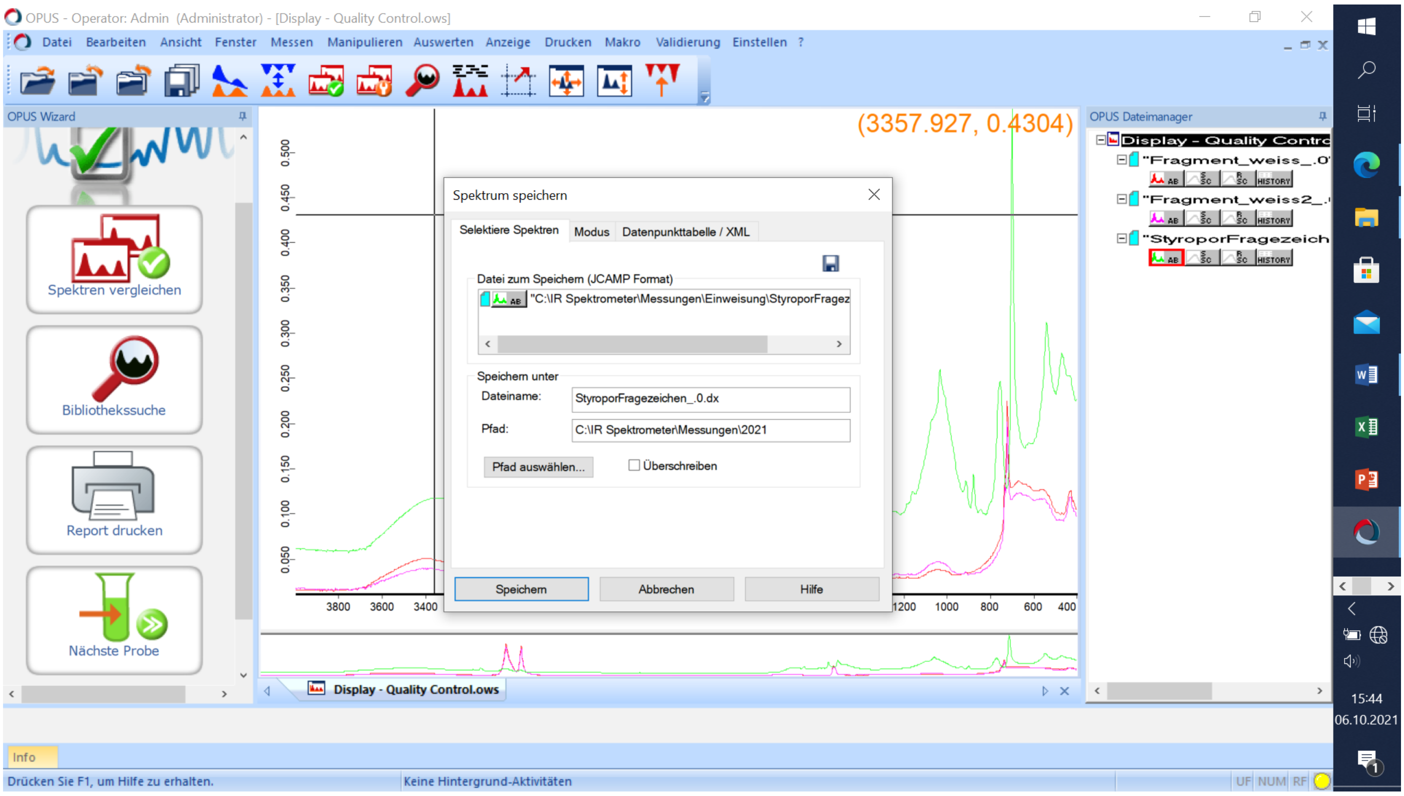


Going back to the tab "Selektiere Spektren", you can change the path where the file is saved by

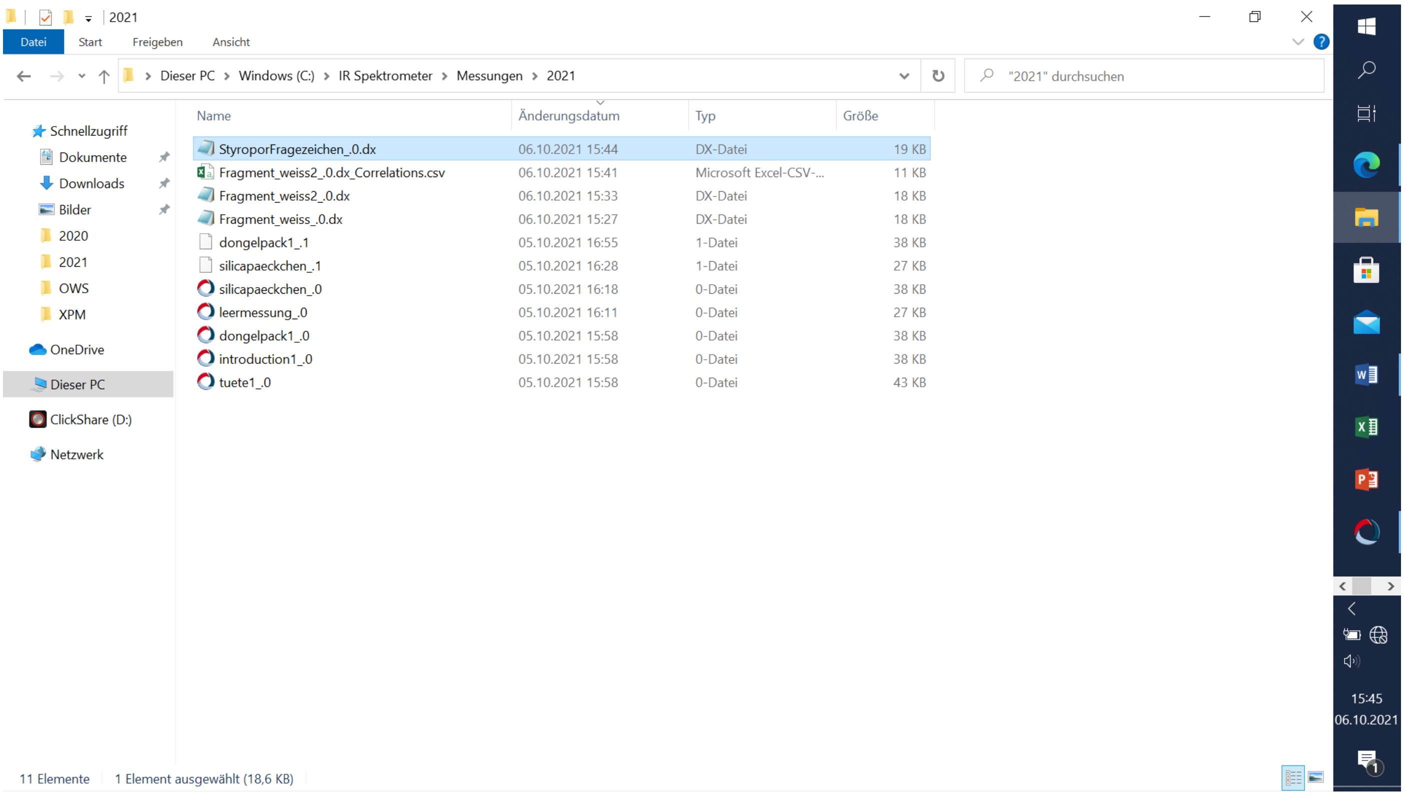
1. Copy-and-paste the path into the window called "Pfad".
2. Click on the button called "Pfad auswählen".



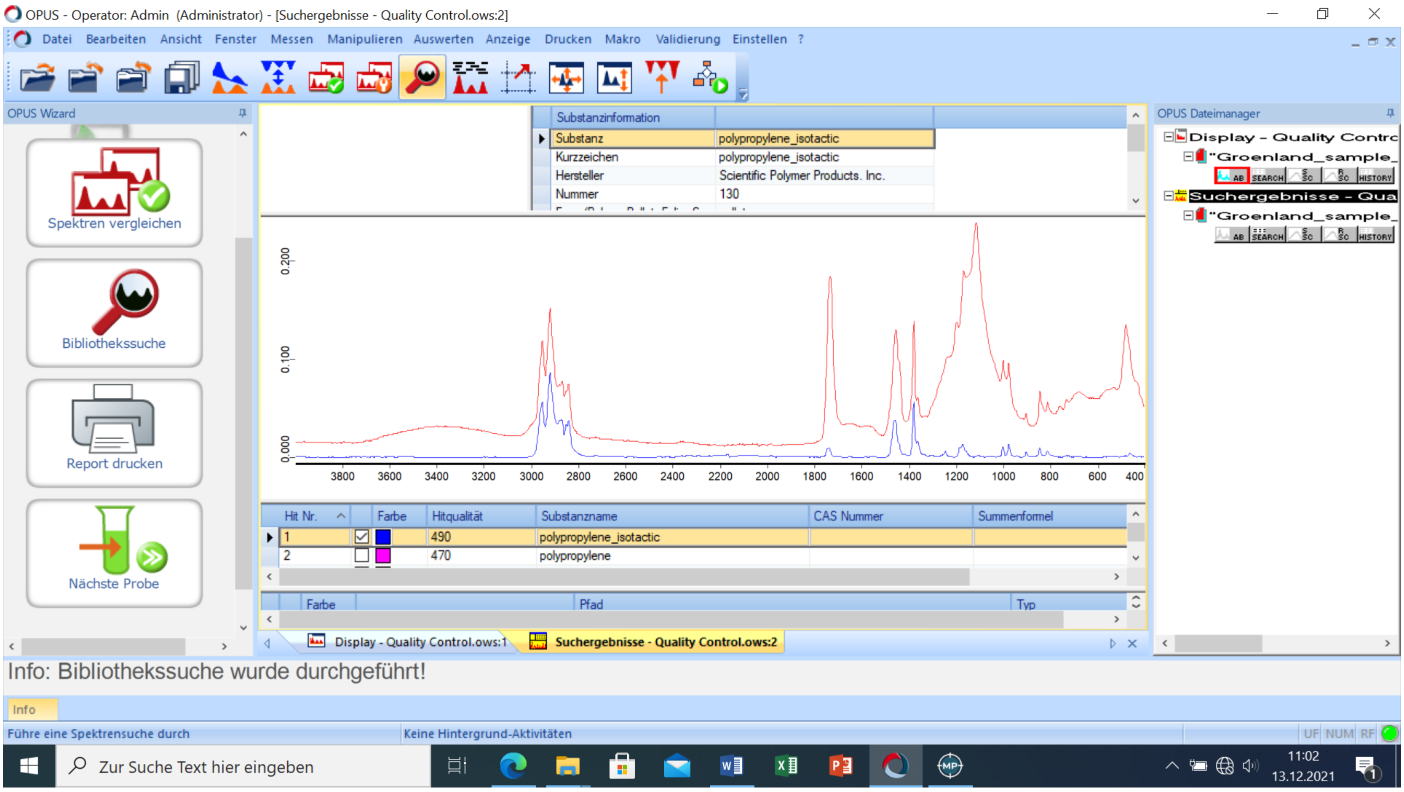
Once you have chosen the necessary options, you can save the file by clicking on “Speichern”.



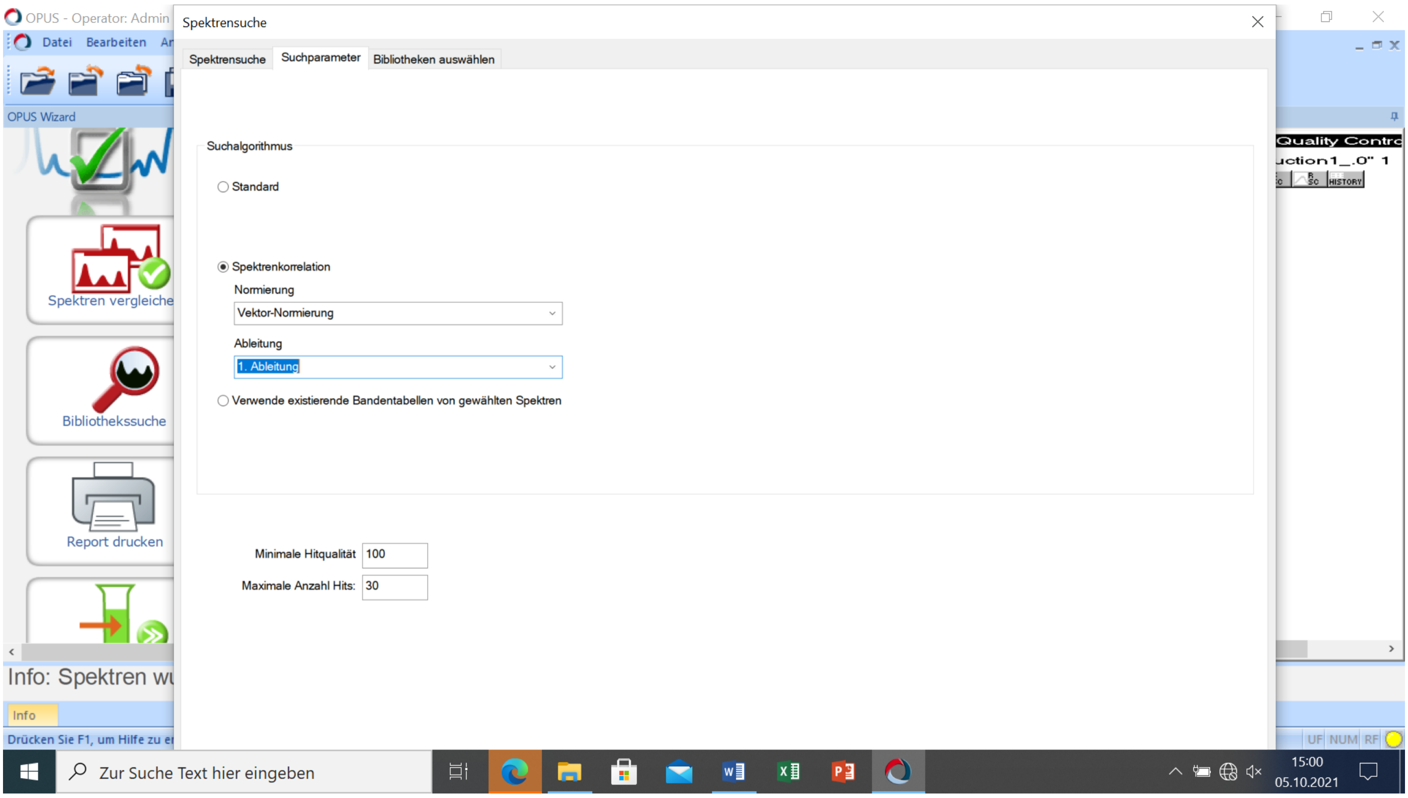
As a result, the corresponding *.dx file will be placed in the target folder (e.g., here StyroporFragezeichen_.0.dx).



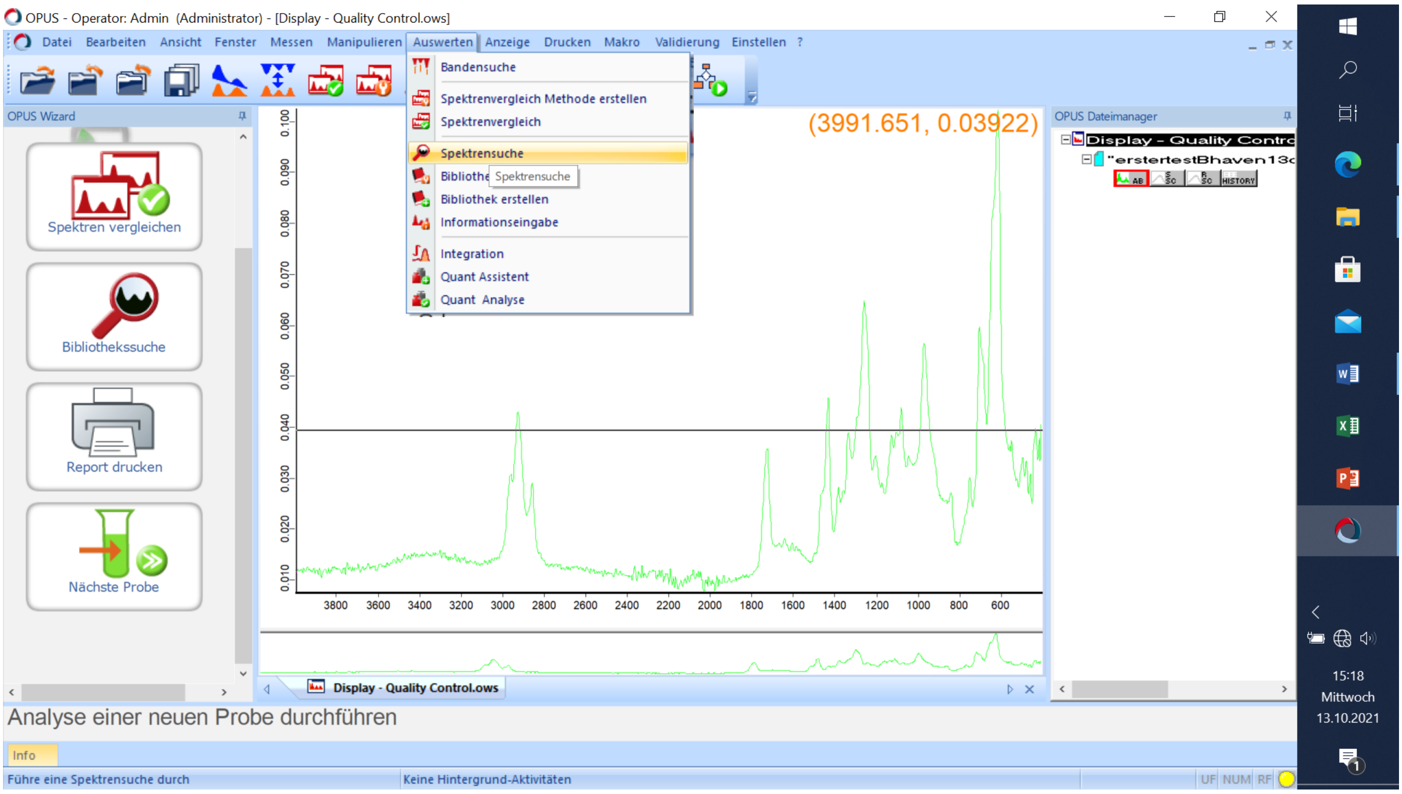
If you want to use search for matching reference spectra in OPUS, you need to click on the button called "Spektrensuche" [highlighted below in faint orange in the top horizontal panel].



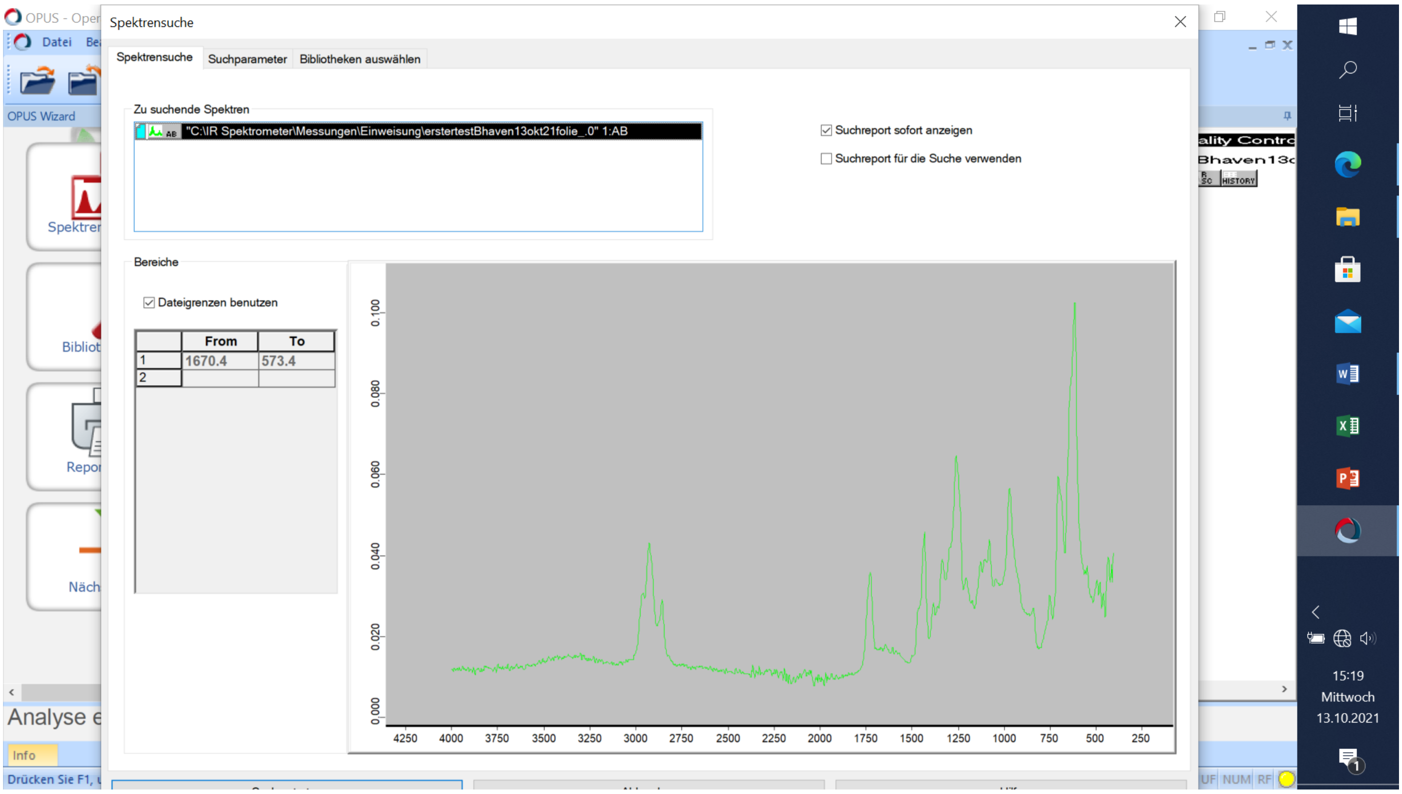
Then set the search algorithm ("Suchalgorithmus") to "Vektor-Nominierung" und "1. Ableitung."



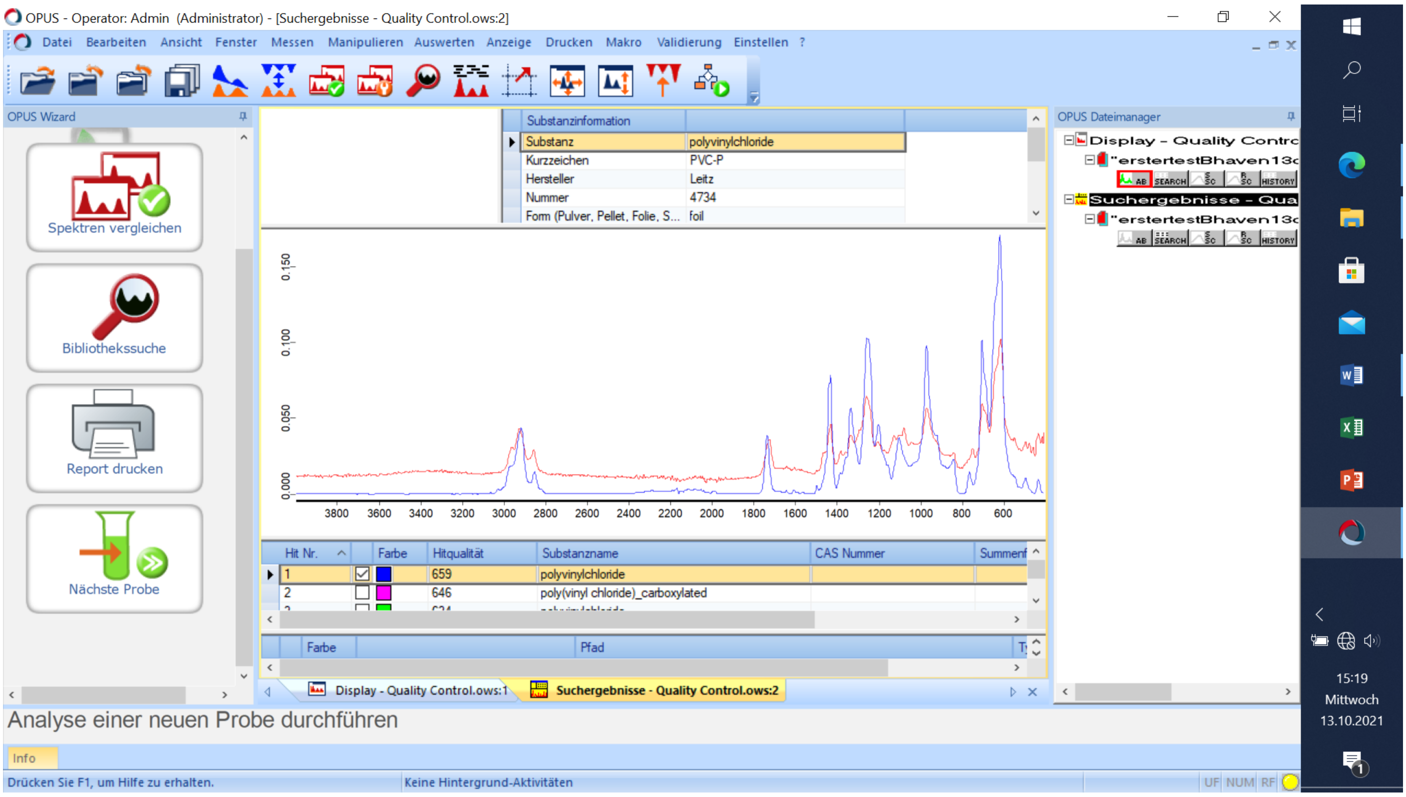
To find matching spectra in the reference libraries, click on "Auswerten" -> "Spektrensuche".



This window will appear. If everything is correct, then click on the almost invisible button at the bottom left (here just visible with a light blue frame).



After the comparison search is complete, a window such as the one below will appear.



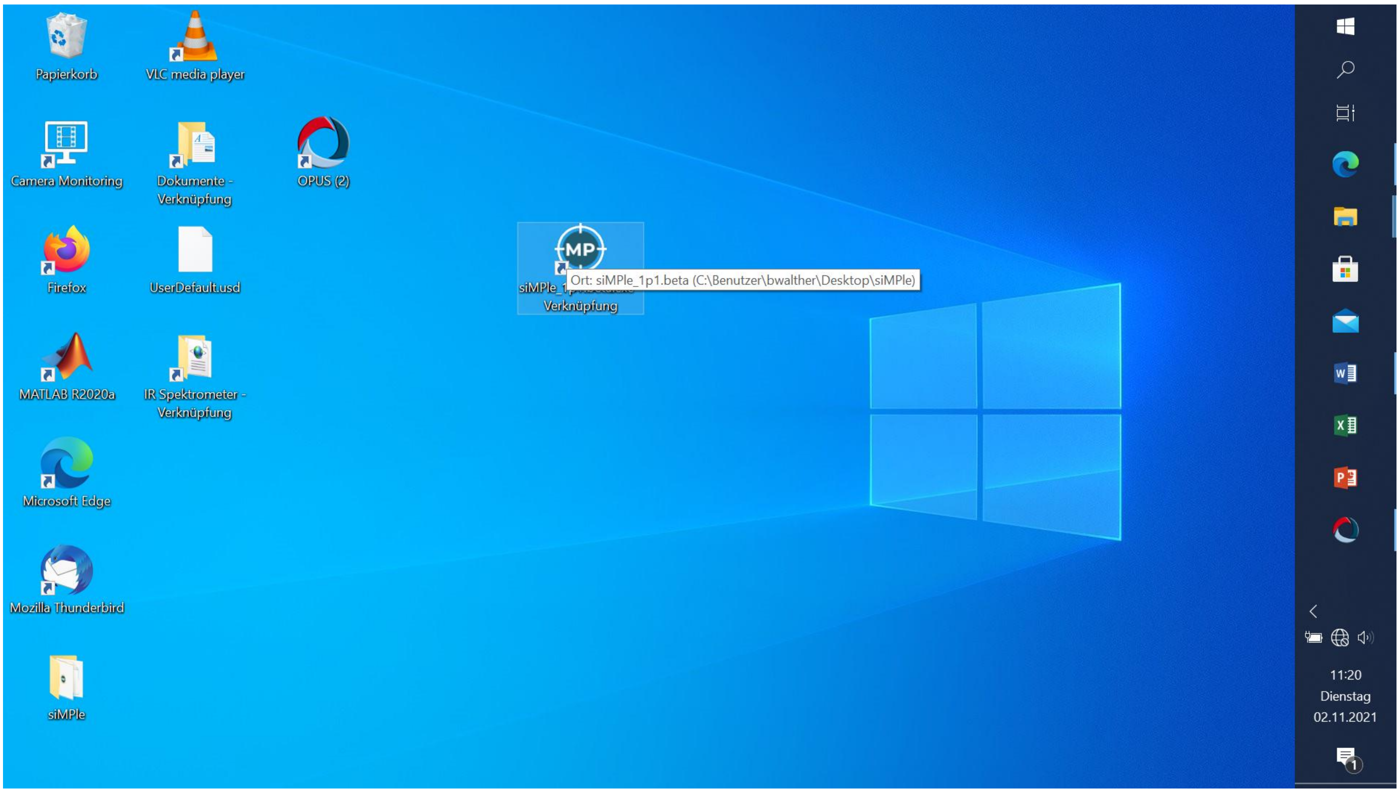
Only the spectrum with the highest hit quality ("Hitqualität" or matching score) will be shown (which ranges from zero to 1000). To see other spectra, click on the little squares left of the colour code of each matching spectra.

A hit quality > 700 is usually considered a positive identification (Renner et al., 2019).

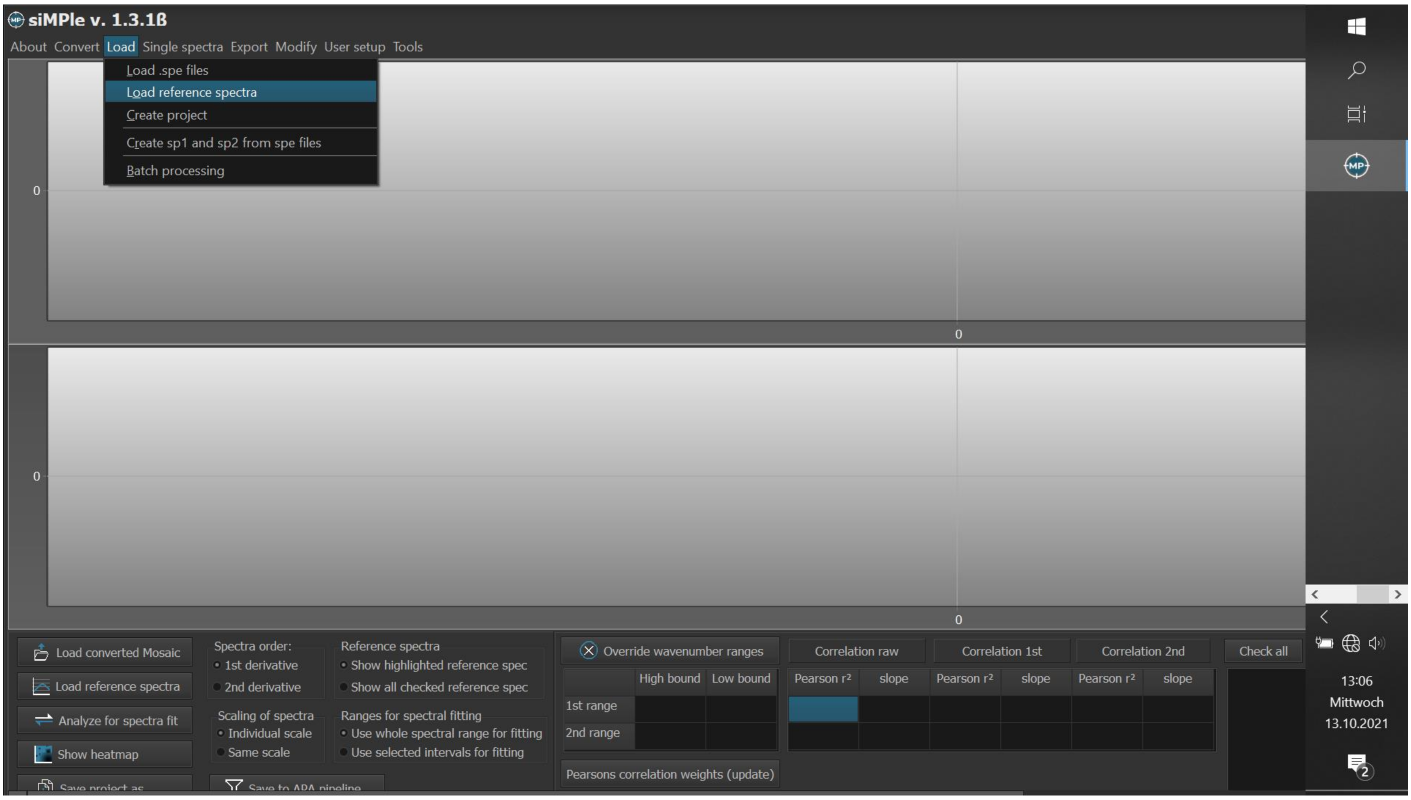
A hit quality 600-700 is considered a likely identification, but perhaps the sample should be re-measured, or the peaks should be individually checked to avoid misidentification.

Use of the siMPle software to determine polymer types

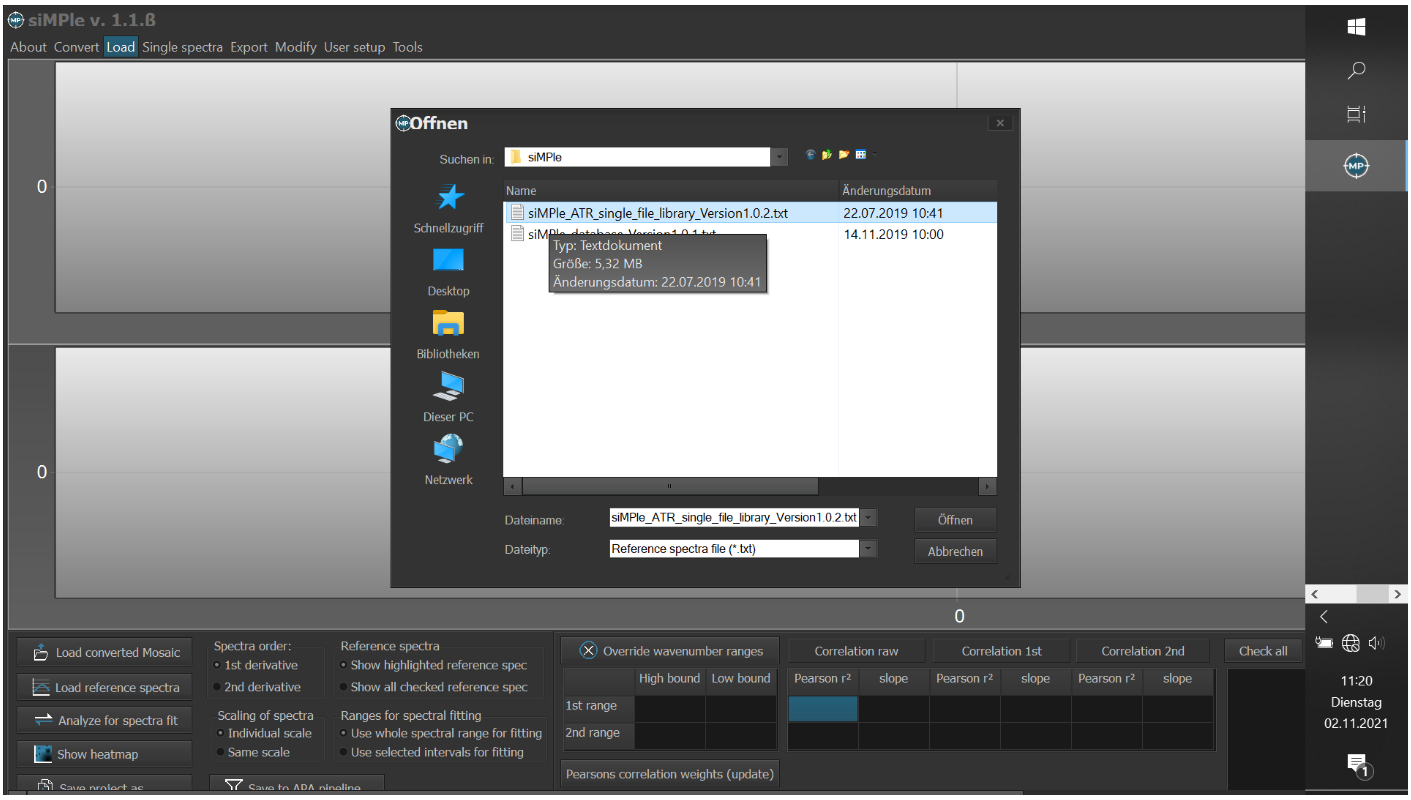
Click on the siMPle icon.



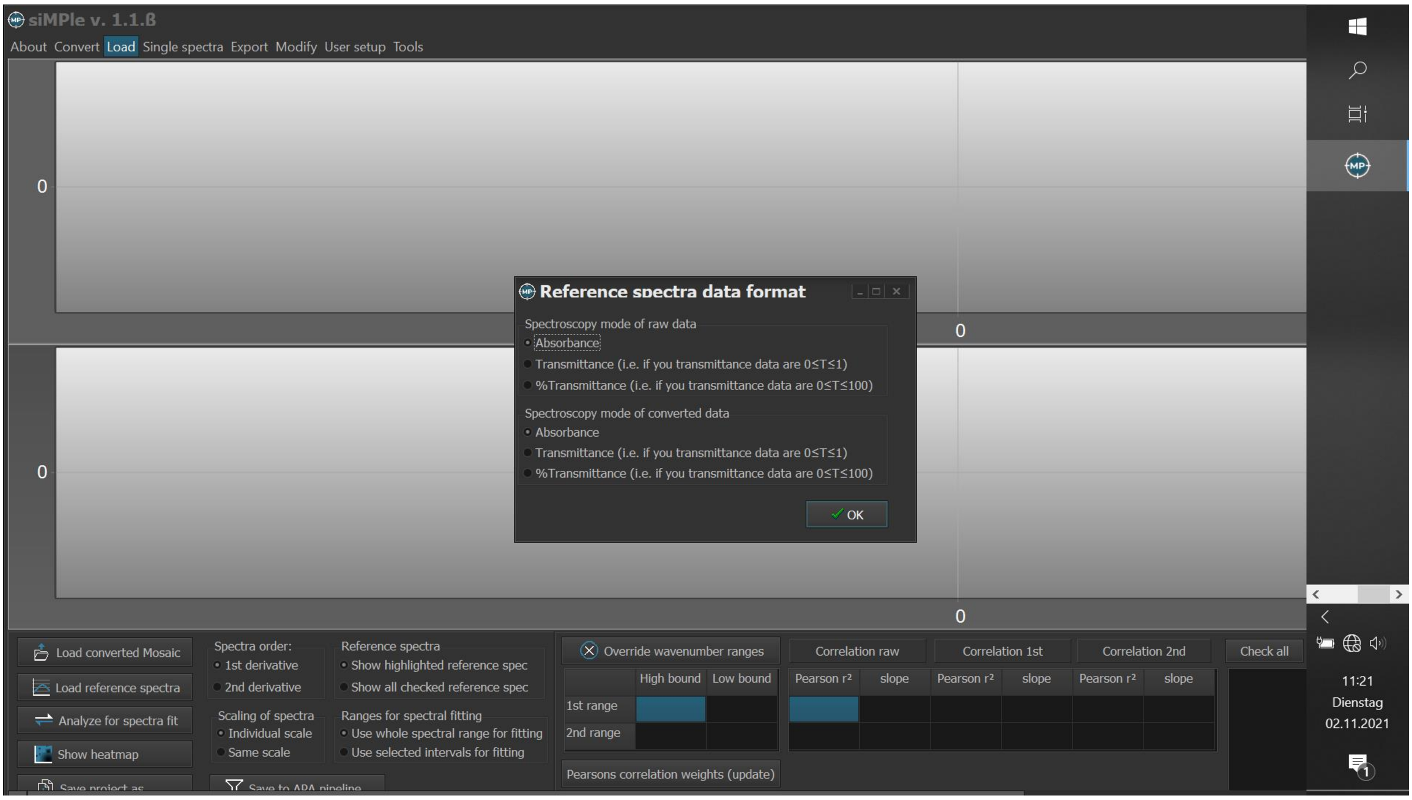
Before identifying spectra, the reference spectra have to be loaded into siMPle, but just once at the beginning. Click on Load -> Load reference spectra.



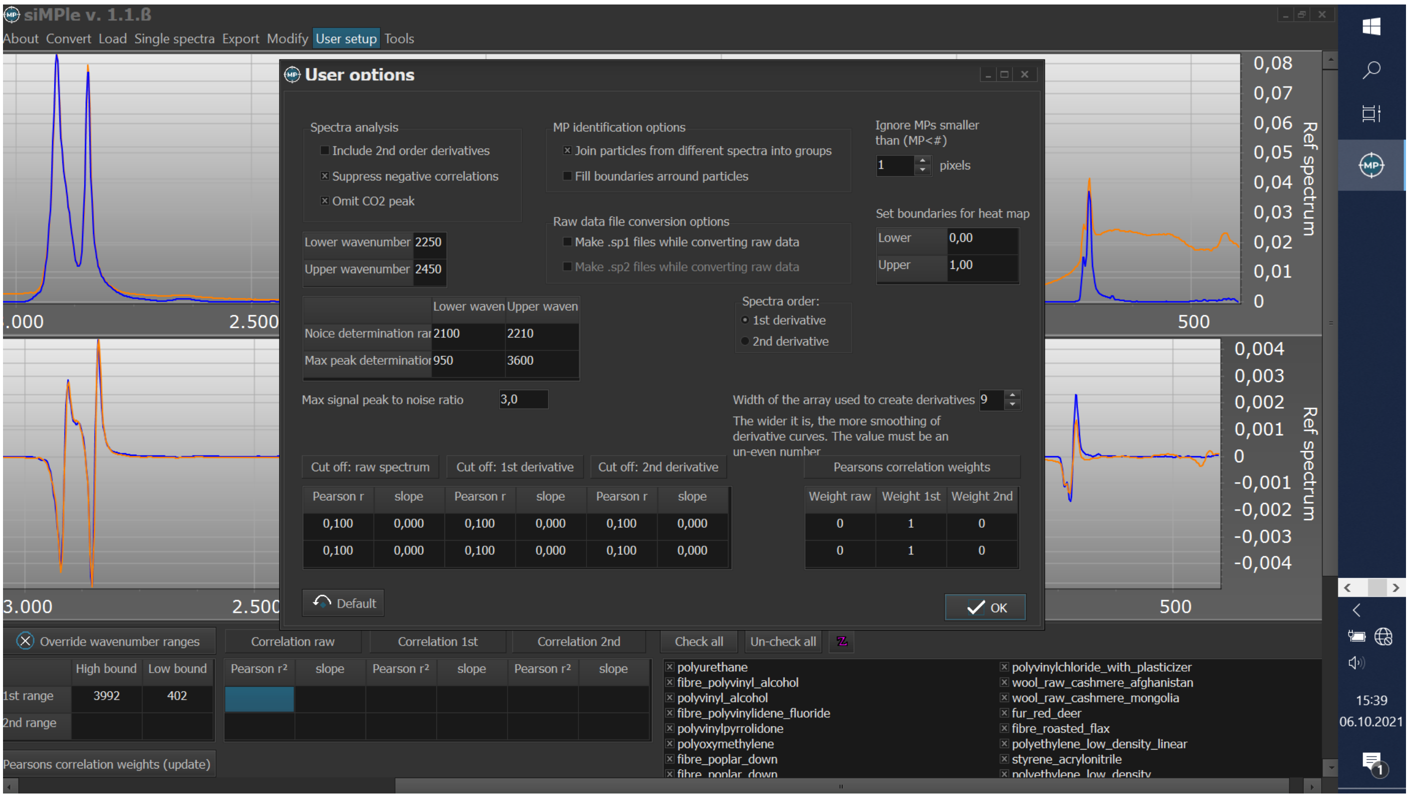
Navigate to the siMPle folder on the desktop (now in Dokumente Folder) and load the file called siMPle_ATR_single_file_library_Version1.0.2.txt [or whatever file with reference spectra you are using with siMPle].



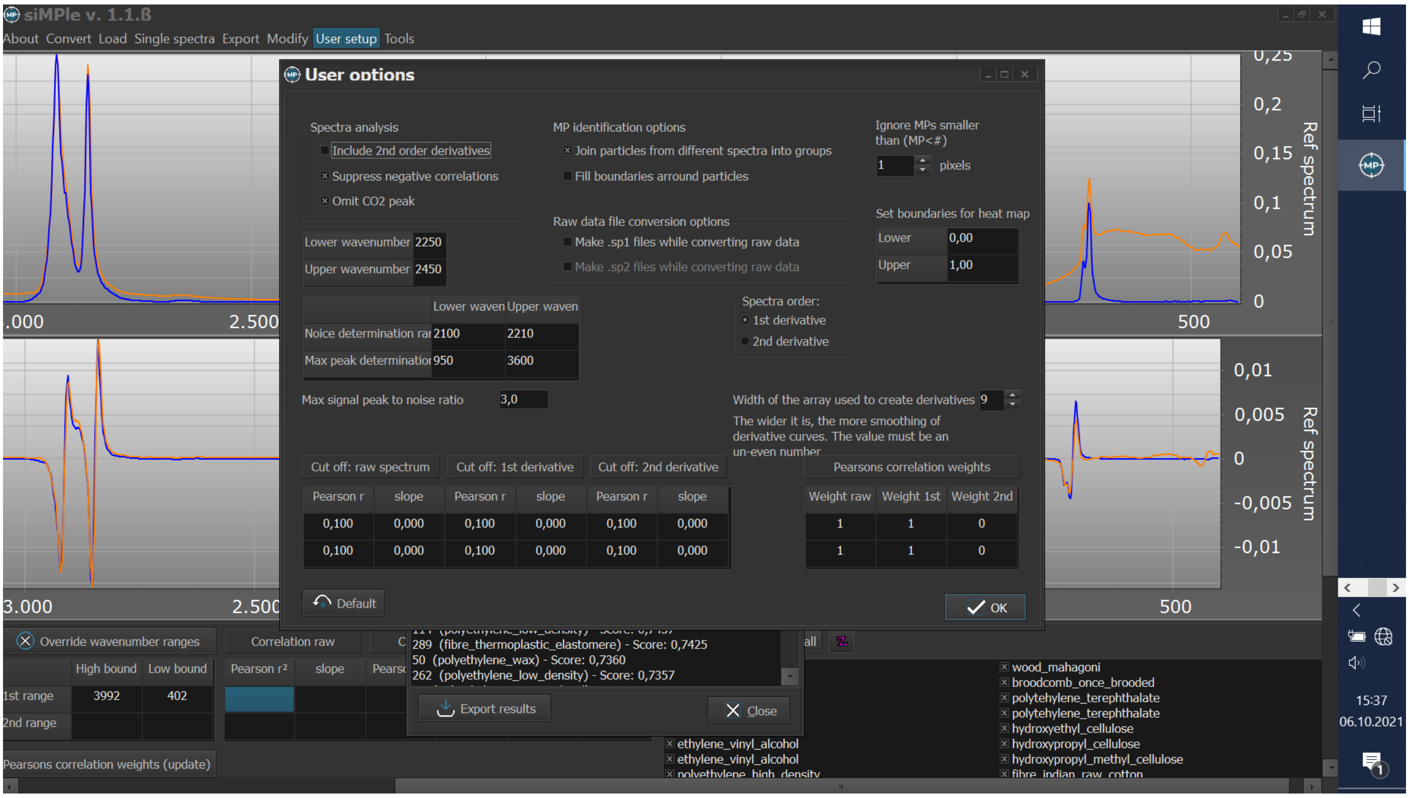
The following window opens. Choose ‘absorbance’ for both options, as below.



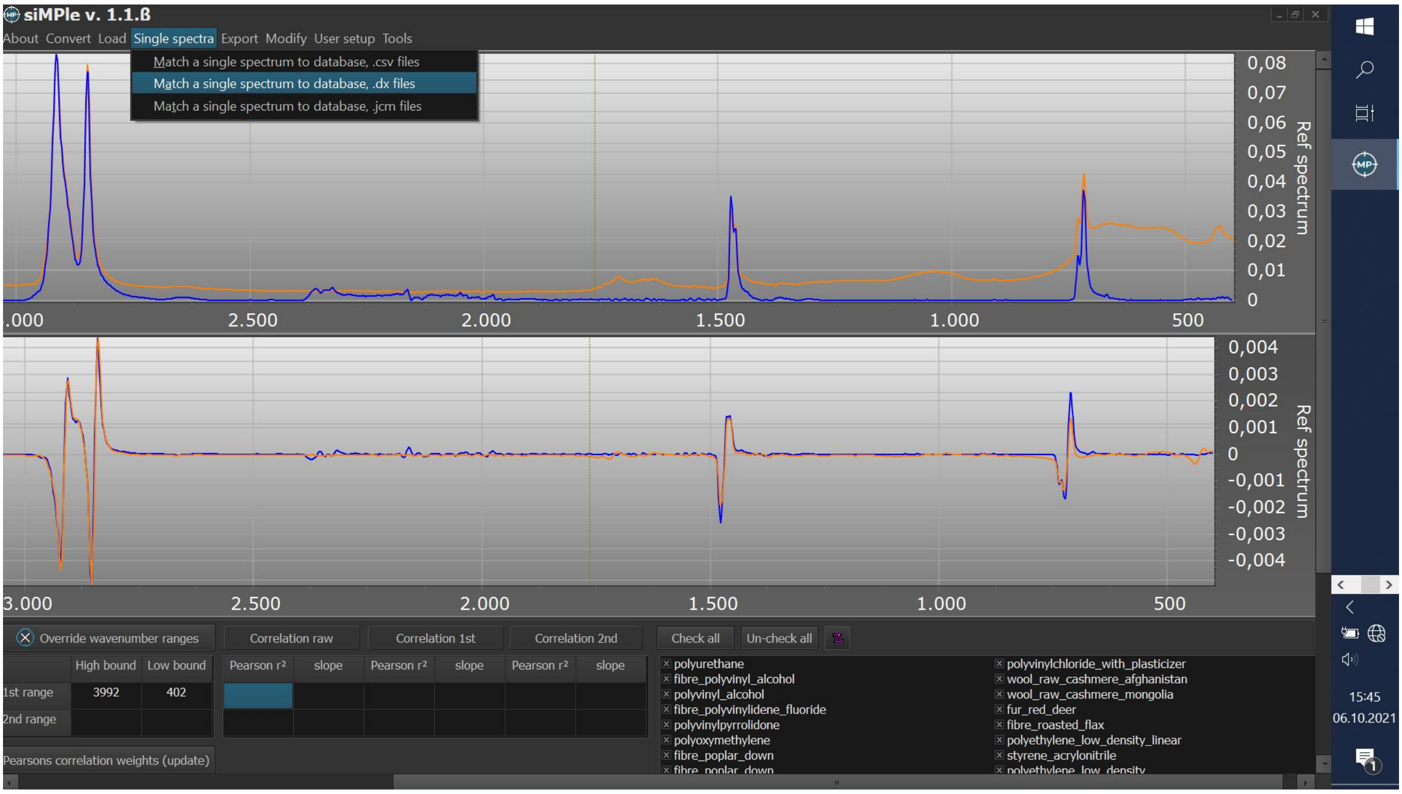
To optimize the search functions, go to User setup -> Options (see pictures below).



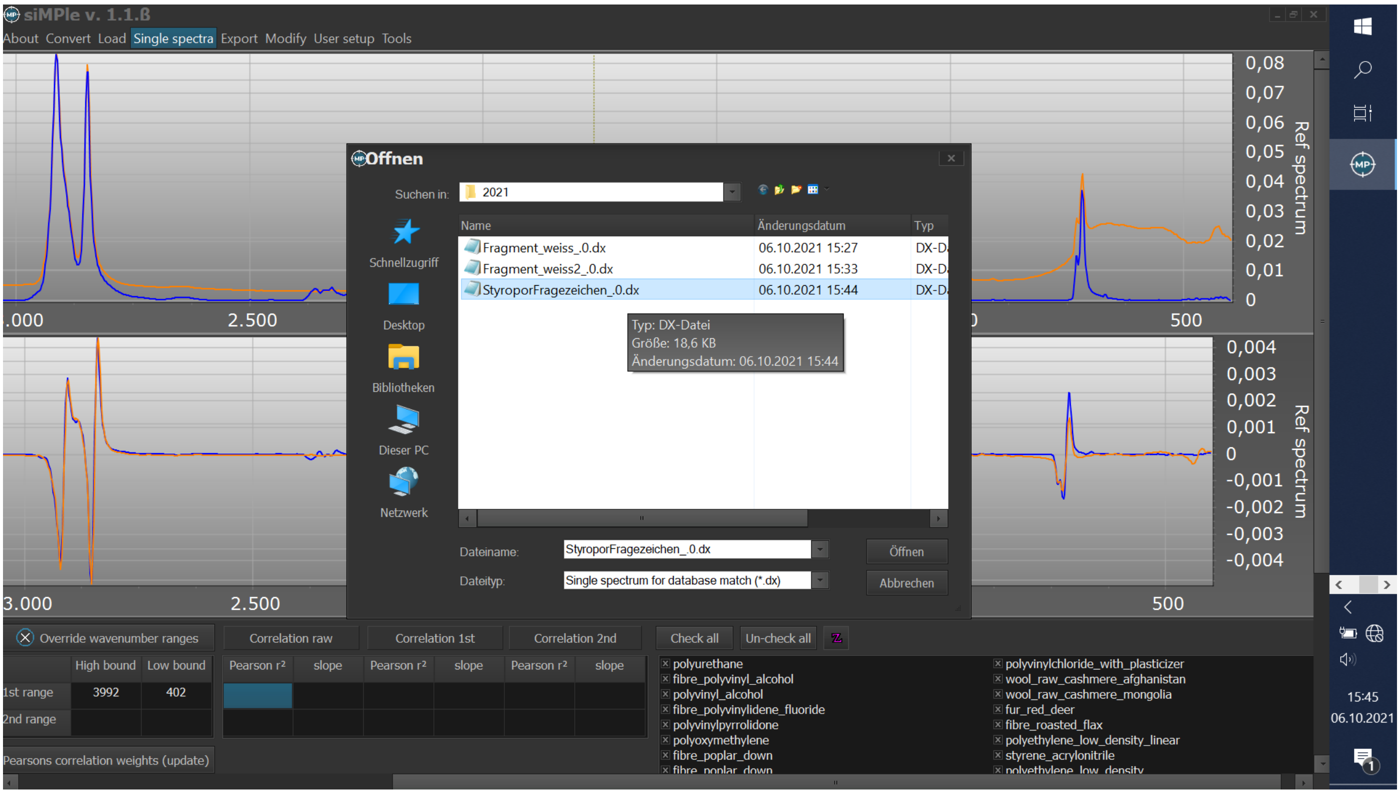
The parameter "Weight raw" can be changed from 0 to 1 which usually changes the performance. Also, the parameter "Width of the array used to create derivatives" can be changed from 9 upwards and downwards.



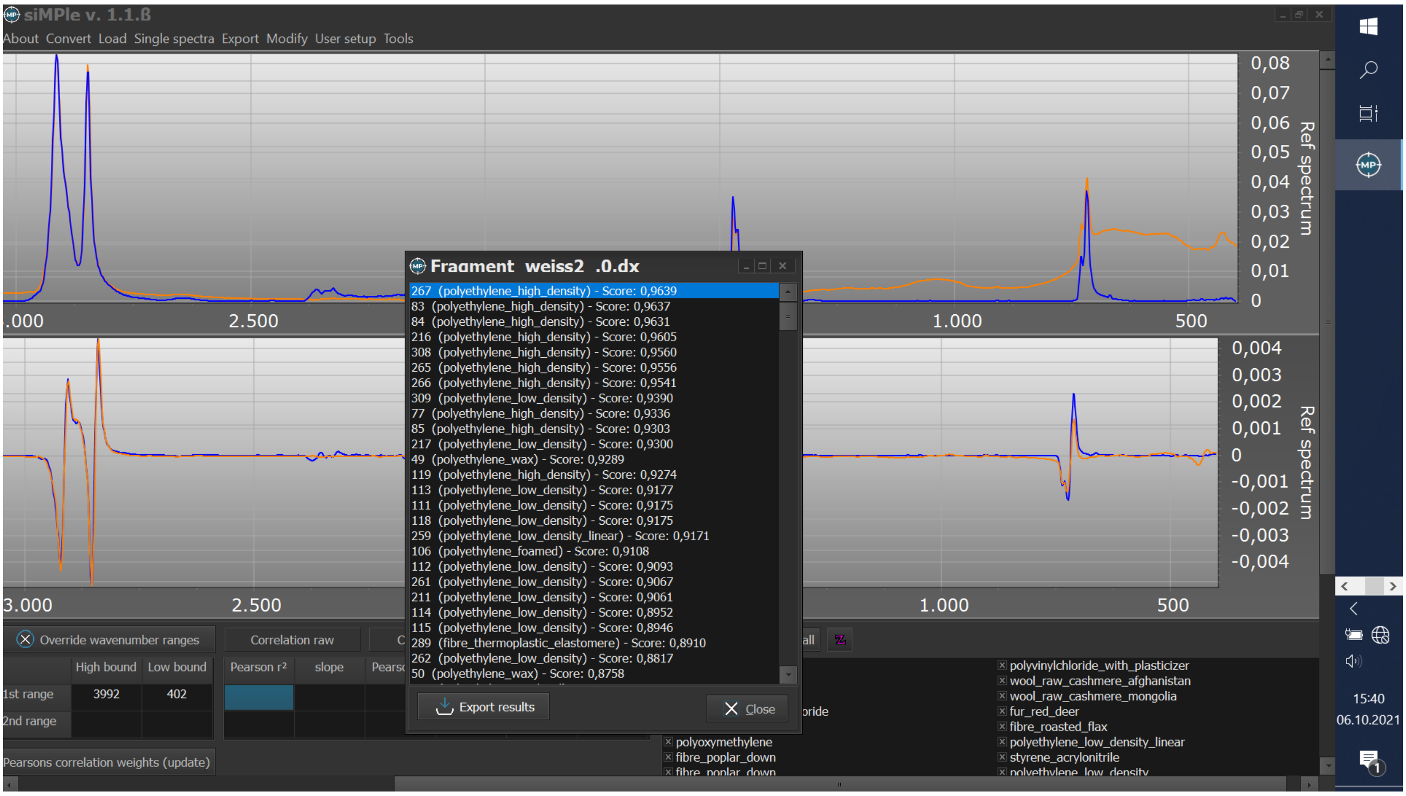
To match a spectra, go to Single spectra -> Match a single spectrum to database, *.dx files.



Then choose the *.dx file which needs to be compared.



A typical search result will look like this.



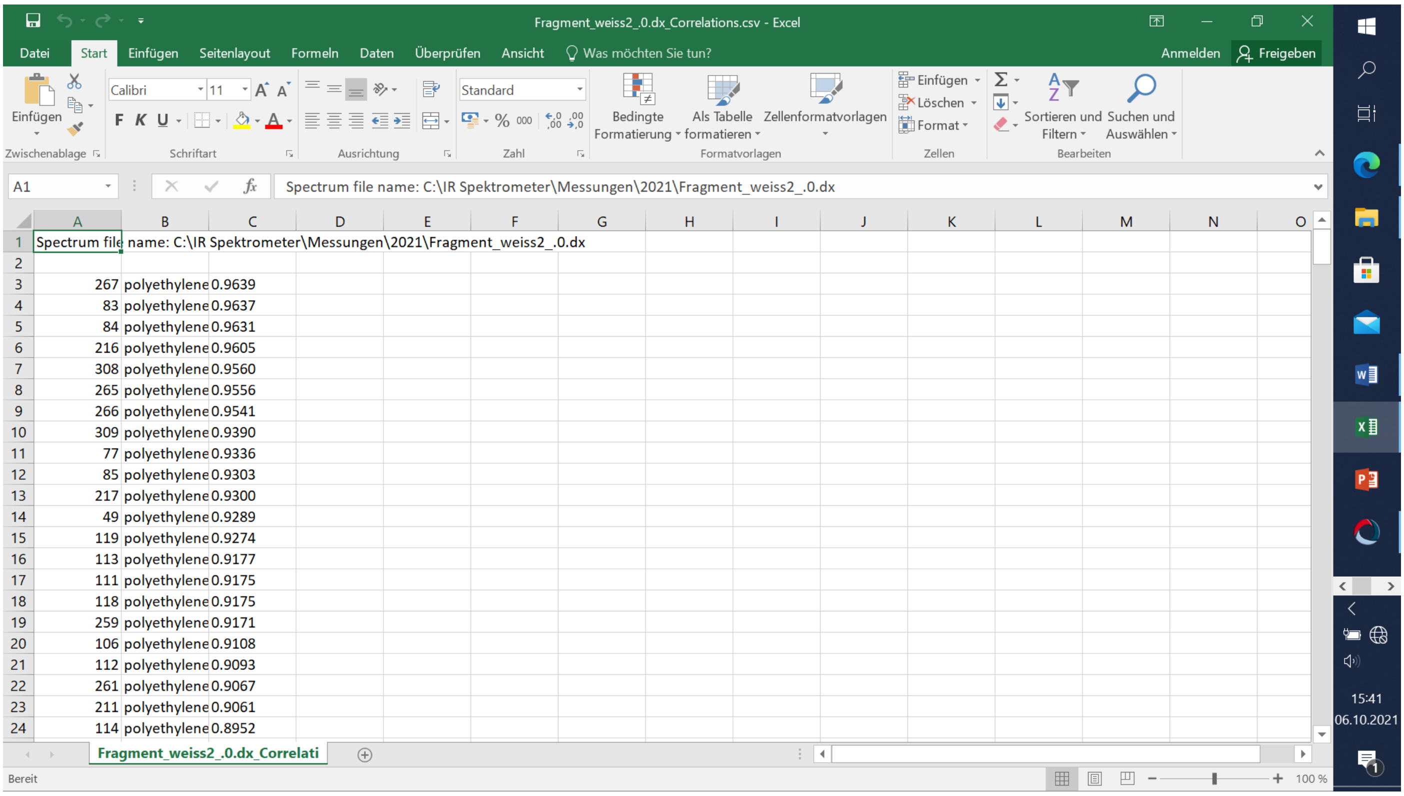
The top window shows the raw spectrum, and the bottom window shows the first derivative.

To export the results of the search, click on “Export results” and save as a *.csv file. The contents of this *.csv file (e.g., the Fragment_weiss2_.0.dx_Correlations.csv file shown below) mirror those of the results window above in siMPle.

Colum 1: the integer ID number of the reference spectrum.

Column 2: the name of the respective reference spectrum

Column 3: the matching score (or hit quality), which ranges from zero to 1 (similar to the hit quality in OPUS which ranges from 0 to 1000).



Text S8.2. Short version of the above manual for routine determination of polymer types.

Step 1. Open OPUS and siMPle.

Step 2. Check if the ATR-FTIR is good to go (green light top of ATR-FTIR, green circle bottom right of OPUS. If no, run the "PQ-Test der Energieverteilung" or do whatever is necessary to get back to the green status. If yes, then go to step 3.

Step 3. Measure the background ("Hintergrund messen") in OPUS.

Step 4. Enter the path for saving spectra in OPUS as follows:

Click on "Messen" → choose „Erstellen von Messexperimenten"

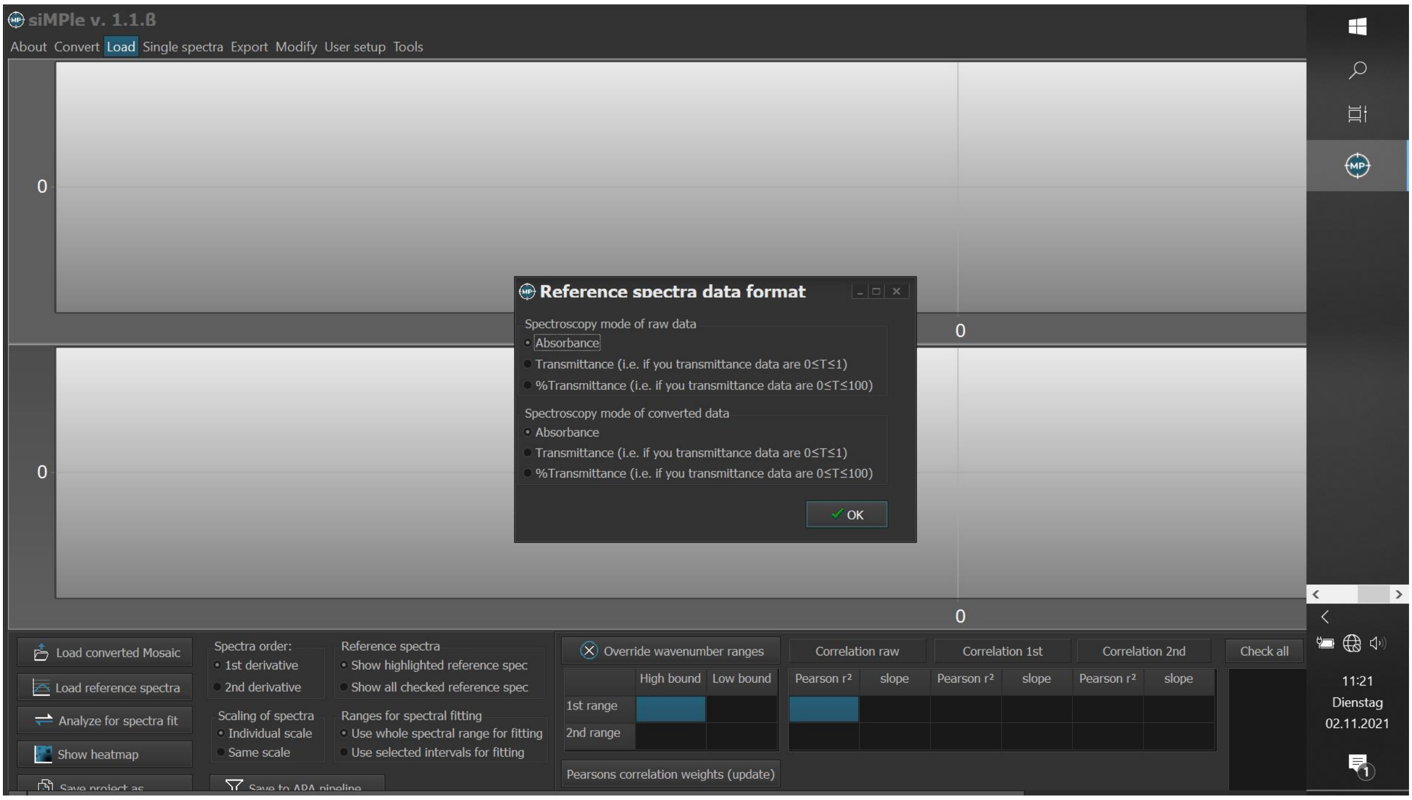
Click on "Erweitert" → choose „Pfad"

Once you have entered the path, choose "Übernehmen & schliessen".

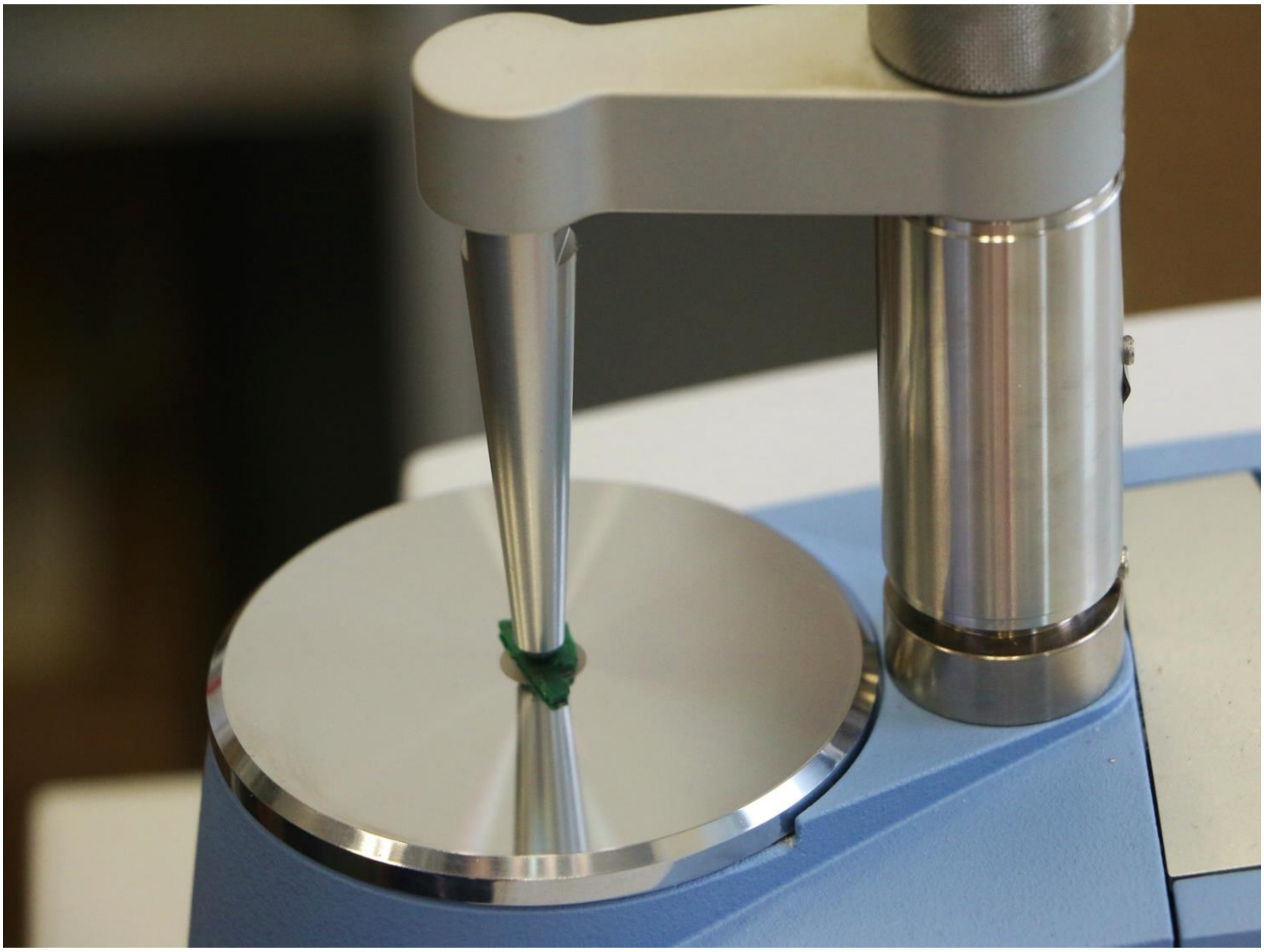
Step 5. Load the reference spectra in siMPle as follows:

Click on "Load" → choose „Load reference spectra"

The following window opens. Choose 'absorbance' for both options, as below.



Step 6. Place the putative plastic particle into the ATR-FTIR between the diamond sensor at the bottom and the holding screw of the top as shown below.



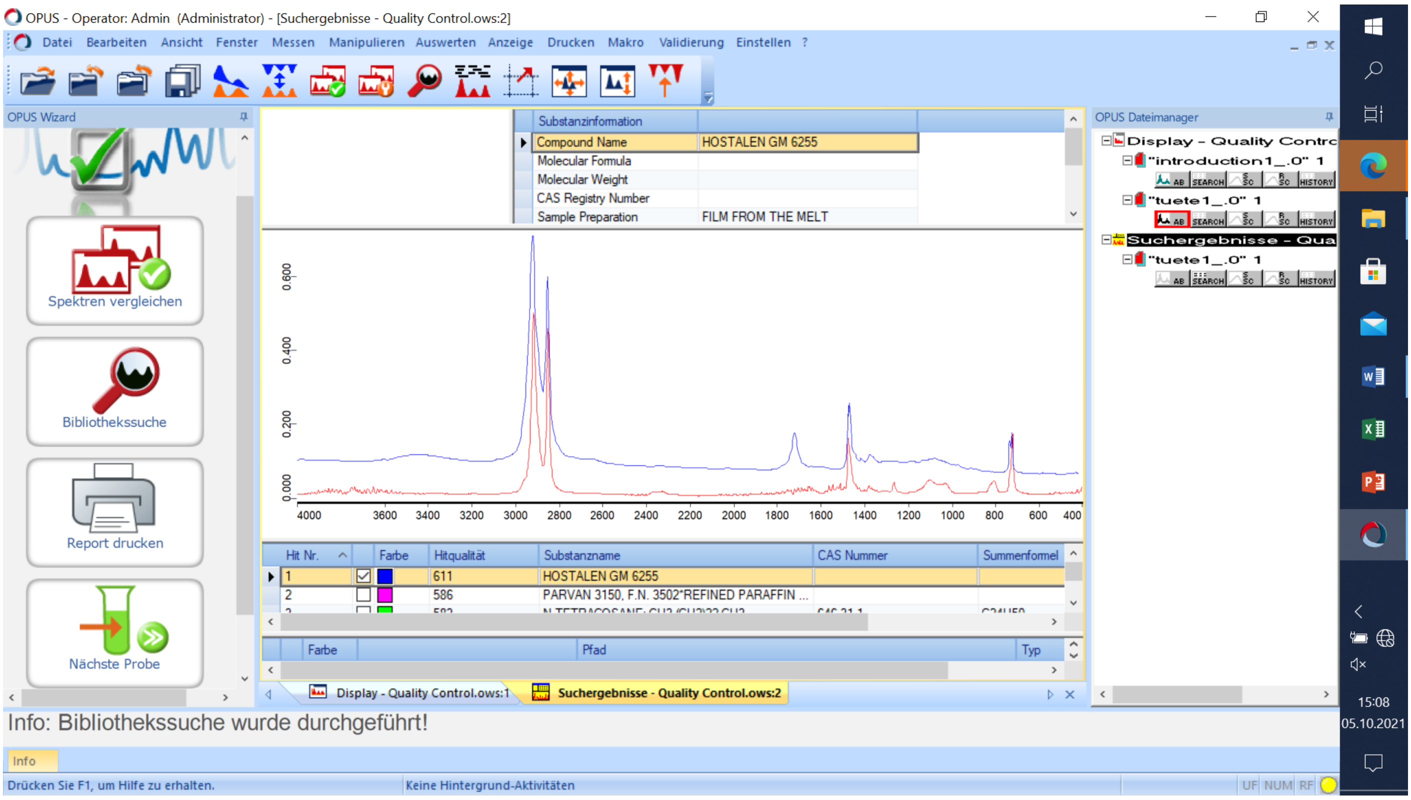
Step 7. In OPUS, click on the button “Probe messen” (or for later measurements “Nächste Probe”) in the left panel.

Step 8. Enter the name of the measurement in the field called “Probenname”.

Step 9. Click on “Probemessung starten” (not “Übernehmen & schliessen”).

Step 10. If the spectrum visible after one scan is satisfactory, click “Messung starten”. The software will then measure the sample with the predetermined number of scans (e.g., 32 scans).

Step 11. Make the respective spectrum active in the right panel. The active spectrum is the one where the small rectangle has a red frame (e.g., the second spectrum from the top in the picture below).

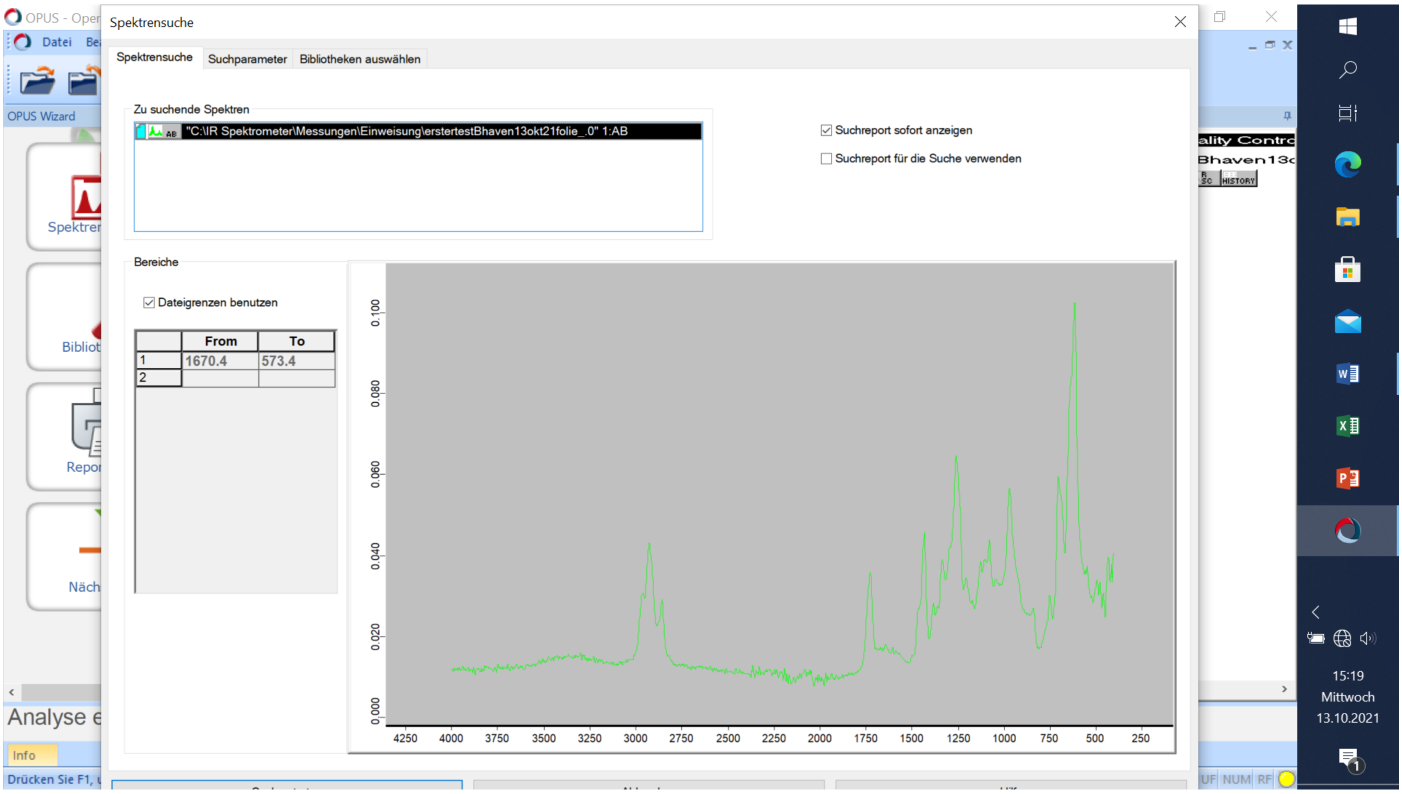


Step 12. Click on “Bibliothekssuche” → choose „Spektrensuche“.

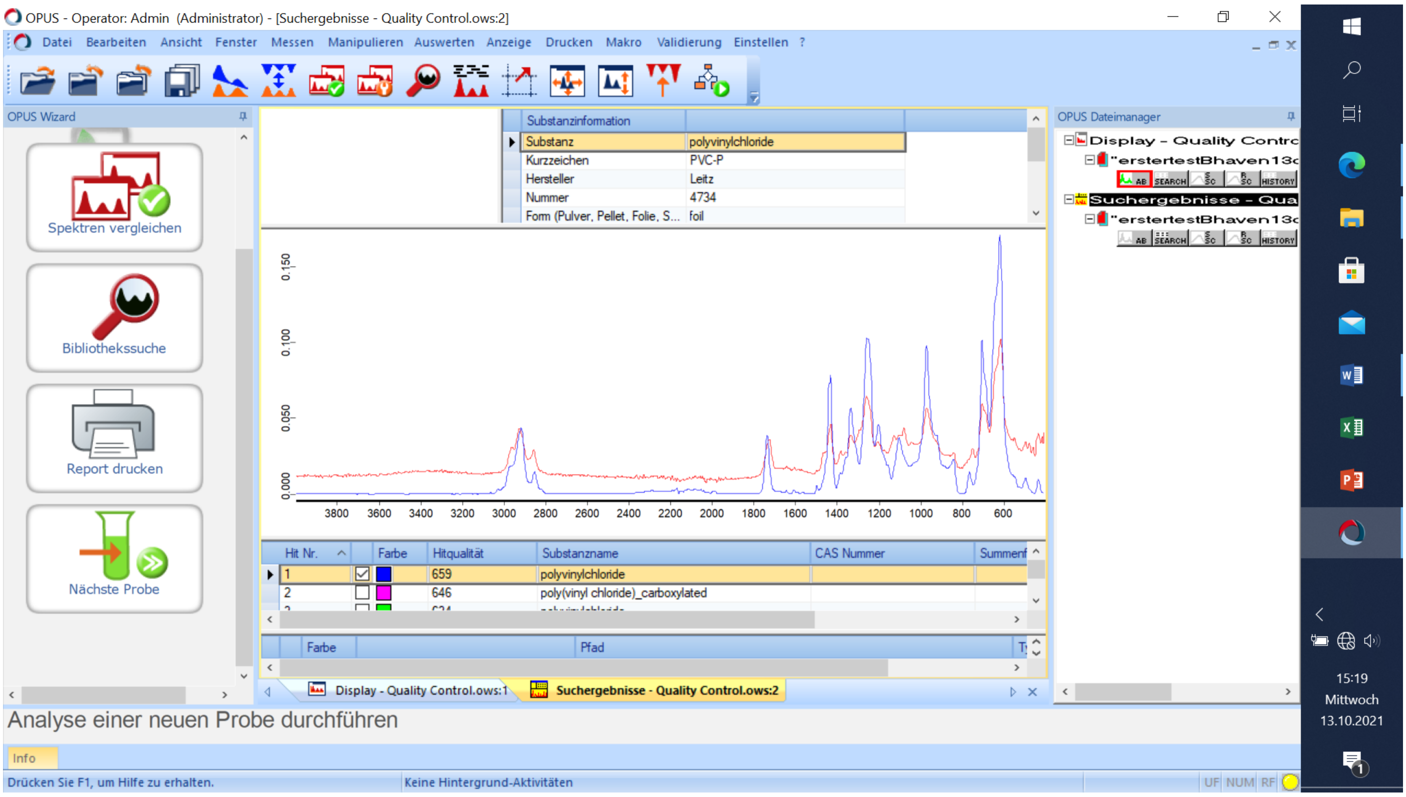
Step 13. Then set the search algorithm (“Suchalgorithmus”) to “Vektor-Nominierung” und “1. Ableitung.”

Step 14. Click on “Auswerten” → choose „Spektrensuche“.

Step 15. The window below will appear. If everything is correct, then click on the almost invisible button at the bottom left (here just visible with a light blue frame; on other computers, this window may well be visible).



Step 16. Record the hit quality (“Hitqualität”) shown in the window below.

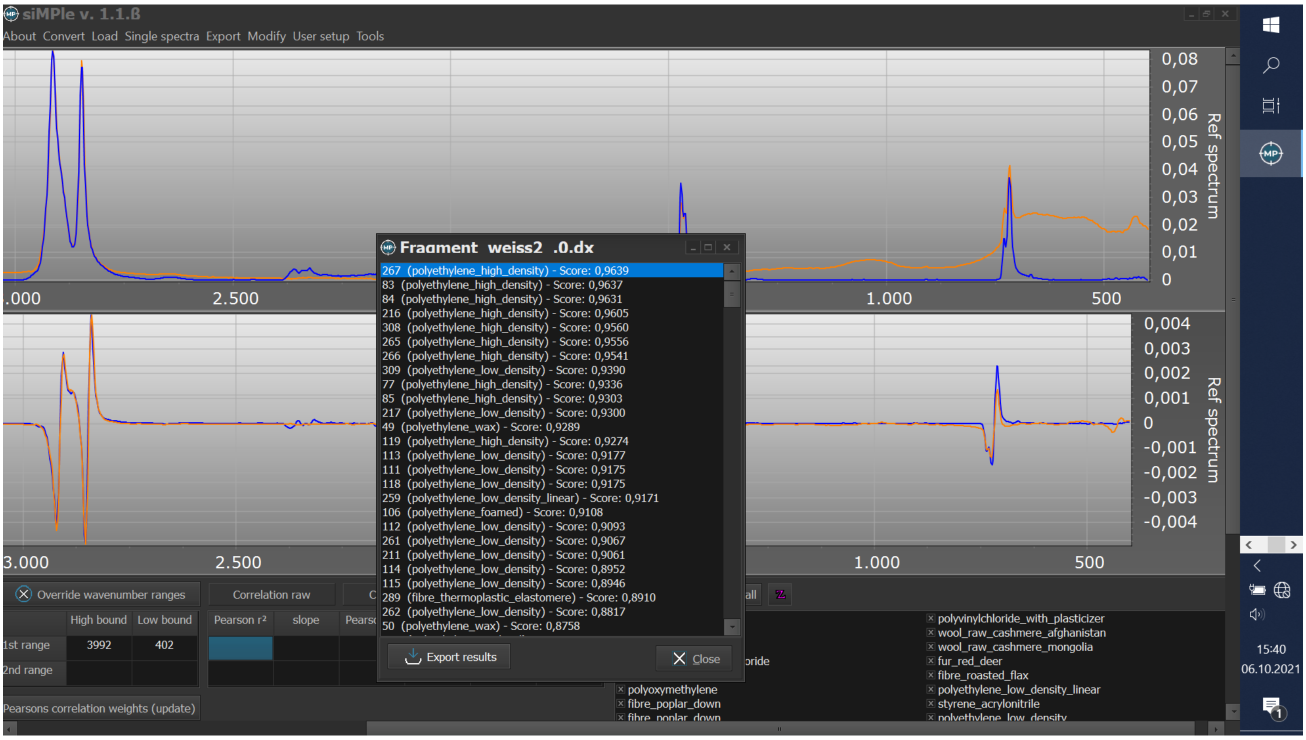


Step 17. Click on “Datei” → choose „Datei speichern“. Choose the correct path (“Pfad auswählen”).

Step 18. Click on “Modus” → choose „ JCAMP-DX “. Save the spectra as *.dx file by clicking on “Speichern”.

Step 19. In siMPle, click on “Single spectra” → choose „ Match a single spectrum to database, .dx files“. Click on the *.dx file of the spectrum which you want to analyze.

Step 20. Once siMPle has produced the search result such as this,



click on “Export results” and save the results of the search as a *.csv file.

The authors who worked in the laboratory and developed the methods presented in the laboratory workflow (Text S7) and the manual for the determination of polymer types (Text S8): From left to right: Franco Pasolini, Sarah Lorenzana, and Bruno Andreas Walther (Tabea Hepfner is not pictured).

Text S9. Short mathematical demonstration that, in our case, calculating the weighted mean is actually the same as simply dividing the total number of PP by the total mass (or volume or area) of sand.

The total sample size of sampling locations is n. Sampling locations 1 through n are noted as subscripts, and number is abbreviated as #. For each sampling location, we calculated the number of plastic particles (PP) per mass of sand (i.e., the density per mass). If we do this calculation for the mass of the sand, we then have the following results for the density per mass (in kg):

Density for sampling location 1 = density_1 = $\#PP_1/\text{mass of sand}_1$
Density for sampling location 2 = density_2 = $\#PP_2/\text{mass of sand}_2$
…
Density for sampling location n = density_n = $\#PP_n/\text{mass of sand}_n$

The **unweighted mean** of the densities is = $(\text{density}_1 + \text{density}_2 + \ldots + \text{density}_n)/n$

The **weighted mean** of the densities, however, is

$(\text{mass of sand}_1 * \text{density}_1 + \text{mass of sand}_2 * \text{density}_2 + \ldots + \text{mass of sand}_n * \text{density}_n)/(\text{mass of sand}_1 + \text{mass of sand}_2 + \ldots + \text{mass of sand}_n)$
=
$([\text{mass of sand}_1 * \#PP_1/\text{mass of sand}_1] + ([\text{mass of sand}_2 * \#PP_2/\text{mass of sand}_2] + \ldots + ([\text{mass of sand}_n * \#PP_n/\text{mass of sand}_n])/(\text{mass of sand}_1 + \text{mass of sand}_2 + \ldots + \text{mass of sand}_n)$
=
$(\#PP_1 + \#PP_2 + \ldots + \#PP_n)/\text{total mass of sand}$
=
total #PP/total mass of sand

The calculations for density per volume (per L) or density per area (per m^2) would be exactly the same.

Table S4. List of 71 sampling locations along the coastlines of the Baltic Sea and North Sea, where citizens scientists took sand samples which were analysed for microplastics. For each location, the sampling date, sample size (N_1 = sample size taken at location, N_2 = sample size analysed in laboratory), geographic coordinates, width of the beach, area sampled, and mass and volume of sand sampled are given. *Location in Denmark, all other locations in Germany. #For the first three sampling locations, the sampling area of one sample was 0.36 m^2; for all other sampling locations, the sampling area of one sample was 0.0576 m^2 (see details in Methods).

No	Location	Day	Month	Year	N_1	N_2	Latitude N	Longitude E	Width (m)	Area (m^2)	Mass (g)	Volume (ml)
1	Weststrand Norderney 1#	14	9	2021	3	3	53.69657	7.15424	50	1.08	3689.5	2600
2	Nordseestrand Norderney 1#	21	9	2021	4	4	53.71590	7.16321	120	1.44	6639.6	4680
3	Strandoase Norderney#	28	9	2021	4	4	53.71982	7.23884	250	1.44	4473.3	3010
4	Weststrand Norderney 2	19	10	2021	20	20	53.70139	7.14194	60	1.152	9633.7	6345
5	Weststrand Norderney 3	20	10	2021	20	20	53.70000	7.14556	80	1.152	11760.9	8440
6	Nordseestrand Norderney 2	21	10	2021	20	20	53.72222	7.21194	80	1.152	12738.0	7850
7	Warnemünde 1	18	11	2021	20	20	54.18164	12.08150	158	1.152	30377.9	19085
8	Hjerpsted*	25	11	2021	4	3	55.02473	8.63857	15	0.173	5210.8	3210
9	Schilksee Kiel	29	11	2021	4	4	54.42396	10.17459	16	0.230	6739.4	4250
10	Hohe Düne	7	12	2021	12	12	54.17845	12.10769	21	0.691	16610.5	9860
11	Nordstrand Wangerooge	17	12	2021	8	8	53.79390	7.87767	107	0.461	13146.2	8910
12	Sylt Hörnum	18	1	2022	20	20	54.79220	8.28244	36	1.152	41849.4	26880
13	Wyk auf Föhr	24	1	2022	20	20	54.67944	8.55250	56	1.152	24516.6	15160
14	Kiel Falckenstein	2	2	2022	8	8	54.40111	10.19139	70	0.461	16809.0	10530
15	Amrum	8	2	2022	20	19	54.69810	8.33573	125	1.094	38707.7	26110

16	Böhl in Sankt Peter Ording	28	2	2022	20	20	54.27361	8.65583	1000	1.152	41589.3	29800
17	Duhnen Cuxhaven 1	23	3	2022	20	20	53.86472	8.59556	38	1.152	51672.7	30690
18	Helgoland	25	3	2022	20	20	54.18806	7.88250	39	1.152	41089.6	25900
19	Holnis	26	3	2022	20	20	54.85667	9.59139	21	1.152	49256.0	31520
20	Solitüde	26	3	2022	20	20	54.82267	9.48833	24	1.152	47398.4	29750
21	Weidefelder Strand	26	3	2022	20	19	54.64972	10.03139	40	1.094	40511.6	24780
22	Duhnen Cuxhaven 2	30	3	2022	12	12	53.88436	8.63263	40	0.691	28114.0	18060
23	Langballigau	2	4	2022	20	20	54.82231	9.65631	30	1.152	48436.5	29450
24	Nordstrand Prerow	9	4	2022	20	20	54.45722	12.55000	40	1.152	41510.5	28440
25	Sellin	23	4	2022	20	20	54.38157	13.70235	25	1.152	50278.3	32190
26	Falckensteiner Strand Kiel	24	4	2022	12	12	54.39945	10.19147	60	0.691	29985.9	18790
27	Falkensteiner Ufer Hamburg	25	4	2022	20	20	53.56250	9.77417	29	1.152	55169.1	33160
28	Norderney	26	4	2022	4	4	53.71472	7.15806	100	0.230	5816.1	3820
29	Wassersleben	26	4	2022	20	20	54.82722	9.41944	35	1.152	48027.3	29300
30	Falshöft	1	5	2022	20	20	54.76750	9.96583	12	1.152	44997.8	29200
31	Övelgönne 1	5	5	2022	20	20	53.54417	9.91139	50	1.152	53077.9	33740
32	Pagensand Nord	8	5	2022	16	16	53.70222	9.50222	28	0.922	41565.7	26310
33	Müllrampe Norderney	9	5	2022	12	12	53.69697	7.15689	39	0.691	5466.4	3680
34	Surfschule Norderney	9	5	2022	12	12	53.70333	7.16861	40	0.691	5411.2	3590
35	Minsener Oog	10	5	2022	12	12	53.74586	8.01805	43	0.691	30354.9	19260
36	Strandbad Wedel Schulau	12	5	2022	20	18	53.57083	9.69389	30	1.037	44102.3	27920
37	Weserstrand Bremerhaven	14	5	2022	20	20	53.53750	8.57694	36	1.152	43421.7	25310
38	Fuhlehörn Nordstrand	15	5	2022	12	12	54.48626	8.81747	90	0.691	21549.3	15040
39	Weiße Düne Norderney	17	5	2022	12	9	53.70611	7.20778	45	0.518	13230.6	8770

40	Meldorfer Bucht	19	5	2022	4	4	54.09389	8.94889	8	0.230	10475.2	6720
41	Haus Detmold Norderney	20	5	2022	12	12	53.71972	7.17583	41	0.691	5291.1	3570
42	Warwerort	20	5	2022	8	8	54.12528	8.93167	3	0.461	20792.3	12930
43	Weststrand Norderney 4	20	5	2022	12	12	53.70167	7.14194	20	0.691	4941.6	2920
44	Pagensand Süd	6	6	2022	12	12	53.67000	9.52222	12	0.691	26811.3	17320
45	Hetlinger Schanze	17	6	2022	20	18	53.60278	9.60167	20	1.037	46841.1	29220
46	Spiekeroog 1	20	6	2022	20	20	53.77972	7.73111	35	1.152	40330.5	26500
47	Mukran/Prora Rügen	25	6	2022	4	4	54.46667	13.56972	12	0.230	9982.0	6430
48	Övelgönne 2	28	6	2022	20	20	53.54417	9.90167	17	1.152	49090.0	30560
49	Elbstrand	29	6	2022	20	20	53.54417	9.90500	24	1.152	27094.0	16820
50	Kinderspielplatz Norderney	19	7	2022	12	12	53.70028	7.14417	99	0.691	5605.3	3780
51	Schönberger Strand	21	7	2022	20	20	54.41861	10.40639	20	1.152	53358.8	34990
52	Spiekeroog 2	29	7	2022	20	20	53.76732	7.67159	194	1.152	41371.0	27250
53	Sierksdorf	6	8	2022	16	16	54.05932	10.76031	28	0.922	31636.2	20070
54	Ahrenshoop	16	8	2022	12	12	54.37583	12.40611	19	0.691	27714.7	17250
55	Dornumersiel	18	8	2022	20	20	53.68209	7.48629	4	1.152	30283.8	18710
56	Rømø*	19	8	2022	12	12	55.08626	8.47527	36	0.691	23053.6	14660
57	Niendorf	20	8	2022	16	16	53.99472	10.81639	42	0.922	28263.2	16860
58	Bensersiel Ost	22	8	2022	20	20	53.68027	7.57251	3	1.152	27892.1	17530
59	Prerow Strandausgang 39	5	9	2022	12	12	54.45139	12.59111	17	0.691	31105.6	20090
60	Harriersand	10	9	2022	20	20	53.33167	8.49722	30	1.152	48356.7	30300
61	Travemünde	10	9	2022	16	16	53.96500	10.88278	102	0.922	28807.5	17750
62	Zingst	13	9	2022	20	20	54.44167	12.73611	24	1.152	46763.6	30290
63	Schillig	22	9	2022	40	40	53.70710	8.02714	30	2.304	72375.2	43520
64	Damp Südstrand	14	10	2022	20	20	54.58081	10.02644	30	1.152	30401.8	19840

65	List auf Sylt Weststrand	30	10	2022	20	20	55.03700	8.38400	60	1.152	45001.2	28530
66	Baabe	2	11	2022	20	20	54.36192	13.71763	36	1.152	54275.1	33710
67	Brake	13	11	2022	20	20	53.30556	8.48806	15	1.152	45158.7	30350
68	Kleinensiel	13	11	2022	20	20	53.44611	8.48472	9	1.152	44213.2	27300
69	Binz	21	11	2022	20	20	54.41702	13.59525	35	1.152	54435.1	34020
70	Gager	1	12	2022	20	20	54.30000	13.71562	21	1.152	54461.6	34280
71	Warnemünde 2	5	12	2022	20	20	54.17737	12.05623	43	1.152	54443.3	33720

Table S5. List of 71 sampling locations (see details in Table S4). For each location, the following data are given: the unique location identifier (ID), number of microplastics (# micro), number of mesoplastics (# meso), number of macroplastics (# macro), and density per m^2 (D_{area}), density per kg (D_{mass}), and density per litre (D_{vol}) for micro- and mesoplastics (MM) or micro-, meso- and macroplastics (PP), respectively. The two PP whose maximum length was not determined (Table S7) were excluded in this table.

No	Location	ID	# MP	# ME	# MA	D_{area} MM	D_{mass} MM	D_{vol} MM	D_{area} PP	D_{mass} PP	D_{vol} PP
1	Weststrand Norderney 1	No11	0	1	0	0.93	0.27	0.38	0.93	0.27	0.38
2	Nordseestrand Norderney 1	No10	0	1	1	0.69	0.15	0.21	1.39	0.30	0.43
3	Strandoase Norderney	No9	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
4	Weststrand Norderney 2	No1	5	6	4	9.55	1.14	1.73	13.02	1.56	2.36
5	Weststrand Norderney 3	No2	1	0	0	0.87	0.09	0.12	0.87	0.09	0.12
6	Nordseestrand Norderney 2	No3	8	2	4	8.68	0.79	1.27	12.15	1.10	1.78
7	Warnemünde 1	Wmd1	4	14	2	15.62	0.59	0.94	17.36	0.66	1.05
8	Hjerpsted	HJ	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
9	Schilksee Kiel	KSch	2	0	2	8.68	0.30	0.47	17.36	0.59	0.94
10	Hohe Düne	HoD	4	11	3	21.70	0.90	1.52	26.04	1.08	1.83
11	Nordstrand Wangerooge	WR	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
12	Sylt Hörnum	SyH	2	0	2	1.74	0.05	0.07	3.47	0.10	0.15
13	Wyk auf Föhr	Wyk	1	3	1	3.47	0.16	0.26	4.34	0.20	0.33
14	Kiel Falckenstein	KFA	1	0	1	2.17	0.06	0.09	4.34	0.12	0.19
15	Amrum	AM	0	1	3	0.91	0.03	0.04	3.65	0.10	0.15
16	Böhl in Sankt Peter Ording	SPO	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
17	Duhnen Cuxhaven 1	Cux	1	6	3	6.08	0.14	0.23	8.68	0.19	0.33
18	Helgoland	Hel	2	2	0	3.47	0.10	0.15	3.47	0.10	0.15

19	Holnis	HO	0	2	0	1.74	0.04	0.06	1.74	0.04	0.06
20	Solitüde	SOL	3	1	0	3.47	0.08	0.13	3.47	0.08	0.13
21	Weidefelder Strand	Weif	0	6	3	5.48	0.15	0.24	8.22	0.22	0.36
22	Duhnen Cuxhaven 2	DUH	1	2	1	4.34	0.11	0.17	5.79	0.14	0.22
23	Langballigau	LABA	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
24	Nordstrand Prerow	NOPR	0	1	0	0.87	0.02	0.04	0.87	0.02	0.04
25	Sellin	Sell	1	1	0	1.74	0.04	0.06	1.74	0.04	0.06
26	Falckensteiner Strand Kiel	FLCK	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
27	Falkensteiner Ufer Hamburg	FALKHH	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
28	Norderney	No12	1	1	1	8.68	0.34	0.52	13.02	0.52	0.79
29	Wassersleben	WASLE	8	17	1	21.70	0.52	0.85	22.57	0.54	0.89
30	Falshöft	FALÖ	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
31	Övelgönne 1	ÖV	14	11	1	21.70	0.47	0.74	22.57	0.49	0.77
32	Pagensand Nord	PaNo	1	0	0	1.09	0.02	0.04	1.09	0.02	0.04
33	Müllrampe Norderney	No7	0	1	1	1.45	0.18	0.27	2.89	0.37	0.54
34	Surfschule Norderney	No6	0	1	0	1.45	0.18	0.28	1.45	0.18	0.28
35	Minsener Oog	MO	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
36	Strandbad Wedel Schulau	SLAU	2	3	1	4.82	0.11	0.18	5.79	0.14	0.21
37	Weserstrand Bremerhaven	WESBRH	0	1	1	.87	0.02	0.04	1.74	0.05	0.08
38	Fuhlehörn Nordstrand	GJSCH	1	0	0	1.45	0.05	0.07	1.45	0.05	0.07
39	Weiße Düne Norderney	No8	0	3	2	5.79	0.23	0.34	9.65	0.38	0.57
40	Meldorfer Bucht	MeHa	2	0	1	8.68	0.19	0.30	13.02	0.29	0.45
41	Haus Detmold Norderney	No4	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
42	Warwerort	WaWe	1	1	0	4.34	0.10	0.15	4.34	0.10	0.15
43	Weststrand Norderney 4	No13	1	2	1	4.34	0.61	1.03	5.79	0.81	1.37

44	Pagensand Süd	PGS	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
45	Hetlinger Schanze	HET	2	7	0	8.68	0.19	0.31	8.68	0.19	0.31
46	Spiekeroog 1	SPOG	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
47	Mukran/Prora Rügen	MP	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
48	Övelgönne 2	ÖVG	1	2	0	2.60	0.06	0.10	2.60	0.06	0.10
49	Elbstrand	ELB	1	0	0	.87	0.04	0.06	0.87	0.04	0.06
50	Kinderspielplatz Norderney	No5	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
51	Schönberger Strand	SSO	0	2	0	1.74	0.04	0.06	1.74	0.04	0.06
52	Spiekeroog 2	SPOO	0	2	0	1.74	0.05	0.07	1.74	0.05	0.07
53	Sierksdorf	Sie	0	1	0	1.09	0.03	0.05	1.09	0.03	0.05
54	Ahrenshoop	Ah	2	1	0	4.34	0.11	0.17	4.34	0.11	0.17
55	Dornumersiel	Dos	0	2	0	1.74	0.07	0.11	1.74	0.07	0.11
56	Rømø	ROO	1	1	2	2.89	0.09	0.14	5.79	0.17	0.27
57	Niendorf	Nie	0	1	0	1.09	0.04	0.06	1.09	0.04	0.06
58	Bensersiel Ost	BEN	1	0	0	0.87	0.04	0.06	0.87	0.04	0.06
59	Prerow Strandausgang 39	PRW	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
60	Harriersand	HSD	0	3	2	2.60	0.06	0.10	4.34	0.10	0.17
61	Travemünde	TRA	0	0	2	0.00	0.00	0.00	2.17	0.07	0.11
62	Zingst	ZST	0	1	0	0.87	0.02	0.03	0.87	0.02	0.03
63	Schillig	SCG	0	1	1	0.43	0.01	0.02	0.87	0.03	0.05
64	Damp Südstrand	DPS	1	1	2	1.74	0.07	0.10	3.47	0.13	0.20
65	List auf Sylt Weststrand	LSW	1	1	0	1.74	0.04	0.07	1.74	0.04	0.07
66	Baabe	BAAB	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
67	Brake	BRA	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
68	Kleinensiel	KLE	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00

69	Binz	BINZ	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
70	Gager	GAGE	0	2	0	1.74	0.04	0.06	1.74	0.04	0.06
71	Warnemünde 2	WAR12	0	3	0	2.60	0.06	0.09	2.60	0.06	0.09

Table S6. List of 71 sampling locations (see details in Table S4). For each location, the following data are given: the density per m^2 (D_{area}), density per kg (D_{mass}), and density per litre (D_{vol}) for microplastics (MP), mesoplastics (ME), or macroplastics (MA), respectively. The two PP whose maximum length was not determined (Table S7) were excluded in this table.

No	Location	D_{area} MP	D_{mass} MP	D_{vol} MP	D_{area} ME	D_{mass} ME	D_{vol} ME	D_{area} MA	D_{mass} MA	D_{vol} MA
1	Weststrand Norderney 1	0.00	0.00	0.00	0.93	0.27	0.38	0.00	0.00	0.00
2	Nordseestrand Norderney 1	0.00	0.00	0.00	0.69	0.15	0.21	0.69	0.15	0.21
3	Strandoase Norderney	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Weststrand Norderney 2	4.34	0.52	0.79	5.21	0.62	0.95	3.47	0.42	0.63
5	Weststrand Norderney 3	0.87	0.09	0.12	0.00	0.00	0.00	0.00	0.00	0.00
6	Nordseestrand Norderney 2	6.94	0.63	1.02	1.74	0.16	0.25	3.47	0.31	0.51
7	Warnemünde 1	3.47	0.13	0.21	12.15	0.46	0.73	1.74	0.07	0.10
8	Hjerpsted	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Schilksee Kiel	8.68	0.30	0.47	0.00	0.00	0.00	8.68	0.30	0.47
10	Hohe Düne	5.79	0.24	0.41	15.91	0.66	1.12	4.34	0.18	0.30
11	Nordstrand Wangerooge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Sylt Hörnum	1.74	0.05	0.07	0.00	0.00	0.00	1.74	0.05	0.07
13	Wyk auf Föhr	0.87	0.04	0.07	2.60	0.12	0.20	0.87	0.04	0.07
14	Kiel Falckenstein	2.17	0.06	0.09	0.00	0.00	0.00	2.17	0.06	0.09
15	Amrum	0.00	0.00	0.00	0.91	0.03	0.04	2.74	0.08	0.11
16	Böhl in Sankt Peter Ording	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Duhnen Cuxhaven 1	0.87	0.02	0.03	5.21	0.12	0.20	2.60	0.06	0.10
18	Helgoland	1.74	0.05	0.08	1.74	0.05	0.08	0.00	0.00	0.00
19	Holnis	0.00	0.00	0.00	1.74	0.04	0.06	0.00	0.00	0.00

20	Solitüde	2.60	0.06	0.10	0.87	0.02	0.03	0.00	0.00	0.00
21	Weidefelder Strand	0.00	0.00	0.00	5.48	0.15	0.24	2.74	0.07	0.12
22	Duhnen Cuxhaven 2	1.45	0.04	0.06	2.89	0.07	0.11	1.45	0.04	0.06
23	Langballigau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Nordstrand Prerow	0.00	0.00	0.00	0.87	0.02	0.04	0.00	0.00	0.00
25	Sellin	0.87	0.02	0.03	0.87	0.02	0.03	0.00	0.00	0.00
26	Falckensteiner Strand Kiel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Falkensteiner Ufer Hamburg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	Norderney	4.34	0.17	0.26	4.34	0.17	0.26	4.34	0.17	0.26
29	Wassersleben	6.94	0.17	0.27	14.76	0.35	0.58	0.87	0.02	0.03
30	Falshöft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Övelgönne 1	12.15	0.26	0.41	9.55	0.21	0.33	0.87	0.02	0.03
32	Pagensand Nord	1.09	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00
33	Müllrampe Norderney	0.00	0.00	0.00	1.45	0.18	0.27	1.45	0.18	0.27
34	Surfschule Norderney	0.00	0.00	0.00	1.45	0.18	0.28	0.00	0.00	0.00
35	Minsener Oog	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	Strandbad Wedel Schulau	1.93	0.05	0.07	2.89	0.07	0.11	0.96	0.02	0.04
37	Weserstrand Bremerhaven	0.00	0.00	0.00	0.87	0.02	0.04	0.87	0.02	0.04
38	Fuhlehörn Nordstrand	1.45	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
39	Weiße Düne Norderney	0.00	0.00	0.00	5.79	0.23	0.34	3.86	0.15	0.23
40	Meldorfer Bucht	8.68	0.19	0.30	0.00	0.00	0.00	4.34	0.10	0.15
41	Haus Detmold Norderney	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	Warwerort	2.17	0.05	0.08	2.17	0.05	0.08	0.00	0.00	0.00
43	Weststrand Norderney 4	1.45	0.20	0.34	2.89	0.40	0.68	1.45	0.20	0.34
44	Pagensand Süd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

45	Hetlinger Schanze	1.93	0.04	0.07	6.75	0.15	0.24	0.00	0.00	0.00
46	Spiekeroog 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	Mukran/Prora Rügen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	Övelgönne 2	0.87	0.02	0.03	1.74	0.04	0.07	0.00	0.00	0.00
49	Elbstrand	0.87	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00
50	Kinderspielplatz Norderney	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	Schönberger Strand	0.00	0.00	0.00	1.74	0.04	0.06	0.00	0.00	0.00
52	Spiekeroog 2	0.00	0.00	0.00	1.74	0.05	0.07	0.00	0.00	0.00
53	Sierksdorf	0.00	0.00	0.00	1.09	0.03	0.05	0.00	0.00	0.00
54	Ahrenshoop	2.89	0.07	0.12	1.45	0.04	0.06	0.00	0.00	0.00
55	Dornumersiel	0.00	0.00	0.00	1.74	0.07	0.11	0.00	0.00	0.00
56	Rømø	1.45	0.04	0.07	1.45	0.04	0.07	2.89	0.09	0.14
57	Niendorf	0.00	0.00	0.00	1.09	0.04	0.06	0.00	0.00	0.00
58	Bensersiel Ost	0.87	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00
59	Prerow Strandausgang 39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	Harriersand	0.00	0.00	0.00	2.60	0.06	0.10	1.74	0.04	0.07
61	Travemünde	0.00	0.00	0.00	0.00	0.00	0.00	2.17	0.07	0.11
62	Zingst	0.00	0.00	0.00	0.87	0.02	0.03	0.00	0.00	0.00
63	Schillig	0.00	0.00	0.00	0.43	0.01	0.02	0.43	0.01	0.02
64	Damp Südstrand	0.87	0.03	0.05	0.87	0.03	0.05	1.74	0.07	0.10
65	List auf Sylt Weststrand	0.87	0.02	0.04	0.87	0.02	0.04	0.00	0.00	0.00
66	Baabe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	Brake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	Kleinensiel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	Binz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

70	Gager	0.00	0.00	0.00	1.74	0.04	0.06	0.00	0.00	0.00
71	Warnemünde 2	0.00	0.00	0.00	2.60	0.06	0.09	0.00	0.00	0.00

Table S7. Characteristics of 260 plastic particles found at 71 sampling locations. All particles had an HQI ≥ 0.70 (*except three particles which were identified visually as plastic particles). The following data are given: the unique location identifier = ID (see Table S5); line ID = the identifier of the collection line (see Figure 1); sample ID = the identifier of the sample's location within the respective collection line (see Figure 1); particle ID = the identifier of each plastic particle which is a combination of the unique location identifier (ID), line ID, sample ID, and a consecutive number x given as MPx (which corresponds with the ID of the photo taken; see Supplemental Materials 'Photos of plastic particles'); shape, maximum length, colour, and polymer type = for definitions of these four categories, see Methods (unknown = data not available for various reasons; MP = this particle was the length of a microplastic, but was not measured to exact millimeters).

No.	ID	Line ID	Sample ID	Particle ID	Shape	Length (mm)	Colour	Polymer type
1	Ah	1L	S4	Ah_1L_S4_MP1	fibre	10.5	black	polyester
2	Ah	1L	S4	Ah_1L_S4_MP2	foam	3.9	beige	polystyrene
3	Ah	1L	S4	Ah_1L_S4_MP3	foam	3.0	white	polystyrene
4	AM	1L	S2	AM_1L_S2_MP1	fragment	28.0	yellow	polypropylene
5	AM	1R	S2	AM_1R_S2_MP1	foil	38.0	translucent	polyethylene high density
6	AM	1R	S2	AM_1R_S2_MP2	fragment	7.0	blue	polyester epoxide
7	AM	1R	S4	AM_1R_S4_MP1	foil	121.0	colourful	polyethylene low density
8	BEN	0L	S4	BEN_0L_S4_MP1	fibre	unknown	white	polyethylene high density
9	BEN	1R	S1	BEN_1R_S1_MP1	fragment	1.0	white	polyethylene high density
10	Cux	0L	S3	Cux_0L_S3_MP1	foam	5.0	white	polystyrene expanded
11	Cux	0L	S4	Cux_0L_S4_MP1	foil	8.0	yellow	polypropylene
12	Cux	1L	S2	Cux_1L_S2_MP1	foil	25.0	white	polypropylene
13	Cux	1L	S4	Cux_1L_S4_MP1	fragment	16.0	green	ethylene vinyl alcohol
14	Cux	1L	S4	Cux_1L_S4_MP2 two separate fragments in 1 photo	foam	12.0	white	polystyrene expanded
15	Cux	1L	S4	Cux_1L_S4_MP2 two separate fragments in 1 photo	foam	10.0	white	polystyrene expanded
16	Cux	1R	S3	Cux_1R_S3_MP1	fragment	2.0	white	polypropylene
17	Cux	2L	S2	Cux_2L_S2_MP1	foil	32.0	translucent	polypropylene
18	Cux	2L	S2	Cux_2L_S2_MP2	foil	58.0	translucent	polyethylene low density
19	Cux	2R	S2	Cux_2R_S2_MP1	foam	5.0	white	polystyrene expanded
20	Dos	2L	S4	Dos_2L_S4_MP1	foam	13.0	white	polystyrene
21	Dos	2R	S2	Dos_2R_S2_MP1	foam	17.9	white	polystyrene

22	DPS	0L	S2	DPS_0L_S2_MP1	fragment	4.4	red	polyester epoxide
23	DPS	0L	S4	DPS_0L_S4_MP1	cigarette filter	23.0	beige	cigarette filter
24	DPS	1R	S1	DPS_1R_S1_MP1	foil	105.6	translucent	polyester
25	DPS	1R	S3	DPS_1R_S3_MP1	foil	33.4	blue	polyethylene low density
26	DUH	0L	S1	DUH_0L_S1_MP1	lollypop stick	73.1	white	polypropylene
27	DUH	0L	S2	DUH_0L_S2_MP1	foam	5.0	white	polystyrene
28	DUH	0L	S3	DUH_0L_S3_MP1	foam	4.9	white	polystyrene
29	DUH	1L	S2	DUH_1L_S2_MP1	fragment	17.2	green	polypropylene
30	ELB	0L	S4	ELB_0L_S4_MP1	pellet	4.8	white	polyethylene low density
31	GAGE	1L	S1	photo not available	fragment	8.8	red	polypropylene
32	GAGE	1R	S3	photo not available	fragment	11.5	white	polyethylene low density
33	GJSCH	1L	S1	GJSCH_1L_S1_MP1	fragment	4.0	white	polyethylene low density
34	Hel	0L	S1	Hel_0L_S1_MP1	fragment	7.0	blue	styrene acrylonitrile
35	Hel	1L	S3	Hel_1L_S3_MP1	foil	4.0	white	polyethylene high density
36	Hel	1R	S2	Hel_1R_S2_MP1	fragment	22.0	blue	polystyrene
37	Hel	2L	S1	Hel_2L_S1_MP1	foil	2.0	white	polyethylene high density
38	HET	0L	S2	HET_0L_S2_MP2	pellet	5.0	brown	polyethylene low density
39	HET	0L	S2	HET_0L_S2_MP3	pellet	5.0	white	polyethylene low density
40	HET	0L	S2	HET_0L_S2_MP4	fragment	4.5	grey	polystyrene
41	HET	0L	S3	HET_0L_S3_MP1	foam	5.5	colourful	polystyrene
42	HET	1L	S1	HET_1L_S1_MP1	fragment	4.0	translucent	polyethylene high density
43	HET	1L	S4	HET_1L_S4_MP1	fragment	14.0	colourful	polyethylene low density
44	HET	1R	S2	HET_1R_S2_MP1	foil	12.0	black	polyethylene low density
45	HET	2L	S3	HET_2L_S3_MP1	fragment	20.0	black	polypropylene
46	HET	2R	S3	HET_2R_S3_MP1	foil	12.0	white	fibre thermoplastic elastomere
47	HO	0L	S3	HO_0L_S3_MP1	foil	5.0	white	polyethylene high density
48	HO	1R	S3	HO_1R_S4_MP1	foil	6.5	blue	polyethylene high density
49	HoD	0L	S1	HoD_0L_S1_MP1	foil	12.0	translucent	polyethylene low density
50	HoD	0L	S3	HoD_0L_S3_MP1	foil	28.0	translucent	polyethylene high density
51	HoD	0L	S3	HoD_0L_S3_MP2	foil	7.0	translucent	polyethylene low density
52	HoD	0L	S4	HoD_0L_S4_MP1	foil	7.5	translucent	polyethylene low density
53	HoD	1L	S1	HoD_1L_S1_MP1	foil	44.0	brown	polypropylene
54	HoD	1L	S1	HoD_1L_S1_MP2	fragment	3.0	white	polyethylene high density
55	HoD	1L	S2	HoD_1L_S2_MP1	foam	8.0	blue	polyethylene high density

56	HoD	1L	S2	HoD_1L_S2_MP2	fragment	3.0	black	polypropylene
57	HoD	1L	S3	HoD_1L_S3_MP1	fragment	1.5	white	polypropylene
58	HoD	1L	S4	HoD_1L_S4_MP1	foam	8.0	blue	polyethylene high density
59	HoD	1L	S4	HoD_1L_S4_MP2	fibre	5.0	blue	polyethylene high density
60	HoD	2L	S1	HoD_2L_S1_MP1	foil	14.0	green	polyethylene low density
61	HoD	2L	S2	HoD_2L_S2_MP1	fibre	6.0	blue	polyethylene high density
62	HoD	2L	S2	HoD_2L_S2_MP2	fragment	5.0	white	polypropylene
63	HoD	2L	S2	HoD_2L_S2_MP3	fibre	5.0	white	polypropylene
64	HoD	2L	S3	HoD_2L_S3_MP1	foil	32.0	brown	polypropylene
65	HoD	2L	S4	HoD_2L_S4_MP1	pellet	4.0	white	polypropylene
66	HoD	2L	S4	HoD_2L_S4_MP2	fragment	5.5	white	polystyrene
67	HSD	0L	S3	HSD_0L_S3_MP1	foil	12.0	red	polyethylene low density
68	HSD	1L	S3	HSD_1L_S3_MP1	cigarette filter	26.0	beige	cigarette filter
69	HSD	1L	S3	HSD_1L_S3_MP2	fibre	36.0	blue	polyethylene high density
70	HSD	1R	S3	HSD_1R_S3_MP1	foam	10.0	white	polystyrene
71	HSD	2L	S2	HSD_2L_S2_MP1	foam	15.5	white	polystyrene
72	KFA	0L	S3	KFA_0L_S3_MP1	fragment	31.0	white	polystyrene
73	KFA	1L	S3	KFA_1L_S3_MP1	pellet	4.0	white	polyethylene low density
74	KSch	0L	S4	KSCH_0L_S4_MP1	foil	46.0	translucent	polypropylene
75*	KSch	0L	S3	photo not available	unknown	150.0	unknown	unknown
76	KSch	0L	S3	photo not available	foam	2.0	white	polystyrene
77	KSch	0L	S3	photo not available	foam	4.0	white	polystyrene
78	LSW	1R	S3	LSW_1R_S3_MP1	foil	11.3	translucent	fibre thermoplastic elastomere
79	LSW	2R	S2	LSW_2R_S2_MP1	pellet	4.0	white	polypropylene
80	MeHa	0L	S4	MeHa_0L_S4_MP1	fibre	36.5	green	polypropylene
81	MeHa	0L	S4	MeHa_0L_S4_MP2	foam	4.0	white	polystyrene
82	MeHa	0L	S4	MeHa_0L_S4_MP4	fragment	3.0	white	polyethylene high density
83	MeHa	0L	S4	photo not available	pellet	unknown	white	polyethylene high density
84	Nie	0L	S4	Nie_0L_S4_MP1	fragment	9.5	pink	polyvinylchloride
85	No1	0L	S1	No1_0L_S1_MP1	foil	18.0	white	polyethylene high density
86	No1	0L	S1	No1_0L_S1_MP2	fragment	5.0	white	polypropylene
87	No1	0L	S2	No1_0L_S2_MP1	fragment	3.0	white	polyethylene high density
88	No1	0L	S2	No1_0L_S2_MP2	fragment	5.0	beige	polyethylene low density
89	No1	0L	S4	No1_0L_S4_MP1	fibre	29.0	white	ethylene propylene

90	No1	1L	S1	No1_1L_S1_MP1	pellet	4.0	white	polyethylene high density
91	No1	1L	S1	No1_1L_S1_MP2	fragment	5.0	white	polyethylene wax
92	No1	1L	S2	No1_1L_S2_MP1	foil	27.0	colourful	polypropylene
93	No1	1L	S2	No1_1L_S2_MP2	fragment	16.0	grey	polyethylene low density
94	No1	1R	S3	No1_1R_S3_MP1	pellet	5.0	white	polyethylene low density
95	No1	1R	S4	No1_1R_S4_MP1	fibre	2.0	white	polyester
96	No1	2L	S2	No1_2L_S2_MP1	fragment	4.0	white	polypropylene
97	No1	2L	S2	No1_2L_S2_MP2	fibre	36.0	white	polypropylene
98	No1	2R	S4	No1_2R_S4_MP1 two separate fragments in 1 photo	foil	3.0	green	polyethylene low density
99	No1	2R	S4	No1_2R_S4_MP1 two separate fragments in 1 photo	foil	70.0	white	polyethylene low density
100	No10	0L	S3	No10_0L_S3_MP1	fibre	32.0	blue	polyethylene high density
101	No10	0L	S4	No10_0L_S4_MP1	foam	15.0	red	polyvinylidene fluoride
102	No11	0L	S1	No11_0L_S1_MP1	fragment	16.5	green	polypropylene
103	No12	unknown	unknown	No12_MP1	foil	15.5	grey	polyethylene high density
104	No12	unknown	unknown	No12_MP3	fragment	42.0	grey	polyethylene low density
105	No12	unknown	unknown	No12_MP5	foam	3.5	white	polystyrene
106	No13	0L	S2	No13_0L_S2_MP1	button	16.0	black	polyacetal
107	No13	0L	S3	No13_0L_S3_MP1	fibre	112.0	green	polypropylene
108	No13	2L	S3	No13_2L_S3_MP1	fragment	14.5	green	polypropylene
109	No13	2L	S3	No13_2L_S3_MP2	pellet	4.5	translucent	polypropylene
110	No2	1L	S1	No2_1L_S1_MP1	fragment	3.0	white	silicone rubber
111	No3	0L	S1	No3_0L_S1_MP1	fragment	4.0	beige	polyethylene high density
112	No3	0L	S1	No3_0L_S1_MP2	fragment	3.0	white	polyethylene high density
113	No3	0L	S1	No3_0L_S1_MP3	fragment	2.0	white	polyethylene high density
114	No3	0L	S3	No3_0L_S3_MP1	fragment	45.0	green	polyethylene low density
115	No3	0L	S4	No3_0L_S4_MP1	foam	29.5	white	polystyrene
116	No3	0L	S4	No3_0L_S4_MP2	pellet	4.5	white	polyethylene high density
117	No3	1R	S1	No3_1R_S1_MP1	fibre	55.0	blue	polyethylene high density
118	No3	1R	S4	No3_1R_S4_MP1	foam	32.0	blue	polystyrene
119	No3	2L	S1	No3_2L_S1_MP1	fragment	3.5	translucent	polyethylene high density
120	No3	2L	S4	No3_2L_S4_MP1	foam	21.0	white	polystyrene
121	No3	2R	S1	No3_2R_S1_MP1	foam	20.0	white	polystyrene
122	No3	2R	S2	No3_2R_S2_MP1	pellet	4.5	orange	polyethylene high density
123	No3	2R	S2	No3_2R_S2_MP2	pellet	4.5	white	polyethylene low density

124	No3	2R	S2	No3_2R_S2_MP3	fragment	MP	blue	polypropylene
125	No6	unknown	unknown	No6_MP1	foil	11.0	white	polyethylene low density
126	No7	0L	S3	No7_0L_S3_MP1	cigarette filter	20.0	white	cigarette filter
127	No7	unknown	unknown	No7_MP1	fibre	56.0	green	polyethylene high density
128	No8	1L	S1	No8_1L_S1_MP1	foil	36.0	translucent	polyethylene terephthalate
129	No8	1L	S3	No8_1L_S3_MP1	foam	10.0	white	polystyrene
130	No8	1L	S4	No8_1L_S4_MP1	fragment	17.0	green	polystyrene
131	No8	unknown	unknown	No8_MP1	foil	40.0	colourful	polypropylene
132	No8	unknown	unknown	No8_MP2	foam	8.0	white	polystyrene
133	NOPR	unknown	unknown	NOPR_MP1	foil	7.0	brown	polypropylene
134	ÖV	0L	S3	ÖV_0L_S3_MP1	pellet	5.0	white	polyethylene low density
135	ÖV	0L	S4	ÖV_0L_S4_MP1	pellet	5.5	white	polyethylene low density
136	ÖV	0L	S4	ÖV_0L_S4_MP10	fragment	2.0	white	polystyrene
137	ÖV	0L	S4	ÖV_0L_S4_MP4	foam	3.9	white	polystyrene
138	ÖV	0L	S4	ÖV_0L_S4_MP5	foam	4.0	white	polystyrene
139	ÖV	1L	S2	ÖV_1L_S2_MP1	foam	8.0	grey	polypropylene
140	ÖV	1L	S2	ÖV_1L_S2_MP2	foil	7.0	black	polypropylene
141	ÖV	1L	S2	ÖV_1L_S2_MP3	foam	4.0	white	polystyrene
142	ÖV	1L	S3	ÖV_1L_S3_MP1	pellet	4.0	white	polyethylene low density
143	ÖV	1L	S3	ÖV_1L_S3_MP2	fragment	9.9	white	polyethylene low density
144	ÖV	1L	S3	ÖV_1L_S3_MP3	fibre	8.0	green	polyethylene low density
145	ÖV	1L	S3	ÖV_1L_S3_MP4	fragment	5.0	white	polypropylene
146	ÖV	1L	S4	ÖV_1L_S4_MP2	foam	4.5	yellow	polystyrene
147	ÖV	1L	S4	ÖV_1L_S4_MP6	foam	2.0	beige	polystyrene
148	ÖV	1L	S4	ÖV_1L_S4_MP8	foam	3.0	white	polystyrene
149	ÖV	1R	S4	ÖV_1R_S4_MP1	fibre	160.0	brown	polyethylene terephthalate
150	ÖV	1R	S4	ÖV_1R_S4_MP2	fibre	12.9	black	polyester
151	ÖV	2L	S2	ÖV_2L_S2_MP1	pellet	6.9	white	polyethylene high density
152	ÖV	2L	S3	ÖV_2L_S3_MP1	pellet	4.5	white	polypropylene
153	ÖV	2L	S3	ÖV_2L_S3_MP2	fragment	4.0	white	polystyrene
154	ÖV	2L	S4	ÖV_2L_S4_MP1	foil	19.0	white	polyethylene low density
155	ÖV	2L	S4	ÖV_2L_S4_MP4	foam	6.0	beige	polystyrene
156	ÖV	2L	S4	ÖV_2L_S4_MP6	foam	2.0	beige	polystyrene
157	ÖV	2L	S4	ÖV_2L_S4_MP7	foam	2.4	beige	polystyrene

158	ÖV	2L	S4	ÖV_2L_S4_MP8	foam	2.5	beige	polystyrene
159	ÖV	2L	S4	ÖV_2L_S4_MP9	fragment	2.5	beige	polystyrene
160	ÖVG	2R	S1	ÖVG_2R_S1_MP1	pellet	5.0	white	polyethylene low density
161	ÖVG	2R	S3	ÖVG_2R_S3_MP1	foam	3.3	white	polystyrene expanded
162	ÖVG	2R	S4	ÖVG_2R_S4_MP1	foam	16.3	white	polystyrene
163	PaNo	1L	S4	PaNo_1L_S4_MP1	foam	3.5	white	polystyrene
164	ROO	0L	S4	ROO_0L_S4_MP1	fibre	101.4	orange	polyethylene high density
165	ROO	1L	S1	ROO_1L_S1_MP1	fragment	3.6	white	polypropylene
166	ROO	1L	S1	ROO_1L_S1_MP2	fragment	10.8	blue	polyethylene low density
167	ROO	1L	S4	ROO_1L_S4_MP1	foil	58.0	colourful	ethylene propylene
168	SCG	1L	S4	SCG_1L_S4_MP1	cigarette filter	21.0	beige	cigarette filter
169	SCG	4R	S4	SCG_4R_S4_MP1	cigarette filter	27.0	beige	cigarette filter
170	Sell	2L	S1	Sell_2L_S1_MP1	fragment	2.5	white	polystyrene
171	Sell	2L	S4	Sell_2L_S4_MP1	fragment	5.0	white	polypropylene
172	Sie	2R	S4	Sie_2R_S4_MP1	fragment	5.5	white	copolyester
173	SLAU	0L	S1	SLAU_0L_S1_MP1	fragment	8.0	grey	polyethylene high density
174	SLAU	1L	S2	SLAU_1L_S2_MP1	fragment	3.0	blue	polyester
175	SLAU	1R	S2	SLAU_1R_S2_MP1	fibre	72.0	black	nylon
176	SLAU	1R	S2	SLAU_1R_S2_MP2	fragment	3.0	translucent	polyethylene high density
177	SLAU	2R	S3	SLAU_2R_S3_MP1	fragment	21.0	black	polypropylene
178	SLAU	2R	S3	SLAU_2R_S3_MP4	fragment	5.0	translucent	polyethylene low density
179	SOL	1R	S4	SOL_1R_S4_MP1	foam	4.0	white	polystyrene
180	SOL	2L	S4	SOL_2L_S4_MP3	foil	9.1	green	polyethylene chlorinated
181	SOL	2L	S4	SOL_2L_S4_MP4	fibre	2.0	black	polyester
182	SOL	2L	S4	SOL_2L_S4_MP5	foam	3.0	white	polystyrene
183	SPOO	0L	S4	SPOO_0L_S4_MP1	fragment	5.0	white	polyethylene high density
184	SPOO	1R	S4	SPOO_1R_S4_MP1	fragment	16.5	white	polystyrene
185	SSO	0L	S3	SSO_0L_S3_MP1	fragment	9.0	black	polyethylene high density
186	SSO	2L	S2	SSO_2L_S2_MP1	fibre	6.0	yellow	polyurethane
187	SyH	0L	S1	SyH_0L_S1_MP1	fibre	95.5	yellow	polyethylene low density
188	SyH	1L	S2	SyH_1L_S2_MP1	fragment	32.5	translucent	polypropylene
189	SyH	2L	S3	SyH_2L_S3_MP1	fragment	2.0	white	polypropylene
190	SyH	2R	S2	SyH_2R_S2_MP1	fragment	1.0	yellow	polyethylene oxidized
191*	TRA	0L	S2	TRA_0L_S2_MP1	bottle cap	32.1	colourful	bottle cap

192*	TRA	1R	S4	TRA_1R_S4_MP1	foil	79.0	yellow	foil
193	WAR12	2R	S3	photo not available	foam	11.2	white	polystyrene
194	WAR12	2R	S1	photo not available	fibre	21.3	orange	polyethylene high density
195	WAR12	0L	S3	photo not available	plastic cap	10.3	white	polyethylene high density
196	WASLE	0L	S1	WASLE_0L_S1_MP1	fragment	5.0	blue	polyethylene high density
197	WASLE	0L	S4	WASLE_0L_S4_MP1	fragment	7.0	green	polypropylene
198	WASLE	0L	S4	WASLE_0L_S4_MP2	fibre	21.0	orange	polyester
199	WASLE	0L	S4	WASLE_0L_S4_MP3	fragment	14.0	white	polyethylene low density
200	WASLE	1L	S1	WASLE_1L_S1_MP1	fragment	7.0	white	polyethylene high density
201	WASLE	1L	S2	WASLE_1L_S2_MP1 two separate pellets in 1 photo	pellet	3.5	white	polyethylene low density
202	WASLE	1L	S2	WASLE_1L_S2_MP1 two separate pellets in 1 photo	pellet	4.5	white	polyethylene low density
203	WASLE	1L	S2	WASLE_1L_S2_MP2	fragment	4.0	white	polypropylene
204	WASLE	1L	S4	WASLE_1L_S4_MP1	fragment	10.0	white	polyethylene low density
205	WASLE	1L	S4	WASLE_1L_S4_MP2	fragment	14.0	beige	polyethylene low density
206	WASLE	1L	S4	WASLE_1L_S4_MP3	fragment	4.0	pink	polyester epoxide
207	WASLE	1L	S4	WASLE_1L_S4_MP4	fragment	10.0	yellow	polyethylene high density
208	WASLE	1R	S1	WASLE_1R_S1_MP1	pellet	5.0	yellow	ethylene vinyl alcohol
209	WASLE	1R	S2	WASLE_1R_S2_MP1	fibre	26.0	grey	polypropylene
210	WASLE	1R	S2	WASLE_1R_S2_MP2	fragment	14.0	translucent	polypropylene
211	WASLE	1R	S2	WASLE_1R_S2_MP3	pellet	5.0	white	polyethylene low density
212	WASLE	1R	S2	WASLE_1R_S2_MP4	fragment	3.0	red	polystyrene
213	WASLE	1R	S2	WASLE_1R_S2_MP5	fragment	3.0	blue	polyethylene high density
214	WASLE	1R	S3	WASLE_1R_S3_MP1	pellet	3.0	beige	polyethylene low density
215	WASLE	1R	S3	WASLE_1R_S3_MP2	fragment	3.0	red	polyethylene low density
216	WASLE	1R	S3	WASLE_1R_S3_MP3	fragment	7.0	blue	polyethylene low density
217	WASLE	1R	S3	WASLE_1R_S3_MP4	fragment	8.0	grey	polypropylene
218	WASLE	2L	S4	WASLE_2L_S4_MP1	fragment	5.0	blue	polyethylene high density
219	WASLE	2L	S4	WASLE_2L_S4_MP2	fibre	7.0	blue	polyethylene high density
220	WASLE	2R	S2	WASLE_2R_S2_MP1	fibre	10.0	blue	polypropylene
221	WASLE	2R	S3	WASLE_2R_S3_MP1	fragment	10.0	black	polyethylene low density
222	WaWe	1L	S2	WaWe_1L_S2_MP1 two separate fragments in 1 photo	fragment	5.0	pink	polyester epoxide
223	WaWe	1L	S2	WaWe_1L_S2_MP1 two separate fragments in 1 photo	fragment	2.0	pink	polyester epoxide
224	Weif	0L	S3	Weif_0L_S3_MP1	fragment	12.0	translucent	polypropylene
225	Weif	0L	S4	Weif_0L_S4_MP1	foil	7.0	colourful	ethylene ethyl acrylate

226	Weif	1L	S4	Weif_1L_S4_MP1	foil	21.0	colourful	polypropylene
227	Weif	1L	S4	Weif_1L_S4_MP2	fibre	18.0	white	polypropylene
228	Weif	1R	S4	Weif_1R_S4_MP1	fibre	26.0	green	polyethylene high density
229	Weif	2L	S1	Weif_2L_S1_MP1	fibre	55.0	black	polypropylene
230	Weif	2L	S4	Weif_2L_S4_MP1	foam	9.0	white	polystyrene
231	Weif	2R	S3	Weif_2R_S3_MP1	fibre	14.0	blue	polyethylene high density
232	Weif	2R	S4	Weif_2R_S4_MP1	fragment	37.0	red	polyurethane
233	WESBRH	2L	S4	WESBRH_2L_S4_MP3	fragment	13.0	grey	polyethylene low density
234	WESBRH	2R	S2	WESBRH_2R_S2_MP1	fibre	95.0	orange	polypropylene
235	Wmd1	0L	S2	Wmd1_0L_S2_MP1	foil	20.0	white	polypropylene
236	Wmd1	0L	S3	Wmd1_0L_S3_MP1	foil	16.0	white	polyethylene low density
237	Wmd1	0L	S3	Wmd1_0L_S3_MP2	fibre	17.0	white	polyethylene low density
238	Wmd1	0L	S3	Wmd1_0L_S3_MP4	foil	7.0	white	polypropylene
239	Wmd1	1L	S1	Wmd1_1L_S1_MP1	foil	20.0	white	polyethylene low density
240	Wmd1	1L	S1	Wmd1_1L_S1_MP2 two separate fragments in 1 photo	fragment	3.0	pink	styrene acrylonitrile
241	Wmd1	1L	S1	Wmd1_1L_S1_MP2 two separate fragments in 1 photo	fragment	2.0	pink	styrene acrylonitrile
242	Wmd1	1L	S3	Wmd1_1L_S3_MP1	fragment	8.0	colourful	polyethylene terephthalate
243	Wmd1	1L	S3	Wmd1_1L_S3_MP2	foil	4.0	white	polypropylene
244	Wmd1	1L	S3	Wmd1_1L_S3_MP3	fibre	33.0	blue	polyethylene terephthalate
245	Wmd1	1L	S4	Wmd1_1L_S4_MP1	foil	18.0	white	polypropylene
246	Wmd1	1R	S1	Wmd1_1R_S1_MP1	fragment	5.0	yellow	polyester
247	Wmd1	1R	S2	Wmd1_1R_S2_MP1	fragment	5.0	brown	polypropylene
248	Wmd1	1R	S3	Wmd1_1R_S3_MP1	foil	3.0	white	ethylene vinyl acetate
249	Wmd1	2L	S2	Wmd1_2L_S2_MP1	foil	11.0	brown	polypropylene
250	Wmd1	2L	S2	Wmd1_2L_S2_MP2	fibre	17.0	green	polypropylene
251	Wmd1	2L	S3	Wmd1_2L_S3_MP1	fibre	7.0	red	polyethylene high density
252	Wmd1	2L	S4	Wmd1_2L_S4_MP1	foil	33.0	white	polyethylene low density
253	Wmd1	2R	S1	Wmd1_2R_S1_MP1	foil	14.0	white	polypropylene
254	Wmd1	2R	S4	Wmd1_2R_S4_MP1	fragment	7.0	white	polypropylene
255	Wyk	0L	S1	Wyk_0L_S1_MP1	foil	9.0	white	polyethylene high density
256	Wyk	0L	S2	Wyk_0L_S2_MP1	foil	10.0	white	polyethylene high density
257	Wyk	2L	S3	Wyk_2L_S3_MP1	fibre	1.9	blue	polyester
258	Wyk	2L	S4	Wyk_2L_S4_MP1	foil	8.0	white	polyethylene high density
259	Wyk	2R	S4	Wyk_2R_S4_MP1	fragment	43.5	green	polyethylene high density

260	ZST	1R	S2	ZST_1R_S2_MP1	fibre	6.4	white	polypropylene

Table S8. Number (#) and percentage (%) of microplastics (MP), mesoplastics (ME), macroplastics (MA), micro- and mesoplastics (MM), and micro-, meso- and macroplastics (PP) in relation to sampling points S1-S4 (Figure 1).

Sampling point	# MP	% MP	# ME	% ME	# MA	% MA	# MM	% MM	# PP	# PP
S1	15	19.7%	19	15.4%	6	13.6%	34	17.1%	40	16.3%
S2	19	25.0%	31	25.2%	12	27.3%	50	25.1%	62	25.3%
S3	18	23.7%	32	26.0%	10	22.7%	50	25.1%	60	24.5%
S4	24	31.6%	41	33.3%	16	36.4%	65	32.7%	83	33.9%

Table S9. Comparisons of pollution levels of plastic particles (PP) between different categories of locations (Mann-Whitney U tests). Numbers in brackets for category 1 and category 2 refer to the sample sizes. Mean 1 and mean 2 refer to the unweighted means of category 1 and category 2, respectively. The independent variables are D_{area} (N m^{-2}), D_{mass} (N kg^{-1}), and D_{vol} (N L^{-1}).

Category 1	Category 2	Mean 1	Mean 2	Ind. Var.	U-value	P-value
Baltic Sea (26)	North Sea (33)	4.72 ± 7.39	3.70 ± 4.24	D_{area} PP	418.0	0.87
Baltic Sea (26)	North Sea (33)	0.15 ± 0.27	0.22 ± 0.34	D_{mass} PP	345.0	0.20
Baltic Sea (26)	North Sea (33)	0.25 ± 0.44	0.34 ± 0.53	D_{vol} PP	348.0	0.21
Baltic & North Sea (59)	rivers Elbe & Weser (12)	4.15 ± 5.82	3.97 ± 6.46	D_{area} PP	330.0	0.71
Baltic & North Sea (59)	rivers Elbe & Weser (12)	0.19 ± 0.31	0.09 ± 0.14	D_{mass} PP	294.0	0.36
Baltic & North Sea (59)	rivers Elbe & Weser (12)	0.30 ± 0.49	0.14 ± 0.22	D_{vol} PP	298.0	0.39
coast (30)	island (29)	5.15 ± 7.06	3.11 ± 4.01	D_{area} PP	373.5	0.35
coast (30)	island (29)	0.16 ± 0.25	0.22 ± 0.36	D_{mass} PP	414.0	0.75
coast (30)	island (29)	0.25 ± 0.41	0.35 ± 0.57	D_{vol} PP	419.0	0.81
coast North Sea (9)	island North Sea (24)	3.92 ± 4.52	3.62 ± 4.23	D_{area} PP	105.5	0.92
coast North Sea (9)	island North Sea (24)	0.09 ± 0.10	0.27 ± 0.39	D_{mass} PP	83.0	0.31
coast North Sea (9)	island North Sea (24)	0.15 ± 0.15	0.41 ± 0.61	D_{vol} PP	86.0	0.37
coast Baltic Sea (21)	island Baltic Sea (5)	5.68 ± 7.95	0.69 ± 0.95	D_{area} PP	24.0	0.06
coast Baltic Sea (21)	island Baltic Sea (5)	0.18 ± 0.29	0.02 ± 0.02	D_{mass} PP	23.0	0.053
coast Baltic Sea (21)	island Baltic Sea (5)	0.30 ± 0.48	0.02 ± 0.03	D_{vol} PP	23.0	0.053
Norderney (13)	North Sea (20)	4.70 ± 5.32	3.05 ± 3.36	D_{area} PP	120	0.71
Norderney (13)	North Sea (20)	0.43 ± 0.47	0.08 ± 0.08	D_{mass} PP	66.5	0.02
Norderney (13)	North Sea (20)	0.66 ± 0.74	0.13 ± 0.13	D_{vol} PP	66.5	0.02

Table S10. Comparison of meso- and microplastic densities between previous studies from the Baltic Sea and North Sea and this study. For this table, we only included studies which (1) sampled sandy sediments on beaches and (2) were conducted along the Baltic Sea coastline or the North Sea coastline. The number of sites is the number of different locations where samples were taken (the number of samples taken is usually much larger). The size definitions of microplastics (MP) are given when available. The mean is always the unweighted mean (see Methods) and given with ± 1 standard deviation if the information was available. MP kg^{-1} always refers to the number of microplastics per 1 kg of dry-weight sediment (abbreviated as D_{mass} in the main text). In this table, we did not account for many differences in methodology between studies: e.g., studies different in the identification of microplastics (visual, ATR-FTIR, or Raman spectroscopy), whether they used density separation or not (and what solution was used for density separation), and various other methodological details. Furthermore, many of these studies did not use a design which selected random sampling points, but purposefully placed sampling points into beach areas known to contain higher numbers of microplastics, such as the drift and wrack lines (e.g., Dekiff et al., 2014; Stolte et al., 2015; Esiukova, 2017; Graca et al., 2017; Chubarenko et al., 2018; 2020; Esiukova et al., 2020; 2021; Schröder et al., 2021; Lenz et al., 2023). *Taken from Figure 4 in Schröder et al. (2021). [£]Taken from Table S1 in Esiukova et al. (2021). [$]In the main text, this size category is called mesoplastics (abbreviated as ME). [§]In the main text, this size category is called meso- and microplastics (abbreviated as MM).

Location	Date	Sites	Size	Mean	Median	Range	Reference
Baltic Sea							
Rostock coast, Germany	Mar-Jul 2014	9 sites	MP	-	-	0-7 MP kg^{-1}, 2-11 fibres kg^{-1}	Stolte et al., 2015
GD site, Gdansk, Poland	Dec 2014-Apr 2015	1 site	MP ≤ 5 mm	43 MP kg^{-1} (all fibres)	-	-	Graca et al., 2017
KA site, Gdansk, Poland	Dec 2014-Apr 2015	1 site	MP ≤ 5 mm	25 MP kg^{-1} (all fibres)	-	-	Graca et al., 2017
Polish coast	Apr-May 2015	12 sites	MP (mean size 0.514 mm)	160.3 ± 72.5 MP kg^{-1}	-	-	Urban-Malinga et al., 2020
Kalinigrad, Russia	Jun 2015-Jan 2016	13 sites	MP (0.5-5.0 mm)	9.2 ± 10.3 MP kg^{-1}	-	1.3-36.2 MP kg^{-1}	Esiukova, 2017
Rügen island, Germany	Jul 2015	4 sites	MP < 5 mm	-	88.10 MP kg^{-1}	-	Hengstmann et al., 2018
Vistula Spit, Curonian Spit, Russia	5-6, 27 May 2016	3 sites	MP (0.5-5.0 mm)	108 MP kg^{-1} (56 when excluding outliers)	-	2-572 MP kg^{-1}	Chubarenko et al., 2018
Bülk, Kiel, Germany	24 Sep-3 Oct 2016	1 site	MP (0.2-0.5 mm)	0.2 MP kg^{-1*}	-	-	Schröder et al., 2021
Bülk, Kiel, Germany	24 Sep-3 Oct 2016	1 site	MP (0.5-1.0 mm)	0.0 MP kg^{-1*}	-	-	Schröder et al., 2021

Bülk, Kiel, Germany	24 Sep-3 Oct 2016	1 site	MP (1.0-5.0 mm)	0.0 MP kg^{-1*}	-	-	Schröder et al., 2021
Falckenstein, Kiel	24 Sep-3 Oct 2016	1 site	MP (0.2-0.5 mm)	0.5 MP kg^{-1*}	-	-	Schröder et al., 2021
Falckenstein, Kiel	24 Sep-3 Oct 2016	1 site	MP (0.5-1.0 mm)	0.7 MP kg^{-1*}	-	-	Schröder et al., 2021
Falckenstein, Kiel	24 Sep-3 Oct 2016	1 site	MP (1.0-5.0 mm)	0.7 MP kg^{-1*}	-	-	Schröder et al., 2021
Tirpitzmole, Kiel	24 Sep-3 Oct 2016	1 site	MP (0.2-0.5 mm)	4.3 MP kg^{-1*}	-	-	Schröder et al., 2021
Tirpitzmole, Kiel	24 Sep-3 Oct 2016	1 site	MP (0.5-1.0 mm)	6.4 MP kg^{-1*}	-	-	Schröder et al., 2021
Tirpitzmole, Kiel	24 Sep-3 Oct 2016	1 site	MP (1.0-5.0 mm)	16.1 MP kg^{-1*}	-	-	Schröder et al., 2021
Polish coast	Nov-Dec 2017	11 sites	MP > 0.032 mm	-	293 MP kg^{-1}	118-1382 MP kg^{-1}	Mazurkiewicz et al., 2022
Baltic Sea coast, Schleswig-Holstein, Germany	7 Mar-16 Apr, 24 Sept-4 Oct 2018	10 sites	MP (0.02-5.0 mm)	7.2 MP kg^{-1}	4 MP kg^{-1}	0-28 MP per kg^{-1}	Lenz et al., 2023
Baltic Sea, Russia	1-2 May 2018	6 sites	MP (0.5-5.0 mm)	115.6 ± 216.8 MP kg^{-1}	-	5-1343 MP kg^{-1}	Esiukova et al., 2020
Baltic Sea, Russia	1-2 May 2018	6 sites	MP (2.0-5.0 mm)	0.70 ± 1.73 MP kg^{-1}	-	0-8 MP kg^{-1}	Esiukova et al., 2020
Curonian Spit, Russia	1-2 May 2018	6 sites	MP (0.5-5.0 mm)	114.8 ± 61.4 MP kg^{-1}	45.5 ± 22.4 MP kg^{-1}	-	Chubarenko et al., 2020
Curonian Spit, Russia	1-2 May 2018	6 sites	MP (0.5-5.0 mm)	73.9 ± 22.6 MP kg^{-1} (excluding outliers)	41.6 ± 22.2 MP kg^{-1} (excluding outliers)	-	Chubarenko et al., 2020
Baltic Sea, Germany/Poland	2-4 May 2019	7 sites	MP (0.5-2.0 mm)	79.8 ± 60.3 MP kg^{-1}£	49.3 MP kg^{-1}£	23.2-182.5 MP kg^{-1}£	Esiukova et al., 2021
Baltic Sea, Germany/Poland	2-4 May 2019	7 sites	MP (2.0-5.0 mm)	3.2 ± 1.5 MP kg^{-1}£	2.6 MP kg^{-1}£	1.7-6.0 MP kg^{-1}£	Esiukova et al., 2021
Baltic Sea, Germany/Poland	2-4 May 2019	7 sites	MP (0.5-5.0 mm)	82.9 ± 61.8 MP kg^{-1}£	51.8 MP kg^{-1}£	25.4-188.4 MP kg^{-1}£	Esiukova et al., 2021
Baltic Sea, Germany/Poland	2-4 May 2019	7 sites	Meso > 5 mm	3.3 ± 3.2 MP kg^{-1}£	2.1 MP kg^{-1}£	0.9-10.3 MP kg^{-1}£	Esiukova et al., 2021
This study	Sep 2021-Dec 2022	26 sites	MP (1.0-5.0 mm)	0.04 ± 0.08 MP kg^{-1}	0.00 MP kg^{-1}	0.00-0.30 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	26 sites	MP (5.0-25.0 mm)$^{\$}$	0.08 ± 0.16 MP kg^{-1}	0.02 MP kg^{-1}	0.00-0.66 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	26 sites	MP (1.0-25.0 mm)§	0.12 ± 0.22 MP kg^{-1}	0.04 MP kg^{-1}	0.00-0.90 MP kg^{-1}	-
North Sea							
North Sea, Belgium	after 2008	3 sites	MP < 1 mm	95.2 ± 35.0 MP kg^{-1}	98.0 MP kg^{-1}	48.7-156.2 MP kg^{-1}	Claessens et al., 2011
Norderney, Germany	6 Apr 2010	2 sites	MP	present	present	present	Fries et al., 2013
North Sea, Belgium	Apr 2011	4 sites	MP < 1 mm	13.4 ± 4.9 MP kg^{-1}	13.8 MP kg^{-1}	7.2-20.4 MP kg^{-1}	Van Cauwenberghe et al., 2013
Norderney, Germany	1-2 Nov 2011	3 sites	small MP < 1 mm	1.77 MP kg^{-1}	-	1.3-2.3 MP kg^{-1}	Dekiff et al., 2014
Norderney, Germany	1-2 Nov 2011	3 sites	visible MP > 1 mm	present	present	present	Dekiff et al., 2014
Kachelotplate, Germany	Dec 2011	13 sites	MP, fibres	-	-	0-62100 MP kg^{-1}, 100-1400 fibres kg^{-1}	Liebezeit and Dubaish, 2012
Spiekeroog, Germany	Dec 2011	15 sites	MP, fibres	present	present	present	Liebezeit and Dubaish, 2012
This study	Sep 2021-Dec 2022	33 sites	MP (1.0-5.0 mm)	0.07 ± 0.14 MP kg^{-1}	0.00 MP kg^{-1}	0.00-0.63 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	33 sites	MP (5.0-25.0 mm)$^{\$}$	0.09 ± 0.14 MP kg^{-1}	0.04 MP kg^{-1}	0.00-0.62 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	33 sites	MP (1.0-25.0 mm)§	0.16 ± 0.25 MP kg^{-1}	0.09 MP kg^{-1}	0.00-1.14 MP kg^{-1}	-

Baltic Sea and North Sea							
This study	Sep 2021-Dec 2022	59 sites	MP (1.0-5.0 mm)	0.06 ± 0.12 MP kg^{-1}	0.00 MP kg^{-1}	0.00-0.63 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	59 sites	MP (5.0-25.0 mm)[$]	0.09 ± 0.15 MP kg^{-1}	0.03 MP kg^{-1}	0.00-0.66 MP kg^{-1}	-
This study	Sep 2021-Dec 2022	59 sites	MP (1.0-25.0 mm)[§]	0.14 ± 0.23 MP kg^{-1}	0.05 MP kg^{-1}	0.00-1.14 MP kg^{-1}	-
Global reviews							
worldwide	various	33 studies	MP	334.23 MP kg^{-1}	-	0.0152 - 4340 MP kg^{-1}	Booth, 2017
worldwide	various	17 studies	MP	-	~200 MP kg^{-1}	-	Harris, 2020
worldwide	various	5 studies	MP	393.7 ± 753.0 MP kg^{-1}	-	0.0-2116 MP kg^{-1}	Peng et al., 2020
ASEAN region	various	11 studies	MP	192.1 ± 211.1 MP kg^{-1}	-	2.5-599 MP kg^{-1}	Curren et al., 2021

Table S11. Summary data taken from Table S10 and rearranged from smallest to greatest mean value (and then smallest to greatest median value, and then smallest to greatest maximum value of the range). In order to test for differences between the Baltic Sea and the North Sea, we separated the results from this study in the top two rows (for summary results of both regions together, see Table S10). Column 2 gives the categorical values used in a Mann-Whitney U test to compare studies from the Baltic Sea versus studies from the North Sea.
For this test, we lumped the results from Germany and Poland of Esiukova et al. (2021) (row 10). Column 3 gives the categorical values used in a Mann-Whitney U test to compare the studies from Poland and Russia versus those studies from the other countries. For this test, we separated the results from Germany and Poland of Esiukova et al. (2021) (rows 9 and 12).

Location	Baltic Sea	Poland/Russia	Size	Mean	Median	Range	Reference
This study, Baltic Sea	1	0	MP (1.0-25.0 mm)	0.12 MP kg^{-1}	0.04 MP kg^{-1}	0.00-0.90 MP kg^{-1}	-
This study, North Sea	0	0	MP (1.0-25.0 mm)	0.16 MP kg^{-1}	0.09 MP kg^{-1}	0.00-1.14 MP kg^{-1}	-
Norderney, Germany	0	0	MP < 1 mm	1.77 MP kg^{-1}	-	1.3-2.3 MP kg^{-1}	Dekiff et al., 2014
Baltic Sea, Schleswig-Holstein	1	0	MP (0.02-5.0 mm)	7.2 MP kg^{-1}	4 MP kg^{-1}	0-28 MP per kg^{-1}	Lenz et al., 2023
Kalinigrad, Russia	1	1	MP (0.5-5.0 mm)	9.2 MP kg^{-1}	-	1.3-36.2 MP kg^{-1}	Esiukova, 2017
Kiel, Germany	1	0	MP (0.2-5.0 mm)	9.64 MP kg^{-1}	-	-	Schröder et al., 2021
North Sea, Belgium	0	0	MP < 1 mm	13.4 MP kg^{-1}	13.8 MP kg^{-1}	7.2-20.4 MP kg^{-1}	Van Cauwenberghe et al., 2013
Gdansk, Poland	1	1	MP ≤ 5 mm	34 MP kg^{-1}	-	-	Graca et al., 2017
Baltic Sea, Poland	-	1	MP (0.5-5.0 mm)	60.8 MP kg^{-1}	51.8 MP kg^{-1}	51.7-78.8 MP kg^{-1}	Esiukova et al., 2021
Baltic Sea, Germany/Poland	1	-	MP (0.5-5.0 mm)	82.9 MP kg^{-1}	51.8 MP kg^{-1}	25.4-188.4 MP kg^{-1}	Esiukova et al., 2021
North Sea, Belgium	0	0	MP < 1 mm	95.2 MP kg^{-1}	98.0 MP kg^{-1}	48.7-156.2 MP kg^{-1}	Claessens et al., 2011
Baltic Sea, Germany	-	0	MP (0.5-5.0 mm)	99.6 MP kg^{-1}	92.3 MP kg^{-1}	25.4-188.4 MP kg^{-1}	Esiukova et al., 2021
Vistula Spit, Curonian Spit, Russia	1	1	MP (0.5-5.0 mm)	108 MP kg^{-1}	-	2-572 MP kg^{-1}	Chubarenko et al., 2018
Curonian Spit, Russia	1	1	MP (0.5-5.0 mm)	114.8 MP kg^{-1}	45.5 MP kg^{-1}	-	Chubarenko et al., 2020
Baltic Sea, Russia	1	1	MP (0.5-5.0 mm)	115.6 MP kg^{-1}	-	5-1343 MP kg^{-1}	Esiukova et al., 2020
Polish coast	1	1	MP (mean size 0.514 mm)	160.3 MP kg^{-1}	-	-	Urban-Malinga et al., 2020
Rügen island, Germany	-	-	MP < 5 mm	-	88.10 MP kg^{-1}	-	Hengstmann et al., 2018
Polish coast	-	-	MP > 0.032 mm	-	293 MP kg^{-1}	118-1382 MP kg^{-1}	Mazurkiewicz et al., 2022
Rostock coast, Germany	-	-	MP	-	-	0-7 MP kg^{-1}	Stolte et al., 2015
Kachelotplate, Germany	-	-	MP	-	-	0-62100 MP kg^{-1}	Liebezeit and Dubaish, 2012

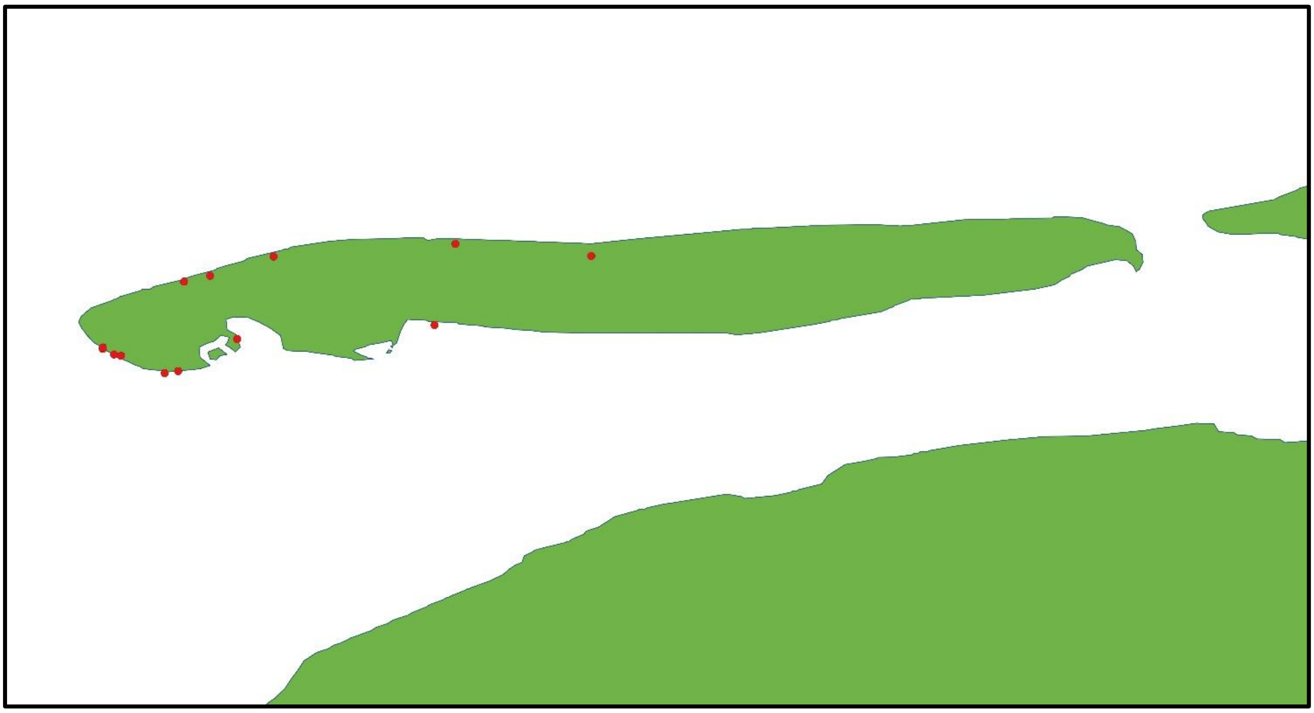


Figure S15. Map of the 13 sampling locations on the North Sea island of Norderney (this is a closeup of the overview map in Figure 2). Two collections overlap on the most westerly collection point.

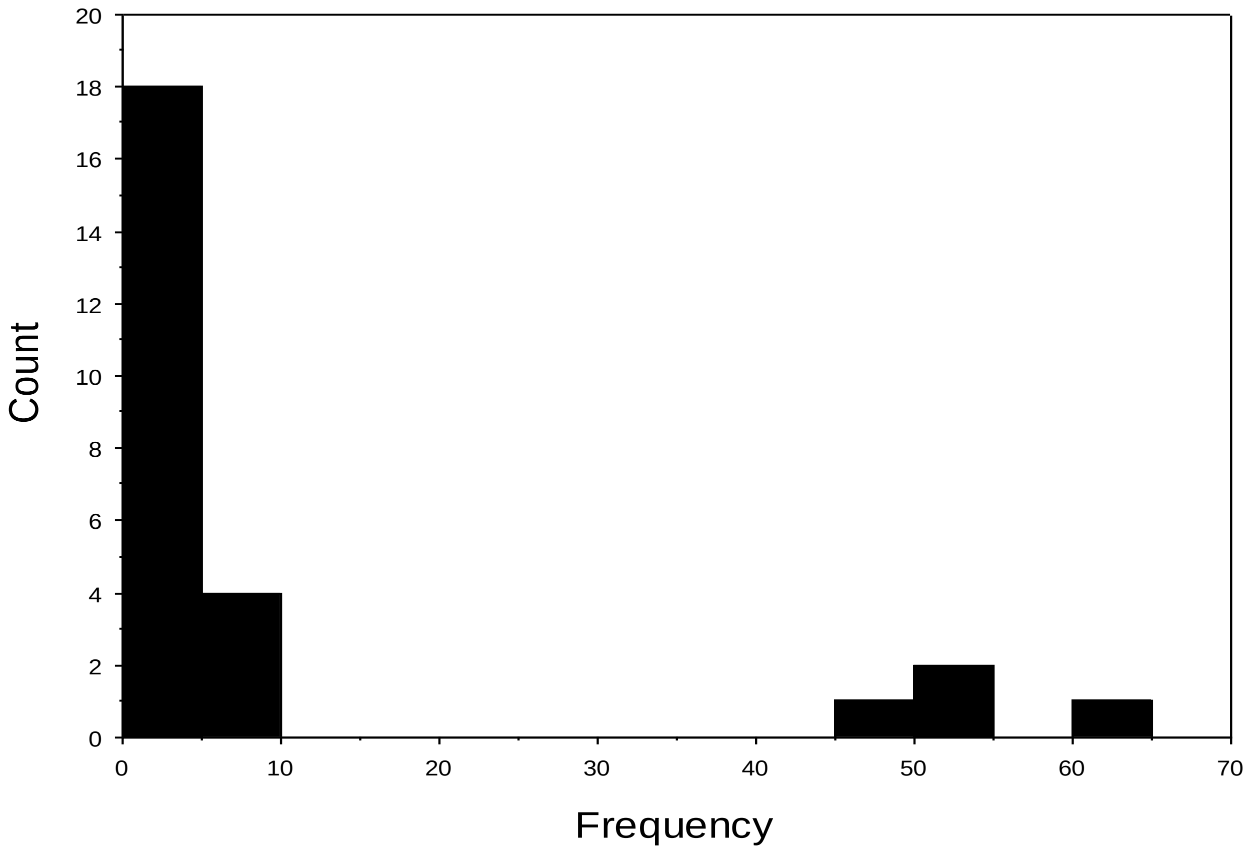


Figure S16. Histogram of the frequency (or number) of PP which belonged to one polymer type (raw numbers in Table 2).

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