Tyre wear particles in the environment

The environmental impact of tyre abrasion is increasingly becoming the focus of public attention, often in the context of the general term micro plastics. According to recent studies, around 500,000 tons of tire abrasion particles are produced annually in the EU [1]. For a long time it was not clear what the size range of rubber particles is and what impact tyre abrasion has on people and the environment.

Test vehicle ADAC tyre test ©Wolfgang Grube/ ISP

Rubber belongs to the family of plastics is one of the plastics and in the form of abrasion from car tyres, accounts for an estimated one third of all microplastic emissions in Germany alone. The particles from tyre abrasion, most of which are over 50 µm in size, are very coarse and even if in the form of airborne particles, they do not penetrate deeply into the human respiratory tract. Nevertheless, the amount of tyre abrasion emitted by road traffic should be kept as low as possible in order to minimise the harmful effects on the aquatic environment, on soils and thus ultimately on human beings.

In ADAC´s tyre test, the evaluation of tyre abrasion has been an integral part of the test methodology for many years. In an elaborate test procedure, the tyres are subjected to real-life driving and laboratory testing on a roller dynamometer and the mileage is calculated until the maximum wear limit is reached. The mileage can be influenced by two parameters. The first is the abrasion rate and the second is the tread height: the higher the tread when new, the longer the tyre can be driven. The actual abrasion rate is not directly relevant for the motorist as the service life of a tyre also depends on the tread height. However, claims related to environmental friendliness of a tyre with regard to the rubber emission into the environment cannot be made entirely on the basis of the results of the abrasion measurements, since it is primarily the weight loss of a tyre over its service life that plays a role and not the tread depth.

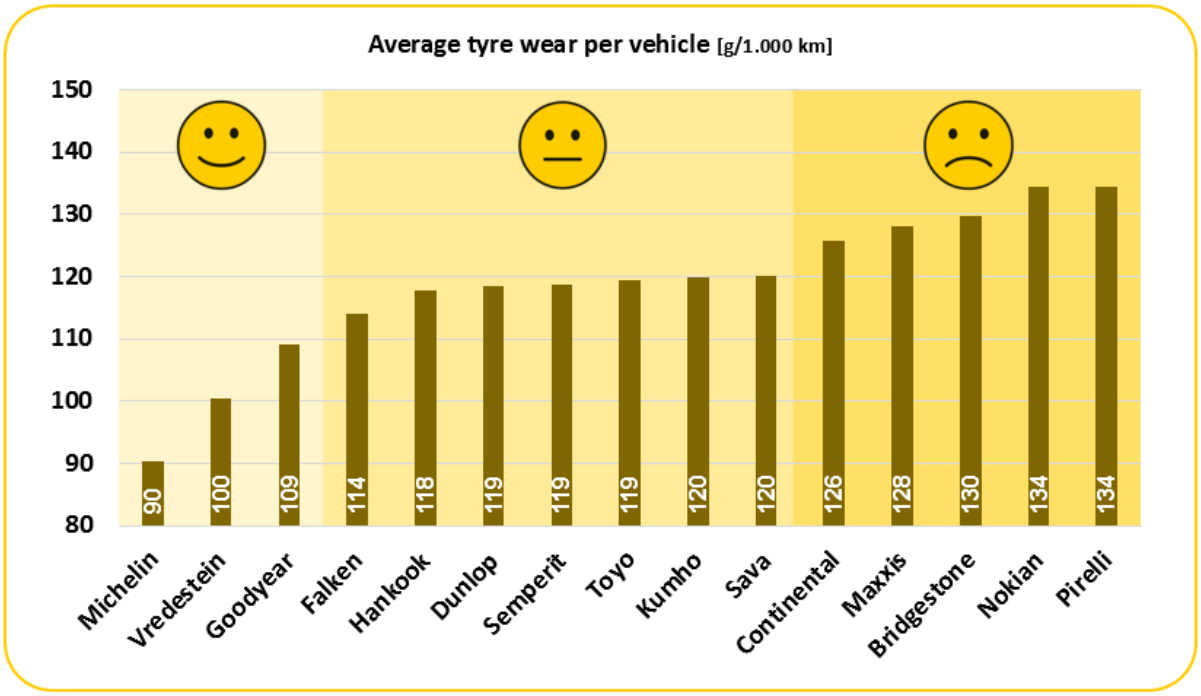
For this reason, ADAC has now for the first time, carried out a comprehensive study to illustrate and evaluate the environmental impact of tyre abrasion on different tyre models in various tyre dimensions. At the same time, an analysis was conducted to determine whether environmentally friendly tyres can also be safe.

Low tyre abrasion and safe driving characteristics: Michelin shows how it´s done

The analysis of the abrasion data of almost 100 summer and winter tyre models of different typical tyre sizes shows a clear result: In almost every tyre size, there are tyre models with both low tyre abrasion and safe driving characteristics.

The Michelin brand stands out in a particularly positive way. In almost every tyre size tested, the Michelin model offers very low tyre abrasion and, at the same time, performs well in the safety-relevant categories. The Vredestein brand is also impressive with its low abrasion and predominantly good driving characteristics.

In the respective tyre sizes, second or third brands also stand out time and again, with individual tyre models at the very top. Here it seems as if the second or third brands are often also being used as technology carriers to launch innovative product advances on to the market.



The analysis of the tyre abrasion of 15 tyre manufacturers reveals that Michelin, with an average tyre abrasion of just 90g per 1,000 km, is way ahead of the competition. A positive aspect is that the Michelin tyres tested consistently achieve good to satisfactory results in the safety category despite their low abrasion.

Vredestein too shows an astonishingly low tyre abrasion of only 100g per 1,000 km with its latest tyre generation. In contrast to Michelin however, the safety characteristics of the Dutch tyre manufacturer are not entirely convincing in all sizes. Even though Vredestein is already on the right track to produce environmentally friendly and safe tyres, it does not yet show a consistently good performance in several different tyre sizes.

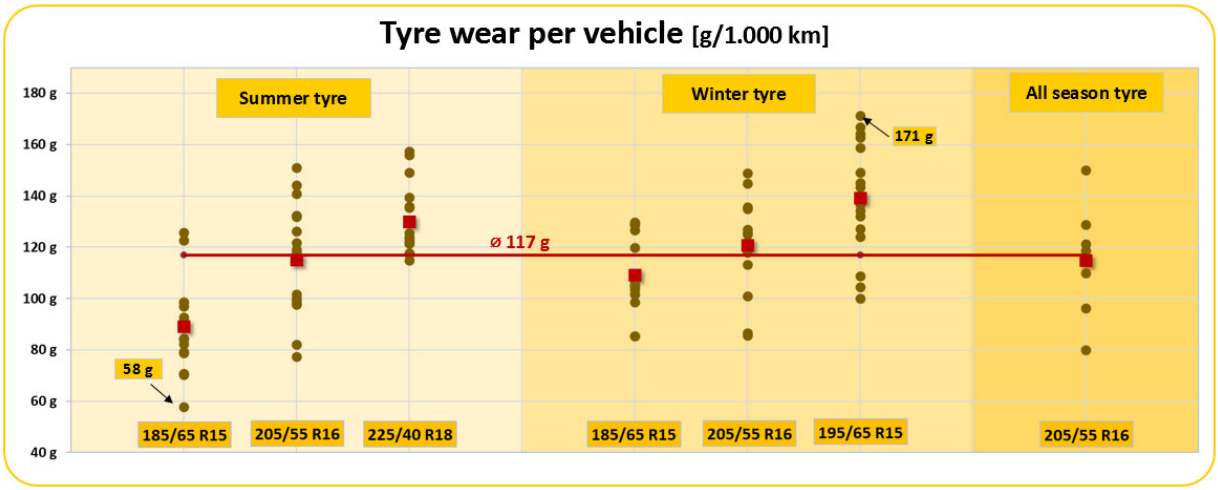
In third place, also with a still respectable average abrasion of 109g/1,000 km, is Goodyear. With its Efficient Grip Performance 2 in particular, Goodyear seems to have made a quantum leap in terms of environmentally friendly tyres, as the 2021 summer tyre test in the 205/55 R16 tyre size shows.

On the other side of the manufacturer evaluation, there are three premium manufacturers – Pirelli, Bridgestone and Continental – that have a lot of catching up to do when it comes to tyre abrasion. Pirelli in particular does not seem to have recognised the environmental relevance of tyre abrasion – and this cannot be compensated by the above-average performance of Pirelli tyres on dry roads. A better balance between tyre performance and environmental protection would definitely be desirable.

Conclusion: Some tyre manufacturers have already recognised that low tyre abrasion is gaining in relevance – because this not only protects the environment, but also the motorist´s wallet as the tyres last longer with the same new tread depth. It is also clear that the trade-off between low abrasion and safety characteristics can be largely resolved by state-of-the-art tyre technology. Now the time has come to rethink. Not just regarding the advertising claims of tyre manufacturers who today often still place their emphasis on the driving performance of their tyres, even though this is, at best, an advantage on the racetrack, but also in the case of consumers who should specifically opt for balanced, safe and environmentally-friendly tyres.

Table / Data evaluation

The weight loss of the tyres, subject to different tyre sizes, is shown in the following graph.



Three summer and three winter tyre sizes from the previous test years (2019-2021) as well as one all-season tyre size (from 2016) were evaluated respectively. More up-to-date measurements on tyre abrasion of all-season tyres are currently not available. Therefore, no conclusions can be drawn on the current generation of these tyres as to whether there are also safe tyres with low abrasion for all-season tyres. However, the analysis shows that the tyre abrasion of all-season tyres is at a similar level as that of summer and winter tyres of the same tyre size.

The evaluation of tyre abrasion reveals the following findings:

- On average, the tyre abrasion of a vehicle is around 120 g pro 1,000 km.
- There are no fundamental differences in tyre abrasion between summer, winter and all-season tyres. There is a tendency for tyre abrasion to be slightly lower on summer tyres than on the comparable winter tyre size.
- In almost all tyre sizes tested, you can find tyres that achieve a low tyre abrasion of < 100 g pro 1,000 km.
- One exception is the summer tyre size 225/40 R18. In this size, the racing tyre models received special attention in the tests and it was concluded that all of them have above average tyre abrasion.
- The summer tyre size 195/65 R15 is also conspicuous. In this size, tyres designed for compact vehicle and vans, tyre abrasion is in general at a very elevated level. Whether this tyre size has design disadvantages or the manufacturers are using outdated tyre technology is something that has not been conclusively clarified.
- The 185/65 R15 tyre size stands out in particular. In this tyre size, which is suitable for small cars, there are many models that produce significantly less than 100 g/1,000 km of tyre abrasion, especially among the summer tyres.
- The tyre with the lowest abrasion is Michelin Cross Climate+ in size 185/65 R15 (58 g/1.000 km). The Cross Climate+ demonstrates what is technically feasible today and at the same time offers the necessary safety features.
- At the opposite end of the scale is the Bridgestone Blizzak LM005 in the 195/65 R15 size, which produces around 171g of tyre abrasion per 1,000 km. This is despite the fact that the tyre cannot even deliver a convincing performance in terms of driving safety.

The study of the correlation between tyre abrasion and tyre performance reveals the following conclusions.

- There are tyre models in all sizes that have low abrasion combined with good driving safety.
- Tyres with low abrasion do not necessarily lead to an increased risk of aquaplaning, as the aquaplaning features depend entirely on the tread design and depth and not on the rubber compound.

- In the case of winter tyres, it is evident that tyres with low abrasion tend to provide poorer snow performance. However, there are tyres that reconcile this conflict of objectives most effectively and still provide an acceptable performance in snow with low abrasion.
- Especially in the case of racing tyres sizes and so-called ultra-high performance tyres (UHP), the focus often seems to be placed only on high performance stability on dry roads. The tyre abrasion that is associated with this is rarely the focus of many manufacturers. The above-average tyre performance on dry roads however, provides hardly any additional safety advantages in normal road use, since the borderline range is extremely high. At best, these tyres are good for the race track.

Results in detail

The individual tyre models tested in the respective tyre sizes are shown below, sorted in ascending order according to tyre abrasion. In addition, the respective overall score was added in the main safety-relevant categories “dry road”, “wet road” and in the case of winter tyres, the main criterion “snow”. In each case, the three summer and winter tyre sizes from the last three years (2019-2021) were assessed where abrasion results were determined in real-life operation (convoy driving) over 15,000 km. The tyre weight, in new condition and after 15,000 km, was determined and the average tyre abrasion per 1,000 km was calculated based on the weight loss.

Tyre abrasion summer tyres 185/65 R15

185/65R15 (summer tyres 2019)	Tyre abrasion [g/1,000 km] ↑	Rating dry road surface	Rating wet road surface
Michelin Cross Climate +	58	2,6	2,4
Vredestein Sportrac 5	70	2,3	2,2
Falken Ziex ZE310 Ecorun	71	1,8	3,0
Kumho Ecowing ES01 KH27	79	2,8	2,8
Firestone Roadhawk	79	1,5	2,8
Giti Gitisynergy E1	82	2,8	3,2
Maxxis Mecotra 3	84	1,9	2,8
Petlas Imperium PT515	84	3,0	3,3
Goodyear Efficient Grip Performance	91	1,9	2,7
Hankook Kinergy Eco 2 K435	91	2,4	3,4
Pirelli Cinturato P1 Verde	93	2,3	3,4
Bridgestone Turanza T005	97	1,5	1,9
Toyo Proxes CF2	99	2,2	2,8
Semperit Comfort-Life 2	99	2,9	3,0
Continental Conti Premium Contact 5	123	2,2	2,4
Linglong Greenmax HP010	126	3,0	2,8
Average tyre abrasion:	**89 g/1,000 km**		

The tyre size 185/65 R15 is one of the best-selling tyre sizes in the small car segment and is suitable for models with a high number of registrations such as VW Polo, Opel Corsa or Renault Clio. Compared to the other tyre sizes evaluated, the small car size produces by far the lowest tyre abrasion, averaging only 89 g/1,000 km. This may be mainly due to the fact that normally small cars have less powerful engines and at the same time, the vehicle weight is low – both relevant factors for the lowest possible tyre abrasion and thus a low environmental impact.

The tyre abrasion of the Michelin Cross Climate + (57 g/1,000 km), an all-season tyre in disguise, which was offered by Michelin as a summer tyre in the test year 2019 in the 185 tyre size, is outstandingly low. Both the Michelin Cross Climate + but also particularly the Vredestein Sportrac 5 (70 g/1,000 km) demonstrate that an environmentally friendly tyre can also be safe.

At the other end of the evaluation scale is the low-priced Chinese tyre from Linglong, which at 126 g/1,000 km, produces more than twice as much tyre abrasion as the Michelin. But even the premium brand Continental cannot compete in this tyre size in terms of environmental compatibility – apparently a premium product does not necessarily appear to be environmentally friendly.

Tyre abrasion summer tyres 225/40 R18

225/40R18 (Summer tyres 2020)	Tyre abrasion [g/1,000 km] ↑	Rating dry road surface	Rating wet road surface
Falken Azenis FK510	115	2,9	2,4
Bridgestone Potenza S001	117	1,7	3,0
Michelin Pilot Sport 4	118	1,9	2,0
Rotalla Setulla S-Pace RU01	118	2,9	3,6
Goodyear Eagle F1 Asymetric 5	121	1,7	2,3
Cooper Zeon CS-Sport	122	2,0	3,3
Maxxis Victra Sport 5	123	2,0	2,2
Vredestein Ultrac Vorti	124	2,5	2,7
Nexen N`Fera Sport	124	2,2	2,6
Continental Premium Contact 6	125	2,4	1,7
Sava Intensa UHP 2	135	1,8	2,7
Hankook Ventus S1 Evo3	136	2,0	3,1
Nokian Powerproof	139	2,4	2,4
Toyo Proxes Sport	149	2,0	2,8
Kumho Ecsta PS71	156	2,4	2,3
Pirelli P Zero	157	1,3	1,8
Average tyre abrasion:	**130 g/1,000 km**		

The racing summer tyre size for the compact class (suitable for the VW Golf, Opel Astra, BMW 1er and Ford Focus), among others, is almost exclusively designed for driving performance; environmental considerations are hardly at the forefront of this tyre.

Nevertheless, the Michelin Pilot Sport 4 demonstrates that safe driving features are also possible with (reasonably) low tyre abrasion.

With the Pirelli P Zero, on the other hand, environmental considerations were not at all on the developers´ list of priorities. Especially on dry roads, the Pirelli shows by far the best result, but this comes at the cost of an extremely high tyre abrasion rate of 157 g pro 1,000 km.

Tyre abrasion summer tyres 205/55 R16

205/55R16 (Summer tyres 2021)	Tyre abrasion [g/1,000 km] ↑	Rating dry road surface	Rating wet road surface
Goodyear Efficient Grip Performance 2	82	2,6	2,3
Fulda Ecocontrol HP2	98	2,5	2,8
Petlas Imperium PT515	98	3,3	3,3
Kumho Ecsta HS51	99	2,6	2,2
Apollo Alnac 4G	100	2,6	2,7
BF Goodrich Advantage	102	2,2	2,9
Bridgestone Turanza T005	118	2,0	2,1
King Meiler Sport 1	119	3,2	3,6
Semperit Speed-Life 3	122	2,0	1,9
Continental Premium Contact 6	126	2,0	1,8
Maxxis Premitra 5	132	1,4	2,2
Hankook Ventus Prime 3 K125	132	1,5	2,7
Uniroyal Rainsport 5	141	2,9	2,1
Pirelli Cinturato P7 C2	144	2,0	2,0
Nokian Wetproof	151	2,1	2,3
Average tyre abrasion:	**118 g/1,000 km**		

The tyre size 205/55 R16 is one of the best-selling tyre sizes on the German market. Environmental compatibility is therefore particularly important here as a very large number of these tyres are sold, used in daily road traffic and therefore contribute significantly to overall tyre abrasion.

It is encouraging that there are some tyres in this compact class size (suitable for the VW Golf, Opel Astra, BMW 1er and Ford Focus), among others, that produce less than 100 g/1,000 km of tyre abrasion, in particular, the Goodyear Efficient Grip Performance 2 as well as the Kumho Ecsta HS51 that show a good to satisfactory safety level.

At the other end of the evaluation scale is the Nokian Wetproof, which at 151 g/1,000 km produces almost twice as much abrasion as the Goodyear. Premium manufacturer Pirelli also stands out in the tyre size with above-average tyre abrasion.

Tyre abrasion winter tyres 185/65 R15

185/65R15 (Winter tyres 2019)	Tyre abrasion [g/1,000 km] ↑	Rating dry road surface	Rating wet road surface	Rating on snow
Kleber Krisalp HP3	85	2,1	2,3	2,5
Michelin Alpin A4	86	2,2	2,1	2,8
Vredestein Snowtrac 5	99	3,0	2,8	2,7
Davanti Wintoura	102	3,4	5,5	3,8
Goodyear Ultragrip 9	104	2,5	1,9	3,1
Toyo Snowprox S943	105	3,0	2,6	5,1
Sava Eskimo S3+	105	3,6	2,8	1,9
Dunlop Winter Response 2	105	2,3	1,9	1,9
Falken Eurowinter HS01	107	2,7	2,5	2,9
Continental Winter Contact TS860	108	2,5	1,8	2,2
Hankook Winter i*cept RS2 W452	109	2,5	2,1	2,5
Nokian WR D4	120	3,1	2,9	2,0
Gislaved Euro Frost 6	127	2,8	3,2	2,7
Kumho Wintercraft WP51	129	2,7	2,8	3,2
Pirelli Cinturato Winter	129	2,4	2,0	2,4
Viking Win Tech	130	2,5	3,2	2,5
Average tyre abrasion:	**109 g/1,000 km**			

In the 185/65 R15 compact car size, the winter tyre picture is similar to that of the summer tyres. Here too, the manufacturer Michelin is far ahead of the competition in terms of abrasion. The French tyre manufacturer is only surpassed in this size by the Kleber Krisalp HP3 which nevertheless achieves a good result in all driving safety tests with very low tyre abrasion. This is a remarkable result, especially for snow performance because the trade-off between low tyre abrasion and good driving safety on snow represents a particularly difficult issue. Kleber demonstrates impressively what can be possible today with the most modern tyre technologies!

At the other end of the evaluation scale is the low-priced tyre brand Viking, which belongs to the Continental Corporation. The Viking Win Tech records the highest tyre abrasion in the comparison with 130 g/1,000 km, at the same time with moderate results in driving safety on wet roads. But also the Pirelli Cinturato Winter as well as the Kumho Wintercraft WP51 are among the tyres with the highest tyre wear in the compact car size.

Tyre abrasion winter tyres 205/55 R16

205/55R16 (Winter tyres 2020)	Tyre abrasion [g/1,000 km] ↑	Rating dry road surface	Rating wet road surface	Rating on snow
Tristar Snowpower HP	86	2,2	5,5	4,3
Michelin Alpin 6	87	2,5	2,0	2,1
King Meiler Winter Tact WT81	101	3,7	5,4	2,9
Falken Eurowinter HS01	113	2,9	2,3	2,7
Dunlop Winter Sport 5	118	2,5	2,3	2,0
Sava Eskimo HP2	120	3,1	3,1	2,5
Hankook Winter i*cept RS2	121	2,5	2,0	2,1
Goodyear Ultra Grip 9+	122	3,0	2,0	1,8
Toyo Observe S944	125	3,2	2,5	2,3
Giti Gitiwinter W1	126	3,4	3,3	2,0
Continental Winter Contact TS860	127	3,0	1,8	2,0
Maxxis Premitra Snow WP6	135	2,0	2,3	2,5
Semperit Speed-Grip 3	136	3,7	2,1	1,9
Bridgestone Blizzak LM005	145	2,1	1,3	2,1
Pirelli Cinturato Winter	149	3,3	2,2	1,8
Average tyre abrasion:	**121 g/1,000 km**			

In the best-selling winter tyre size 205/55 R16, a no-name product is at the top of the list in terms of tyre abrasion. With 86 g/1,000 km, the Tristar Snowpower HP achieves an impressive result. At the same time, however, the Tristar fails on wet roads with a poor result and cannot be recommended despite its low abrasion. Reason: Poor driving safety should never be outweighed by environmental protection considerations. An unsafe tyre remains unsafe even if it is designed to be environmentally friendly.

The Michelin Alpin 6 resolves the trade-off more effectively. With only 87 g/1,000 km the Michelin produces only slightly more abrasion than the Tristar, but shows consistently positive results in the driving safety criteria.

Tyre abrasion in the 205 size is particularly high for the two premium manufacturers Pirelli and Bridgestone. The Cinturato Winter from Pirelli shows particularly safe driving characteristics on snow, but this comes at the cost of a very high tyre abrasion of 149 g/1,000 km. The Bridgestone Blizzak LM005 with 145 g/1,000 km gets a similarly poor rating as the Pirelli, but still excels with outstanding driving features on wet roads. Here too, the trade-off between tyre abrasion and driving features on snow and wet roads becomes particularly clear. Both Pirelli and Bridgestone fail to resolve this trade-off in the 205/55 R16 winter tyre size.

Tyre abrasion winter tyres 195/65 R15

195/65R15 (Winter tyres 2021)	Tyre abrasion g/1,000 km] ↑	Rating dry road surface	Rating wet road surface	Rating on snow
BF Goodrich G-Force Winter 2	100	2,2	2,6	1,9
Michelin Alpin 6	105	1,9	2,5	2,2
Vredestein Wintrac	109	2,5	2,3	2,2
General Tire Altimax Winter 3	124	3,4	3,5	1,9
Nokian WR Snowproof	127	2,5	3,3	2,3
Dunlop Winter Response-2	132	2,0	2,1	2,0
Goodyear Ultra Grip 9+	134	2,3	1,8	2,0
Kumho Wintercraft WP51	137	3,6	3,0	2,5
Barum Polaris 5	143	3,0	3,2	2,0
Continental Winter Contact TS860	145	2,7	1,6	1,9
GT Radial Winter Pro 2	149	3,5	3,5	2,4
Laufenn i Fit+ LW31	159	2,6	2,2	1,9
Yokohama Bluearth*Winter V906	163	2,1	3,1	2,2
Falken Eurowinter HS01	164	2,3	2,7	2,4
Maxxis Premitra Snow WP6	167	2,2	2,3	2,6
Bridgestone Blizzak LM005	171	2,5	1,7	2,8
Average tyre abrasion:	**139 g/1,000 km**			

The results in the winter tyre size 195/65 R15 are surprising. This tyre size is suitable for many compact cars (VW Golf, Opel Astra), but also for vans such as the VW Touran or Renault Kangoo. This particular tyre size consistently reveals above average tyre abrasion, which must be due to the tyre construction. Compared to the 205/55 R16 size, the average tyre abrasion is about 10% higher. With an average of 139 g/1,000 km, the 195 winter tyre size produces the highest abrasion in comparison.

At the top of the list is the BF Goodrich G-Force Winter 2 with 100 g/1,000 km, followed by the Michelin Alpin 6 (105 g/1,000 km) and the Vredestein Wintrac (109 g/1,000 km). All three tyres show both good to satisfactory driving features on snow and wet roads.

All other tyres tested in this size show significantly higher tyre abrasion. The tail end of the rating scale, the Bridgestone Blizzak LM005 with 171 g/1,000 km has the highest tyre abrasion of all tyres tested. And this, although the tyre even performs only adequately on snow. It seems that many manufacturers use outdated tyre technology, which is no longer up to date for this tyre size. And this despite the fact that the 195/65 R15 tyre size is still one of the best-selling winter tyre sizes in Germany.

Tyre abrasion by manufacturer

Manufacturer	Average tyre abrasion [g/1,000 km]	Number of tyre models under evaluation
Michelin	90	5
Vredestein	100	4
Goodyear	109	6
Falken	114	5
Hankook	118	5
Dunlop	119	3
Semperit	119	3
Toyo	119	4
Kumho	120	5
Sava	120	3
Continental	126	6
Maxxis	128	5
Bridgestone	130	5
Nokian	134	4
Pirelli	134	5

In order to determine the average tyre abrasion per manufacturer, all six selected tyre sizes (three winter and three summer tyre sizes) were evaluated and the average value was calculated for all tyre manufacturers that were represented in at least 50% of the sizes (i.e. at least 3x). In the evaluation, particular attention was paid to the manufacturers that were only represented in three or four sizes to ensure that they were not only tested in particularly advantageous or disadvantageous tyre sizes.

On the basis of the collected data, it can be assumed that the survey of the average tyre abrasion per tyre manufacturer is indeed representative.

The evaluation shows that not all tyre manufacturers have yet integrated the highest possible driving safety and low environmental impact into the tyre development process. This also applies to the marketing of the individual manufacturers. In advertising messages, often only tyre performance is emphasised, but not the environmental features of a tyre.

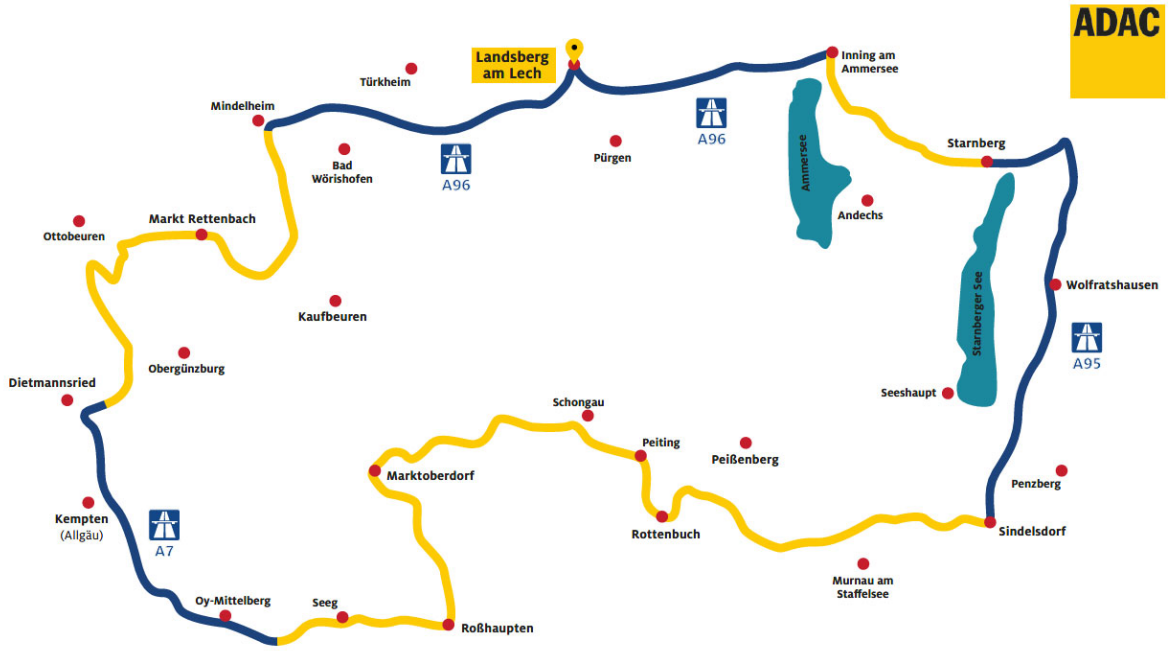
It is imperative to raise public awareness even further and to emphasise not only tyre performance in driving conditions, but also the environmental behaviour of a tyre in particular.

Michelin is one of the few tyre manufacturers to have recognised this need and has specifically geared its tyre development towards this. Other premium manufacturers such as Pirelli or Bridgestone, on the other hand, still seem to focus almost exclusively on the driving features of a tyre. As a result, the environmental impact of tyre abrasion is up to 50% higher for these manufacturers than for Michelin, whose tyre technology currently gives them an enormous lead over the competition.

Test methodology

Every year, ADAC tests summer and winter tyres in several sizes. The wear behaviour of the tyres is determined for one of the two sizes by using road convoys with several identical vehicles in the vicinity of Landsberg am Lech over a distance of 15,000 km. The wear behaviour of the second size is carried out at a special test facility provided by the tyre manufacturer, Bridgestone. The test bench simulates the route of the road convoy test drives. The test bench results are checked by means of several test tyres during the test drives under realistic conditions.

For many years, the tyre wear test has been an integral part of ADAC´s tyre test, which is carried out twice a year. One tyre size per season is driven over 15,000 km under realistic conditions to determine the wear. Every 2,500 km, the tread depth and weight loss are measured using a laser measuring device and digital scales. Over one million measuring points are evaluated during the tread depth measurement.



ADAC Wear test: Test-drive route for convoy drives

The wear-and-tear test drives are conducted on a route totalling about 300 km with approx. 60% urban and suburban traffic and 40% motorway. Every day, this circuit is driven once clockwise and once anti-clockwise in a four-vehicle convoy. A GPS data logger is used to ensure a reliable and comparable measurement method.

The following information is recorded:

- Distance travelled
- Speed
- Lateral and longitudinal acceleration
- Driving and braking times
- Route recording

Tyre abrasion as plastic in the environment

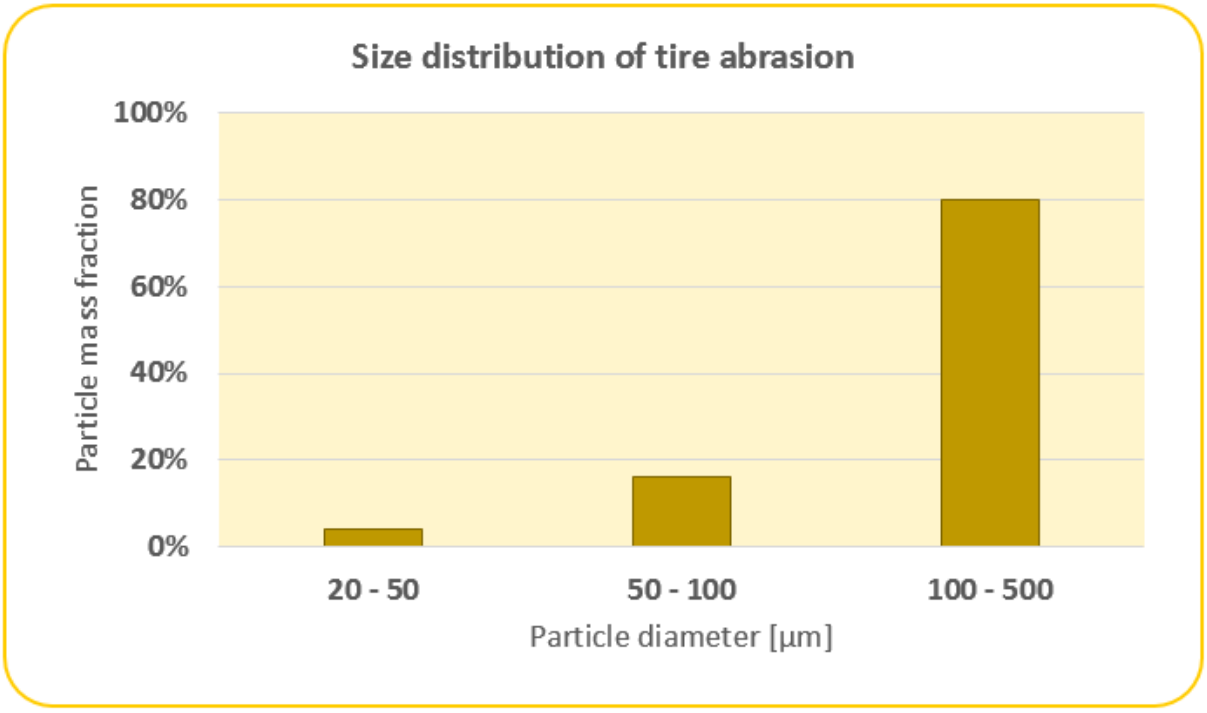
Plastic waste in the environment and in the world's oceans is an increasing problem of our civilization. Plastic particles can be found in the soil, in drinking water and even in the air we breathe. This also poses a growing risk to human health.

Synthetic rubber is one of the plastics and, as abrasion from car tires, accounts for around one third of all German microplastic emissions, according to estimates [2]. Based on ADAC measurements of tire wear, which determined an average tire abrasion of 117 g/1,000 km and a total mileage of 644.8 billion kilometers [5], the tire abrasion caused by passenger car traffic in Germany can be estimated at around 80,000 tons per year.

Abrasion occurs during power transmission at the contact surface between the tire, the road surface and the dirt lying on the road surface (e.g. leaf residues, blown soil from farmland, sand, water, etc.). The abrasion particles therefore do not consist of pure tire wear, but are a conglomerate of different substances. The technical term "TRWP" (tire and road wear particles) reflects the complex composition better than the term "tire wear".

The size of the tire wear particles determines their whereabouts. Particles with a diameter of less than 10 µm, which belong to PM10 as fine dust, can remain suspended in the air for hours or days, are transported over long distances and can also be inhaled. Particles larger than 10 µm sink rapidly with sedimentation velocities of 1 cm/s and more and are deposited on the road or in the immediate vicinity of it.

As part of the project "RAU - Tire Abrasion in the Environment" (founded by German Federal Ministry of Education and Research) at the Technical University of Berlin, Institute of Civil Engineering, Department of Urban Water Management [3], particles generated on a laboratory test rig for tire abrasion as well as particles collected on the road from tire and road abrasion were investigated. The size distribution of these samples, shown in the figures, indicates that only a very small proportion of tire abrasion has a diameter below 10 µm. In airborne particles analysed in the project, the proportion of tire material (synthetic rubber SBR) ranged from 2 to 13%.



Only a small fraction of tire abrasion remains in the atmosphere for a longer period of time and affects humans through the air they breathe. Compared to the inhalable fraction of particulate matter (PM10 and PM2.5 with a diameter below 10 µm and below 2.5 µm, respectively), particles of tire abrasion are very coarse and do not penetrate deeply into the respiratory tract of humans.

The majority of tire and road abrasion remains on the roadway or in the near vicinity of the road. Most of it is collected and carried away by the road surface water during precipitation. In the municipal environment, it flows through the sewer system and is treated in wastewater treatment plants (combined

sewer system) or discharged directly into bodies of water (separate sewer system). Outside of towns, road surface water is usually drained openly, i.e. over the verge and infiltrated into swales or the naturally occurring soil. Closed drainage is required on trunk roads if there is no soil capable of infiltration or if the route is located in a drinking water protection zone. In such cases, the surface water is collected at the edge of the paved area and led via pipes or drainage troughs, usually to rainwater retention basins. There, after purification of the water (oil separator, sedimentation basin), the throttled release (retention basin) takes place to the receiving water [4]. The roadbed "grows" due to the input of road dirt and must therefore be milled off every 5 to 20 years. The resulting roadbed debris must be disposed of properly.

As a general rule, the amount of riprap emitted by road traffic should be kept as low as possible to minimize the harmful effects on the aquatic environment, on soils, and ultimately on humans.

Tips for the consumer

- Frequent drivers in particular should buy tyres with a low level of wear – this not only saves money, but also protects the environment
- Summer/winter tyres should be changed according to the season so that they do not drop out of the appropriate temperature window and thus unnecessarily increase wear
- Tyre pressure should be checked regularly. Under-inflation can increase wear just as much as over-inflation.
- The axle settings should be checked at regular intervals at a specialist repair workshop, at the latest when an uneven wear pattern is noticed on the tyre.
- An even and proactive driving style not only ensures low fuel consumption, but also reduces tyre wear.

Factors influencing tyre abrasion

„Tyre wear in everyday use is strongly influenced by operating and driving style. A fuel-efficient driving style also ensures lower tyre abrasion."

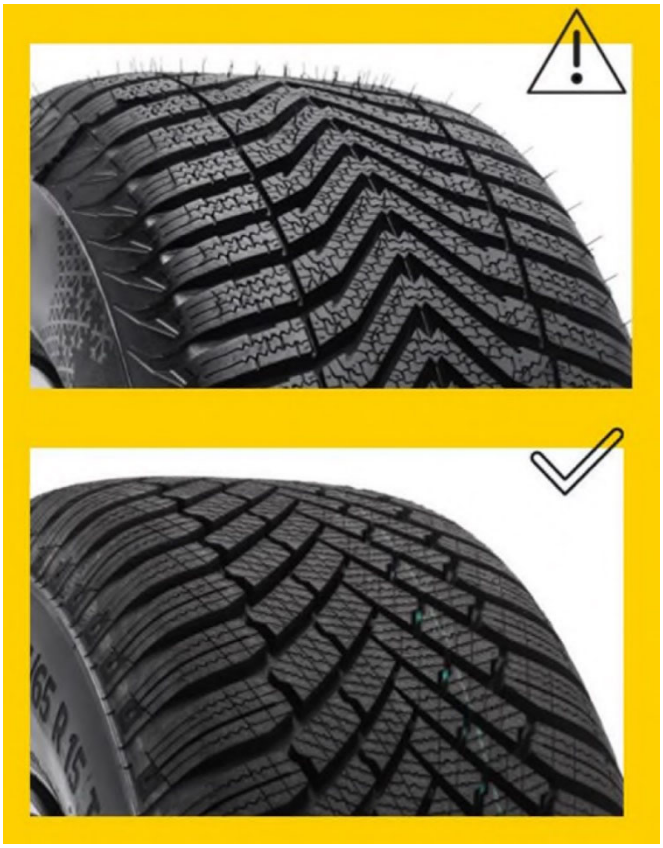
- **Topography:** driving in mountainous regions increases tyre abrasion
- **Driving surface:** concrete surfaces cause higher tyre abrasion than asphalt
- **Weather conditions:** wet road surfaces cause higher tyre abrasion
- **Air temperature:** higher temperatures increase tyre abrasion
- **Vehicle Weight:** the higher the vehicle weight, the higher the tyre abrasion
- **Axle geometry:** sporty chassis setup increases tyre abrasion
- **Engine charakteristics:** higher torque increases tyre abrasion
- **Driving speed:** higher speed causes higher tyre abrasion
- **Driving style:** proactive, fuel-efficient driving reduces tyre abrasion

Recommendations to manufacturers

- Modern tyres can be low-wear and safe at the same time. Tyre manufacturers must make better use of this technological advance in future tyre developments in order to reduce the environmental impact of tyre abrasion.
- Today, a premium tyre is no longer defined only by safe and driver-friendly tyres. The so-called premium manufacturers in particular should be aware of their responsibility and place much greater importance on the issue of tyre wear, especially regarding the public´s perception and in advertising slogans.
- Ultra-high-performance tyres hardly improve driving safety in normal road traffic any more, but instead belong on the race track. Tyre manufacturers should therefore focus more on safe and simultaneously environmentally friendly tyres in the future.
- Environmentally friendly tyres should be made available in all standard tyre sizes. If, due to the design, there are tyre sizes that cannot fully resolve the trade-off with regard to driving safety, this should also be clearly communicated to consumers, or a more appropriate tyre size should be recommended.

Production residues on the tyre surface

Some factory residues may be found on the tread of some tyres when they are brand new. These fine rubber threads have no technical benefit to tyre performance and the rubber residues lead to increased tyre wear during the first kilometres of driving with the new tyres. This is an unnecessary environmental hazard that could easily be remedied by the tyre manufacturer through an additional production step or appropriate manufacturing procedures. The lack of production residues is therefore not only a quality feature of new tyres but also reduces the unnecessary environmental impact caused by the abrasion of the rubber threads.



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Publisher/Imprint

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