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A problem to tackle: soccer players' awareness of microplastic infill in soccer fields predicts support for pro-environmental interventions

Introduction

Sport is an important pillar of our society and fulfills essential social functions through its wide-ranging activities in areas such as inclusion, education, youth work, volunteering, and health (Kauder, Ramsauer, & Struck, 2008). With over 7 million members and approximately 24,000 clubs, the German National Football Association (DFB) is the largest top-level Olympic association in Germany (Bestandserhebung DOSB, 2019). There are over 30 million people in Germany who describe themselves as soccer fans, and the German "Bundesliga" has a public awareness level of 99%. This makes soccer not only the most popular but also the best-known sport in Germany. Its enormous acceptance among the German population means that it can also assume great social responsibility (Rauball, 2014).

The popularity of soccer in Germany is accompanied by a high demand for sports facilities. Soccer requires playing fields that can be used for training and matches even during winter months. For this reason, artificial turf systems (ATS), which are made of synthetic material, have been available for many years now (FIFA and eunomia, 2017). According to the DFB, there are approximately 5000 actively used artificial turf pitches (ATP) in Germany. These fulfill special sport-relevant and technical functions and are therefore popular among players, clubs, and municipalities (DOSB and BISp, 2019). The artificial grass fibers of the ATS used in soccer can be filled with synthetically produced plastic granulate (Schüler and Stahl, 2008). Among other things, these infills and parts of the grass fibers can be released into the environment through sports use, where they pose numerous risks (Fath, 2019). The World Health Organization (WHO) suggests that the polymer composition of particles is a major analytical challenge, and background contamination in the environment is likely to increase as particle size decreases (WHO, 2022, p. 44). Accordingly, the aim of this study was to analyze soccer players' awareness of the problems that follow from the discharge of synthetic infill materials from ATS into the environment. We explored whether users are aware of their own contribution to this discharge, and whether they know about the consequences for the environment. In addition, possible interventions to prevent the discharge of ATS and possible willingness to act were assessed.

Discharge of synthetic material from ATS

One of the most important advantages attributed to ATS in soccer and other turf sports is their intensive usability (DOSB and BISp, 2019). An ATP is more durable and weather-resistant than a natural grass pitch due to its synthetic components. This enables a high-frequency use of the pitch, both over the course of a day and a year (Polytan, 2020; Schüler and Stahl, 2008).

The artificial turf fibers of the turf pile are usually made of polyethylene, which is consolidated and made durable with the help of different additives such as UV stabilizers and flame retardants (Fath, 2019; FIFA and eunomia, 2017). Depending on the construction of the pitch, several centimeters of infill material must be placed between the artificial turf fibers. This infill material, also called "performance infill," serves as shock absorption for injury prevention and creates optimal playing characteristics for soccer by imitating a natural sports surface (Alcantara et al., 2006; DOSB and BISp, 2019; Stadionwelt, 2016). In Germany, synthetic infill (elastic granulate infill) as well as cork and sand are used as infill materials (DOSB and BISp, 2019). Styrene-butadiene rubber (SBR), ethylene-propylene-diene rubber (EPDM), or thermoplastic elastomer (TPE) granules are primarily used as synthetic infill for ATS in soccer. These materials differ in their mechanical–thermal properties due to their chemical nature (Hoinkis and Lindner, 2001). The most widely used infill material in Germany and other EU countries are SBR granules, which are produced from used tires and, as mixed polymers,

The paper is previously unpublished and has not been submitted to any other journal.

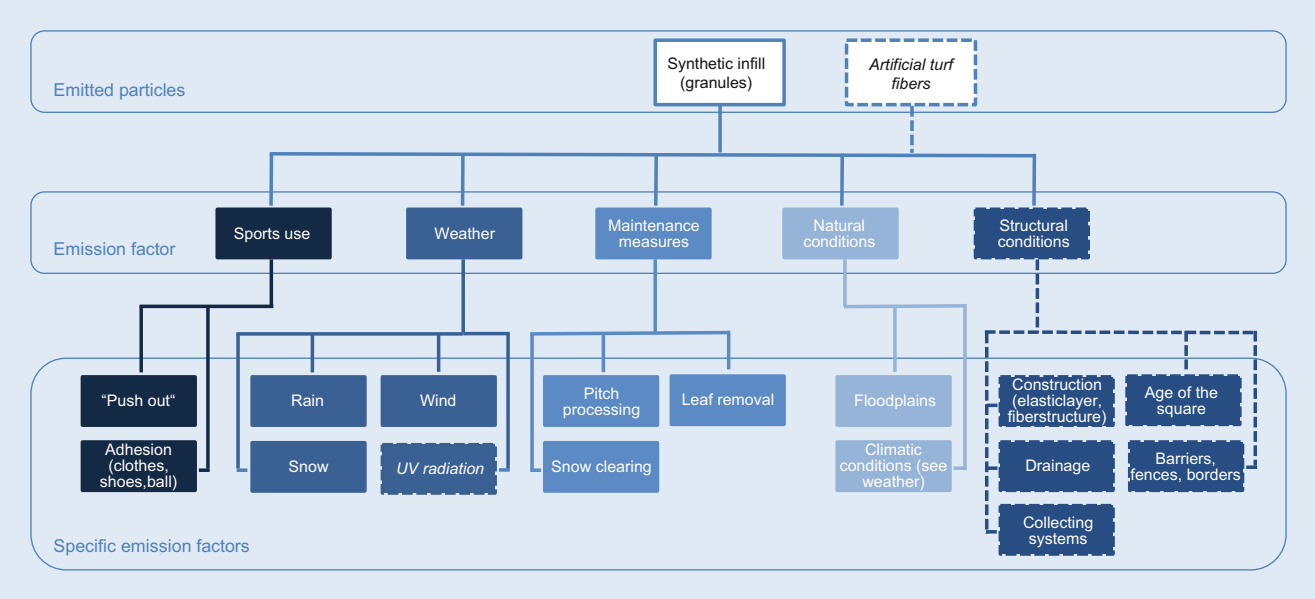

Fig. 1 ▲ Factors influencing granulate emissions (own representation, based on EuRIC, 2020)

withstand particularly strong mechanical loads (FIFA and eunomia, 2017; Hoinkis and Lindner, 2001). During the lifetime of an ATP, it is necessary to replenish the granules between the synthetic turf fibers, as displacement and loss of granules occur during use.

The discharge of plastic granules from ATS is thought to be driven by several emission factors and a combination of these, as shown in **Fig. 1** (Korbøl, 2018). A major factor for the emissions of granules from ATS is formed by the players and the game operation itself. Due to the mechanical force of the kicks on the pitch, the granules are pushed to the outer edges and ultimately transported out of the turf system into the surrounding terrain. In addition, the synthetic granules stick to the players' shoes and clothing, which means that when they leave the pitch they can be carried into the surrounding environment (e.g., changing rooms, showers, or the washing machine). Consequently, particles will enter sewage treatment plants via the sewer system, and deploy into natural rivers and groundwater (DOSB and BISp, 2019; EuRIC, 2020). Weather conditions also constitute another relevant factor. Due to heavy rainfall events, the granules can be flushed out of the ATP. If no special drainage system is built into the site, the potentially hazardous constituents of the infill may be emitted into the environment and enter the water system. Likewise, there is a risk of wind blowing the infill out of the ATP unless granulate containment structures are built around the site (DOSB and BISp, 2019; EuRIC, 2020).

Since the fate of the particles in this process is not precisely known, it is assumed that the lost granules are discharged into the environment surrounding the pitch (Bertling and Weidner, 2019; Korbøl, 2018). Korbøl (2018) analyzed the fate of plastic granules from ATP in Norway using sediment analyses from rivers and streams adjacent to ATP. Up to 47.3 g/L of plastic granules were found in samples both downstream and upstream of ATP (Korbøl, 2018). Since a different placemaking method is preferred in Norway, the figures cannot be transferred to ATS in Germany without further analysis. Nevertheless, Korbøl (2018) shows the possible extent to which microplastic particles from ATS can be spread into the environment and that they spread widely and randomly.

The exact amount of microplastic granulate discharged from ATS, however, is currently unknown (DOSB and BISp, 2019). FIFA estimates the emissions per year at 1–4% of the originally filled granulate quantity (FIFA and eunomia, 2017). This would correspond to a discharge to the environment of about 350–1400 kg per year if 35 t of synthetic granules were filled in a large playing field. A Dutch study by Weijer and colleagues (2017) found a granule discharge of 500 kg per ATP per year, and a study by the Institute Frauenhofer UMSICHT speaks of ATP as the fourth largest emission source for microplastic pollution (Bertling and Weidner, 2019; Weijer et al., 2017). However, given the many different conditions and designs of ATPs, it is not possible to conclude on a generally applicable emission level (Bertling and Weidner, 2019; DOSB and BISp, 2019). However, it is evident that parts of the infill materials are lost from the pitches.

Microplastics and ecosystem

Due to the interconnectedness of ecosystems and high volumes of plastic production worldwide, plastic pollution is a challenge for the entire planet and is changing the global environment (Zhang et al., 2019). Due to the bioavailability and persistence of plastic parts in the environment, they can lead to the degradation of survival and growth opportunities for living organisms across the food chain, and can as release toxic pollutants into aquatic and terrestrial habitats (Fath, 2019). Plastic granules discharged from

ATS into the environment thus pose a risk to terrestrial and aquatic ecosystems and their biota (Zhang et al., 2019). However, the biological impacts as well as the specific consequences for humans and the environment have not yet been fully understood (Zhang et al., 2019).

In general, microplastics act as attractors for pollutants. These connect with the plastic particles and become transported further. If a living being ingests the microplastic, the bound toxic substances are also transferred into the organism (Fath, 2019). In addition, due to their high bioavailability, microplastic particles can become embedded in the tissue of plants and animals, where they release the chemical substances added to them. Once microplastics are in animal tissues, there is likewise a risk that they can also be transferred to the human organism via the food chain (i.e., bioaccumulation, Fath, 2019). In addition, polymers in particular are tailored with additives to withstand resistance against biological and chemical degradation (persistence). Although evidence on synthetic plastic half-lives vary widely from 50 to more than 1000 years, depending on environmental conditions and composition, the annual emission amounts add up steadily (Chamas et al., 2020; Koltzenburg, Maskos, & Nuyken, 2014; WWF, 2019).

Perceptions of and responses to the ATS issue

In addition to the risks described above, a social and societal component comes into play: The confrontation of users with the potential environmental harmfulness of the sports surfaces they use. The debate about the existence and harmfulness of synthetic infill materials from ATS in the environment shows that the practice of sports activities creates a conflict between the people who practice the sport and the environment in which the sport is practiced (Schemel, Erbguth, & Reichholf, 2000). However, many athletes do not recognize possible direct or indirect conflicts between his or her actions and their effects in the practice of his or her preferred sports. Furthermore, it is often seen that it is not their personal business to deal with these effects (Schemel et al., 2000).

These behavioral aspects can be approached from an environmental psychological perspective. In this paper, we focus on the extent to which soccer players are aware of the problem of ATS and to what extent this is accompanied by a willingness to act to change the problem of synthetic infill materials. Our conceptualization of problem awareness is based on a multidimensional understanding of environmental awareness (De Haan and Kuckartz, 1996; Langeheine and Lehmann, 1986; Maloney and Ward, 1973).

Environmental awareness

Environmental awareness can be understood as the actual behavioral expression of individuals toward the environment, or it can refer to a person's attitudes toward the environment in its individual components or as a whole (De Haan and Kuckartz, 1996; Fuhrer and Wölfing, 1997). Due to the fuzzy delineation of definitions, inconsistencies in research findings often occurred in environmental awareness research because studies were often not comparable (De Haan and Kuckartz, 1996; Kuckartz, 1995). Preisendörfer (1998) assumes that most empirical work conceptualized environmental awareness as a survey of attitudes. In this work, therefore, environmental awareness is understood as a person's distinct attitudes, i.e., positive or negative evaluations toward the attitude object "environment" (Fuhrer and Wölfing, 1997; Milfont and Duckitt, 2010).

Measures of such environmental attitudes may differ not only in their choice of attitude object but also in the number of their attitude components surveyed. Multiple attitude components allow for a multidimensional assessment of environmental issues (Oerke, 2007). Since there is no research in the field of environmental attitudes of soccer players to be consulted yet, in this paper we resort to the internationally established instrument New Ecological Paradigm (Dunlap, Van Liere, Mertig, & Jones, 2000) to determine the ecological orientation of the participants.

Abstract

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A problem to tackle: soccer players' awareness of microplastic infill in soccer fields predicts support for pro-environmental interventions

Abstract

On behalf of the European Commission, the European Chemicals Agency (ECHA) published a restriction proposal in early 2019 to minimize the EU-wide placement of intentionally added microplastics in products (ECHA, 2019). Soccer fields in the sense of artificial turf systems (ATS) and their infill are included in this definition and are suspected to be the fourth largest source of microplastic emissions. In the present study, we queried a sample of 191 soccer players regarding their awareness of the problem of synthetic infill discharge from ATS into the environment and whether they are aware of its environmental consequences. In addition, we investigated whether the soccer players expressed a willingness to implement interventions against the discharge of microplastic granules. Results suggest a moderate (rather than high or low) level of problem awareness among soccer players. In particular, issue-specific problem awareness was significantly related to the willingness to implement an intervention measure, being its strongest predictor. Our results further suggest that in order to optimize the awareness and legitimation of intervention measures among club members, more information (i.e., environmental knowledge) should be provided. The present work makes a first important research contribution to the awareness analysis regarding microplastic granulate from ATS.

Keywords

Artificial turf systems · Soccer · Synthetic infill · Awareness · Intervention

Environmental knowledge

Kuckartz (1995) understands environmental knowledge as the "knowledge and […] information that individuals possess about the environment and nature, flora and fauna, about ecological

relationships and problems" (Kuckartz, 1995, p. 72). However, the way of surveying environmental knowledge often turns out to be a particularly "precarious matter" (Preisendörfer, 1998, p. 30), since the questions used are often formulated remote from everyday life and very fact-based, which can be an explanation for the usually only weakly developed connection between environmental knowledge and environmental behavior (Bilharz, 1996; Preisendörfer, 1998; Szagun, Mesenholl, & Jelen, 1994). However, a lack of environmental knowledge might prevent people from taking environmentally friendly actions, while strong knowledge might be a predictor of awareness of environmental problems (Bord, O'Connor, & Fisher, 2000; Shi, Visschers, & Siegrist, 2015). Furthermore, Schahn and Holzer (1990) hypothesize that environmental attitudes are more likely to lead to pro-environmental behavior when high environmental knowledge is present. In particular, they refer to specific environmental knowledge. This concretizes the connection of the causes and consequences of environmental problems to possible problem-reducing actions and is therefore more consistent with a target behavior (Schahn and Holzer, 1990; Shi et al., 2015). Consequently, we assume that specific knowledge about microplastics is a relevant predictor of willingness to intervene.

Problem awareness

Environmental problems result from the understanding of environmental phenomena as "dangers and threats to the biosphere and humans" (Lehmann, 1999, p. 49). The demarcation of environmental phenomena to environmental problems thereby forms the resulting reaction of society to communicated phenomena. The term "infill discharge" can be seen as a direct threat to the environment, be perceived as unproblematic, or take on any form in between, depending on knowledge, experiences, and points of contact with the topic of soccer. Bord et al. (2000) argue that the perceived risk of an environmental problem is a fundamental factor in evaluating it (Bord et al., 2000). Along with this, the perceived personal or societal concern and threat of an environmental problem can vary as much as the existence attributed to it (Lehmann, 1999) and motivate behavior (Rost, Gresele, & Martens, 2001). In the present research, problem awareness is understood as a threat and specific problem perception. For this purpose, we are guided by the partial constructs of the anthropological–psychological characteristics of environmental problems defined by Lehmann and Gerds (1991).

Willingness to intervene

Many models for explaining (environmental) behavior argue for a more or less linear process about changes in attitudes toward pro-environmental behavior (Ajzen, 1991; Rost et al., 2001). However, these constructs rarely translate exactly to reality. This is because the intention or motivation to protect the environment does not necessarily lead to an active action to protect the environment (Gatersleben, 2013; Schlüter, 2007; Stern, 2000). Different motives, such as cost–benefit considerations, individual well-being, or lifestyle, as well as incentives, offers, and consequences, may determine the behavioral expression (De Haan and Kuckartz, 1996; Fietkau and Kessel, 1981; Klöckner and Blöbaum, 2010). As Rost et al. (2001) suggest, the respective components of action emergence depend on situational, personal, and social factors. As a result, a consistent prediction of behavior and action from environmental knowledge and attitudes is often impossible (Fietkau and Kessel, 1981; Martens and Rost, 1998; Rost et al., 2001; Schlüter, 2007). Additionally, definitions of environmental behavior differ. For example, Maloney and Ward (1973) differentiate the domain of environmental action in their multidimensional consciousness research into actual action ("actual commitment") as a person's current self-reported environmental behavior and willingness to act. They understand the term "willingness to act" as a so-called verbal commitment, i.e., a verbally communicated intention to do something about environmental problems (Kuckartz, 1995; Maloney and Ward, 1973). This integrates the willingness to commit to environmentally protective measures in the future (De Haan and Kuckartz, 1996; Gatersleben, 2013). In the context of this paper, verbal commitment is equated with the notion of *willingness* to intervene, or to act.

Current study

Based on the description of the psychological aspects of ATS consequences, five topic-specific hypotheses (H) were derived to answer the research question. Specifically, we hypothesized that the environmental awareness of soccer players regarding the environmental impact of plastic granules from plastic turf systems is low (i.e., below the mean of the respective scale, H1), and that environmental awareness, problem awareness, and environmental knowledge are correlated positively (H2). More specifically, we assumed that greater environmental knowledge among participants is associated with greater problem awareness (H2.1) as well as greater environmental awareness (H2.2). Furthermore, with greater environmental awareness, we hypothesize greater problem awareness as well (H2.3). Following on from this, we predict that basic chemical and ecological knowledge about the effects of microplastics in the environment is rather low (H3). We further hypothesize that participants with greater awareness of the problem are more likely to actively advocate for intervention measures than participants with lower awareness of the problem (H4), which is also assumed for the parameters of environmental awareness (H4.1), problem awareness (H4.2), and environmental knowledge (H4.3). Finally, we assume that participants who would currently actively advocate for intervention measures would have a lower intervention threshold for environmental impacts of ATS than participants who did not actively advocate for intervention measures (H5).

Method

Study design

Awareness of the topic of microplastics and their environmental impact in

the ATS context was investigated using a sample of soccer players and club members. Data collection was conducted with an online questionnaire, SoSci-Survey (computer software, version 3.1.06, https://www.soscisurvey.de), during the period 24.02.2020–19.04.2020.

A minimum number of 111 participants was required to statistically validate a medium-size correlation at 0.3 (at 1-β = 0.95; Faul, Erdfelder, Lang, & Buchner, 2007). As a participation criterion, the minimum age of the participants was limited to 18 years. A total of 225 clubs from the four sports districts of Birkenfeld, Bad Kreuznach, Rhein-Pfalz, and Südpfalz of the Southwest German Football Association (SWFV) were selected as the sampling pool. This selection resulted from the public availability of the club names, provided by the SWFV, as well as the geographical proximity to the university location. A list of all clubs in the selected four sports districts of the SWFV was created and supplemented with the contact data of the clubs freely available via the Internet. Subsequently, the online questionnaire was sent via e-mail to the contact persons of the clubs with the request to forward it to all football-playing members via the club-internal mail distribution list. In addition, the SWFV published an appeal for participation in the study with a link to the online questionnaire on its homepage. Participants could access the questionnaire via the URL link that was sent out. All participants were informed comprehensively about the study procedure and data protection issues.

Sample description

A total of 191 persons (25 female, 165 male, one person not specified) fully participated in the study. The participants were between 18 and 73 years old, with an average age of 39.2 years (SD = 14.9). Of the respondents, 182 indicated German as their native language (95.3%), five indicated a language other than their native language (2.6%), and four persons did not provide any information (2.1%). With regard to their function in the club, a total of 76 respondents described themselves as soccer players (39.8%). In addition, 42 participants stated that they were a board member (22.0%), 31 participants were coaches (16.2%), and 31 participants stated other functions such as youth leader, general manager, or spectator (16.2%). Another 11 persons did not provide any information about their function in the club (5.7%). When asked about their use of ATS, 178 respondents (93.2%) answered that they had already used an ATS, while 13 respondents (6.8%) stated that they had never used an ATS.

Instruments

In order to investigate the issue of soccer players' awareness of the environmental impact of microplastic granulate from ATS, existing survey tools were used, some of which were adapted to specific topics, and new item sets were constructed. As the main part of the study, three content areas were analyzed, which were subsequently combined into a common main variable, namely, topic awareness (TA).

Environmental awareness. The NEP scale (Dunlap et al., 2000) was used to measure environmental awareness. The 15 items were measured on a six-point Likert scale with response options ranging from 1 ("strongly disagree") to 6 ("strongly agree"). Negatively polarized items were inverted so that a higher scale value reflects a positive environmental attitude.

Problem awareness. Problem awareness was measured with six items from the *Threat and Vulnerability* questionnaire by Martens et al. (2014), each of which addressed environmental problems from microplastics in general (PA_g) or specifically from ATS (PA_{s1}). First, six items were recorded to assess the threat posed by microplastics in general (general threat perception PA_g) and then the same items were recorded with the addition of the threat posed by microplastic granules from ATS (specific threat perception PA_{s1}). The threat items, humans themselves as well as plants and animals, were retained and an additional item, "environment," was added. On a six-point Likert scale, participants could select the response options to the corresponding statements from 1 ("do not agree at all") to 6 ("fully agree").

Specific problem awareness. In a third step, four additional items based on the questionnaire *Specific Problem Awareness* by Hunecke et al. (2014) were used to additionally test the specific problem awareness. This questionnaire captures the affective and cognitive evaluation of the environmental impact of car traffic and was adapted topic-specifically according to the research question of this paper (PA_{s2}; Hunecke et al., 2014). In both item clusters, the respondents were able to select the possible answers to the corresponding statements on a six-point Likert scale ranging from 1 ("strongly disagree") to 6 ("strongly agree").

To generate a variable for the specific problem awareness of the participants regarding microplastic granules from ATS, PA_{s1} and PA_{s2} were combined to a common variable PA_s. This variable PA_s is used in the evaluations of the hypotheses.

In all three levels of problem awareness (PA_g, PA_{s1}, PA_{s2}), items were alternated in positive and negative questions to avoid response bias (Schleyer-Lindenmann, Ittner, Dauvier, & Piolat, 2018). Negative items were inverted, which means that a high scale value also implies a high level of problem awareness. For all levels of awareness, higher values thus indicated stronger awareness.

Environmental knowledge. Using the World Wide Fund (WWF) fact sheet *Microplastics* (2019), eight statement items were created to determine the respondents' specific environmental baseline knowledge (EK) about the environmental impacts of microplastics (see Appendix 1). While we are fully aware that the WWF fact sheets are not peer reviewed, we were trustful such that the numbers presented in the fact sheet resemble realistic ranges (with uncertainties). For example, one item states that "approximately 3.2 million tons of microplastic are released into the environment every year," but there are also other numbers discussed in the literature (e.g., EFSA CONTAM Panel, 2016; for emissions from textiles alone,

Table 1 Descriptive statistics of key measures

	N	M	SD	Min	Max	
Environmental awareness (EA)	191	4.35	0.64	2.4	5.67	0.79
General problem awareness (PA_g)	191	4.39	0.91	1.17	6	0.81
Specific problem awareness (PA_s)	191	3.38	1.08	1	6	0.91
Environmental knowledge (EK)	191	4.65	1.73	1	9	0.55
Topic awareness (TA)	191	4.13	0.84	1.82	5.87	0.79
Collective efficacy (CE)	191	5.17	1.21	1.5	7	0.89

see, e.g., Periyasamy & Tehrani-Bagha, 2022). Among the items we developed there were both correct and incorrect statements. These could be answered by the respondents with "true," "not true," or "I don't know," whereby the answer option "I don't know" was counted as a false answer. If all statements were answered correctly, a maximum value of eight knowledge points could be achieved. For the analysis, we assumed that a higher number of knowledge points also implies greater knowledge about the possible environmental consequences of microplastics in the environment. For better comparability with the other data collected, the values from 0 to 8 were converted to the values 1 to 9. Expression values below the possible scale mean (5) were classified as low environmental knowledge.

Willingness to intervene. To assess the willingness to intervene and to discuss possible starting points for the participants' understanding of intervention, questions were asked about the willingness to intervene, the intervention threshold, and possible intervention measures with regard to microplastic granulate from ATS. The intervention threshold for the participants' own active action was analyzed with the help of a scale from 1 ("in the case of minor environmental impacts such as local pollution at the edge of the playing field, active intervention would be taken") to 101 ("in the case of extreme environmental impacts such as mass mortality of marine and terrestrial organisms, active intervention would be taken"). Furthermore, participants were able to indicate ideas on possible interventions for discharged microplastics from ATS using a free listing option.

Additionally collected data

For explorative reasons, intervention behavior, collective effectiveness (Hamann and Reese, 2020), artificial lawn behavior as well as the demographic data of the participants were determined as additional components of the questionnaire. The respective items were adapted and specifically constructed according to the research question. These analyses are presented in the supplementary material.

Results

Data were analyzed using IBM SPSS Statistics (version 25.0.0.2). Missing values in individual scales were excluded from the respective calculations. Cronbach's alpha was used to determine the internal consistencies of the various scales. We first present the analysis of our hypotheses, followed by additional, explorative tests.

Descriptive statistics of and bivariate correlations between the measured constructs are displayed in **Tables 1 and 2**. **Table 3** summarizes the hypotheses and results.

Hypothesis testing

Hypothesis 1—Issue awareness in soccer players

To analyze the main variable "topic awareness" (TA), the three content areas environmental awareness (EA), problem awareness (PA), and environmental knowledge (EK) were first evaluated separately.

For EA, participants' overall mean score was significantly above the scale mean, $M_{EA} = 4.35$, $SD_{EA} = 0.64$, $t(190) = -4.66$, $p < 0.05$, $d = 0.34$. To determine problem awareness, a similar overall mean value in the upper half of the possible values was recorded for the participants' general threat perception (PA_g): $M_{pAg} = 4.39$, $SD_{pAg} = 0.91$, $t(190) = 15.11$, $p < 0.05$, $d = 1.09$. In their specific threat perception (PB_{s1}), participants expressed a significantly lower value than in the PB_g ($M_{pAs1} = 3.35$, $SD_{pAs1} = 1.02$). When the third aspect of the discussion of problem awareness, the specific problem awareness (PA_{s2}), was additionally analyzed, similarly lower values were found as in PA_g ($M_{pAs2} = 3.42$, $SD_{pAs2} = 1.28$). Combining the variables PA_{s1} and PA_{s2} to a common variable of specific problem awareness (PA_s) resulted in an overall mean value in the middle range of possible score values: $M_{pAs} = 3.38$, $SD_{pAs} = 1.08$, $t(190) = 8.32$, $p < 0.05$, $d = 0.60$. In the further course of the evaluation of the results, the variable PA_s was used as a reference of the topic-specific problem awareness. The players expressed a significantly lower value in the specific problem perception of microplastics from ATS than in their problem perception of microplastics in general: $t(190) = 15.07$, $p < 0.05$, $d = 1.09$. The overall mean value of the surveyed environmental knowledge (EK) was in the middle of the possible scores ($M_{EK} = 4.65$, $SD_{EK} = 1.73$). Overall, 12% of the participants could answer more than two thirds of the questions correctly; 24.1% of the participants knew the correct answer for less than one third of the statements.

To evaluate the scores, the deviations of the content areas from their respective possible mean scores were examined using one-sample *t* tests. Environmental awareness deviated significantly from its possible mean score (3.5) with a mean difference of 0.85: $t(190) = 18.51$, $p < 0.01$, $d = 1.34$. The overall mean of environmental knowledge is significantly smaller than its possible mean score (5): $t(190) = -2.8$, $p < 0.01$, $d = 0.2$. Specific problem awareness (PA_s) shows no significant deviation from its possible mean score (3.5): PA_s, $t(190) = -1.49$, $p = 0.14$, $d = 0.11$.

In order to analyze whether participants' awareness of the environmental impact of discharged plastic granules from ATS was low, the values of the variables EA, PA_s, and EK were combined to

Table 2 Bivariate correlations between the measures of the unit of study

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Environmental awareness (EA)	–	–	–	–	–	–	–	–
(2)	General problem awareness (PA_g)	0.42**	–	–	–	–	–	–	–
(3)	Specific problem awareness (PA_s)	0.41**	0.58**	–	–	–	–	–	–
(4)	Environmental knowledge (EK)	0.14*	0.28**	0.23**	–	–	–	–	–
(5)	Collective efficacy (CE)	0.18*	0.30**	0.27**	0.00	–	–	–	–
(6)	Topic awareness (TA)	0.73**	0.60**	0.77**	0.64**	0.21**	–	–	–
(7)	Intervention threshold	−0.25**	−0.30**	−0.36**	−0.14	−0.30**	−0.34**	–	–
(8)	Political orientation	−0.15*	−0.01	0.00	−0.17*	−0.10	−0.15*	0.31**	–
(9)	Age	0.14	0.03	0.07	0.01	0.12	0.10	−0.05	−0.07

**The correlation is significant at the $p < 0.01$ level (2-sided)
*The correlation is significant at the $p < 0.05$ level (2-sided)

form the main variable topic awareness (TA).

This resulted in an overall mean score for TA of 4.13 ($SD = 0.84$). To test the hypothesis, the deviation of the overall mean from the value of 4 was compared as the possible mean score of TA. With a significant mean difference of 0.13, TA proved to be in the upper range of possible expressions, albeit very low: $t(190) = 2.14$, $p = 0.03$, $d = 0.15$. Thus, the first hypothesis—low awareness prevails—can be rejected.

Hypothesis 2—Relationship between environmental knowledge, environmental awareness and problem awareness

Pearson correlations were calculated to test the relationships between the key measures (EA, PA_s, EK). The overall mean score of environmental awareness (EA) correlates significantly positively with specific problem awareness (PA_s): $r = 0.41$, $p < 0.01$. Similarly, there was a significant positive correlation between environmental knowledge (EK) and problem awareness (PA_s): $r = 0.23$, $p < 0.01$. Environmental awareness (EA) and environmental knowledge (EK) were also significantly positively correlated with each other ($r = 0.14$, $p < 0.05$). This confirms hypothesis 2 along with its subhypotheses.

Hypothesis 3—Chemical and environmental knowledge

The third hypothesis investigated whether respondents' basic chemical and environmental knowledge regarding the effects of microplastics in the environment was low. As already explained in the results for hypothesis 1, an overall mean value in the middle range of possible values ($M_{EK} = 4.65$, $SD_{EK} = 1.73$) was found. A one-sample t test was used to compare the deviation of the overall mean from the value of 5, as the possible mean expression of environmental knowledge. With a mean difference of −0.35, the overall mean falls significantly short of the possible mean expression of environmental knowledge, thus the hypothesis can be retained: $t(190) = -2.8$, $p < 0.01$, $d = 0.2$.

In total, 75% of the participants were able to correctly confirm the formation of microplastics through the wear and tear of larger plastic parts and the use of microplastics, e.g., in cosmetics (statement 8). Likewise, about 64% of the participants knew that the ingredients of microplastic particles can contain toxic substances (statement 2). Furthermore, 77.5% were able to correctly confirm that microplastic particles can lodge in the gastrointestinal tract of animals (statement 5). By contrast, 50% of the respondents were unable to answer whether microplastic particles act as pollutant vectors (statement 3). Another 11% assumed the statement to be false. Overall, 84.3% could not correctly classify the particle size of microplastics according to the definition of the Federal Environment Agency (statement 1). The degradation time of microplastics in the environment of 20,000 years was wrongly assessed by 67% of the participants as correct and 25% stated that they could not comment on the statement (statement 4). The statement that approximately 3.2 million tons of microplastic are released into the environment every year (WWF, 2019) was confirmed by 48% of the participants and another 48% did not know how to answer this statement (statement 6). Regarding the false claim that the consequences of the effects of microplastics on the environment and humans are known, 33.5% of the respondents agreed with it, 39.3% disagreed with it, and 27.2% could not give an answer to this statement (statement 7). Given that the numbers of microplastic particles in the environment vary starkly in magnitude and are unspecified (Akdogan, & Guven, 2019; Morgado, Palma, & Bettencourt Da Silva, 2022), we deem it important to note that statement 6 in particular should be interpreted with caution.

Hypothesis 4—Willingness to intervene

In the intervention behavior category, 35.1% of the respondents stated that they would currently actively promote intervention options for ATS with synthetic infill, while 61.8% would not do so. A further 3.1% of the participants did not make any statement in this respect.

A multiple linear regression was used to test the fourth hypothesis, i.e., whether participants with a greater awareness of the topic would be more likely to actively advocate for intervention options than participants with a lower awareness of the topic. The EA, PA_s, and EK were significant predictors of intervention behavior as a model of TA, explaining 20% of the

Table 3 Summary of hypotheses testing

Hypothesis	Analysis and results	Accept/Reject
Hypothesis 1—Topic awareness of soccer players	Variables EA, PAs, and EK were combined to form the main variable topic awareness (TA): $M = 4.13$, $SD = 0.84$ A one-sample t test was used to compare the deviation of the overall mean from the value of four as the possible mean expression of TA. With a significant mean difference of 0.13, TA proved to be in the upper range of possible expressions, albeit very low: $t(190) = 2.14$, $p = 0.03$, $d = 0.15$	The first hypothesis—low awareness prevails—is rejected
Hypothesis 2—Relationship between environmental knowledge environmental awareness, and problem awareness	Pearson correlations were calculated to test the relationships between the key measures (EA, PA_s, EK). There were significant positive correlations between all variables (cf. **Table 2**)	The second hypothesis—positive correlations between the variables—is accepted along with its subhypotheses
Hypothesis 3—Chemical and environmental knowledge	A one-sample t test was used to compare the deviation of the overall mean from the value of 5, as the possible mean expression of environmental knowledge. With a mean difference of –0.35, the overall mean falls significantly short of the possible mean expression of environmental knowledge: $t(190) = -2.8$, $p < 0.01$, $d = 0.20$	The third hypothesis—low chemical and environmental knowledge of the effects of microplastic in the environment prevails—is retained
Hypothesis 4—Willingness to intervene	Multiple regression analysis was used to analyze the content of the three criteria of subject awareness (EA, PAs, and EK) that explains the participants' intervention activity. The EA, PAs, and EK were significant predictors of intervention behavior as a model of TA, explaining 20% of the variance in intervention readiness: $F(3, 181) = 14.78$, $p < 0.01$, $R^2 = 0.20$. However, when analyzing the individual coefficients, only specific problem awareness emerged as a significant predictor of participants' willingness to intervene	The fourth hypothesis could be accepted. Of its subhypotheses, H4.1 and H4.3 were rejected
Hypothesis 5—Intervention threshold	Within the question to personally take action against the discharge of the granules, the overall mean value of the respondents was in the middle-to-upper range of the possible expression values ($M = 60.32$, $SD = 26.76$). Thus, the intervention threshold for the participants is more likely to be in the range of stronger environmental impacts. An unpaired t test was conducted and it was found that respondents who previously indicated they were currently actively advocating for intervention opportunities reported significantly lower values in their intervention threshold than respondents who did not want to advocate for intervention opportunities: $M_{threshold,\ advocacy} = 48.84$, $M_{threshold,\ no\ advocacy} = 67.93$, $t(183) = -3.91$, $p < 0.01$, $d = 0.29$	The fifth hypothesis is retained

variance in intervention readiness: $F(3, 181) = 14.78$, $p < 0.01$, $R^2 = 0.20$. However, when analyzing the individual coefficients, only specific problem awareness emerged as a significant predictor of participants' willingness to intervene (see **Table 4**).

Hypothesis 4 could be thus be accepted, while the subhypotheses, H4.1 and H4.3 were rejected.

Hypothesis 5—Intervention threshold

When asked how great the environmental impact of microplastic granules from ATS would have to be for the respondents to personally take action against the discharge of the granules, the overall mean value of the respondents was in the middle-to-upper range of the possible expression values ($M = 60.32$, $SD = 26.76$). Thus, the intervention threshold for the participants is more likely to be in the range of stronger environmental impacts. An unpaired t test was conducted to test whether the participants who are currently actively in favor of intervention options also have a lower intervention threshold for environmental impacts caused by ATS than those who are opposed to intervention. It was found that respondents who previously indicated that they were currently actively advocating for intervention opportunities reported significantly lower values in their intervention threshold than respondents who did not want to advocate for intervention opportunities: $M_{threshold,\ advocacy} = 48.84$, $M_{threshold,\ no\ advocacy} = 67.93$, $t(183) = -3.91$, $p < 0.01$, $d = 0.29$. Consequently, this hypothesis is retained.

Discussion

The current study set out to analyze topic awareness (TA) of ATS microplastic discharge and willingness for pro-environmental interventions among soccer players. The main findings suggest that overall, there is a moderate level of awareness of the topic, and the more often players played on a synthetic turf pitch, the lower was their awareness. A second main finding was that issue-specific problem awareness in particular was significantly related as a predictor to the willingness to implement an intervention measure. Finally, we also identified that overall, soccer players would intervene against infill discharges if they thought the environmental impacts were rather severe.

Even if a club had its own pitch with synthetic infill, an equally significant lower TA was found among these players. Although these results showed only small effects, it is nevertheless recognizable that soccer players who have a "closer connection" to ATS have a lower perception of the consequences and problems

Table 4 Multiple linear regression analysis of predictors EA, PA_s, and EK for intervention readiness

	β	t	*p*
Environmental awareness (EA)	0.04	–0.81	0.42
Specific problem awareness (PA_s)	0.19	5.71	0.00*
Environmental knowledge (EK)	–0.01	0.57	0.57

Independent variable: willingness to intervene
$R^2 = 0.20$; $F(3, 181) = 14.78$; $p < 0.01$
*The correlation is significant at the $p < 0.05$ level (2-sided)

of the discharge of granules than players who rarely play on an ATS. The different expressions of TA across the variables show that it is not possible to speak of an overarching pronounced TA of all soccer players.

Nevertheless, the results imply that TA is a possible predictor of players' willingness to intervene, as the model of TA (from EA, pAs, and EK) significantly predicted "verbal commitment" to interventions. The fact that the TA has an influence on the players' willingness to intervene can be shown by the negative correlation between TA and the players' intervention threshold. These assumptions can be transferred to the model of integrated action according to Rost et al. (2001), which will be discussed in detail in the following. The factors that formed TA in this study (environmental awareness, specific problem awareness, and environmental knowledge) correlated with each other, allowing reliable statements of the TA to be assumed (Cohen, 1988). In their environmental attitudes, the soccer players showed an average pronounced ecological orientation. This leads to the assumption that the players' attitudes are not a main focal point for optimizing and refining TA for the discharge of microplastics from ATS. Although there are no comparable study results for this group of participants, the present values can be considered robust due to the meaningful measurement instrument and a good internal consistency of the variables (Dunlap et al., 2000). A strong positive correlation between the environmental attitudes of the soccer players and the specific problem awareness could be determined. According to the conception of the integrated action model according to Rost et al. (2001), which depicts individual attitudes and values as the target value of reality within the target-actual trade-off, it can be assumed that a greater perceived threat of an environmental problem results from a pro-ecological attitude (Rost et al., 2001; Schlüter, 2007). Applied to the results of the present study, it can be assumed that the pronounced pro-ecological attitude of the interviewed soccer players forms an important basis for the development of TA.

Regarding the analysis of problem awareness, the strong negative correlation between specific problem awareness and the reported intervention threshold is noteworthy. The more soccer players perceived the infill material as a threat to the environment, the lower their threshold for intervention. This finding also fits into the integrated action model, according to which the expected level of damage caused by an environmental problem essentially influences threat perception, i.e., specific problem awareness (Rost et al., 2001; Schlüter, 2007). Consequently, if the expected impact of the granules in the environment for the soccer players were concretized and thus the perceived amount of damage increased, this would have a positive influence on the specific problem perception, so that an intervention action against the granule discharge would become more likely. Therefore, future research should investigate communicated strategies that would induce a willingness to intervene.

The fact that PA_s predicts the indicated intention to intervene also lends support to the integrated action model (Rost et al., 2001). The presence of a specific problem awareness about microplastics from ATS might have activated an action motive that led to the development of an intervening intention to act (Schlüter, 2007). It is interesting to note at this point that the players expressed a significantly lower value in the specific problem perception of microplastics from ATS than in their problem perception of microplastics in general. Accordingly, the soccer players perceived microplastics from ATS as a lower threat to humans and the environment. Since the predictor effect of specific problem awareness seems crucial for the formation of an intention to intervene accordingly, while at the same time, the specific threat of granules in the environment is underestimated by players, this specific threat should be focal for respective interventions. At this point, further research on the intervention behavior of soccer players along the integrated action model could investigate which factors enable an actual intervention execution and where soccer players see their scope of action in this debate.

Environmental knowledge, in contrast to specific problem awareness, did not predict action intention. This finding is consistent with previous research findings (Bilharz, 1996; Preisendörfer, 1998; Szagun et al., 1994), suggesting conceptual knowledge may be less relevant for intentions to act. Yet, within the integrated action model (Rost et al., 2001), knowledge is a fundamental factor for evaluating the actual state of the environment. Our results show this connection in the correlation between environmental knowledge and specific problem awareness. Therefore, we claim that environmental knowledge should not be neglected in the development of problem awareness (see also Shi et al., 2015). One major limitation lies in the measure we developed. There is a strong uncertainty about the exact figures of how much microplastic is emitted into the environment, or how long it would take to degrade. As such, our measure that is based on the WWF fact sheet (2019) does not do justice to this uncertainty. Future studies should implement knowledge measures that provide possible ranges.

As discussed above, specific problem awareness is an essential basis for the development of an intention to intervene and develops in part from individual environmental knowledge (Schlüter, 2007). According to the low environmental knowledge and the low specific problem awareness, only one third of the soccer players in this study declared their willingness to actively undertake intervention options for discharged granules at the current moment. Equivalent to the previous assumptions, the intervention supporters also considered the sever-

ity of the environmental problem of microplastics from ATS to be more extreme compared to the intervention opponents. Nevertheless, the overall mean intervention threshold of all participants was in the range of more severe environmental impacts from granules from ATS. This could be due to the fact that the players' awareness of the issue is not high enough to classify the topic as a relevant problem (Schlüter, 2007). Accordingly, greater impacts than those currently perceived by soccer players would have to be communicated in order for them to legitimize a motive for action that would allow them to develop an intention to actively intervene in the environmental problem.

The need for additional discussion of expertise is also reflected in the fact that more than two thirds of the soccer players interviewed said that ATS filled with plastic granules were not necessary in sports. Consequently, they do not necessarily attribute a raison d'être to this sports surface. Whether this is due to the pronounced TA (those who attributed no necessity to the granulate-filled ATS had a greater expression in the TA) or due to the lack of assessment of the actual sports' functional properties of an ATS cannot be determined at this point. This would have required an analysis of knowledge about the sport-functional properties of ATS. A particularly relevant aspect, which could be integrated into a large part of future considerations on the handling of the topic regarding soccer players, is that the clear majority of the soccer players see in an ATS, above all, an increase in the reputation of a soccer club. Here, the environmental impact is legitimized by an increase in social status, which could make it more difficult to establish a corresponding issue awareness and intervention behavior. For this to happen, there would have to be a change in trend that declares the use of, for example, alternative infill to be the new status symbol. Significant results of status perception, and thus the actual relevance of the variable, could not be established, however.

Since the clear majority of the respondents had already used an ATS and almost half of the respondents had a club-owned ATS, it can be assumed that the respondents were very familiar with the ATS medium and the data can therefore be assumed to be reliable values. Finally, since there are no comparable studies or results in the research to date on the topic analyzed here and there is an urgent need for action to prevent the discharge of granules as ATS, the present values and results can be used as an important basis for further necessary investigations. For example, future studies could test how the awareness and knowledge could be increased to result in stronger policy support or collective action, both within local teams but also with regard to regional and national policy regulations.

Conclusion

Our study suggests that awareness of the artificial turf system (ATS) problem may become a crucial factor for interventions and for a transformation of these turf systems into more sustainable methods. To raise awareness among soccer players, we first suggest improving the communication (through media and official association-specific channels) of the causes and possible consequences of plastic granules from ATS for humans and the environment. Second, communication of the expected impact of synthetic granules from ATS to the environment should be made more specific to increase awareness of the problem. Third, specific communication of the ecological and health consequences of discharged synthetic components from ATS should be made visible to illustrate the individual hazard potential. And finally, we propose providing widespread specific and conceptual information about synthetic infill from ATS (functions, discharge causes, consequences in the environment, possible intervention measures)—both to increase awareness of the problem but also to provide a path for developing action knowledge: Knowledge that involves how and with whom (i.e., stakeholders) this challenge can be addressed. This is a long way, but we hope that this study provides a first step for both research and educational endeavors to raise awareness of potential discharge of ATS microplastic.

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Declarations

Conflict of interest. K. Breuhauer and G. Reese declare that they have no competing interests.

All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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