Environmental Science and Policy 153 (2024) 103666

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Citizens' opinions on (non-)essential uses of persistent chemicals: A survey in seven European countries

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ARTICLE INFO

Keywords:
Persistent chemicals
PFAS
(non-)essential use
European Chemicals Strategy for Sustainability
Risk management
Citizen involvement

ABSTRACT

In accordance with the European Chemicals Strategy for Sustainability towards a Toxic-free Environment, the European Commission plans to phase out persistent chemicals, such as per- and polyfluoroalkyl substances (PFASs), except for uses classified essential for society. Until now, empirical research on what is considered an essential or non-essential chemical use has been lacking. Furthermore, as such criteria are bound to be subjective, different parties can have different views. In this study we explored which uses of persistent chemicals citizens from seven EU countries consider (non-)essential for society. As EU citizens are directly impacted by policy decisions based on (non-)essentiality criteria, we also investigated the influence of emphasis on the consequences of banning vs. allowing persistent chemicals, the association with demographics, and of having heard of persistent chemicals or PFAS prior to the study. We found substantial variation in essentiality ratings within and between use categories and between countries. Uses related to safety were frequently considered essential, whereas uses related to recreation, household, and personal care were frequently considered non-essential. Emphasis on different consequences did not influence essentiality ratings. Gender, age, education, and political orientation were to some extent associated with essentiality ratings. People who had not heard of persistent chemicals or PFAS prior to the study rated uses of persistent chemicals less frequently as non-essential or essential. Our findings offer insight into EU citizens' opinions on (non-)essential uses of persistent chemicals, and provide empirical input to the scientific and public debate on framing the concept of essential use.

1. Introduction

Persistent chemicals are compounds that are known to be chemically stable, causing them to degrade slowly or not at all. When emission rates exceed degradation rates, persistent chemicals accumulate in the environment and in organisms over time, triggering concerns of harmful impacts on ecosystems and humans (Cordner et al., 2021; Sunderland et al., 2019). In accordance with the European Green Deal (European Commission, 2019), the European Parliament has adopted a new European Chemicals Strategy for Sustainability towards a Toxic-free Environment (EU-CSS, see European Commission, 2020). One goal of the strategy is to phase out 'the most harmful chemicals' including persistent chemicals, a large subgroup of which are per- and polyfluoroalkyl substances (PFAS), comprising over 5000 highly persistent compounds that are widely used in technical applications and consumer products (see Glüge et al., 2020 for an overview). The EU-CSS urges for a rapid phase out of the most harmful chemicals unless their use deems essential for society (European Parliament, 2020)).

The call for phasing out harmful chemicals in general, and of persistent chemicals in particular, raises the question of what is to be considered 'essential for society' and whose perceptions on essentiality ought to be leading in legislation. Initially, the concept of essential use has been used in a regulatory context in the Montreal Protocol, a multinational environmental agreement to phase out ozone-depleting substances (Kaljo, 2012). Here, the use of a chemical is considered essential for society "only if (i) it is necessary for health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and (ii) there are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health" (UNEP, 2022).

In addition to the Montreal Protocol, past work on the essential use concept includes reviewing studies on applications of the concept in EU

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https://doi.org/10.1016/j.envsci.2023.103666
Received 19 June 2023; Received in revised form 7 November 2023; Accepted 26 December 2023
Available online 16 January 2024

law (Garnett and Van Calster, 2021) as well as proposals for applying the concept to specific chemical groups, for example PFAS (Cousins et al., 2021). Here, uses are proposed to be classified essential if they contribute to health, safety, or are critical for the functioning of society assuming that no alternatives are available. In contrast, uses for which safer alternatives are available are classified as substitutable and should thus be replaced. A third category suggested by the authors are non-essential uses which are driven primarily by 'convenience and market opportunity' (e.g., dental floss or ski waxes; Cousins et al., 2019). Furthermore, following-up on stakeholders such as industry (Cefic, 2021)), non-governmental organizations have proposed lists of essential and non-essential use categories (Chemsec, 2021), and flowcharts on how to integrate the concept of essentiality into the socioeconomic authorisation route of persistent chemicals (ClientEarth, 2021).

So far it is unclear which uses of persistent chemicals should be considered essential or non-essential for society in the EU. Moreover, the essentiality of a chemicals' use may also be seen as a matter of degree: a use may be more or less essential, or not essential at all. Further, any categorization of uses as essential (and thus, allowed) or non-essential (and thus not allowed), or categories in-between, will cause both benefits and costs to society. For instance, a continued use of persistent chemicals will allow to provide products for which there is a demand, but it will also cause additional emissions and, therefore, increase the risks to humans and the environment. In contrast, banning persistent chemicals from certain uses may lead to reduced emissions, but may also lead to reduced product quality and functionality.

Despite the potentially substantial impacts on EU citizens, insight on citizens' views about essential use of persistent chemicals have, to the best of our knowledge, not been addressed in the development of the essential use concept. Furthermore, criteria for characterizing chemical uses as essential or non-essential rely on opinions on essentiality. Implementing the concept of essential use in European legislation would, then, mark a significant shift in the European risk management logic away from information based on hazard, risk and in some cases socio-economic analysis outcomes, towards an approach based on basic hazard information and opinion-based criteria as primary guidance for decision-making. Ensuring sufficient agreement and acceptance of a risk management regime which includes opinion-based criteria requires, a priori, a careful investigation of perspectives of all societal actors who will be affected by decisions that are based on such criteria. This includes policy actors or industry representatives, but also the general public (i.e., non-experts). Recent research underlines that opinions and perspectives can diverge considerably between societal groups (Marques dos Santos et al., 2022) and emphasizes the importance of including citizens in public decision-making (Mouter et al., 2018). Furthermore, past and recent studies have emphasized the importance of citizens' participation in defining rules and institutional mechanisms for risk management (Fiorino, 1990; Renn, 2008; Collins et al., 2020).

The aim of this study is, therefore, to investigate EU citizens' opinions on essentiality and non-essentiality of uses of persistent chemicals and the effect of information on these opinions, by conducting a survey amongst citizens in seven European countries, i.e., Germany, Denmark, The Netherlands, Italy, Hungary, Lithuania, and Romania. Our study is, to the best of our knowledge, the first addressing the views of citizens on (non-)essential uses of persistent chemicals in a systematic manner. First, we examined which uses of persistent chemicals European citizens consider essential or non-essential for society. Second, we exploratively examined whether information received about the consequences of allowing the use of persistent chemicals (i.e., to the environment and human health) and banning the use of persistent chemicals (i.e., to product quality and functionality) affects essentiality judgments. Third, we explored the extent to which citizens' views on essentiality depend on gender, age, education, and political orientation. Finally, we analyzed if participants' essentiality ratings depend on whether they had heard about persistent chemicals or PFAS prior to this study.

2. Materials and methods

2.1. Questionnaire development

We developed a questionnaire that consists of an introduction, a set of use items (to pursue aim 1), an experimental manipulation (to pursue aim 2), and a set of standardized questions on demographic variables (to pursue aims 3 and 4). The introductory texts and the use items were especially designed for this study.

To generate use categories of persistent chemicals, and use items per category, we used input from three stakeholder group interviews (11 to 15 participants each), facilitated by the consultancy company "The Argumentation Factory", in February and March 2021, literature on the uses of persistent chemicals (e.g. Glüge et al., 2020), and written input from five experts in the domain of persistent chemical use and regulation, both internal and external to the authors' affiliation. This resulted in 11 categories of uses of persistent chemicals; i.e., health, safety, building and construction, infrastructure, transport, food and food packaging, security, climate and environment, recreation, household products, and personal care, with a total of 60 use items. Each use category contained 4 to 6 use items. Experts who reviewed and commented on the categorization of uses of persistent chemicals did not participate in the survey, nor were they involved in the analysis.

Participants were asked to rate the items on the 5-point Likert type answer scale "Definitely non-essential for society ('nice-to-have')", "Probably non-essential (leaning towards 'nice-to-have')", "Indecisive", "Probably essential (leaning towards 'need-to-have')", and "Definitely essential for society ('need-to-have')" complemented with "I do not want to answer this question", and "I do not know".

The master questionnaire was developed in English and translated by Kantar, a commercial party that maintains international panels (www.kantar.com), in the main national language of the countries included. Translated questionnaires were checked by native speakers in the authors' networks and adjusted where deemed necessary.

A pilot study was conducted to test the complete, translated questionnaire. Use items were presented *per* category, with categories and the items randomized. The pilot questionnaire was distributed by Kantar in February 2022. The final sample sizes were 190 to 249 respondents per country, drawn from Kantar's national panels. We looked, amongst other things, into drop-out patterns, partial response patterns, correlations between items within use categories, time taken to complete the survey, and text comments by panel members.

The results of these analyses led to shortening and simplification of the introductory text, the definition of essential use, the manipulation, and 14 use items. Furthermore, we eliminated three use items, and moved one use item to a different category. Additionally, criteria for exclusion of participants were formulated based on the experience gained in the pilot.

2.2. Final questionnaire

The final questionnaire of our survey is provided in the Supplementary Material (S2).

2.2.1. Introductory text and definition of essential use

Before accessing the questionnaire, participants consented to take part in an EU survey on the use of persistent chemicals. Because we expected people's prior knowledge considering persistent chemicals to vary widely, an introductory text was presented to give participants a sufficient basis to make judgments on essentiality of different uses of persistent chemicals (see Appendix A). After the introductory text, participants were presented the following definition of essential use:

*"A use of persistent chemicals is considered **essential for society** if it is **indispensable** for societal wellbeing or for the functioning of society **('need-to-have')**. In contrast, a use of persistent chemicals is considered **non-essential for society** when it is **merely convenient ('nice-to-have')**."*

2.2.2. Experimental manipulation

Next, participants were randomly assigned to one of three conditions; (1) the condition providing additional, specific information and an example of possible consequences of not phasing out persistent chemicals (i.e., harm to the environment and human health), (2) the condition providing information and an example of possible consequences of phasing out persistent chemicals (i.e., losses to product quality and functionality), and (3) the 'control' condition, providing both the information (1) and (2) (see Appendix A).

2.2.3. Use items

Participants were presented the use items *per* use category, with one use category per page and both the use categories and the items per category randomized. Participants were asked to rate uses of persistent chemicals on their essentiality or non-essentiality for society assuming that no alternatives are available for these uses. The definition of essential use was always provided on top of the screen and participants could access a shortened version of the introductory text (see Appendix B) throughout rating the use items.

2.2.4. Demographic variables

Participants reported their gender as female, male, or other. Age was reported in years, which we then collapsed into three country-specific categories to avoid numerical issues in the multinomial logistic regressions (Supplementary Material, Table S1). For each country the middle age category was based on the population mean age + /- ½ standard deviation (SD), and the two other categories were thus lower than the average age - ½ SD and higher than the average age + ½ SD, based on census data from Eurostat (Eurostat, 2011).

The education measure was based on the International Standard Classification for Education (ISCED) categorization, which is collapsible into: low education (ISCED 0–2), medium education (ISCED 3–4), and high education (ISCED 5–8). We used this collapsed categorization.

Political orientation was measured with two items used frequently in political psychology (e.g., Croteau, 1999; Davidai and Ongis, 2019; Klar, 2014). Namely, "When it comes to social issues, I consider myself…" rated from 1 = Very liberal to 7 =Very conservative, with 4 =Moderate, and "When it comes to economic issues, I consider myself…" rated from 1 =Very left-wing to 7 =Very right-wing, with 4 =Moderate.

Social status was measured with the MacArthur Scale of Subjective Social Status (Adler et al., 2000). It asks participants to "think of the ladder below as representing where people stand in [their country] in terms of education, income, and income security. The people who are the worst off are on the left, and the people who are the best off are on the right. Where would you place yourself relative to the people who are the best off and the people who are the worst off in terms of education, income, and income security?". Participants could place a pin on their chosen point on the scale. The last question asked was "Before this survey, had you ever heard of persistent chemicals or PFAS?" with answer options yes and no. The questionnaire concluded with a debriefing text explaining the research questions.

2.3. Participants

Germany, Denmark, The Netherlands, Italy, Hungary, Lithuania, and Romania were chosen with respect to geographic region (i.e. to have a balanced set of countries from Northern, Western, Eastern, Southern and Central Europe) and population size (i.e. countries with a relatively large (Germany) and a relatively small population size (Lithuania)).

Data collection was done by Kantar using their national panels. The questionnaire was distributed in April/May 2022. Participants were compensated by reward points that could be exchanged for online gift cards, charity donations, or PayPal cash deposits. Kantar's standard procedure includes a soft launch, in which 10% of the sample was collected and data were checked for the absence of any coding errors, and a need for oversampling of specific groups (e.g. age groups or region) to enhance representativity. Kantar excluded data from people who did not complete the questionnaire ($n = 682$). We further excluded data from people who spent less than two minutes on the questionnaire ($n = 82$). Data was collected until at least effective samples sized $N = 1200$ were reached for each country (in line with the methodology of the European Values Study; (Methodology, 2017)). The average completion times in different countries ranged from 8 to 10 min. Using the Random Iterative Method (RIM; Deming and Stephan, 1940; Sharot, 1986), Kantar then calculated weights to ensure representativity in terms of gender, age, and region. Weighting efficiency was high, ranging from 96.8% in Romania to 99.8% in the Netherlands.

2.4. Statistical analysis

For all analyses the answer categories of the use items were collapsed into the three categories: "(leaning towards) essential for society", "(leaning towards) non-essential for society" and "neither essential nor non-essential" (combining the answer options "indecisive" and "I do not know").

To answer research question one (i.e. identifying uses of persistent chemicals European citizens consider essential or non-essential for society), descriptive statistics were calculated using the weighted responses from the control group only, as this group received full information. The uses were categorized as essential, non-essential or 'neither/nor' according to two separate decision rules: when > 50% (or >75%) of participants in a particular country rated a use as either essential or non-essential the use was categorized as such for that country. In all other cases, the use was classified as 'neither/nor'.

To answer research questions two and three (i.e. the effect of information about the consequences of allowing or banning persistent

Table 1
Non-/Essentiality ratings (control group, all countries, $N = 2907$). Grey-shaded cells highlight the rating assigned to the majority of use items.

Use category (n = number of items per category)	Non-essential	Neither/nor	Essential
Personal care ($n = 7$)	5	2	0
Household products ($n = 6$)	4	2	0
Recreation ($n = 5$)	3	2	0
Food and food packaging ($n = 4$)	2	2	0
Transport ($n = 6$)	1	4	1
Security ($n = 4$)	0	3	1
Infrastructure ($n = 5$)	0	4	1
Climate and environment ($n = 5$)	0	3	2
Health ($n = 5$)	0	3	2
Building and construction ($n = 6$)	0	2	4
Safety ($n = 4$)	0	0	4

chemicals, and the effect of demographic variables, on essentiality ratings), unweighted data was used. Multinomial logistic regression models were fit for each use item separately for each country. The dependent variables were the essentiality ratings with the three collapsed categories, with 'neither/nor'' as the reference. Considered as explanatory variables in the models were: experimental condition (with the control condition as reference), gender (with male as reference), age (with around average as the reference), political orientation, and social status.

To investigate numerical and interpretation issues due to the high dimensionality of the contingency table in relation to sample size, a series of multinomial logistic regression models was tested for each country on use items with different essentiality rating distributions (e.g. skewed, uniform, u-shaped). As too few people categorized themselves as being neither male nor female to yield stable models (Appendix C, Table C1), we excluded the data of people with gender 'other' from the models. The test models also suggested that in Denmark, Lithuania, and Romania the lowest education category contained too few participants to yield stable models. Thus, to avoid numerical issues, we combined the low and medium education categories into one category for these three countries. The inclusion of the political orientation items and subjective social status yielded numerical issues and not interpretable modelling outcomes. As a solution, we decided to combine the two original political orientation questions into one new political orientation variable with 5 categories (i.e. economically left-wing and moderate or liberal socially; economically right-wing and moderate or liberal socially; economically right-wing and conservative or moderate socially; economically left-wing or moderate and conservative socially; economically moderate and moderate socially (the reference category)). Answers of "I do not want to answer" on either of the two original political orientation questions were excluded from the analyses. This solved the numerical issues for the test models. We decided to exclude subjective social status from the analyses, because the test models revealed that it was not justifiable to treat the measure as a continuous variable. Concluding, for each country 57 multinomial logistic regression models were fitted with experimental condition, gender, age, education and political orientation as explanatory variables. Although our approach to answering the question of whether citizens' views on essentiality were associated with the demographics was explorative, we generated results with Benjamini-Hochberg correction for multiple hypotheses testing (Anon 2022a, 2022b) with a family-wise error of.20 per country.

Finally, to investigate the possible influence of having heard of persistent chemicals or PFAS prior to this study on answering the use items, answering research question four, we first tested for a difference between the average total number of use items to which respondents replied "I do not know" and "I do not want to answer" by means of a t-test per country. Then, we calculated the proportion of the rated use items scored as 'neither/nor' compared to all use items, and compared the average proportions between the two groups (i.e. those who have heard about persistent chemicals or PFAS, and those who have not) by means of a t-test. Lastly, we calculated the difference between the proportions of rated use items scored as non-essential and essential. We then tested, per country, whether there is a difference between the respondents who reported to having heard about persistent chemicals or PFAS and those who had not. Here, we used a Bonferroni correction and considered tests statistically significant if $p < .017$.

All the analyses were conducted using SPSS version 28.0.1.1 (15).

3. Results

3.1. Essentiality ratings of uses of persistent chemicals

Table 1 below shows for each use category the summary of (non-) essentiality ratings by the control groups in all countries, using the 50% threshold. Details of the descriptive statistics, with and without weights used, are presented in Appendix C (Table C1). Essentiality ratings for individual countries are provided in in Table C2 of Appendix C.

Notably, changing the decision threshold from > 50% to > 75% resulted in almost all uses to become categorized as 'neither/nor' (see Supplementary Material, Table S3 for the detailed results per item and Table S4 for a summary per item category). The only exceptions were use items still categorized as non-essential in Denmark (kiss-proof

lipsticks, waterproof mascaras, and easily spreadable anti-aging cream) and in Italy (kiss-proof lipsticks). Furthermore, with a more stringent decision threshold none of the use items were categorized essential. Below we report the results when using the > 50% decision rule.

Most use items in the categories 'personal care', 'household products', and 'recreation' were considered non-essential. In contrast, most use items in the category 'building and construction', and all items in the category 'safety' were considered essential. Note that the latter is the only category where participants in all countries rated all use items 'essential'. For several use categories respondents rated the majority of items as 'neither/nor'. We observed that ratings within a particular use category can differ considerably across countries (see Appendix C, Table C2). For instance, in the category 'health' the use of persistent chemicals for cancer drugs was considered essential across all countries, whereas in only two countries (Denmark and Italy) antidepressants were regarded essential. Aerosol propellant for asthma inhalers was considered essential in six countries, fluid-repellent surgical gowns in two countries, and protective packaging for medicine in just one country.

Furthermore, participants of four countries (Denmark, Italy, Hungary, Romania) rated most use items in the category 'climate and environment' essential. Moreover, long-lasting filters for wastewater treatment and drinking water purification, as well as surface treatments for solar panels, were considered essential in most countries.

The use categories 'food and food packaging', 'transport', and 'infrastructure' contain items which were both considered non-essential, neither/nor, or essential at country level. Of the use items in 'food and food packaging', protective plastic packaging and grease-proof wrapping paper for takeaway food were considered non-essential in most countries. Using persistent chemicals for refrigeration of food in warehouses, in contrast, was considered essential in Denmark, Italy, and Hungary. In the 'transport' category, only fire-resistant airplane passenger compartments were considered essential in most countries (all but Germany). Water-repellent bicycle chain spray was considered non-essential in most countries, and the other items were mostly considered 'neither/nor'. Regarding the category 'infrastructure', only filter systems in coal, gas, and nuclear power plants were considered essential in all countries except Germany. High temperature-resistant heat pumps and semiconductors were considered essential in three countries (Lithuania, Italy, Romania). The other use items in this category were mostly regarded as 'neither/nor'.

Overall, comparing patterns in the essentiality ratings between countries, we found substantial variation in (non-)essentiality ratings between countries (see also Table C2 in the Appendix). Patterns were similar between Italy and Romania, and between Germany and The Netherlands. Specifically, in Germany and the Netherlands only few use items were considered essential (six and eight, respectively), with 'safety' being the only category in which all use items were considered essential. In contrast, in Italy and Romania, most use items were considered essential in five categories ('health', 'safety', 'building and construction', 'infrastructure', and 'climate and environment').

3.2. Effect of experimental condition and demographic characteristics on essentiality ratings

Overall, the experimental manipulation and the demographics had low explanatory power over the (non-)essentiality ratings: Nagelkerke's R squared ranged from .01 to .14 per use item across all countries. Table C3 in the Appendix provides the number of use items which showed an overall association between (non-)essentiality rating and each explanatory variable per country (see Supplementary Material, Table S5 for all the associations in each country, and Table S6 for a summary of the direction of the associations). The experimental condition showed very few associations with essentiality ratings, suggesting that the experimental condition did not, overall, affect the essentiality ratings of participants. When looking at the demographic variables across countries, it seemed that gender, age, education, and political orientation are to some extent associated with rating of uses as essential or non-essential for society. However, the explanatory power of these variables was, overall, low.

3.3. Effect of having heard of persistent chemicals or PFAS before on essentiality ratings

Overall, there was no evidence for an association between having heard of persistent chemicals or PFAS before the study and choosing "I do not know" or "I do not want to answer" when rating the use items (see Supplementary Material, Table S7). The lack of such an association suggests that the introductory text provided sufficient information for people to be willing and able to rate the use items.

In all countries, the average proportion of uses scored as 'neither/nor', was associated with not having heard of persistent chemicals or PFAS before (all p's $< .001$). That is, people who reported not having heard of persistent chemicals or PFAS prior to the introductory text, were somewhat more likely to rate uses as neither essential nor non-essential than people who had heard about them prior to this study, with differences in proportions ranging from.03 in Romania to.12 in the Netherlands.

We did not find a significant difference in any of the countries in the contrast between the proportions of rated use items scored as non-essential and essential between the people who reported having heard about persistent chemicals or PFAS prior to this study and those who did not (Supplementary Material, Table S7). This suggests that people who have heard about persistent chemicals or PFAS before are not more likely to rate use items as essential versus non-essential than those who have not.

4. Discussion

This study is, to the best of our knowledge, the first large-scale multinational study exploring citizens' views on which uses of persistent chemicals are essential or non-essential for society. Specifically, we found substantial variation in essentiality ratings within and between use categories, both within and between countries. These results underline that the essentiality or non-essentiality of persistent chemicals' uses cannot be defined a priori. Furthermore, societal preferences cannot be expected to be uniform at the levels of individual countries, or the EU. Emphasis on the consequences of defining uses of persistent chemicals essential or non-essential did not influence essentiality ratings. Furthermore, the explanatory power of demographic variables for use ratings was very limited. There was, however, an association between people (not) having heard of persistent chemicals or PFAS prior to the study and rating uses as neither essential nor non-essential. Our analysis provides a number of novel and interesting insights about public perceptions of (non-)essentiality in relation to the use of harmful chemicals, which may be particularly relevant for the on-going debate about the applicability of the concept in the context of the European Strategy for Chemical Sustainability. These will be discussed in more detail below.

4.1. Distinguishing essential from non-essential uses of persistent chemicals

Current definitions of the concept of essential use, e.g. in the Montreal Protocol (UNEP, 2022) and in the EU-CSS (European Parliament 2020), propose the necessity for health and/or safety, and the criticality for the functioning of society (encompassing cultural and intellectual

aspects) as main qualifiers for determining whether a chemical is considered essential or non-essential for society. Our results suggest that this may not be sufficient to depict which uses of persistent chemicals can possibly be considered essential or non-essential. Specifically, the results of the survey illustrate that there may be uses in categories other than health and safety (e.g. uses contributing to improving environmental quality) which many citizens perceive essential. Likewise, it cannot be assumed a priori that all uses of persistent chemicals contributing to health and safety will necessarily be considered essential. Nonetheless, our results give insight into the kind of uses that may be considered (non-)essential within different use categories, and can thus aid in defining criteria for what is meant by 'necessary for' and by 'critical for the functioning of society'. In addition, the heterogeneity of results within use-categories, and considering that in several use categories the fraction of 'neither/nor' responses was high (i.e., health, infrastructure, transport, environment, security, and food), suggests that the essential use concept, as it is now, cannot be applied to entire chemical use categories but to individual uses only. Finally, our results show that citizens' perceptions are not homogeneous between countries. This result emphasizes that an implementation of the concept, for example as part of a risk management approach to harmful chemicals in Europe, requires transparent and targeted communication to different societal groups in all EU member states.

4.2. Policy implications for improving chemicals' risk management and regulation

So far, the concept of essential use has been presented as a binary concept (non-essential and essential uses). The frequent neither/nor ratings in many use categories (e.g. infrastructure, transport, security) suggest that many chemical uses (if not the majority) cannot unambiguously be denoted fully essential or non-essential (being at the end of a continuous scale). Furthermore, rather than focusing on identifying essential uses for which exemptions from a ban will be possible, our results indicate that societal consensus could probably be achieved more easily for the non-essential uses of persistent chemicals. In particular, our results on the non-essentiality ratings suggest that policy makers could make a head start by banning some of the uses related to recreation, household and personal care. In such cases, i.e. where there is societal consensus about a persistent chemical's use to be non-essential, an extensive and resource-demanding risk assessment may no longer be needed. Banning persistent chemicals when there is agreement on them being non-essential could, then, speed-up the phase-out of harmful chemicals. Note that this requires carefully defining the required level of agreement (i.e. the decision or majority threshold). Moreover, as in all majority rules, there may be minority groups whose preferences, or needs even, remain unattended. This raises the question under what conditions derogations of decisions should be considered.

4.3. Limitations of the study and implications for further research

The current study had a large sample size (N = 8678) and was conducted over multiple countries in different parts of Europe. Nonetheless, it was conducted in seven out of the 27 EU countries. Consequently, the patterns observed regarding essentiality/non-essentiality ratings cannot be regarded representative for the EU as a whole. We surveyed people's opinions on many uses of persistent chemicals over a variety of use categories. Respondents were not randomly sampled from the population, but survey-panel based. Although the distributions of the demographic characteristics of the effective samples were very close to the distributions in the populations in terms of age, gender and region (as evidenced by the very high weighting accuracy), the samples may be not representative of the populations in other respects (e.g., income, willingness to share opinions). We noted that many participants took a short time to answer the survey, and in a more participatory setting with more time to reflect and the opportunity to request additional information, results may be different.

To make sure that the assessment was about the use of persistent chemicals and not about the availability or functionalities of alternative chemicals or technologies, participants were instructed to assume that alternative chemicals or technologies are not available. We cannot be sure whether the respondents fully understood the consequences thereof, although the requested assumption may help explain the ratings of uses as neither/nor. Future studies are needed to examine how information about the availability and functionality of alternatives may impact citizens' ratings, for example by adopting an experimental approach.

We found no effect of the different emphasis participants received in the introductory text (emphasis on consequences of allowing vs. banning persistent chemicals). The potential effect of the manipulation may have been muted by the information on both the costs and benefits of banning persistent chemicals to all participants that we shared for ethical reasons. In a different setting, more explicit preferences might be developed– i.e., when citizens reflect on the consequences together or with experts. A disadvantage of such an approach would be the limited numbers of citizens that can be included, whereas in a study such as ours thousands of people can participate.

The limited explanatory power of the fitted models suggests future research which should include other factors than demographics, such as attitudes towards nature, environment and technology (e.g., as expressed in Cultural Theory, see Thompson, Ellis and Wildavsky, 1990), risk perceptions (Ono and Tsunemi, 2017), risk acceptance (Verbeek, 2021), and solidarity to future generations (Takle, 2021). Finally, our survey provides a snapshot of which uses of persistent chemicals European citizens consider essential or non-essential for society. Obviously, as peoples' views and opinions can change, also their judgments about essentiality and non-essentiality may change over time. Though considered highly important in the context of the EU-CSS, investigating the impact of such changes on peoples' essentiality/non-essentiality ratings was beyond the scope of our study and is left for further research.

5. Conclusions

Within the EU, but also globally, persistent chemicals are considered to be of high concern. Decisions on exempting the phase-out of persistent chemicals (when their use deems essential for society), or for removing them from the market (when their use deems non-essential for society) are, therefore, of high impact for environmental functioning and human well-being in the short, medium and long-term. The essential use concept as suggested in the EU-CSS marks a fundamental shift from a data- and evidence-based approach to an opinion- and value-based approach to risk management of chemicals. Focusing on persistent chemicals, the analysis is, to the best of our knowledge, the first to shed light on citizens' opinions on (non-)essentiality. Though citizens represent a large societal group (compared to, for example, companies, NGOs, or other stakeholders) being affected by decisions based on (non-)essentiality criteria, this group's perceptions have not been analyzed systematically so far. The findings of our survey provide empirical input to the ongoing discussion on implementing the essential use concept into the EU chemicals' policy, and offer insight into some fundamental features of the essential use concept which need to be addressed in order to make the concept of added value for decision-making on persistent chemicals' use. Based on our results, it can be expected that the (non-) essentiality ratings of uses of persistent chemicals differ within and between use categories as well as between EU countries. Since gender, age, education, political orientation, and information received prior to the study explained the observed ratings only marginally, we conclude that peoples' opinions regarding the essentiality or non-essentiality of persistent chemicals' uses when asked in a way we did, depend on (multiple) other factors. This makes it challenging to define criteria for categorizing a use of a chemical 'essential' or 'non-essential' for which

broad agreement among citizens in the EU can be reached. Defining criteria based on policy-makers' preferences may appear less challenging, however, it bears a risk that the perceptions of some population groups will be ignored (irrespective of whether these groups represent the majority or a minority of the EU population). Although both the Montreal Protocol and the EU-CSS conceptualize the concept of essential use as an approach to justify exemptions from a ban, thus focusing on essentiality, our findings illustrate that starting with banning non-essential uses of (persistent) chemicals may be more effective because agreement may be easier to achieve, resources for a comprehensive risk assessment could be saved for other uses, and acting upon this agreement may accelerate a phase-out of harmful chemicals considerably.

For the majority of uses of persistent chemicals, it can be expected that an unambiguous classification of a chemical's use being either essential or non-essential will not be possible. Hence, decision-making based on (non-)essentiality judgments *alone* will remain imprecise. In particular, social costs in case of granting an exemption from a ban due to essentiality (e.g. on-going emissions and, therefore, an increase of negative impacts to human health and the environment), or forgone social benefits in case of a ban due to non-essentiality (e.g. the availability or a certain functionality of a product), will be ignored. To avoid potentially high costs of making errors, a granular assessment of all impacts under different risk management options, and a transparent balancing of social costs and benefits, will remain indispensable for decision-making in many cases. Socio-economic analysis as conducted for authorization and restriction processes under the EU chemicals' legislation REACH offers a toolbox that has proven successful in this context (Montfort, 2021).

Moreover, it remains to be clarified *at what phase* in the risk governance process (non-)essentiality criteria could best be applied (see, for example, Wahlström and Pohjalainen, 2021, chapter 8), and how they relate to environmental and human health risk assessment considering that the properties and risks of persistent chemicals vary considerably.

In particular, classifying a use of a harmful chemical as (non-) essential early on could save substantial resources (and, thus, costs) because, for instance, exposure and impact assessments may become redundant. Finally, it is important to clarify whom to involve in decisions about the (non-)essentiality of chemicals' uses. For example, in accordance with the procedure of the Montreal Protocol (D'Souza, 1995), experts may be consulted. A recent report to assist the European Commission in framing the essential use concept for chemicals risk management in the EU (Bougas et al., 2023) included input from stakeholders (Member State competent authorities, private sector companies, NGOs, academia, EU institutions, and international organizations). Complementary to expert and stakeholder consultations, our results highlight that citizens can be involved as well. The involvement of citizens, next to experts and stakeholders, could ensure that basic democratic principles in value-judgments such as banning and allowing harmful persistent chemicals, are preserved.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

Financial supportfrom the Safety of Substances and Products Unit of the RIVM is gratefullyacknowledged. We wish to thank Martijn Beekman, Maryam Zare Jedi, Wobbe van derMeulen, Sebastiana Hard, Christoph Rheinberger, Evgenia Stoyanova, CarlAlbrecht Dannenberg, Jurgita Žiemiene, Mihala Erswik, Mihai Chiriac, GáborUngvári, Claus Strøm, and Matteo Campanelli for helpful comments to an initialdraft of the survey. Furthermore, we thank Kantar for their support with theexecution of the survey. Finally, we thank three anonymous reviewers for theirconstructive feedback.

Appendix A. Introduction text of the survey and experimental manipulation text

The first bold text was only shown to experimental conditions 1 and 3. The second bold text was only shown to experimental conditions 2 and 3.

Phasing out persistent chemicals

Persistent chemicals, such as PFASs, are chemicals which accumulate over time in the environment. They are sometimes called 'forever chemicals', because once released, persistent chemicals can be difficult or impossible to remove from the environment. Persistent chemicals are widely used because they have unique properties, ensuring a longer lifespan of products. The use of persistent chemicals poses risks of irreversible damage to ecosystems, animals, and humans.

The continued use of persistent chemicals may induce long-term water and soil contamination. Furthermore, their use can cause health damage, e.g. it can increase cancer incidence.

The European Union's Chemical Strategy for Sustainability aims to better protect humans and the environment against the risks of persistent chemicals. Therefore, the EU plans to abandon persistent chemicals, except for uses essential for society and for which no alternatives are available.

Abandoning the use of persistent chemicals may lead to reduced quality or functionality of products. Furthermore, abandoning persistent chemicals can result in loss of longevity of products.

You are part of society. Therefore, we are interested in your opinion.

In the following, you will be asked to rate multiple current uses of persistent chemicals on how essential or non-essential you think these uses are for society. When answering, please assume that no alternatives are available for these uses. Completion of the questionnaire will take between 10–20 min.

Appendix B. Text in the pop-up icon that was accessible throughout rating the uses on essentiality

Persistent chemicals, often called 'forever chemicals', are widely used because of their unique properties. The use of persistent chemicals can cause irreversible harm to humans and the environment.

Appendix C

Table C1
Descriptive statistics of the main study, with and without weights used (UW = unweighted; W = weighted; SD = standard deviation).

	All countries		Germany		Denmark		The Netherlands		Italy		Hungary		Lithuania		Romania	
	UW	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**
N	8678	-	1230	1232	1245	1245	1221	1223	1239	1241	1242	1243	1247	1248	1254	1257
Mean age (SD)	44.97 (15.81)	-	47.48 (16.67)	49.70 (16.44)	49.33 (18.01)	48.95	47.16 (17.49)	48.61 (17.38)	44.87 (14.13)	50.11 (15.43)	44.28 (14.15)	48.37 (15.21)	40.62 (14.16)	47.40 (15.68)	41.16 (13.41)	47.32 (15.23)
Age range	18-100	-	18-85	18-85	18-88	18-88	18-89	18-89	18-88	18-88	18-100	18-78	18-81	18-81	18-79	18-79
Gender																
Women (%)	4371 (50.4%)	-	620 (50.4%)	620 (50.3%)	635 (51.0%)	624 (50.1%)	617 (50.5%)	613 (50.1%)	619 (50.0%)	621 (50.0%)	650 (52.3%)	623 (50.1%)	627 (50.3%)	612 (49.0%)	603 (48.1%)	630 (50.2%)
Men (%)	4290 (49.4%)	-	605 (49.2%)	612 (49.7%)	608 (48.8%)	622 (49.9%)	602 (49.3%)	610 (49.9%)	620 (50.0%)	620 (50.0%)	590 (47.5%)	620 (49.9%)	617 (49.5%)	636 (51.0%)	648 (51.7%)	626 (49.8%)
Other (%)	17 (0.2%)	-	5 (0.4%)	0 (0%)	2 (0.2%)	0 (0%)	2 (0.2%)	0 (0%)	0 (0%)	0 (0%)	2 (0.2%)	0 (0%)	3 (0.2%)	0 (0%)	3 (0.2%)	0 (0%)
Education																
Low	1296 (14.9%)	-	304 (24.7%)	299 (24.3%)	116 (9.3%)	116 (9.3%)	229 (18.8%)	239 (19.5%)	200 (16.1%)	204 (16.4%)	241 (19.4%)	237 (19.1%)	159 (12.8%)	121 (9.7%)	47 (3.7%)	45 (3.6%)
Medium	3588 (41.3%)	-	555 (45.1%)	556 (45.1%)	505 (40.6%)	506 (40.7%)	526 (43.1%)	524 (42.9%)	608 (49.1%)	632 (50.9%)	500 (40.3%)	494 (39.7%)	346 (27.7%)	318 (25.5%)	548 (43.7%)	541 (43.0%)
High	3794 (43.7%)	-	371 (30.2%)	377 (30.6%)	624 (50.1%)	623 (50.0%)	466 (38.2%)	460 (37.6%)	431 (34.8%)	405 (32.7%)	501 (40.3%)	512 (41.2%)	742 (59.5%)	808 (64.8%)	659 (52.6%)	671 (53.4%)
Political orientation		-														
Economically left-wing and moderate or liberal socially	1408 (16.2%)	-	249 (20.2%)	249 (20.2%)	262 (21.0%)	263 (21.1%)	211 (17.3%)	211 (17.2%)	271 (21.9%)	285 (23.0%)	179 (14.4%)	202 (16.3%)	121 (9.7%)	135 (10.8%)	115 (9.2%)	126 (10.0%)
Economically right-wing and moderate or liberal socially	1286 (14.8%)	-	184 (15.0%)	182 (14.8%)	167 (13.4%)	166 (13.3%)	174 (14.3%)	176 (14.4%)	163 (13.2%)	144 (11.6%)	146 (11.8%)	143 (11.5%)	187 (15.0%)	181 (14.5%)	265 (21.1%)	261 (20.8%)
Economically right-wing and conservative or moderate socially	1574 (18.1%)	-	177 (14.4%)	176 (14.3%)	289 (23.2%)	291 (23.3%)	272 (22.3%)	268 (21.9%)	210 (16.9%)	227 (18.3%)	277 (22.3%)	265 (21.3%)	178 (14.3%)	186 (14.9%)	171 (13.6%)	166 (13.2%)
Economically left-wing or moderate and conservative socially	568 (6.5%)	-	97 (7.9%)	96 (7.8%)	72 (5.8%)	73 (5.8%)	95 (7.8%)	95 (7.8%)	52 (4.2%)	50 (4.1%)	82 (6.6%)	86 (6.9%)	85 (6.8%)	89 (7.2%)	85 (6.8%)	85 (6.8%)
Economically moderate and moderate socially	2992 (34.5%)	-	439 (35.7%)	445 (36.2%)	308 (24.7%)	307 (24.6%)	389 (31.9%)	393 (32.1%)	357 (28.8%)	354 (28.5%)	447 (36.0%)	446 (35.8%)	494 (39.6%)	505 (40.4%)	558 (44.5%)	570 (45.4%)
'I do not want to answer'	850 (9.8%)		84 (6.8%)	84 (6.8%)	147 (11.8%)	147 (11.8%)	80 (6.6%)	80 (6.5%)	186 (15.0%)	180 (14.5%)	111 (8.9%)	101 (8.1%)	182 (14.6%)	151 (12.1%)	60 (4.8%)	49 (3.9%)
Heard of persistent chemicals																
Yes	3645 (42.0%)	-	257 (20.9%)	251 (20.4%)	647 (52.0%)	646 (51.9%)	648 (53.1%)	659 (53.9%)	489 (39.5%)	488 (39.3%)	411 (33.1%)	409 (32.9%)	630 (50.5%)	671 (53.8%)	563 (44.9%)	567 (45.1%)
No	5033 (58.0%)	-	973 (79.1%)	981 (79.6%)	598 (48.0%)	599 (48.1%)	573 (46.9%)	564 (46.1%)	750 (60.5%)	754 (60.7%)	831 (66.9%)	834 (67.1%)	617 (49.5%)	577 (46.2%)	691 (55.1%)	690 (54.9%)

Note. Education is collapsed according the ISCED system. ''I do not want to answer' = choosing "I do not want to answer" on either the economic or social political orientation question. Heard of persistent chemicals = whether or not the participant had heard of persistent chemicals or PFAS before. The weights are country-specific, hence there are no weighted descriptive statistics for all countries combined.

Table C2

Essentiality ratings per use category and use items in different countries. Numbers in brackets denote the percentage of respondents categorizing a use item as 'definitely essential' or ' definitively non-essential'.

Use category	Use	All countries combined	DE	DK	NL	IT	HU	LT	RO
Health1	Fluid-repellent surgical gowns	NN (24.6%)	NN (33.1%)	NN (28.7%)	NN (29.6%)	E (52.8%)	NN (27.7%)	NN (25.1%)	E (56.9%)
Health2	Aerosol propellant for inhalers, e.g., for asthma treatment	E (57.0%)	NN (34.3%)	E (61.5%)	E (51.1%)	E (56.6%)	E (53.4%)	E (60.1%)	E (63.5%)
Health3	Antidepressants, e.g., SSRIs	NN (26.1%)	NN (31.7%)	E (57.9%)	NN (28.4%)	E (53.6%)	NN (32.4%)	NN (23.5%)	NN (23.6%)
Health4	Cancer drugs, e.g., for lung cancer	E (67.1%)	E (52.4%)	E (74.9%)	E (62.8%)	E (74.6%)	E (66.6%)	E (62.7%)	E (69.5%)
Health5	Protective packaging for medicine	NN (25.2%)	NN (31.2%)	NN (28.0%)	NN (28.8%)	NN (23.1%)	NN (28.7%)	NN (26.3%)	E (54.3%)
Safety7	Clothing to protect rescue workers against dangerous chemicals	E (69.8%)	E (63.0%)	E (74.7%)	E (65.0%)	E (73.3%)	E (70.9%)	E (69.1%)	E (74.8%)
Safety8	Clothing to protect firefighters against heat	E (70.3%)	E (62.0%)	E (74.3%)	E (63.5%)	E (72.4%)	E (72.0%)	E (68.2%)	E (73.3%)
Safety9	Firefighting foams that diffuse quicker and thereby better suppress the fire	E (64.5%)	E (59.6%)	E (60.7%)	E (56.6%)	E (67.6%)	E (68.0%)	E (67.0%)	E (71.1%)
Safety10	Non-flammable insulation of electricity cables in buildings	E (65.3%)	E (58.3%)	E (62.2%)	E (56.4%)	E (69.7%)	E (67.9%)	E (68.1%)	E (69.2%)
Building11	Anticorrosive paints	NN (27.9%)	NN (36.3%)	NN (32.0%)	NN (28.9%)	NN (25.6/%)	NN (30.2%)	NN (25.4%)	E (55.5%)
Building12	Weather-resistant roof coatings	E (52.3%)	NN (28.1%)	NN (24.2%)	NN (26.8%)	E (53.7%)	E (55.5%)	E (59.7%)	E (66.3%)
Building13	Long-lasting pipes in buildings	E (56.3%)	NN (27.2%)	E (54.8%)	NN (25.2%)	E (56.4%)	E (59.3%)	E (62.7%)	E (66.6%)
Building14	Weather-resistant cement	E (52.1%)	NN (32.9%)	E (50.4%)	NN (30.3%)	E (59.7%)	E (51.2%)	E (55.4%)	E (63.4%)
Building15	Fire- and high-temperature resistant metal coatings	E (55.7%)	NN (32.8%)	E (52.1%)	NN (26.7%)	E (57.7%)	E (56.5%)	E (59.2%)	E (65.6%)
Building16	Preserving coatings for historical buildings	NN (26.3%)	NN (37.1%)	NN (40.6%)	NN (31.2%)	E (50.5%)	NN (28.4%)	E (51.2)%	E (58.8%)
Infrastructure17	Filter systems in coal, gas, and nuclear power plants	E (59.0%)	NN (30.5%)	E (60.6%)	E (51.8%)	E (66.8%)	E (63.1%)	E (58.4%)	E (66.1%)
Infrastructure18	High temperature -resistant heat pumps	NN (26.8%)	NN (35.9%)	NN (30.5%)	NN (33.2%)	E (50.4%)	E (50.2%)	NN (27.1%)	E (61.1%)
Infrastructure19	Lithium-batteries for electronic devices	NN (28.5%)	NN (36.5%)	NN (30.9%)	NN (32.1%)	NN (29.0%)	NN (27.7%)	NN (24.9%)	E (57.8%)
Infrastructure20	Components for the functioning of computers and phones (semiconductors)	NN (26.4%)	NN (37.0%)	NN (31.2%)	NN (31.6%)	E (53.3%)	NN (26.8%)	E (51.5%)	E (59.8%)
Infrastructure21	Fingerprint-resistant screen coatings for electronic devices	NN (27.8%)	NN (33.5%)	N (57.5%)	NN (30.4%)	NN (24.8%)	NN (32.6%)	NN (31.5%)	NN (24.1%)
Transport23	Long-lasting hydraulic fluids in car breaks	NN (26.0%)	NN (33.1%)	NN (29.1%)	NN (31.5%)	NN (22.1%)	NN (28.0%)	E (51.1%)	E (59.0%)
Transport24	Silencers for engine noise reduction in cars	NN (26.0%)	NN (34.5%)	NN (27.6%)	NN (26.7%)	NN (23.3%)	NN (32.90%)	NN (20.6%)	NN (18.1%)
Transport25	Anti-fouling paint for boats to reduce fuel and energy consumption	NN (27.7%)	NN (34.5%)	NN (31.9%)	NN (33.0%)	NN (24.1%)	NN (29.5%)	NN (25.2%)	NN (23.3%)
Transport26	Fire resistant airplane passenger compartments	E (60.0%)	NN (29.7%)	E (62.6%)	E (51.6%)	E (64.9%)	E (64.3%)	E (61.8%)	E (66.0%)
Transport27	Water-repellent bicycle chain spray	N (53.2%)	N (56.3%)	N (61.4%)	N (55.5%)	N (59.6%)	N (50.4%)	NN (28.9%)	NN (19.4%)
Transport28	Anti-corrosive batteries for electric vehicles	NN (26.5%)	NN (32.0%)	NN (32.4%)	NN (34.4%)	E (51.6%)	NN (30.5%)	NN (21.8%)	E (56.8%)
Food29	Refrigeration of food in warehouses	NN (22.4%)	NN (32.9%)	E (52.2%)	NN (24.4%)	E (54.1%)	E (58.9%)	NN (22.3%)	NN (18.6%)
Food30	Protective plastic packaging for food	N (52.8%)	N (51.9%)	N (52.7%)	N (55.5%)	N (58.8%)	N (53.8%)	NN (19.2%)	N (52.9%)
Food31	Protective packaging for animal feed	NN (26.3%)	NN (31.8%)	N (50.9%)	N (50.1%)	NN (21.7%)	NN (30.2%)	NN (25.6%)	N (51.1%)
Food32	Grease-proof wrapping paper for takeaway food	N (55.4%)	N (57.8%)	N (64.0%)	N (60.2%)	N (62.7%)	NN (30.3%)	NN (22.9%)	NN (16.6%)
Security33	Oil that reduces maintenance of military vehicles	NN (27.6%)	NN (35.9%)	NN (30.0%)	NN (31.6%)	NN (27.7%)	NN (27.5%)	NN (25.2%)	NN (19.7%)
Security34	Waterproof clothing for soldiers	NN (23.5%)	NN (31.7%)	NN (24.3%)	NN (27.2%)	NN (23.5%)	NN (26.1%)	E (53.1%)	E (57.8%)
Security35	Bullet proof coatings for protective vests	E (54.1%)	E (50.7%)	E (56.0%)	NN (28.8%)	E (52.4%)	NN (21.5%)	E (60.9%)	E (62.1%)
Security36	Lubricants that make data storage systems (e.g., magnetic tapes and computer disk \	NN (29.1%)	NN (37.4%)	NN (32.9%)	NN (31.6%)	NN (26.0%)	NN (21.5%)	NN (24.7%)	NN (20.7%)
Environment38	Energy efficient greenhouse glass	NN (26.0%)	NN (35.1%)	NN (31.7%)	NN (27.9%)	NN (21.9%)	E (54.1%)	NN (21.7%)	E (51.0%)
Environment39	Surface treatments to help solar panels yield more energy	NN (24.4%)	NN (36.7%)	E (51.8%)	NN (31.5%)	E (50.8%)	E (56.7%)	NN (22.3%)	E (55.5%)
Environment40	Weather-resistant coating of wind turbine plates	NN (25.9%)	NN (36.8%)	NN (29.5%)	NN (31.3%)	E (50.1%)	E (56.7%)	NN (24.8%)	E (53.2%)
Environment41	Long-lasting filters for wastewater treatment	E (55.8%)	NN (33.7%)	E (57.2%)	NN (27.1%)	E (59.4%)	E (64.6%)	E (56.8%)	E (63.5%)
Environment42	Long-lasting filters for drinking water purification	E (58.1%)	NN (31.9%)	E (61.6%)	NN (27.2%)	E (61.6%)	E (67.3%)	E (53.9%)	E (65.2%)
Recreation43	Easily-sliding ski waxes	N (61.3%)	N (59.5%)	N (73.5%)	N (62.1%)	N (68.5%)	N (58.4%)	N (52.7%)	N (58.0%)
Recreation44	Coatings that make the surface of recreational boats weather-resistant	NN (24.7%)	N (54.9%)	N (64.0%)	N (54.3%)	NN (21.4%)	N (54.9%)	NN (28.0%)	NN (23.7%)
Recreation45	Preserving coatings for historical art	NN (27.7%)	NN (35.9%)	NN (30.8%)	NN (30.1%)	NN (25.7%)	NN (32.1%)	NN (23.8%)	NN (21.1%)
Recreation46	Quality-enhancing stabilizers for films and papers for photography	N (52.3%)	N (50.7%)	N (58.2%)	N (51.0%)	N (57.9%)	N (51.4%)	NN (28.5%)	NN (23.0%)
Recreation47	Grease-repellent guitar strings	N (64.4%)	N (61.6%)	N (74.7%)	N (63.3%)	N (69.9%)	N (61.8%)	N (58.2%)	N (63.4%)
Household49	Nonstick cookware	NN (25.8%)	NN (34.5%)	N (59.1%)	NN (31.1%)	NN (24.5%)	NN (31.4%)	NN (23.6%)	NN (19.0%)
Household50	Dirt- and water-repellent outdoor clothes	NN (25.3%)	NN (33.1%)	N (56.7%)	N (51.3%)	N (61.6%)	NN (29.8%)	NN (24.8%)	NN (22.9%)
Household51	Dirt- and water-repellent everyday clothing	N (54.4%)	NN (34.1%)	N (66.5%)	N (57.6%)	N (66.7%)	NN (31.3%)	NN (26.2%)	N (51.0%)
Household52	Stain-resistant home textiles (e.g., rugs, curtains, furniture upholstery)	N (54.0%)	N (53.7%)	N (65.2%)	N (54.9%)	N (62.6%)	N (50.6%)	NN (24.2%)	N (52.1%)
Household53	Easy to rinse-off cleaners for furniture and floors	N (53.0%)	N (53.0%)	N (61.3%)	N (55.3%)	N (57.7%)	N (50.5%)	NN (24.1%)	NN (19.0%)
Household54	Anti-corrosive coatings for beer cans	N (59.0%)	N (59.4%)	N (65.3%)	N (58.5%)	N (62.2%)	N (58.1%)	N (54.1%)	N (56.8%)
PersCare55	Kiss-proof lipsticks	N (69.2%)	N (65.8%)	N (79.3%)	N (67.0%)	N (75.9%)	N (65.9%)	N (63.5%)	N (63.7%)
PersCare56	Waterproof mascaras	N (66.3%)	N (62.2%)	N (76.2%)	N (65.5%)	N (71.1%)	N (65.9%)	N (59.2%)	N (57.8%)
PersCare57	Propellant for perfumes and fragrances	N (64.3%)	N (59.3%)	N (72.5%)	N (64.4%)	N (69.9%)	N (63.0%)	N (56.3%)	N (61.0%)
PersCare58	Dirt- and oil repelling contact lenses	NN (24.8%)	NN (33.1%)	N (52.8%)	NN (27.2%)	NN (21.5%)	NN (31.2%)	NN (20.3%)	NN (21.2%)
PersCare59	Anti-fogging coatings in eye glasses	NN (24.3%)	NN (32.2%)	N (61.8%)	N (51.3%)	N (55.6%)	NN (32.7%)	NN (23.1%)	NN (19.0%)
PersCare60	Easily spreadable anti-aging cream	N (64.3%)	N (63.1%)	N (75.1%)	N (66.7%)	N (68.8%)	N (61.8%)	N (56.9%)	N (55.5%)
PersCare61	Easily sliding dental floss	N (60.7%)	N (60.0%)	N (69.7%)	N (62.6%)	N (58.5%)	N (63.2%)	N (53.6%)	N (55.6%)

Note. Only the control condition was included, with weighted data used ($N = 2907$). E = > 50% of participants rated as (leaning towards) essential (blue coloring); N = > 50% of participants rated as (leaning towards) non-essential (yellow coloring); NN = no majority of ratings of essential or non-essential, hence categorized as Neither/Nor (grey coloring). All countries combined = analyses ran on a data set that includes all countries. DE = Germany, DK = Denmark, NL = The Netherlands, IT = Italy, HU = Hungary, LT = Lithuania, RO = Romania.

Table C3

Number of use items out of 57 which showed an association* with the explanatory variable (row) per country (column).

	DE	DK	NL	IT	HU	LT	RO
Experimental condition (1, 2, 3)	2	3	3	5	8	1	5
Gender (female, male)	15	14	16	16	15	18	19
Age (younger, older, average)	24	15	28	16	15	14	14
Education (lower, medium, higher)* *	15	9	16	14	19	15	14
Political orientation (1, 2, 3, 4, 5)	23	14	32	13	14	6	15

Note. * $p < 0.05$ in model with all main effects. * *For DK, LT and RO: (lower&middle, higher). Experimental condition: 1 =consequences of not phasing out persistent chemicals, 2 =consequences of phasing out persistent chemicals, 3 =control condition. Political orientation: 1 = Economically left-wing and moderate or liberal socially; 2 = Economically right-wing and moderate or liberal socially; 3 = Economically right-wing and conservative or moderate socially; 4 = Economically left-wing or moderate and conservative socially; 5 =Economically moderate and moderate socially. DE = Germany, DK = Denmark, NL = The Netherlands, IT = Italy, HU = Hungary, LT = Lithuania, RO = Romania.

Appendix D. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2023.103666.

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