



Perceptions on mine water and mine flooding – An example from abandoned West German hard coal mining regions

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ABSTRACT

For the first time, this paper describes the climate of opinion of mine water and mine flooding in three German hard coal post-mining regions, Ibbenbüren, the Ruhr area and the Saarland. Each region has unique geographical, political and mining-historical characteristics, and the underground mines were closed in 2018 (Ibbenbüren and Ruhr area) and 2012 respectively. People's prevailing opinion and emotions regarding mine water, mine water treatment, mine flooding as well as the level of acceptance of the remediation measures and the mining company was investigated. The study is based on a representative telephone and online survey with 1527 participants for the respective regions.

Results show that the local public opinion towards mine flooding and mining issues are not substantially different, but generally more positive in the Ibbenbüren area compared to the Ruhr area and the Saarland. In general, interest in mining related issues as well as environmental or renewable energy issues is low, but those interested in one of the subjects are also interested in the others. Participants indicated that they wanted more information about mine flooding. Of the actors dealing with mine water, the mining company is thought to be best situated to solve potential problems, whilst politicians were least expected to solve them.

People see the term mine flooding slightly more positive than the term mine water rebound, but based on the Student's *t*-test, there are no statistically significant differences. Compared with other surveys worldwide, the results are similar, indicating that experience with the mining company influence the emotions towards remediation measures and the risks people attribute to them. However, people want transparent and understandable information, feel positive towards mine water treatment and oppose mine flooding in general.

1. Introduction

Mine flooding is a common process that starts once the pumps in an operating mine are shut off, either because of raw material depletion, an accident, bankruptcy of the mine operator or based on political decisions (Wolkersdorfer, 2008; Younger et al., 2002). In most cases, the mine flooding process is not noticed by the local population because it seldom causes environmental issues if monitored and managed properly. Two recent cases where the decision to flood abandoned mines caused an intense emotional public discussion are the Witwatersrand in South Africa and the West German hard coal mines (e.g. McKay and Milas, 2017; Ruhland and Wolkersdorfer, 2016; Schleunig, 2021; Turton, 2015), of which the latter will be discussed in more detail in this paper.

New mining operations often cause various interest groups to act against the raw material extraction, because they see uncertain risks for their surroundings. Therefore, it is essential for mine operators to interact with all stakeholders as early as possible to ensure, besides having all legal permits in place, they also receive the social licence to mining (e.g. Hall et al., 2015; Walter, 2021). Often, mine closure causes stakeholders to interfere, be it from the Workers Union side or from environmentalists insisting on sustainable mine closure protocols to be followed. Though these processes and activities pre-mining have been studied extensively (e.g. Stacey et al., 2010a, b), post-mining activities or concerns are less understood so far. This paper, therefore, wants to fill this gap through investigating the perceptions of the public in the West German hard coal mining regions of Ibbenbüren, the Ruhr area and the

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Saarland. One of the reasons for this survey was a discussion about the emotions of the public towards the terms “mine water rebound” and “mine flooding”, the latter by the former mine operator to be negatively connected to their mine closure activities, and therefore avoided in official documents. Yet “mine flooding”, is not only the historically grown *terminus technicus*, but also the commonly used terminology internationally. Furthermore, during numerous discussions about the flooding process and its planning, the question arose, how the public is involved and how they inform themselves.

In December 2019, the Higher Administrative Court ruled in favour of the Nalbach municipality (Saarland, Germany) that the pump shut-down relating to the partial flooding of the RAG Aktiengesellschaft (German hard coal mining, RAG AG) collieries in the Saarland authorised by the mining authorities was unlawful (Bauer, 2018). This court case might have influenced the public opinion in the Saarland, as can be seen in the results. Meanwhile, the mining authority permitted the mine flooding level up to −320 mNHN once all additional preconditions are met and additional court cases closed. Annually, the operation of the dewatering pumps costs RAG AG about 300 million euros. Because at the end of 2018, all German hard coal mines were closed for economic and ecological reasons, and therefore, RAG AG can no longer derive economic benefit from coal mining. After the underground mines have been cleared of potentially toxic substances, the mine water can rebound to a pre-defined level (Kretschmann et al., 2017) controlled by a set of high capacity pumps in selected shafts. However, the local population associates mine flooding with fears, such as contamination of drinking water, environmental damage, damage to their property and unknown risks, resulting in protests or legal actions against the flooding process. This might be a reason why RAG AG and many authorities involved in the mine closure process prefer the term “mine water rebound” (*Grubenwasseranstieg*) over “mine flooding” (*Grubenflutung*). They claim that mine flooding has a more negative connotation to the population than mine water rebound – which this survey will show, is the opposite.

Surveys about the public attitudes towards mining projects, compared to environmental impacts, are rarely conducted. Moeng (2019) ran a survey over the public opinion relating to acid mine drainage (AMD) near Carolina in South Africa, interviewing 56 people. She noticed that most people have a limited knowledge of mining influenced water (MIW) but relate health problems commonly to MIW affecting their drinking water. In addition, she noticed poor knowledge about general environmental issues and that the locals complained about limited participation in planning and decision-making relating to the MIW. Lyytimäki and Peltonen (2016) investigated the public opinion towards a new mining operation in Kuusamo, Finland by evaluating social media and newspaper discussions. They conclude that local interests and concerns need to be heard and included in the planning process, though this does not completely avoid conflicts. Yet, they must not be feared once one understands the interest of the affected population and their questions relating to the effects of the planned operations. Khaknazarov (2017) investigated the public opinion relating to mining in the Russian Nefteyugansk mining region (Нефтеюганск, Khanty-Mansi Autonomous Okrug). One of his findings showed that the population considers mining to be of great threat to rivers and water bodies, but because mining results in job creation, most of the population feels positive towards mining in their region. This is different from a survey conducted in Guatemalan mining regions, where 57% of the population is not in favour of metal mining (Parker, 2009), but 88% think that mining causes water contamination, and 68% feel not enough informed by the mining companies. This results in many people wishing to increase consultations with affected communities. Yet, Vatalis and Kaliampakos (2006) identified that the population considers air and soil pollution more relevant than water pollution.

Even more seldom are screenings relating to post-mining effects or the special differences in the public opinion and emotions towards these questions. Pérez-Sindín and Blanchette (2020) investigated the public opinion towards an open pit lake at the As Pontes, Spain colliery before,

during and after flooding. They used case studies and interviews and analysed news events and internet forums. Though the public broadly accepted the new pit lake, one of their key findings was that previous experience with the mining company influenced the public opinion more than the technical success of the remediation measures. According to these authors, personal social experiences have a greater influence on perception than ecological or aesthetic aspects. Especially before the flooding started, there were strong media and NGO activities against the open pit flooding, which ceased after the lake was fully flooded. From their study, it became also evident, that solutions to optimise interaction and communication with the local communities are lacking when it comes to agreeable post-mining procedures. Though Arbogast et al. (2000) did not conduct a survey *per se*, their review of case studies brought forth the positive and negative circumstances leading to successful mine reclamation projects and to a positive perception of the public. Relevant, based on their results, are aesthetics including information on “ecology and development, research and technology, culture and nature, science and art”. Page and Atkinson-Grosjean (2013) investigated the public opinion towards ecogenomics supported bioremediation of tailings drainage at an operating copper-gold mine in British Colombia, Canada aiming to find a post mining solution for the discharge into a local stream.

Bishop (2013) has shown that the thinking of individuals is influenced by the location where these individuals live. In addition to the location, the personal context and experience of an individual rules their opinion (Sears and Funk, 1991). It was therefore of interest, if attitudes of the local population towards mine flooding and mine water management in the three West German post-hard-coal-mining-regions of Ibbenbüren, the Ruhr area and the Saarland also show a location bias. This paper will demonstrate that some post-mining issues are, indeed, location dependent while others are more general.

To identify what the real opinion of the local population in the Ibbenbüren, the Ruhr and Saarland areas are relating to mine flooding, a representative online and telephone survey with 1,527 participants was initiated in 2020. Data based on this survey will show, among other things, (i) how big the general interest in mine water and mine flooding is, (ii) what sources of information the population in the three former coal mining areas use for opinion building, (iii) how they characterise mine water and (iv) what concerns they have. Different opinions and expectations regarding mine flooding and its consequences will be identified and similarities in the individual mining areas will be depicted.

This survey also included questions relating to partisan preferences, as it is known from “climate change” vs “global warming” studies that these strongly correlate with both political preferences and environmental thinking of an individual (Schuldt et al., 2011). Yet, only a small number of participants provided information about their partisan preferences, which renders conclusions unreliable. Common scientific knowledge is that risk taking individuals show greater willingness to accept potentially dangerous technologies (Slovic, 1987) and that education and information is important for increasing an individual’s acceptance. Also emotions towards concepts like “mine water”, “flooding” or “treatment” that might be new to the public, play a role when it comes to opinion building (Ruhland and Wolkersdorfer, 2016). The question is, if this might also depend on the location of individuals and their experience related to mining or technologies in post-mining environments.

This paper, therefore, investigates the public support and opposition to post-mining measures planned by the past mining operator RAG AG. Specifically, the survey included questions about the population’s attitude towards environment, renewable energy, mine flooding, mining and how they inform themselves. The aim of this paper was to identify the involvement of the local population relating to environment, mining and mine water and the opinion about mine flooding in these post-mining areas. In addition, the study identified communication lacks and whom the public trusts most when it comes to mine water

remediation activities and how that knowledge can be used for projects in other locations around the world. The literature review results show that this is the first time that such a comprehensive survey was conducted in a post-mining area.

2. Methodology

2.1. Survey regions and sample size

To determine the public opinion about mine water in the three former West German coal mining areas (Fig. 1), survey regions of Ibbenbüren, the Ruhr area and Saarland were isolated by postcode. This postcode area selection used a GIS (geographical information system, QGIS) and includes all postcodes within the catchment perimeter of the

abandoned mines. Basis for this procedure was the assumption that people interested in or affected by mining related issues live within close proximity to the mines. In each area, the respective number of inhabitants for the relevant postcode areas was identified with an online database (Gemeindeverzeichnis 2019: Statistisches Bundesamt – Destatis); the total number of inhabitants for the survey regions could be determined (Fig. 2). The outcome for the Ibbenbüren region resulted in 303,511 inhabitants (20 postcode areas), 4,909,885 inhabitants in the Ruhr area (229 postcode areas) and 730,990 inhabitants in the Saarland (48 postcode areas).

To define the sample size for a survey, a large number of literature exists, which discusses the requirements to determine an adequate sample size (e.g. Ryan, 2013; Trotter, 2012). For this survey, equation (1) to calculate the minimum required representative sample size n for

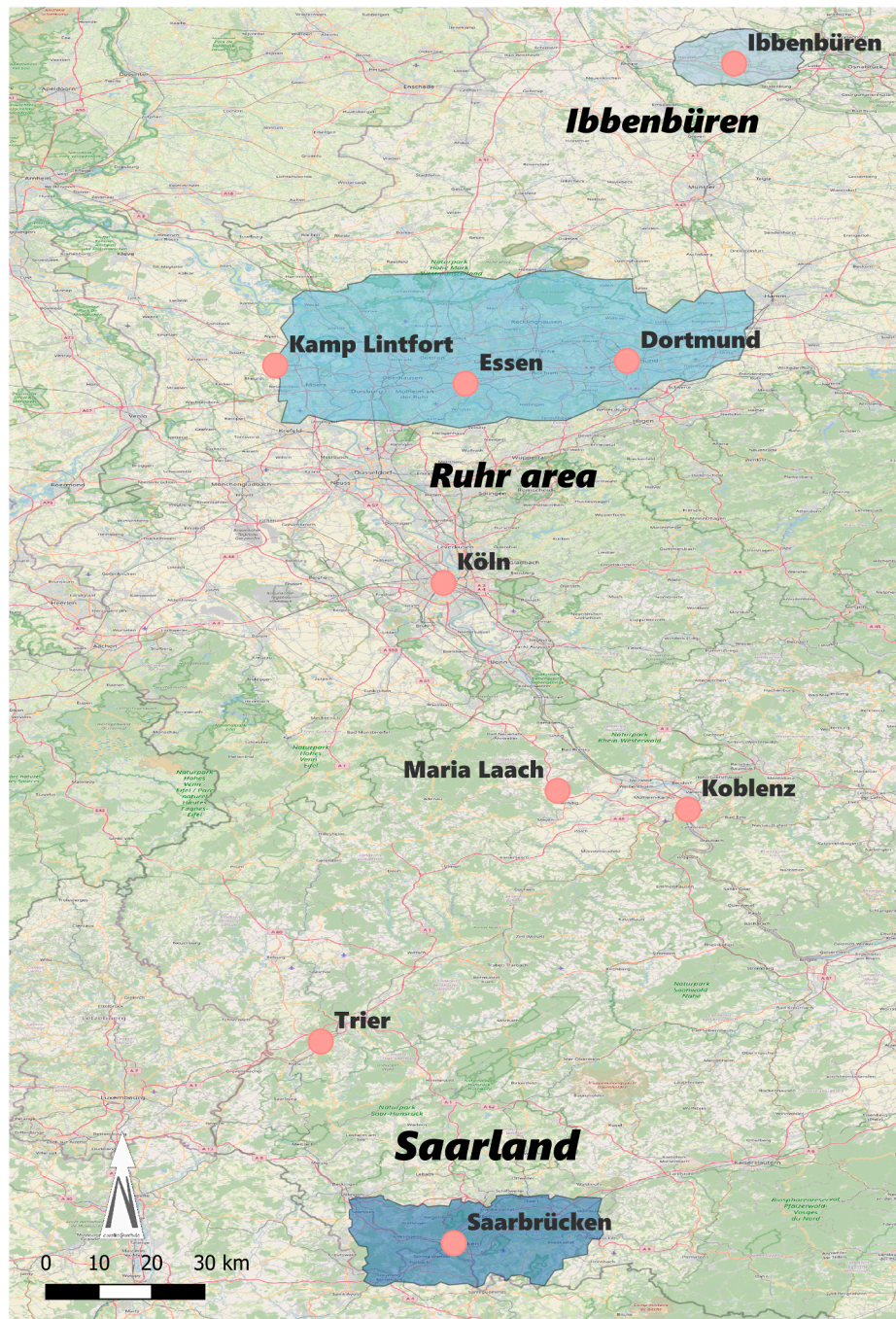


Fig. 1. Geographical location and perimeter of the three mining regions studied (background map © Open Street Map contributors).

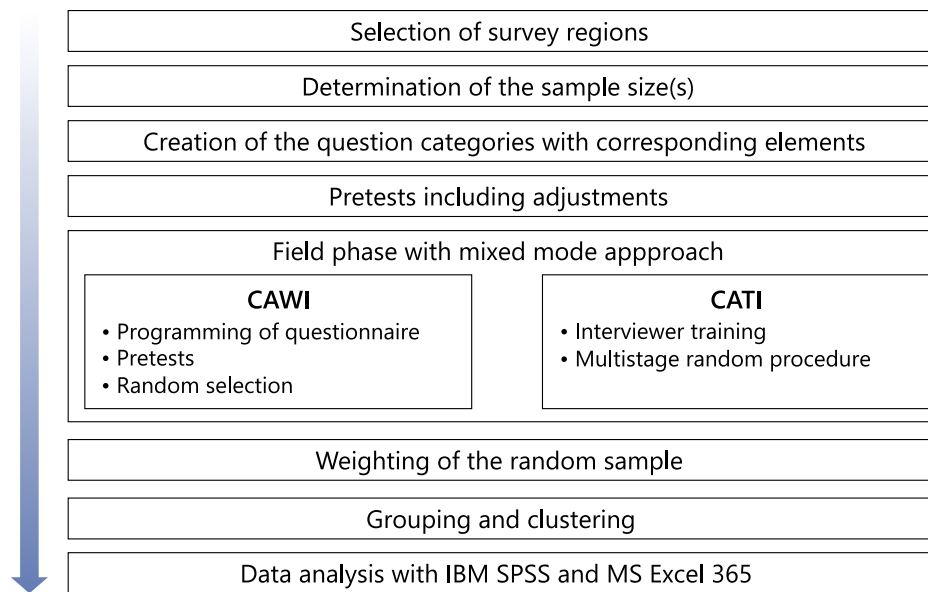


Fig. 2. Summary of the procedure for this survey (CAWI: Computer Assisted Web Interview, CATI: Computer Assisted Telephone Interview).

the respective number of inhabitants was used, which is commonly cited on web pages for survey software (e.g. SurveyMonkey, Creative Research Systems) and is discussed in detail by Gabler and Häder (2015):

$$n \geq \frac{N \cdot z_{\alpha/2}^2 \cdot p(1-p)}{Z_{\alpha/2}^2 \cdot p(1-p) + N \cdot e^2} \quad (1)$$

As the confidence level, the commonly used $z = 95\%$ was chosen, the standard deviation was set to $p = 0.5$ and the confidence interval $e = 0.05$. For a population size $N = 303,511$ in Ibbenbüren, $N = 4,909,885$ in the Ruhr area and $N = 730,990$ in the Saarland, using the above equation, a minimum of 384 people per area is required to draw statistically representative conclusions. In the survey, an unweighted subset of 502 could be fully interviewed in Ibbenbüren, 532 in the Ruhr area and 493 people in the Saarland, thus proving the survey data to be statistically sound.

2.2. Questionnaire

With the representative survey described here, the attitudes of the population towards mine water, mine flooding and the environment was identified by means of explicit attitude measurement (electronic appendix 1). For this purpose, a questionnaire that follows the principles of quantitative social research was designed (Mayer, 2013; Schnell et al., 2018; Scholl, 2009). The survey comprised 20 questions in the categories interest and involvement, degree of information, acceptance and opinion including socio-economic and demographic attributes. Closed and open questions, single/multiple choice, filter questions, ordinal rating scales and statement batteries were used.

In the first set of questions, participants were asked about their relationship to mining and mine water, terms that come to mind in connection with mine water, their personal interest in these and related topics, their degree of involvement with the topic and the sources of information they use. These topics include raw material extraction/mining, renewable energies and environmental protection/nature conservation. Not all these topics will be discussed in this paper as some were primarily included for comparing and classifying the determined data. This was particularly necessary because comparisons with other surveys are not possible due to the lack of comprehensive surveys about this matter as described above. One exception is a Forsa survey in the Saarland for the weekly newspaper FORUM – Das Wochenmagazin in view

of the 2017 state parliament elections, where 1001 people were surveyed (Hilt, 2017), and 68% were against mine flooding, 17% in favour and 15% indifferent.

In the second question complex, the level of information on the main topics were surveyed. This included questions about whether other regions are known to be affected by mine water problems, as well as whether the mine water issues in Germany are estimated to be of greater or lesser concern than in other regions.

In the question complex “acceptance and opinion” the following information was asked for: the personal attitude to the topics studied, the assumed characteristics of mine water, the assessment of benefits and problems and, related to this, the explicit naming of these problems and benefits from the point of view of the participants, as well as the influence of actors to solve the problems with mine water. Finally, personal data such as age, gender, level of education, postcode, political orientation and net income were collected.

All questions were developed according to the objectives of the study, passed a pre-test and were given to a market research company (CONOSCOPE GmbH, Leipzig) to conduct the field phase. Data was stored digitally on a server of the research company and handed over to the authors in their entirety. All analysis was conducted with MS Excel 365 (Microsoft Corp., Redmond) and SPSS 27 (IBM, Armonk).

2.3. Mixed-mode approach

For the data collection, the mixed-mode approach was applied, meaning that the data was collected via several channels (Dillman et al., 2014). This guarantees access to all target groups, as older people, for example, could rather be contacted via telephone survey. Therefore, the survey was conducted via telephone and online, and the population was defined as all German-speaking, adult inhabitants of Ibbenbüren the Ruhr, and Saarland areas (*sensu* the postcode definition described above). In all the three areas, sampling was carried out according to the stepwise stratified random principle (VanderStoep and Johnston, 2009), which ensures that each group is represented according to its proportion (in this case primarily age within each mining area and between the mining regions) as it reduces the bias in selecting the participants.

2.3.1. Online survey

The online questionnaire for the Computer Assisted Web Interview (CAWI) was programmed with the software LimeSurvey (LimeSurvey

GmbH, Hamburg), which provides software-based filter guidance and logical control. After the questionnaire was checked for content and filter logic features by means of several pre-tests, it was released for the survey. All online participants were randomly recruited from relevant panel lists via the Payback online access panel according to the specifications of the target matrix, with Payback controlling the invitation management and test person handling. It regulated the contact requests to the participants and carried out follow-up activities to achieve the desired number of cases. Each panel participant carried a personal ID with them via an invitation link, which was read into the online questionnaire as a separate variable. This ID was returned to the panel via a redirect link after the questionnaire had been completed in full, which enabled the panel to determine if the participant had completed the questionnaire in full.

2.3.2. Telephone survey

For telephone surveys, a Computer Assisted Telephone Interview (CATI) was primarily used (Storck, 2014). The questionnaire was programmed with the CATI software Voxco Interviewer Suite (Group Voxco, Montreal, Canada), and after successfully finishing the pre-tests, the field phase was initiated. Filter guidance, skip instructions, logical control, selection of households, choice of telephone numbers and sample management were done by Voxco Interviewer Suite, so that the interviewers could fully concentrate on the interview situation.

All telephone interviewed households were selected according to the Gabler-Häder design with the random-last-digit selection procedure, being considered a methodological standard in German empirical social research (Gabler and Häder, 1999). In this process, landline and mobile phone numbers are selected by unrestricted random selection from the telephone directory of the survey regions, the last two digits are removed and then replaced by random numbers. Consequently, telephone connections which are not listed in the public directory are also reached, and the telephone numbers obtained were fed into the CATI software. Thereafter, the number was called and if the number was valid, not a fax number or a company line and if a person answered, only the person in this household who had the last birthday was interviewed (last-birthday method) (Salmon and Nichols, 1983), so that bias effects could be avoided (Oldendick et al., 1988).

2.4. Field report

The gross sample of the online survey consisted of 1375 people. Of these, 20 people were excluded due to poor data quality: These were, e. g., alleged “speeders”, who completed the survey in too short a time to have read the questions. There were 1358 people in the adjusted sample. Of these, 18% dropped out of the interview, 6% were excluded from the survey because the quota in a particular group of people was reached and the interview was not started (“screenout”). Ultimately, a total of 1111 complete interviews were conducted between 27 March and April 14, 2020 and included in the analysis.

In case of the telephone survey, the gross sample consisted of 7741 telephone numbers, of which 3918 dropped out because they could not be reached. Thus, 3823 numbers remained in the adjusted sample of which 87% were not interested in participating in the survey and 2% dropped out during the interview. Finally, 416 interviews were completed between 11 May and June 19, 2020 and could be included in the analysis. This relatively low response rate is not uncommon and steadily increased in recent years, as Wolf et al. (2021) have shown. Consequently, 1527 inhabitants in the three survey regions were interviewed for the study (Table 1).

2.5. Socio-demographics and weighting

To achieve a correctly composed sample, which represents the population, and to avoid too extensive subsequent weighting of the data, quota selection during telephone recruitment was employed (Table 2).

Table 1

Participation in the survey according to the survey form. “Screenout” refers to individuals who were excluded because a given quota was already reached.

	CAWI		CATI		Total	
	n	%	n	%	n	%
Gross sample	1375	101%	7741	202%	9116	161%
Neutral failures/rejects	20	1%	3918	102%	3158	61%
Adjusted sample (set to 100%)	1358	100%	3823	100%	5181	100%
Rejection, no interest	–	–	3325	87%	3325	64%
Termination after interview begun	241	18%	82	2%	323	6%
Screenout	82	6%	–	–	82	2%
Interviews complete	1111	76%	416	11%	1.527	29%
Field time	27.3. – April 14, 2020		11.5. – June 19, 2020		27.3. – June 19, 2020	
Survey regions	Ibbenbüren, Ruhr area, Saarland		Ibbenbüren, Saarland		Ibbenbüren, Ruhr area, Saarland	

Table 2

Socio-demographics and weighting according to groups. Weighting factor rounded to two decimal places.

Groups		n prior to weighting	Weighting factor	n after weighting
total		1527	0.98	1500
Gender	male	771	0.94	728
	female	756	1.02	772
Age group	18–29	151	1.62	245
	30–45	339	0.93	316
	46–59	476	0.87	412
	60–75	435	0.74	321
	>76	126	1.63	206
Education	low	135	1.07	145
	medium	673	0.94	632
	high	705	0.99	701
Net Income	low	201	1.10	221
	medium	458	1.00	456
	high	353	0.90	318
Region	Ibbenbüren	502	1.00	500
	Ruhr	532	0.94	500
	Saarland	493	1.01	500

This quota selection was done by choosing the characteristic “age” based on the current population statistics and is controlled by the CATI software. As soon as a certain age quota was reached during the survey, people from this quota were no longer interviewed. By means of this pre-quoting, the randomly generated selection of contacts and the last-birthday principle, the sample should be a structurally identical image of the population. Nevertheless, due to various factors, such as the individual accessibilities of the target people, slight distortions occur. These are compensated for by a subsequent mathematical weighting of individual parameters and adjusted to the distribution of the population which is known from data of the Federal German Statistical Office and represents the weighting basis for the survey. All survey results were therefore weighted according to age in the three regions.

In addition, a common weighting factor was formed from this population based weighting factor, taking correlation effects into account. This forms the basis for the final, weighted evaluations of this study. If a characteristic of the sample, such as age, is weighted, this simultaneously influences the distribution of the other variables, e.g. educational attainment (correlative effects). To compensate for these mutual dependencies, the simple weighting factors are converted to a corrected total weight via an iterative procedure that takes all these correlative effects into account. This weighting factor results in a distribution of characteristics within the sample that is consistent with the population. These principles allow the results determined in the sample to be considered valid in the survey regions within the error tolerance limits.

The structure of the sample is thus representative regarding these characteristics based on this multi-stage weighing procedure.

2.6. Group formation

For a clear presentation and for comparisons, people were assigned to individual groups based on the answers given by them (Table 3). Depending on their education, the **educational levels** on the 3-point-scale “low”, “medium” and “high” were developed. The **net income groups** “low”, “medium” and “high” were formed according to the information about net income. If no information was given, no classification was made. Based on the response about the frequency of involvement with mine water, **information behaviour** was grouped according to “frequently”, “rarely” and “not at all”.

For the **interest groups**, the mean value (between 1 for “very high interest” and 5 for “no interest”) was formed (“index”) from the information on personal interest in the listed topics. If the index was less than 1.5, the participants were assigned to the interest group “very interested”, if it was between 1.5 and 2.5, they were considered “interested” and greater than 2, “not interested”. **Involvement groups** were composed of the interest index and the degree of involvement. If the index was below 2.25, participants were assigned to the “very involved” group, between 2.25 and 3.5 to the “involved group” and above 3.5 to the “not involved” group. The **information groups** were formed using the index from the answers to the question about the degree of being informed. If this index (from 1 for “very well informed” to 5 for “not informed at all”) was below 2.0, the participant was considered “very informed”, below 2.6 “informed” and above 2.6 “not informed”.

In surveys on acceptance, a dichotomous definition for acceptance groups is commonly used, although the forms of expression or appearance can differ (Schäfer and Keppler, 2013), so that this does not fully do justice to the phenomenon of acceptance (Walter, 2021). Accordingly, the classification according to Sauer et al. (2005), based on Hofinger (2001a, 2001b), was used in a modified form (Walter, 2021). There, eight acceptance levels are formed on the basis of the components evaluation, emotional reference and action tendency (Hofinger, 2001b),

Table 3
Grouping used for education level, net income group and information behaviour.

Educational level	low	medium	high
No school qualification	X		
Secondary school diploma	X		
Other degree	X		
Secondary school leaving certificate (Realschule)		X	
Completed vocational training		X	
Advanced technical college/specialist university entrance qualification			X
Abitur (grammar school)			X
University degree			X
Net Income	low	medium	high
<500 €	X		
500 € – 1000 €	X		
1001 € – 1500 €	X		
1501 € – 2000 €		X	
2001 € – 3000 €		X	
3001 € – 4000 €			X
4001 € – 5000 €			X
>5000 €			X
Information behaviour/interest	frequent	rare	not at all
Daily	X		
Several times a week	X		
Several times a month	X		
Once a year		X	
Rarer		X	
Not at all			X

and these are assigned to the categories “unacceptance”, “indifference” and “acceptance” (Table 4). Unacceptance means that the active opponents have a strong negative attitude towards the object of acceptance, see their own goals threatened and have a high readiness to act (Hofinger, 2001b; Sauer et al., 2005). Rejectors also have a strongly negative attitude towards the object, but do not see their personal goals threatened; their willingness to act can be described as low to medium, typical are verbal and non-verbal expressions (Hillebrand and Erdmann, 2015; Hofinger, 2001b; Sauer et al., 2005). Indifference implies that the group is ambivalent or is in a conflict between criticism and approval; their attitude is rather changeable, their willingness to act rather low. The indifferent have no interest in the object of acceptance and thus no willingness to act. Tolerant people also perceive no threat to their own goals, but also see no benefit; accordingly, their willingness to act is to be classified as low (Hofinger, 2001b; Sauer et al., 2005). Acceptance is classified as conditional acceptance, consent and commitment (Sauer et al., 2005). People in the first group have a low level of acceptance, which is based on rational reasons and linked to conditions or one of these (Hillebrand and Erdmann, 2015; Sauer et al., 2005). Agreeing people have a high level of acceptance because they see the object of acceptance as useful for their own goals (Hofinger, 2001b; Sauer et al., 2005). Their willingness to act is lower than that shown by people in the committed group. The committed show a very high acceptance and see a necessity in the acceptance object (Hofinger, 2001b; Sauer et al., 2005; Walter, 2021).

A clear distinction between individual levels, such as between indifference and acquiescence, is difficult, as in some cases they only slightly differ (Lindow, 2016). Nevertheless, this classification was used to allow for more well-founded statements than a binary assessment of “acceptance”/“no acceptance”.

2.7. Cluster

Three open questions were included in the survey: For spontaneous terms about mine water, as well as the benefits and problems with mine water. These answers were clustered accordingly either in a 3-, 5- or 8-point-scale and discussed in the relevant sections.

2.8. Mine flooding and mine water treatment

From a long-term perspective, the mine flooding process and consequently the mine water treatment will be the most prominent effects of mine closure. Therefore, the public attitudes towards these two aspects were investigated in more detail. First, the four factors relating to the public’s attitude towards mine flooding were combined into a single factor by taking the arithmetic mean of the participant’s four answers. Then, this factor and the attitude towards mine water treatment, individually, were correlated with all other factors and the 20% with the highest correlation coefficients chosen for further investigation ($0.13 \leq R^2 \leq 0.96$).

3. Results

3.1. General overview

Many answers in the survey are divided into the categories “interest and involvement”, “degree of information”, “acceptance and opinion” and “personal data”. In the evaluation, individual, selected questions are dealt with thematically and local conspicuities of the survey regions will be highlighted in each case. Though there are gender differences in the answers, it seems that these differences are more related to the social status than to the gender difference. The only clear trend is that female participants are less interested in mine water or mining issues and that they consider themselves less informed. Yet, there was no substantial gender difference in the personal connections to mining.

As Hampel et al. (1986) or Andersen (2008) have shown, outliers are

Table 4

Acceptance–Inacceptance Scale (Walter, 2021, modified after Hillebrand and Erdmann, 2015; Hofinger, 2001b; Sauer et al., 2005).

Category	Level	Designation	Explanations		
			Evaluation	Emotional reference	Action behaviour/readiness
Inacceptance	1	Active opposition	Strong rejection, opposition and threat to own goals	Strong negative emotional	High willingness to act
	2	Rejection	Strong rejection, opposition but no threat to own goals	Low negative or low emotional	Lower to medium willingness to act (rather “follower”), verbal and non-verbal expressions
Indifference	3	Discord	Conflict between criticism and approval, both threat and promotion of own goals	Changing emotional attitude	Currently rather low willingness to act, substantial increase to be expected when the mood “tips”.
	4	Equal-validity	No interest, no threat to own goals but also no other points of contact	Anyway, distant	No willingness to act
	5	Toleration	Very low acceptance with tendency to slight rejection but tolerating/slightly approving, no threat to own goals but also little benefit	Waiting sceptically	Little willingness to act, would comply with minor restrictions
Acceptance	6	Conditional acceptance	Low acceptance based on rational reasons and/or linked to conditions (e.g. compensation payments)	Little emotional	Low willingness to act
	7	Consent	High acceptance, useful for own goals	Positive emotional, but not very strong	Rather low to medium conditional readiness to act
	8	Engagement	Very high acceptance, favouring of own goals, necessity	Strongly positive emotional	High willingness to act, active willingness to help shape the future

relevant for the results and conclusions drawn from surveys. It can be assumed that up to 10% of the data can be considered an outlier, even when the experiment or survey is conducted as precisely as possible. Twenty survey results were excluded from the results as they were assumed to originate from “speeders”. Also excluded was the discussion about patrician preferences, as the subset of 246 answer related to 1500 participants was too small and comparing the survey results with the last election results clearly shows a discrepancy in the answers. Other outliers could not be identified in the data, though this does not imply that they are not hidden therein.

3.2. Personal interest

At the interview’s beginning, personal interests as well as the involvement of the participants were recorded, especially on the topic of mining and mine water. In addition to the general mood, local differences in the three former coal mining regions of Ibbenbüren, the Ruhr area and the Saarland are to be considered. Therefore, the questions about personal interest in raw material extraction and mining in Germany were related to the respective region of the survey participants. Of all the participants in the three mining regions, the personal interest in German raw material extraction or mining shows 7.9% very high, 34.2% high, 37.1% low, 13.6% very low and 7.2% non-existent. If the question relates to the specific mining region in which the participant lives, the percentages are higher for very high (11.9%) and high (37.0%), showing that there is somewhat more personal interest in local raw material extraction/mining than cross-regional. However, no major differences

between the individual mining regions were recorded.

Since there can be tension between the topics of mining, renewable energies, environmental protection and nature conservation, participants were also interviewed regarding their interest in these topics. Both for Germany (35.1% and 49.5%) and for the respective region (38.4% and 45.4%), the participants indicated a very high or high personal interest in renewable energies in general. In relation to Germany, there is a very high (38.9%) or high (49.7%) interest in environmental protection and nature conservation. If the participants were asked about their interest in environmental issues in their own region, the very high interest (42.8%) is slightly higher and the high interest slightly smaller (47.6%) (Table 5). Personal interest in the topic of mine water in Germany is predominantly low (43.7%). For 34.2% of the participants, the personal interest is very high and high, for 22.1% of them it is very low and non-existent. Strong regional differences can be discerned for the three survey regions (Table 5). In Ibbenbüren and the Saarland there is more interest in the topic of mine water in one’s own region than in the Ruhr area, which is obvious considering the much larger region and number of inhabitants not connected to mining anymore. In comparison, the highest interest in local mine water issues exists in the group of people that are classified as very involved, compared to those who consider themselves not informed at all about mining in their respective region. As assumed, the interest in environmental issues is much larger than that for mine water.

One of the main objectives of the survey was to assess the emotions towards mine flooding in the respective mining regions, as flooding will start soon in some regions and is therefore being discussed by various

Table 5Participants’ personal interest in mine water and environment in the respective mining region. A mean below 2.69 indicates more interest (bold) and above 2.69 less interest than the average. For environment the mean of ≈ 1.7 indicates that the interest in environment is equal in all the three mining regions.

		total	very high	high	low	very low	not there	mean value
Age group	total	1471	12.6%	33.8%	34.5%	10.3%	8.8%	2.69
	18–29	235	11.8%	24.6%	37.0%	15.3%	11.3%	2.90
	30–45	314	8.7%	32.4%	38.3%	13.4%	7.2%	2.78
	46–59	407	14.7%	34.2%	33.8%	9.2%	8.1%	2.62
	60–75	314	13.3%	36.1%	34.6%	7.2%	8.8%	2.62
	>76	200	14.5%	42.3%	27.2%	6.3%	9.7%	2.55
Mine Water – Region	Ibbenbüren	473	14.3%	37.4%	32.2%	8.1%	8.0%	2.58
	Ruhr area	500	10.0%	26.1%	38.6%	12.8%	12.5%	2.92
	Saarland	498	13.6%	38.1%	32.8%	9.8%	5.7%	2.56
Environment – Region	total	1499	42.8%	47.6%	7.1%	1.4%	1.1%	1.70
	Ibbenbüren	499	37.9%	56.0%	4.3%	0.7%	1.1%	1.71
	Ruhr area	500	45.2%	43.9%	7.7%	1.3%	1.9%	1.71
	Saarland	500	45.3%	42.9%	9.2%	2.2%	0.4%	1.70

stakeholders, the press and in court cases. Since mine flooding in the three hard coal mining regions has been carried out by RAG AG, the question was: “How interested are you personally in mine flooding in your region by RAG AG?” There, 16.1% of the participants indicated a very high interest and 33.5% a high interest. This contrasts with 30.8% with little interest, 9.3% with very little interest and 10.4% with no interest. However, the results of all participants differ substantially in the three regions, as in the Saarland and in Ibbenbüren the very high and high levels of interest each receive greater approval than in the Ruhr area (high and very high together: 53.8% and 56.4% respectively). The question about the consequences of mine flooding showed that the participants are even more interested in this topic. Among all participants, the sum of very high and high interest is 58.5%, i.e. more than half of all participants. It is striking, however, that compared to all participants, the group of 18- to 29-year-olds has a very low (16.3%) or

no interest (13.3%). In the Saarland and in Ibbenbüren, as with the question about “mine flooding by RAG”, interest is higher than in the Ruhr area. If the question about the consequences of mine flooding is excluded, those people who stated that they were personally affected by mine water, an astonishing 13% indicated a low level of interest. Furthermore, 49.1%, i.e. almost half of the participants, stated that they had a very high to high interest in legal questions concerning mine flooding. Especially in the Saarland, 22.8% (compared to 11.3% in the Ruhr area and 13.1% in Ibbenbüren) indicated a very high personal interest in legal issues, which could be explained by the public hearing of the mine flooding process and its discussion in the media that was taking place at the time of the survey. In general, the interest relating to mine water or mining is low, which goes hand in hand with the results of [Sears and Funk \(1991\)](#) about political engagement. They found that “the general public seems to think about most political issues, most of the

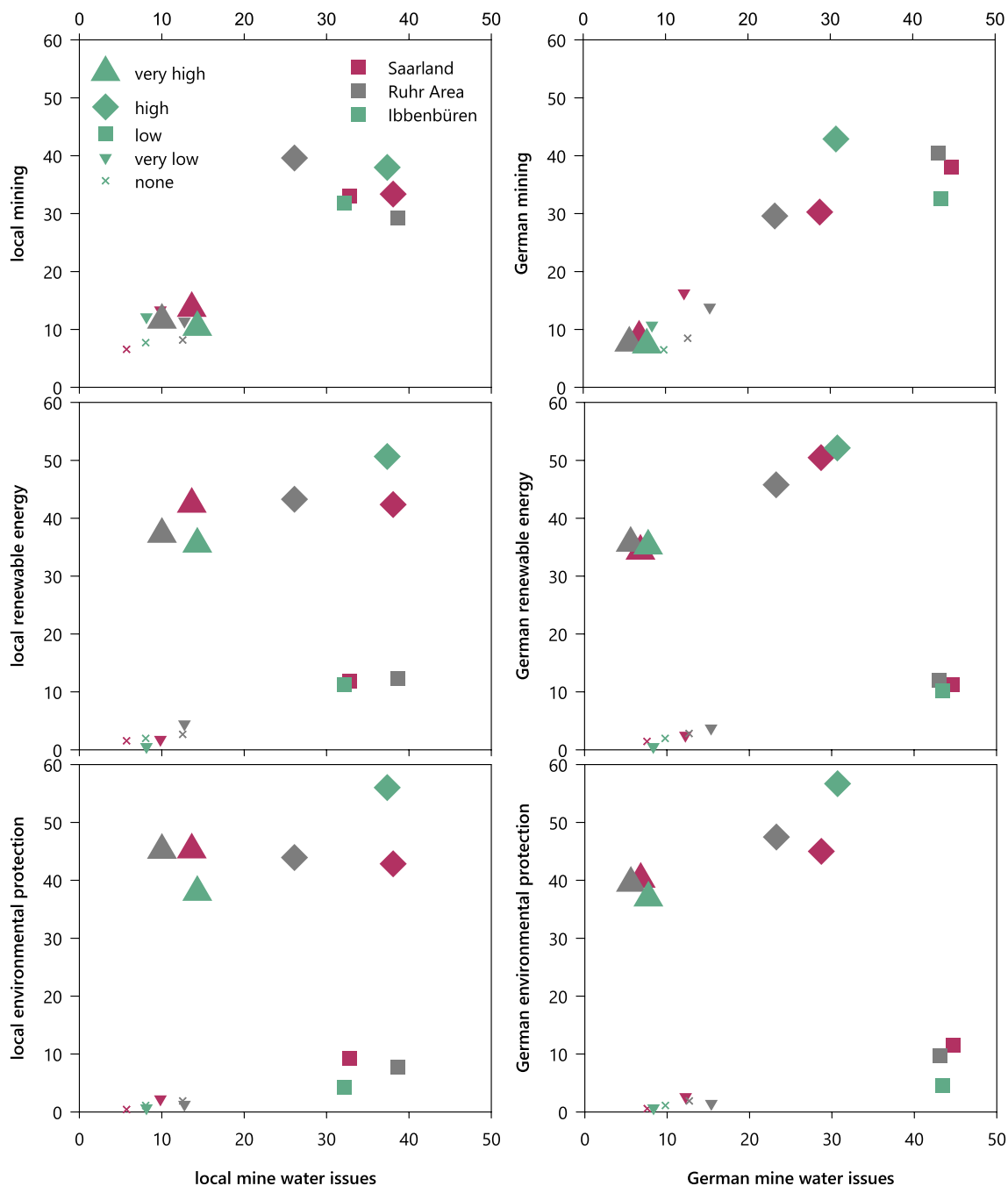


Fig. 3. Percentage scatter plots of various personal interest vs local and German mine water interest.

time, in a disinterested frame of mind” (Sears and Funk, 1991).

To identify if the answers about local and German interests relating to environment, renewable energy and mining correspond, scatter diagrams of the 5-point interest scale for the three post-mining regions were constructed (Fig. 3). As can be seen, no substantial differences between the local and the German personal interests exist. Someone interested in local issues relating to environment, renewable energy and mining, shows a similar interest on the national scale. A major difference exists in the renewable energies and environmental issues – the personal interest in these matters is throughout higher than in mining or mine water. This higher relevance and interest in renewables and environment of the public was also shown by Grunow et al. (2013) in a survey about underground pumped storage plants in the Ruhr area. Stunning, still, is the fact, that someone not interested in one of the four subjects is not interested in any of the other, which again proves the observations of Sears and Funk (1991). From a local perspective, those with a high interest show not much of a difference. Yet, the population with a high interest is lower in the Ruhr area compared to Ibbenbüren and the Saarland. Not much of a local difference exists in the population group with a low and very low interest in German issues and the group with no interest is larger in the Ruhr area compared to Ibbenbüren and the Saarland.

Other than in previous results, there is a stronger relationship between the grade of personal interests in mine water issues and German mine water issues, local mine flooding, local consequences from mine water and local legal issues (Fig. 4). Those with a high interest in local issues generally have also a high interest in the four other aspects of mine water. The same is true for those with a low interest. As seen before, the interest in the Ruhr area is generally lower than in the two

other regions.

3.3. Reference to the topic of mine water

Relating to the question of the participant’s mining connection, 40.5% of all age groups had no connection, 30.7% a local connection and 39.0% a personal connection. It is striking that 53.1% of the over-75s have no connection to mining. If the question is asked in more detail, the personal connection is mainly established through family and friends who work in the industry. In Ibbenbüren, a large percentage of 18.5% of the participants have a personal connection through their job or studies.

Answers on the relation to mine water show similar tendencies. A vast majority of 71.9% of the participants have no relation to the topic of mine water. Only 5.6% are personally affected, but 21.1% of the participants know people who are affected. Within the three mining regions, the answers are more different. The highest number of participants who answered that they have no connection, was in the Ruhr area (80.7%), followed by Ibbenbüren (72.7%) and the Saarland (62.3%) (Fig. 5). In case of the Saarland, the answers are striking in that 33.3% stated that they had a connection to the topic of mine water professionally, through their studies or for other reasons. Of the 5.6% and thus 71 people who are personally affected, this could be narrowed down more precisely by multiple selection. It is particularly noteworthy that 45.6% of all 71 participants stated that they had been affected by building damages, and in the 18 to 29 age group this figure even rose to 65.1%. The percentages are much lower for “due to contamination of groundwater” (19.9%) and “due to polder measures on my property” (10.6%), whereby in the latter case, the 18- to 29-year-olds clearly

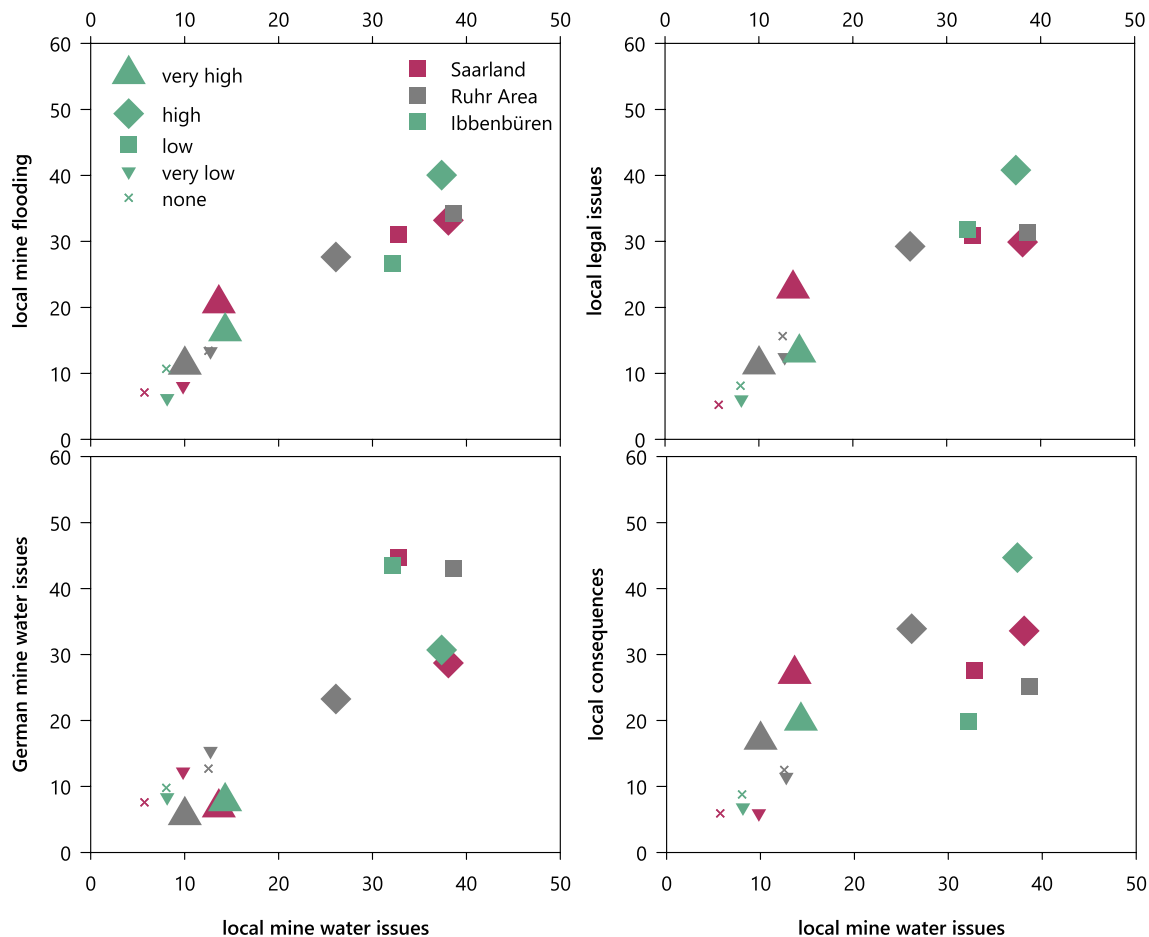


Fig. 4. Percentage scatter plots of various personal local interest and German mine water interest.

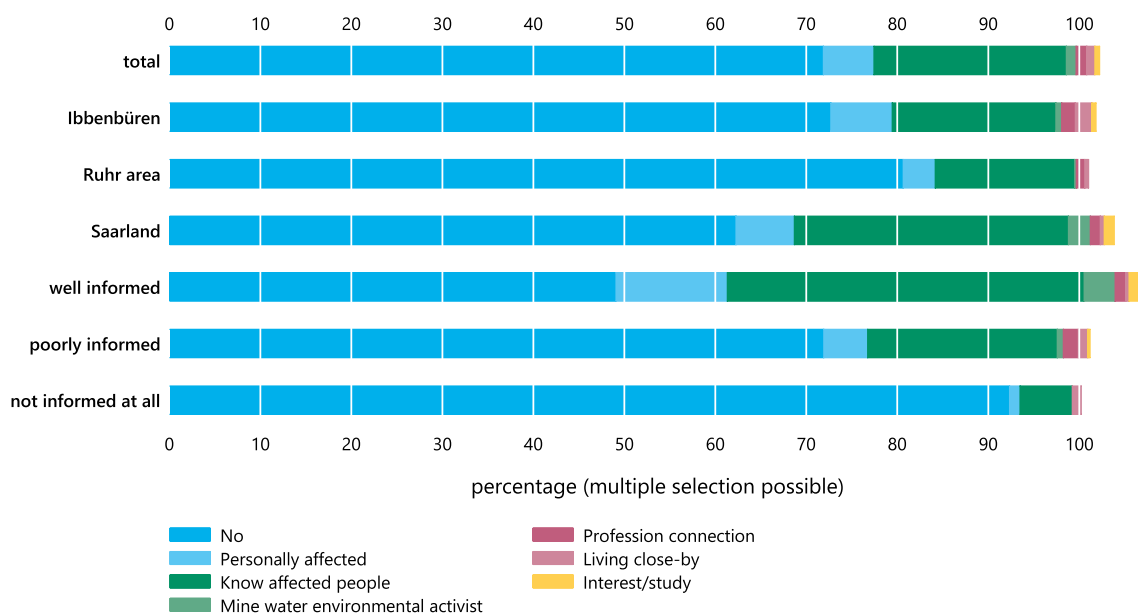


Fig. 5. Do you have a personal connection to the topic of mine water vs. mining region and information status? (Multiple selection possible).

deviates from all participants with 41.1%. There are also major differences between the three regions in terms of those personally affected. While 57.3% in the Saarland feel affected by building damage (Ruhr area 43.1% and Ibbenbüren 38.2%), groundwater contamination plays a more prominent role in Ibbenbüren (24.0% compared to 17.7% in Ruhr area and 15.7% in the Saarland).

3.4. Occupation with the topic

In connection with the occupation related to mine water, the participants were asked how often they deal with the topic. Most answers were “several times a month” (24.8%), “once a year” (15.6%), “less often” (26.6%) and “not at all” (27.6%) (Fig. 6). It is surprising that almost a quarter of the participants deal with the topic of mine water several times a month, whereby there are clear differences between the regions (30.2% in Ibbenbüren, 29.8% in the Saarland, but only 14.7% in the Ruhr area).

3.5. Informed

The way in which people inform themselves about mine water varies greatly according to age. In the answers (Table 6), it can be seen that “exchanges with family” (27.2%), “exchanges with friends/neighbours/acquaintances” (41.2%), “local media” (67.2%) and “national media” (34.0%) have the majority, although social media such as Facebook, Instagram and Twitter are also relevant in the group of 18- to 29-year- and 30- to 44-year-olds, with 31.7% and 21.5% respectively. People over the age of 75 mainly inform themselves about mine water via local media. If the 75 people personally affected by mine water are asked about the type of information source, the exchange with family/friends/neighbours/acquaintances is substantially higher compared to all other participants. There are also large differences in the use of websites. Both through websites of mining and energy companies (35.0%) and through websites of public authorities (44.3%), personally affected people inform themselves more often than all other

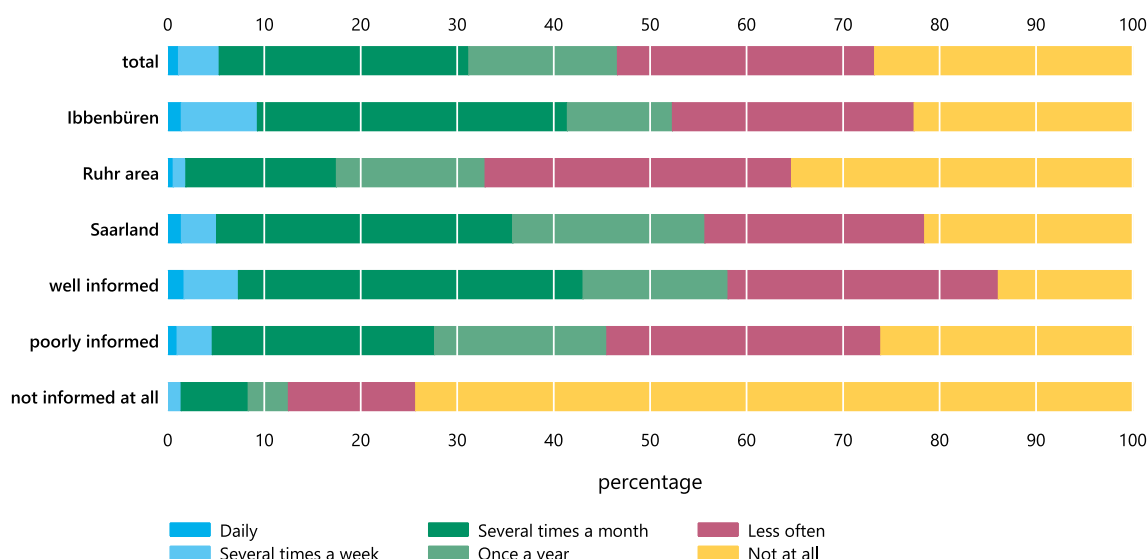


Fig. 6. How often do you deal with the topic of mine water?.

Table 6

Responses on how participants inform themselves about mine water (multiple answers were possible).

Total	1076
Local media, e.g. Westfälische Allgemeine, Saarbrücker Zeitung (also online)	67.2%
Exchange with friends/neighbours/acquaintances	41.2%
Cross-regional media, e.g. ARD, ZDF, RTL, Die Welt, BILD, Spiegel (also online)	34.0%
Exchange with the family	27.2%
Websites of authorities, e.g. environmental agency	19.3%
Mining and energy company websites	15.8%
Social media, e.g. Facebook, Instagram, Twitter	14.4%
Other Internet sources, e.g. websites, forums, blogs, Wikipedia	14.1%
Websites of environmental protection organisations	12.2%
Work/study	0.5%

participants. In Ibbenbüren and in the Saarland, substantially more people obtain information through local media, while in the Ruhr area local and cross-regional media are equally important for obtaining information on the topic of mine water.

Obviously, local media and the exchange with friends, neighbours or acquaintances is the most common information source about mine water issues in the three mining regions. In addition, the websites from the authorities are more often consulted than those of the mining company or NGOs with no substantial differences observed between the three regions. Yet, people who consider themselves informed or who are involved in mine water issues, have a more intensive exchange with friends and families. In addition, they obtain more information from various web pages, both from the company and independent sources. Highest variability was seen in the age groups. It becomes obvious that younger people get more information from social media as well as blogs and less from local print media.

Participants were also asked how well informed they feel about various topics (Table 7). The topics “Mine water in Germany” and “Mine water in your region” will be discussed in more detail. The vast majority (together 78.2%) feel rather poorly or not at all informed on the topic. This is astonishing, because when asked about their involvement with the topic, almost 25% of the participants said they deal with it several times a month. Slightly more people feel informed about mine water in their own region, but 67.9% still feel rather badly or not at all informed. The situation is different when the group of those personally affected is

Table 7

How well informed do you feel about the following topics (sorted by the mean)? Smaller means indicate better informed, larger ones less informed.

Total	very good	good	rather bad	bad	not at all	Mean
Environmental protection and nature conservation in your region						
1500	11.0%	57.5%	22.2%	5.5%	3.7%	2.33
Environmental protection and nature conservation in Germany						
1500	9.6%	56.0%	25.8%	4.9%	3.7%	2.37
Renewable energies in your region						
1500	8.8%	51.1%	28.3%	7.9%	3.8%	2.47
Renewable energies in Germany						
1500	7.1%	53.0%	29.1%	6.9%	3.9%	2.48
Extraction of raw materials/mining in your region						
1474	7.0%	39.3%	33.5%	11.0%	9.2%	2.76
Extraction of raw materials/mining in Germany						
1477	3.3%	35.7%	40.9%	11.6%	8.6%	2.87
Mine water in your region						
1471	4.8%	27.3%	33.3%	16.3%	18.3%	3.16
Mine flooding in your region by RAG AG						
1466	5.1%	21.3%	33.7%	17.9%	22.0%	3.30
Consequences of mine flooding in your region						
1465	5.1%	19.5%	34.3%	17.6%	23.5%	3.35
Mine water in Germany						
1470	2.2%	19.6%	39.2%	18.7%	20.3%	3.45
Legal issues of mine flooding						
1459	3.1%	13.8%	34.1%	20.1%	28.8%	3.58

considered. There, 56% feel very well to well informed and 44% rather badly or not at all informed. There are also differences between the regions. In Ibbenbüren and in the Saarland, people feel better informed about mine water than in the Ruhr area, but still the majority (62.8% and 62.0%) feel rather badly or not at all informed. When comparing the eleven topics, individuals feel best informed about local environment protection and nature conservation compared to legal issues of mine flooding – possibly because the latter is commonly considered a dry topic and more tedious to communicate.

Similar trends were also seen in dialog forums conducted by the research group “Forum Bergbau und Wasser”. Many participants complained about not having received enough information on one hand, while the mining company mentioned that they held dozens of information meetings in the three regions.

The question on the consequences of mine flooding in the participant’s region reflects a similar picture. Of all participants, only 24.5% feel very well to well informed, although more than half of the participants (58.5%) claim to have a very high to high interest in the topic, which is like the general interest in mine water (Table 5). The few people personally affected feel much better informed (49.1% very well to well), and regionally it can be seen that more people in Ibbenbüren and in the Saarland feel informed compared to the Ruhr area.

3.6. Acceptance and attitude

To draw conclusions about the attitude of the population towards mine water, questions about the attitude or acceptance of various topics were asked. Acceptance towards mining (37.6%) outweighs unacceptance (12.3%), with most participants, i.e. 50.1%, being indifferent towards it. The acceptance values towards mining in the Ibbenbüren region is interesting, because 44.5% accept it, but 17.3% indicated unacceptance. Consequently, the opinion in Ibbenbüren is much more divided, as indifference is only found among 38.2% of participants. There is also a very high level of indifference about mine water. Among all participants, 67.3% stated that they were indifferent about it, and acceptance (18.3%) was slightly higher than unacceptance (14.4%). This is also true, with slightly different percentages, for Ibbenbüren and the Ruhr area; in the Saarland, the unacceptance (19.7%) is slightly higher than the acceptance.

Whether there is a different acceptance or attitude towards the terms “mine water rebound” (*Grubenwasseranstieg*) or “mine flooding” (*Grubenflutung*) was to be clarified by another question using an 8-point-scale ranging from “I campaign against it” to “I advocate for it”. Generally, regardless of the term “mine water rebound” or “mine flooding”, it has a negative connotation among the participants (Table 8). It is striking that the unacceptance of both terms increases with the age of the participants. If the question about mine flooding in the participant’s region was asked in more detail, 3.6% say “I campaign against it”, 19.3% “I oppose it”, 33.6% “I am ambivalent”, 18.4% “I am indifferent”, 11.2% “I tolerate it”, 10.2% “I accept it”, 3.4% “I support it” and 0.4% “I advocate for it”. The highest degree of unacceptance is found in the Saarland

Table 8

Total attitude towards the terms “mine water rebound” (*Grubenwasseranstieg*) and “mine flooding” (*Grubenflutung*) summarised for the three regions. A larger 8-point-scale mean relates to a more positive opinion.

Total	Unacceptance	Indifference	Acceptance	8-point-scale \bar{x}	8-point-scale σ
Mine water rebound in Germany					
1420	24.4%	62.4%	13.2%	3.617	1.448
Mine flooding in Germany					
1411	22.1%	63.8%	14.1%	3.633	1.450
Mine water rebound in your region					
1420	24.9%	61.8%	13.3%	3.600	1.474
Mine flooding in your region					
1411	22.9%	63.2%	13.9%	3.615	1.476

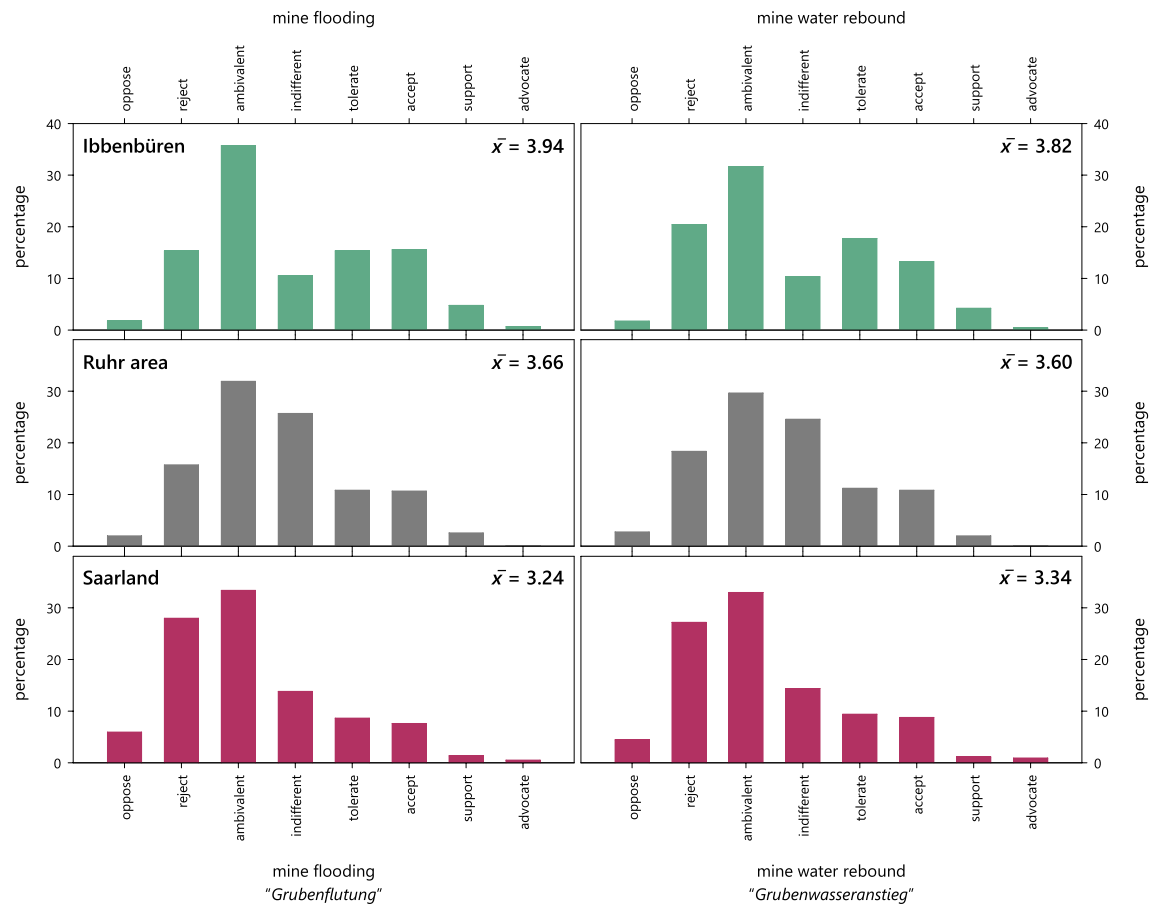


Fig. 7. Histograms for the acceptance of local mine flooding vs mine water rebound in the three regions. A smaller 8-point-scale mean (\bar{x}) relates to a more negative opinion.

(Fig. 7). In the case of mine water rebound and mine flooding, 31.0% and 33.1% respectively indicate unacceptance of “mine water rebound in your region”. Even when asked more precisely, the response from the Saarland is rather negative with 5.9% “I campaign against it” and 27.2% “I oppose it”. A statistically significant difference between the two terms “mine water rebound” and “mine flooding” cannot be discerned (Table 9) as can also be seen by the similar mean value, although the unacceptance of the term “mine water rebound” is slightly higher (Table 8). The only statistically significant difference can be seen when the attitude towards the terms mine water rebound, and mine flooding is compared on a German and a local scale. In this case, local mine flooding has a slightly more negative attitude by the population within the same word group but not between them. There is an indication for the reason of the bimodal distribution of the Ibbenbüren area acceptance levels. Linear regression showed that the participants with a relation to mining, which in Ibbenbüren is higher than in the other two areas, have a more positive view of mine flooding than those without a mining connection.

Attitudes towards the issue of mine water treatment are dominated

by acceptance (42.0%) and indifference (54.4%), with a detailed answer to the question showing that 10.4% condone it, 14.3% accept it, 25.5% support it and 2.1% advocate for it. The high percentage of 26.0% for “I am ambivalent” is striking. Presumably these people cannot relate to the term mine water treatment. In Ibbenbüren, as many as 31.3% said they were ambivalent about mine water treatment. It is possible to speculate whether this is related to the active and passive mine water treatment systems at site. In a recent online stakeholder dialog, one environmental activist from the Ibbenbüren area indicated that the existing treatment systems are not tackling the pollution issue in a holistic way, but just the Fe and TSS concentrations.

Another interesting question is whether the participants see more benefits or problems from mine water (Fig. 8). Most participants (54.9%) said they see “more” and “many more” problems, 35.5% opted for “neither”, and only 9.6% of participants see “more benefits” in mine water. The percentage of people who see “more problems” in mine water increased with age. In addition, more participants with a grammar school degree stated “more problems” than people with a medium or low

Table 9

Results of paired samples Student's *t*-test for the terms “mine water rebound” (Grubenwasseranstieg) and “mine flooding” (Grubenflutung) using the 8-point-scale values. The results show no statistically significant difference between the two terms. Bold indicates a statistically significant difference. *t*: test variable, σ : sigma (2-tailed), *x*: difference of the mean, *s*: standard deviation.

	Rebound Germany		Flooding Germany		Rebound region		Flooding region	
Statistics upper			<i>t</i>	σ	<i>t</i>	σ	<i>t</i>	σ
Rebound Germany			−0.493	0.622	2.113	0.035	0.720	0.471
Flooding Germany	−0.011	0.855			−1.465	0.143	2.767	0.006
Rebound region	0.022	0.396	−0.033	0.863			−0.239	0.811
Flooding region	0.017	0.878	0.028	0.380	−0.006	0.883		
Statistics lower	<i>x</i>	<i>s</i>	<i>x</i>	<i>s</i>	<i>x</i>	<i>s</i>		

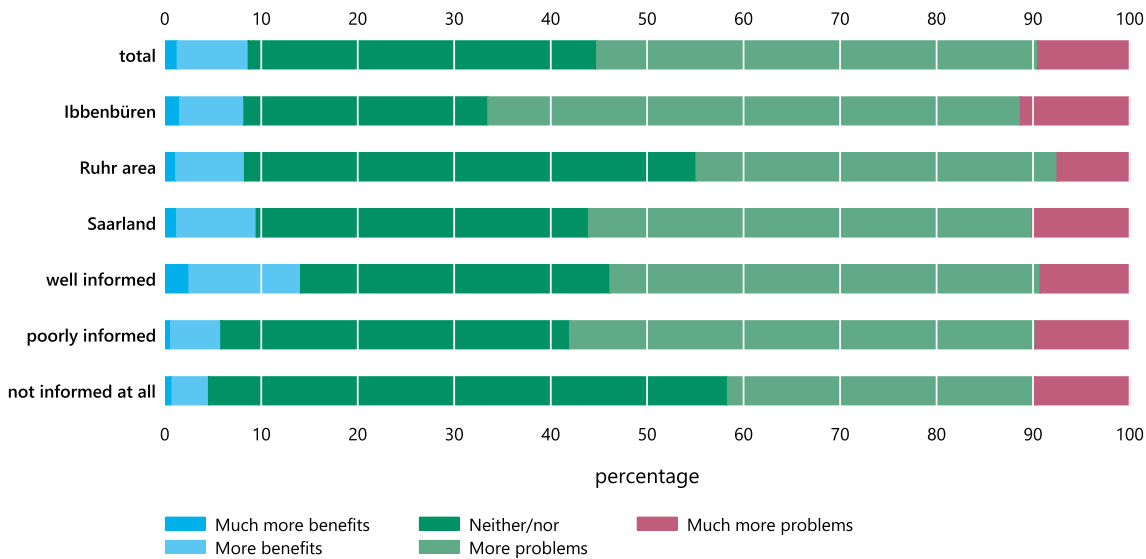


Fig. 8. In your opinion, do the benefits or problems of mine water predominate?.

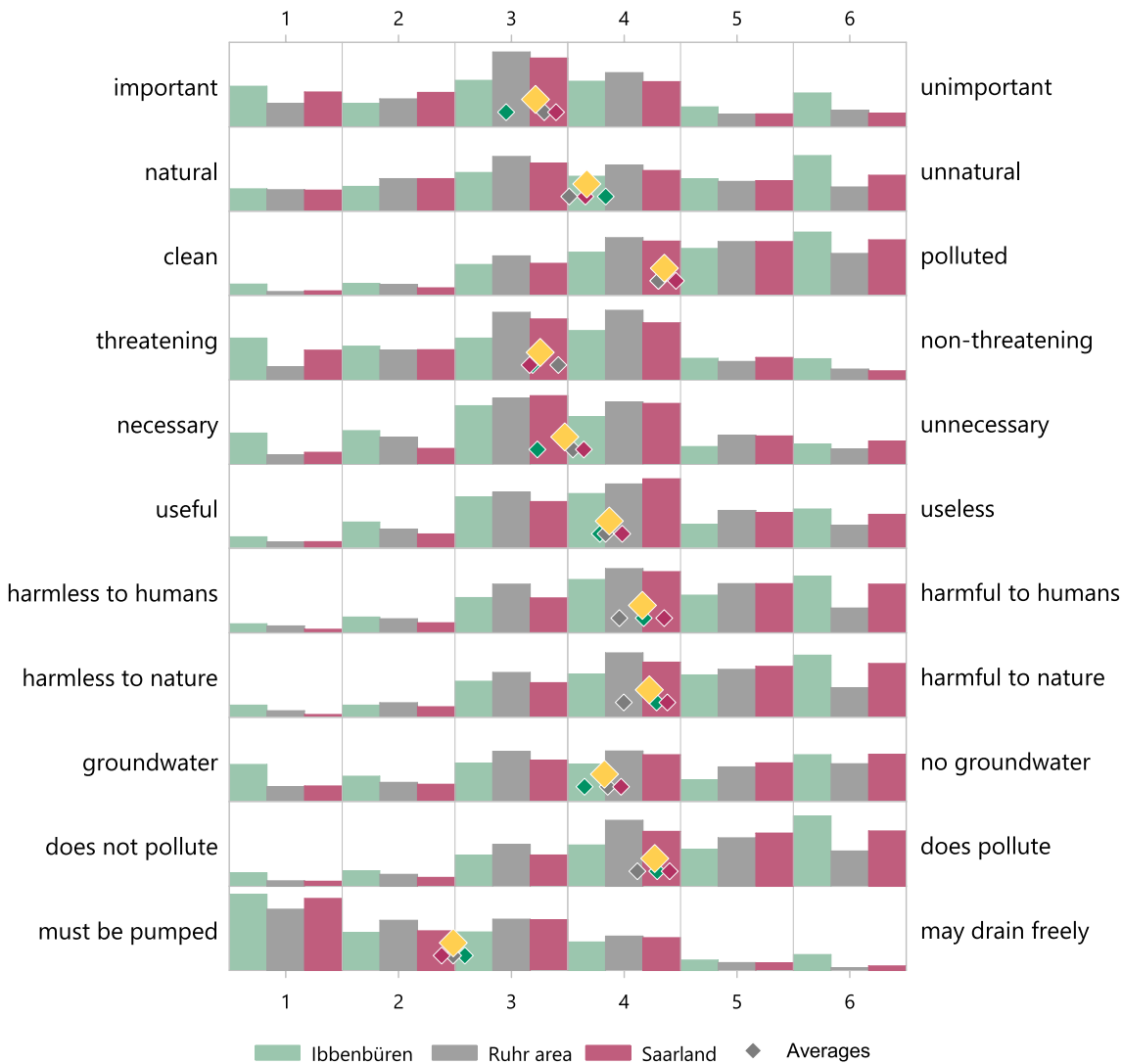


Fig. 9. Categorised answers relating to the question "How would you characterise mine water". Ordinate 0–40% for all groups. Total and individual regional averages indicated as diamonds.

school degree. Although mining is more accepted in Ibbenbüren than in the other regions investigated, most problems (63.1%) are associated with mine water there, but also substantially fewer “neither” answers (26.7%). The answer “more benefits” was about the same in all the three mining regions.

3.7. Characterisation of mine water

By means of various questions, the term mine water had to be characterised. Though the answers of all participants show a high variability, the tendency is clearly to the negative (Fig. 9) as already seen by the above results. Obviously, mine water is rated as “dirty”, and the characterisation clearly is biased towards “harmful to humans” vs “harmless to humans”. This negative impression becomes clear when looking to the answers to “does not pollute water bodies | pollutes water bodies”. 42.4% of the participants state that mine water pollutes water bodies. When asked whether mine water must be pumped or shall be allowed to run off freely, the majority clearly decides in favour of “must be pumped”, indicating the information deficit discussed about in the previous section. The opinion that mine water causes more problems than benefits also prevails. If the regional differences are considered, the tendencies in the Saarland are more negative, but the inter-regional differences are small. Ibbenbüren stands out in the question of “necessary | unnecessary”, as it is seen as clearly more necessary in Ibbenbüren. Mine water is also seen more as “natural groundwater” in Ibbenbüren than in the other regions. Likewise, a larger percentage in Ibbenbüren is in favour of free run-off than in the other coalfields. People in Ibbenbüren and the Saarland see more problems with mine water than in the Ruhr area.

In response to the question “What terms come spontaneously to your mind when you think of mine water?“, the participants were asked to give one or more answers by themselves. 23.5% of the participants could not name any other terms related to mine water. If all other answers are classified, the terms mining (20.1%), water/groundwater (19.8%), pumping (11.1%) and damage/pollution (10.6%) came up most frequently. Other terms mentioned were pollutants/toxic (9.9%),

flooding (7.7%), subsidence/collapse (6.1%), perpetuity/costs/burdens (4.9%) and environment (3.5%). The remaining terms account for 2.7%. No clear positive or negative tendencies can be derived from the terms mentioned. However, there are clear differences in the various age groups. Among the over-75s, 10.5% mention eternal tasks/costs/burdens, and among the youngest group of 18- to 29-year-olds, 30.0% mention mining. Substantial differences can also be seen in the different regions (Table 10).

Particularly striking is the regular mention of the terms contamination/pollution. In the Ruhr area only 6.7% associate this term with mine water, in the Saarland 20.0% and in Ibbenbüren even 25.9%. On the other hand, damage/pollution is more present in the Saarland with 16.2% than in Ibbenbüren with 5.0%. Reason for that might be that mining there came to an end after a mining induced earthquake stroke

Table 10

Classified terms that spontaneously come to mind when participants are asked about mine water. Sorted by percentage of the total. To allow identification of the terms in the word cloud (Fig. 10), German translations are given.

	Ibbenbüren	Ruhr area	Saarland	All three
Total	500	500	500	1500
None	25.3%	27.1%	18.1%	23.5%
Mining [<i>Bergbau</i>]	14.5%	25.9%	20.0%	20.1%
Water/groundwater/mine water [<i>Wasser/Grundwasser/ Grubenwasser</i>]	17.0%	20.8%	21.7%	19.9%
Contamination/Pollution [<i>dreckig/verseucht</i>]	23.7%	6.7%	13.5%	14.6%
Pumping [<i>abpumpen/pumpen</i>]	12.2%	12.4%	8.9%	11.2%
Damage/load [<i>Gefahr/Belastung</i>]	5.0%	10.6%	16.2%	10.6%
Pollutants/toxic [<i>schmutzig/giftig</i>]	12.1%	7.7%	9.9%	9.9%
Flooding [<i>Flutung</i>]	4.6%	6.1%	12.2%	7.6%
Subsidence [<i>Absenkung</i>]	2.0%	5.5%	11.0%	6.2%
Eternal task/costs/burdens [<i>Ewigkeitslasten/Kosten</i>]	6.5%	3.8%	4.5%	4.9%
Environment [<i>Umwelt</i>]	2.7%	2.4%	5.5%	3.5%
Other terms	5.0%	1.7%	1.4%	2.7%



Fig. 10. Word cloud “mine water” based on the free answers (Table 10 with translation of most prominent words). The most prominent words are mining, groundwater, water, pumping, salt, mine water, PCB, danger and subsidence.

the Primsmulde region on February 23, 2008, causing substantial surface damage (Fritschen, 2010). The mention of the terms flooding and subsidence/collapse is also astonishing. While in the Saarland, these are mentioned with 12.2% and 11.0% respectively, they received lower attraction in the other two districts in the mid to lower single-digit range. The word cloud (Fig. 10) gives a broader overview of terms that the participants associate with the word mine water.

Only of anecdotal interest might be that people connect the term to an alcoholic drink produced in two of the three regions. Six out of the 1308 participants that answered mention this drink.

3.8. Benefits, problems and solutions

To explore the opinion picture on benefits, problems and solution in connection with mine water, the participants were also asked if they know of other German regions that are affected by mine water problems. Most participants (78.0%) answered “no, none”. In the Ruhr area, as many as 94.2% answered “no, none”. This suggests that most participants do not inform themselves about other mining regions. Relating to the question “In your opinion, are the problems with mine water in Germany compared to other regions in the world”, 11.3% answered “greater”, 36.4% “same”, 13.3% “smaller” and 38.9% “don’t know”. Among those who have an opinion on this matter, the assumption that mine water problems in Germany would be comparable to those worldwide therefore predominates.

When asked about the benefits of mine water (Fig. 11), very few people (84 out of the 1500 participants) participated. The majority of these choose water/irrigation (35.7%) and protection/stability/support (33.5%). Only a small proportion of 12.4% see the potential benefit of “heat”. In the Ruhr area, “heat” was slightly higher with 17.5%, whereas in Ibbenbüren 22.5% (compared to 7.8% in the Saarland and 7.4% in the Ruhr area) did not see any benefit or gave the answer “don’t know”.

What problems are seen with mine water was answered by 641 people: many more than the question of the benefits. Above all, water pollution (42.4%) and environmental pollution/damage (24.5%) are seen as problems (Fig. 12). Costs and possible problems with flooding (7.8% and 4.7%) play a subordinate role. However, if the people personally affected are compared to all people, they see generally more problems with flooding (14.8% vs 4.7%) but fewer with water pollution (34.5% vs 42.4%). It is noteworthy that especially in Ibbenbüren 20.6% (compared to 12.5% in the Saarland and 6.6% in the Ruhr area) of the participants see problems with pollutants. It is conceivable that this

relates to the current discussion regarding potential mine water pollution in this region.

Participants were asked whom they trust most to solve the potential problems associated with mine water and increasing its benefits (Fig. 13). Local politicians tend to receive high approval in smaller regions such as the Saarland and Ibbenbüren, but the differences between the three regions are not large. If the statements “very high” and “high” are added together, it shows that politicians (38.6%) are trusted least to solve problems with mine water and to increase its benefits, a result that has also been shown by Grunow et al. (2013). Mining company (RAG AG) gets the highest approval with 72.4%. Even among those personally affected, 36.8% of 83 people voted “very high” and 28.5% “high”. Mining company in Ibbenbüren receives the most approval with a combined (“very high” and “high”) 77.0%. Interestingly, scientists are only seen third in solving problems. A reason for that might be that many scientists speak “science” language, which sometimes is hard to understand by laypeople.

3.9. Mine flooding and mine water treatment opinions

3.9.1. Overview

Generally, the public opinion about “mine flooding” or “mine water rebound” can be considered similar (Table 8), as the Student’s *t*-test did not show substantial differences. Therefore, their combination into one “mine flooding” factor can be accepted. A summary of the aspects mine flooding and treatment shows for flooding, that 15% are against it, 19% are in favour and 66% indifferent, whilst for treatment, 3% are against it, 43% are in favour and 54% indifferent. In general, a higher degree of information or interest about mine water favours treatment but tends to oppose flooding, though the groups supporting (25.4%) and opposing (28.6%) are similarly large. These results shall be presented in more detail in the next two sections, because it was not possible to get a statistically sound multiple linear regression model of the factors mine flooding or mine water treatment. Therefore, selected answers with higher regression coefficients were chosen for that purpose. When the terms treatment or flooding are used in this section, they always refer to mine flooding and mine water treatment, respectively.

3.9.2. Mine flooding

The largest percentage of active and passive opposition are from mine water environmental activists (45.5%), those very much interested in the subject (45.7%) and those that are very involved (37.8%). Also the

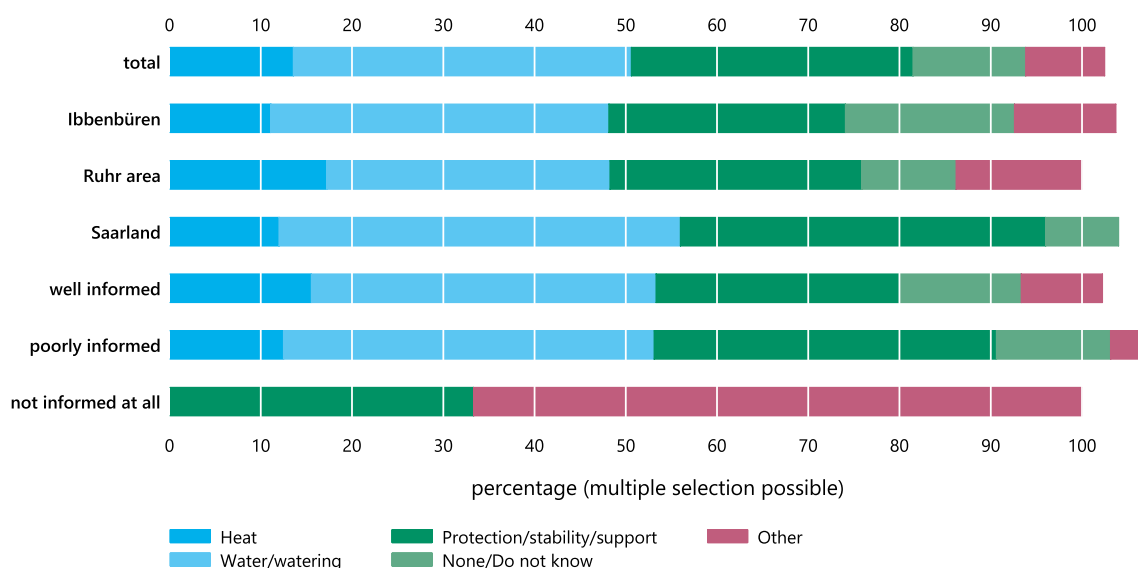


Fig. 11. Which advantages do you see with mine water?

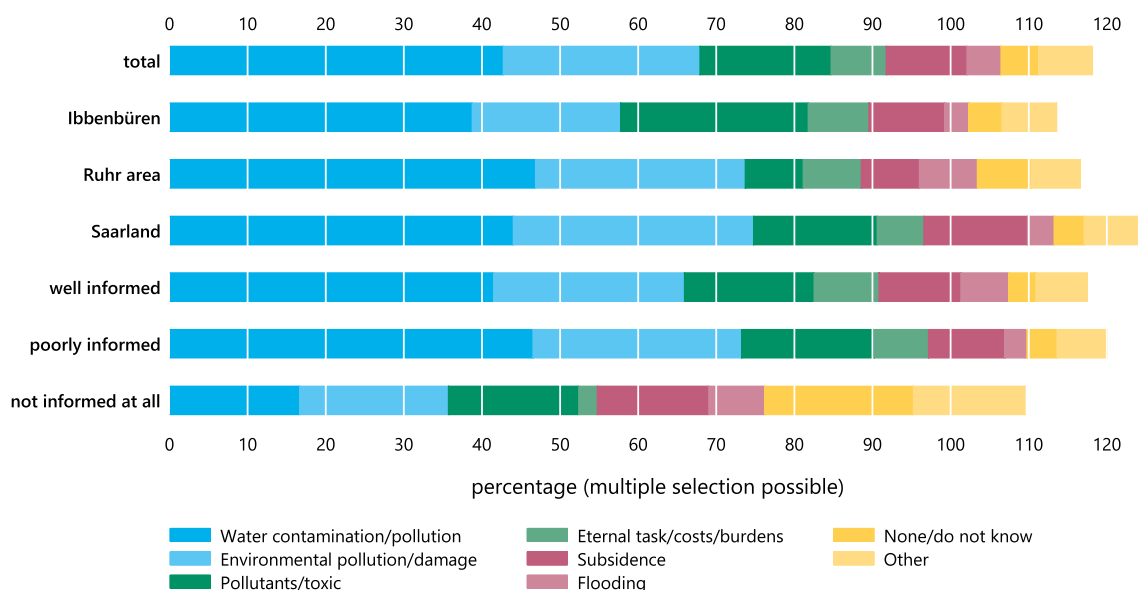


Fig. 12. Which problems do you see with mine water?

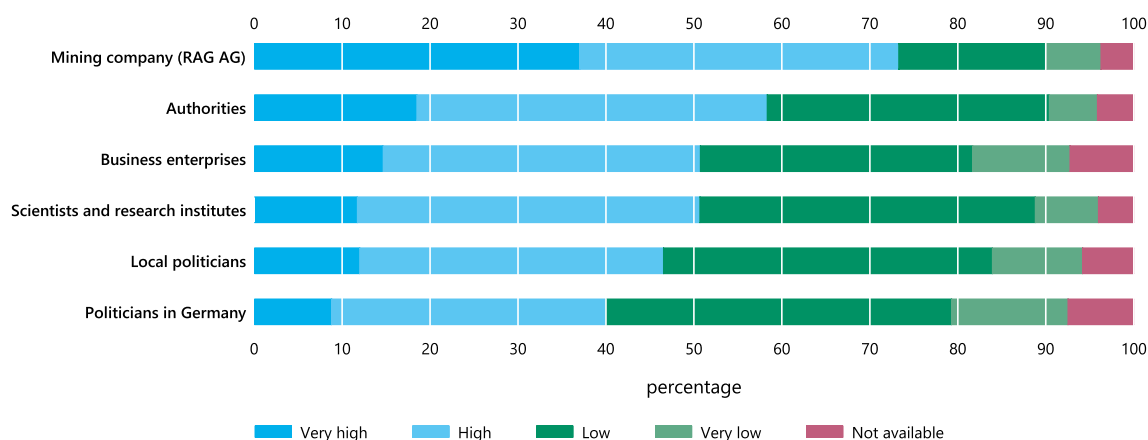


Fig. 13. In your opinion, how high is the influence of the following actors to solve problems with mine water and to increase the benefits? Results sorted by the sum of Very high and High replies.

group of those living close to the mines is against mine flooding (33.3%). Relating to the way of how people inform themselves, shows a large opposition in those reading the company's web pages (30.8%) and those getting information through social media (29.5%). The largest group of those that are indifferent are those that don't inform themselves at all or are not interested, have a low net income, live in the Ruhr area or are female (82.8–71.3%). In general, people that have a positive attitude towards mining see flooding more positive than people that consider environmental protection or renewable energies more important.

Support for the flooding is generally low, but it is higher when participants were very informed (28.6%), very involved (18.2%) or live in the Ibbenbüren region (18.9%). Males and diverse people tend more positive to flooding compared to females. Also those who are informed by their friends and family show more positive attitudes towards flooding (17.3%). Younger participants (<44 years) tend to see flooding more positive (8.1%) than older ones (5.6%) and participants with a high interest in renewable energies tend to oppose flooding.

In a Forsa survey conducted for the newspaper FORUM – Das Wochenmagazin (Hilt, 2017), 68% of the participants in the Saarland were against mine flooding, 17% in favour and 15% indifferent. This differs substantially from the results of this survey, where the numbers

for the Saarland were 27% (19%) against, 10% (14%) in favour and 63% (76%) indifferent (numbers in brackets are for all three areas). A reason for that difference might be that the Forsa survey was conducted in the light of the 2017 state elections, where press releases by some interest groups were mainly negative connotated towards mine flooding (Bündnis 90/Die Grünen, 2017). It could also be that the substantial information campaign by RAG AG and the "Forum Bergbau und Wasser" changed the emotions to the positive.

Though the survey did not explicitly investigate why people prefer the term mine flooding (*Grubenflutung*) over mine water rebound (*Grubenwasseranstieg*), we have the hypothesis that people connect mine water rebound with "It is just happening, and no one is paying attention" while mine flooding might be connected to "They will actively flood the mine and impose monitoring and control measures. We trust the mining company to do it right."

3.9.3. Mine water treatment

In relation to mine water treatment, most participants are in favour, with the highest percentage in Ibbenbüren (33.1%) and the lowest one in the Ruhr area (22.0%), but a large number is still undecided (26.4%) or indifferent (17.2%). Participants with a low net income show the least

support for treatment (23.4%), and those that are very interested, very informed, very involved or get information on the mining company's web pages are the strongest opponents (10.8%, 7.2%, 8.8%, 6.3%), these groups of people being predominantly identical. A similar percentage of participants with a low education opposes treatment (6.6%), but these groups are not identical, as most of the interested ones have a higher education. Environmental activists (75.0%), very interested participants (42.0%), those that are connected to mine water through work or study (62.5%) and participants informing themselves via company web pages (44.0%) or other web applications (39.3%) generally have the most positive attitude towards treatment. Compared to flooding, participants are generally more positive towards treatment.

4. Discussion

Interestingly, it was not possible to build a meaningful unifying multiple linear model, because the variation in the sample and the regional differences were possibly too large. These differences between the populations' attitudes are mainly due to the emotions in the three regions, the mining history and experience they have with the mining company. In the Ruhr area, not many are personally connected to mining anymore, while in Ibbenbüren, mining is generally seen more positive due to the more recent mining connection and the associated power plant. Obschonka et al. (2018) showed for England and Wales that these differences can persist even long after coal mining ceased and "that the historical local dominance of large-scale coal-based industries predicts today's markers of psychological adversity". In relation to the West German post mining areas, the higher the number of people that has a personal connection to mining or mine water, the higher is the positive attitude towards the measures proposed by the mining company.

An interesting aspect is, though the population considers mine water to be an environmental threat, that they also think that RAG AG is best suited to improve the situation. This is similar to public opinion survey results from the Romanian Jiu Valley (Valea Jiului, Schiltal) coal mining region, where people think that the mining industry irreparably affects the environment, but modernizing the mines could considerably reduce pollution (Stanimirescu et al., 2020). In relation to legal aspects of mine water, there is a lack of knowledge of the population in the three post-mining regions with similar findings in Guatemalan mining regions, where knowledge about mining law and related subjects is also low (Parker, 2009).

Though one might think that the public bases its decisions on science based rational thinking about mine flooding and mine water treatment, feelings and emotions play a substantial role in evaluating the risk of an unknown technology or remediation measure. This has been shown extensively by the studies of Slovic who could prove that "the concept risk" is not only judged by thinking or facts but also by feeling (e.g. Slovic, 2000; Slovic and Peters, 2006). Already their earliest investigations about people's attitudes towards the concept in the 1970ies showed that people think differently about risk. However, once the individual knowledge about a technology increases, acceptance of this technology often increases as well. Though thousands of mines worldwide have already been flooded with minimal to no known environmental impact (Melchers et al., 2020; Wolkersdorfer et al., 2016), participants are in fear of mine flooding. This might evolve from the fact that they don't know these flooded mines from personal observations, as can be seen by the answers relating to knowledge of other flooded mines in Germany or worldwide.

Public opinion, consequently, is a complex interwoven network influenced by many actors and personal experiences, as Ruhland (2019) demonstrated for Wismut's Ronneburg, Germany post uranium mining landscape. Above all, she points out that emotions substantially influence the public's attitude towards mining and post-mining measures. She also noticed that information and transparency relating to environmental monitoring and the remediation measures increased trust and

lowered the risk perception in the Wismut post-mining area. This has also been shown in this study: participants dealing more intensively with a topic generally have a more positive view of mine water in their region, of RAG AG's mine flooding and the consequences of mine water compared to participants who deal less intensively with the topic. This is another indication for knowledge and information being important for the personal attitude towards the respective topic.

Therefore, the findings of Grunow et al. (2013), who identified that most of the population would prefer information via circulars or public dialog- and discussion meetings supplemented by online information are relevant for the Ibbenbüren, Ruhr and the Saarland areas. It is a common procedure for Super Fund sites in the USA, where, in addition, all this information is easily accessible on the project web pages. Though RAG AG maintains a public information (*Bürgerinformationsdienst*) web page (<https://geodaten.rag.de>), it is hard to understand for a layperson to use it and a lot of information is still missing. Though the Acceptance-Inacceptance-Scale shall be further analysed (Walter, 2021), especially in the group of undecided or indifferent participants, i.e. those who neither agree nor disagree, there is a potential to increase their acceptance (Hillebrand and Erdmann, 2015). However, if this group can be motivated to change their attitudes by these information measures remains to be seen. Taking into consideration that the large group of indifferent people is ready to change their attitudes and emotions when transparent information in their language reaches them (Table 4) – without hiding negative facts by whitewashing with word constructions like "mine water rebound" instead of "mine flooding" – the following conclusions will be helpful to transport facts to them.

5. Conclusions

After a public survey in the Australian Brukunga township, which is affected by AMD from the Nairne pyrite mine, Armstrong and Fanning (1994) concluded that the "failure to be honest with the public over environmental issues will only lead to confrontation and possibly costly litigation". Pérez-Sindín and Blanchette (2020) noticed that even when all the post-mining remediation information is openly provided by the mining company, people might question the information obtained, based on experience with the company. This goes with the results of this survey that showed that people who were positively involved with the mining company tend to see the proposed mine flooding scenario more positive than others. In addition, this survey and the dialog meetings of the "Forum Bergbau und Wasser" identified a discrepancy between the grade of information provided by the mining company and the informedness feelings of the people. Similar results can be seen from the evaluation of the situation in Ibbenbüren, the Ruhr area and the Saarland, and it can therefore be concluded that the more someone feels informed, the more positive is their attitude towards the measures taken by the mining company and towards mine flooding.

It is obvious that more easily understandable information in local and social media and on company and authority web pages is needed (e.g. Walter, 2021). Problem is that bad news sells better than the good ones or information content. The positive aspects of mine water and the advantages of mine water treatment need to be mentioned more often because the group of people indifferent is still quite large.

This, and other surveys showed that many people feel not sufficiently informed about the activities of the mining companies. Based on the survey results, informing the population via local media and circulars in their letter boxes is a way to close this information gap. Additional options might be regular blogs or e-mail newsletters. Therefore, it can be concluded that being honest and transparent on all fronts, improving communication with local communities as opposed to mantra-like repeating the term "mine water rebound", will substantially improve the general public's attitude towards the planned mine flooding in the three post-mining regions of Ibbenbüren, the Ruhr area and the Saarland. This communication can be used to increase the trust of the population in mining companies tackling the opportunities and risks

associated with mine flooding.

These research results will help to develop information and communication measures adapted to respective mining regions. These serve as a template for future mine flooding plans worldwide and will result in substantial cost savings for mining companies. In addition, emotions and the acceptance level, or its increase, relating to mine water and mine flooding explicitly is essential for implementing future R&D projects in all post-mining regions around the world.

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Author statement

This is to certify that all authors have seen and approved the final version of the manuscript being submitted. They warrant that the article is the authors’ original work, hasn’t received prior publication and isn’t under consideration for publication elsewhere.

CrediT taxonomy

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Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. “Forum Bergbau und Wasser” is an independent entity based within the “Stifterverband für die Deutsche Wissenschaft [Donors’ association for the promotion of humanities and sciences in Germany]” financed by the RAG Foundation.

Data availability

Data can be downloaded from this web site: www.wolkersdorfer.info/PublicPerceptionsData.

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Appendix A. Supplementary data

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