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Public Perception of CO₂ Pipelines

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Abstract

To date, the transportation aspect has received little attention in social science research on the public perception of CCS. This study contributes to filling this gap by investigating the public perception of CO₂ pipelines among the German public. For this purpose, a representative survey was carried out and analysed with methods of descriptive and inductive statistics. The results showed that on average CO₂ pipelines are perceived neutrally by the general public in Germany. With respect to the acceptance of CO₂ pipelines close to one's home, the involvement of environmental organizations in the assessment of the safety and environmental compatibility of the pipeline and a convincing safety concept on the part of the pipeline operator were identified as likely to be more effective than other measures such as financial compensation or participation in the planning process. However, factual knowledge of pipelines, risk perceptions, general attitude and willingness to protest against a CO₂ pipeline close to one's home, as well as the level of agreement with factors for the acceptance of CO₂ pipelines, vary significantly according to gender, age and professional qualifications. The characteristics and perceptions of the citizens affected should therefore be taken into account for the siting of CO₂ infrastructure projects.

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1. Introduction

CO₂ capture and storage (CCS) was first discussed in the 1980s as an option for climate change mitigation [1]. With the further development of CCS, it became clear that a lack of public acceptance may be a “potential show stopper” [2] for the large-scale demonstration and implementation of the technologies. Thus, scientific interest in exploring public perception of CCS evolved and in 2002 the first article on this topic was published [3]. Since then

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the number of scientific studies concerned with investigating the public perception of CCS in different countries has grown continuously and by 2012 more than 40 journal articles had been published [4]. The majority of these studies either examine the public perception of the whole CCS chain or concentrate on CO₂ storage as the central subject of research [for reviews of CCS public perception studies see e.g. 4, 5, 6-8]. Only one article, published in 2014, focuses on the public perception of CO₂ pipelines as the central subject of research [9]. In this study, deliberative focus groups were set up with a total of 19 participants in two village locations along a proposed CO₂ pipeline route in the UK. The aim was to explore the response by members of the lay public to the prospect of an onshore CO₂ pipeline through their locality as part of a proposed CCS development. With regard to CO₂ pipelines, the study identified five areas of main concern among citizens: “(i) safe operation of the pipeline; (ii) the risks to people, livestock and vegetation arising from the leakage of CO₂ from the pipeline; (iii) the innovative and ‘first of its kind’ nature of the pipeline and the consequent lack of operational CO₂ pipelines in the UK to demonstrate the technology; (iv) impacts on coastal erosion at the landfall site; and (v) the potential disruption to local communities during pipeline construction” [9, p. 106]. In addition, scepticism about the motivations of CO₂ pipeline developers was articulated by focus group participants.

Prior to the study in [9], [10] used a conjoint measurement of CCS acceptance and analysis of variance to examine the preferences of a random, non-representative sample of 139 Swiss citizens for twelve different CCS scenarios in which the type of CO₂ source, storage location and type of pipeline were varied. They discovered that the pipeline has the highest importance for the public acceptance of CCS and the storage location the lowest. Furthermore, people seemed unwilling to live near any type of pipeline, although CO₂ pipelines were assessed less negatively than natural gas pipelines [10].

[11] applied an experimental approach in an online survey with a representative sample of the German public with 1830 participants in order to analyse the perception of 18 different CCS settings in which the type of CO₂ source, transport and storage location were systematically varied. They found that mentioning pipelines has an effect on how the storage option is evaluated: CO₂ storage in a depleted natural gas field is assessed less positively if a pipeline is mentioned and more positively if no transport option is mentioned, whereas storage in saline aquifers and a combination with enhanced gas recovery are always evaluated the same irrespective of whether a pipeline is mentioned or not.

Besides articles [9-11], several studies examine the public perception of CO₂ transportation in pipelines systematically, but not centrally, by posing questions about it in their surveys or interviews or by discussing it as one topic in moderated discussions [12]. Others present anecdotal evidence about the public perception of CO₂ pipelines, either as verbatim quotations of recorded evidence or as descriptions, where the origin and motivation of the quotations are somewhat unclear. In these studies, which employ qualitative methods such as qualitative interviews, deliberative mini-publics or case studies, it does not become clear whether the issue of pipelines and storage was deliberately raised by the researchers, interviewers or moderators, or by the participants themselves. The information on the public perception of CO₂ pipelines which can be derived from these studies is scattered and not systematic and empirical findings seem to be highly context-dependent [12].

Against this background, the aim of this paper is to analyse the public perception of CO₂ pipelines in more depth. For this purpose, a representative survey was carried out in Germany in 2013 by means of which information on factual knowledge about pipelines, risk perceptions and general attitude towards CO₂ transport by pipeline was collected. Furthermore, willingness to protest actively against a CO₂ pipeline close to one’s own home, as well as factors for the acceptance of a CO₂ pipeline close to one’s own home, were explored. The methodology of the study will be described first (cf. Section 2) and the results of the survey discussed in Section 3 of this paper. Finally, the conclusions which can be derived from the analyses will be presented (cf. Section 4).

2. Methods

In order to draw generalizable conclusions regarding the public perception of CO₂ pipelines in Germany it was necessary to have a sufficient number of cases for statistical analysis and these were gathered by a random selection procedure. Therefore, a standardized, representative survey of the German public was conducted from mid-March 2013 to mid-April 2013.

The population for the survey was German citizens above the age of 18 with a landline connection (cf. Table 1). The participants for the survey were recruited by a professional polling firm using multi-stage systematic random sampling. The last-birthday selection method was used to select the respondents, i.e. the person above the age of 18 who had the most recent birthday in the household was interviewed. The survey was conducted by the professional polling firm with computer-aided telephone interviewing (CATI) using a questionnaire developed by the author. 1000 interviews were undertaken nationwide.

Table 1. Parameters of the survey

Parameter	Specification
Population	German citizens above the age of 18 with landline connection
Sampling procedure	Multi-stage systematic random selection from the existing landline numbers in Germany
Selection of the respondent	Last-birthday selection: person above the age of 18 who had the most recent birthday in the household
Sample size	1000 respondents
Criteria for the representativeness of the sample	Gender, age, professional qualifications, household size
Database for examining the reproduction accuracy of the sample	Data of the Federal Statistical Office (Microcensus)
Survey method	Computer-assisted telephone interviews (CATI)

Source: Authors' own

Table 2. Participant structure of the survey sample compared to the Microcensus

Characteristic	Microcensus ^a	Survey sample ^b	Deviation
Gender			
Male	48.8 %	48.8 %	0.0
Female	51.2 %	51.2 %	0.0
Age			
18-29 years	17.3 %	16.6 %	-0.7
30-39 years	14.4 %	15.0 %	0.6
40-49 years	20.0 %	20.1 %	0.1
50-59 years	17.2 %	17.7 %	0.5
60-69 years	13.5 %	14.3 %	0.8
>= 70 years	17.6 %	16.3 %	-1.3
Professional qualifications			
Certified vocational training	52.0 %	62.4 %	10.4
Training at a post-secondary vocational school	8.9 %	7.9 %	-1.0
Degree from a university	13.3 %	15.6 %	2.3
No professional qualifications/still in education	25.8 %	14.1 %	-11.7
Household size			
1 person	23.6 %	25.2 %	1.6
2 persons	39.2 %	42.4 %	3.2
3 persons	17.3 %	17.3 %	0.0
4 persons	14.8 %	12.1 %	-2.7
More than 4 persons	5.1 %	3.0 %	-2.1

Source: Authors' own. ^a Results of Microcensus (2011), n=830,000 persons at least 15 years of age in 370,000 private households. ^b Survey "CCS-Chances" 2013, n=1000 persons at least 18 years of age.

The reproduction accuracy of the survey sample was examined by comparing the distributions of the characteristics of gender, age, professional qualifications and household size with the data of the Microcensus, which is a representative household survey from the official statistics in Germany (cf. Table 2).

The comparison revealed no deviations of the sample from the Microcensus with regard to gender, only very small deviations with regard to age and slightly higher deviations concerning household size (cf. Table 2). Regarding professional qualifications, the deviations are higher in the two categories “certified vocational training” and “no professional qualifications/still in education”. This due to the fact that the population for the Microcensus is the population at least 15 years of age in private households, whereas the population for our survey was at least 18 years of age. However, overall, the comparison shows that the reproduction accuracy of the sample is very high despite these deviations.

The perception of CO₂ transport by pipeline among the German public was measured in the survey by using the indicators of factual knowledge, risk perceptions and general attitudes. In addition, the willingness to protest actively against a CO₂ pipeline close to one’s own home and factors for the acceptance of a CO₂ pipeline close to one’s own home were surveyed. The results of the survey were analysed and compared for the sociodemographic characteristics of gender, age and professional qualifications by using the methods of descriptive statistics (frequencies, means, standard deviations) and inductive statistics (Mann-Whitney U tests, Kruskal-Wallis tests).

3. Results

In this section, the results of the comparative statistical analyses are explained firstly with respect to the indicators of factual knowledge about pipelines, perceptions of personal and societal risks of CO₂ transport by pipeline and general attitude towards CO₂ pipelines. Subsequently, the results regarding willingness to actively protest against a CO₂ pipeline close to one’s own home and factors for the acceptance of a CO₂ pipeline close to one’s own home are described.

3.1. Factual knowledge about pipelines

Factual knowledge about pipelines among the German public was measured in our survey by presenting the five statements shown in Table 3 to the respondents and then asking them to decide whether these statements were true or false.

The results from this question show that the level of factual knowledge about pipelines among the German public is very low. First of all, the percentage of respondents who answered that they do not know whether the statement is true or false was high with regard to all five propositions (cf. Table 3). Furthermore, only less than half of the respondents were aware that approximately 80 % of the crude oil for the production of petrol, diesel, kerosene and heating oil is transported via pipeline in Germany. 44.8 % knew that the overall length of existing pipelines in Germany is more than 25,000 kilometres[†] and 40.9 % recognized that onshore pipelines are normally constructed at a depth of not less than one metre below ground. 35.0 % of the respondents correctly recognized that the statement asserting that the transport of large quantities of CO₂ via pipeline would be much more expensive than transport by train or lorry is false. However, only 17.1 % knew that the statement that as yet there are no pipelines for the transport of carbon dioxide anywhere in the world is not correct.

In order to investigate whether the level of knowledge about pipelines varies according to sociodemographic characteristics, an additive index was calculated by counting the correct answers across the five statements concerning pipelines. Afterwards, the number of correct answers was aggregated to the three categories “low” (=0-1 correct answers), “medium” (=2-3 correct answers) and “high” (=4-5 correct answers) level of knowledge.

[†] A map of the UK pipeline network shown to the participants of the deliberative focus groups in the study of [9] met with surprise at its extent and coverage. Thus, it can be assumed that the level of factual knowledge about pipelines among the public is also low in the UK. Low levels of factual knowledge about CCS among the general public were also detected in [13-16].

Table 3. Factual knowledge about pipelines

Statement	True	False	Don't know	Total
The overall length of existing pipelines for natural gas and mineral oil in Germany is more than 25,000 kilometres.	44.8%	12.5%	42.7%	100.0%
Pipelines onshore are normally at a depth of not less than one metre below ground.	40.9%	22.0%	37.1%	100.0%
In Germany, approximately 80 percent of crude oil for the production of petrol, diesel, kerosene and heating oil is transported via pipeline.	45.6%	14.4%	40.0%	100.0%
The transport of large quantities of carbon dioxide via pipeline would be much more expensive than transport by train or lorry.	17.4%	35.0%	47.6%	100.0%
As yet there is no pipeline worldwide for the transport of carbon dioxide.	34.8%	17.1%	48.1%	100.0%

Data source: Survey “CCS Chances” 2013 (n=1000). Question: “Please tell me to the best of your knowledge whether each statement is true or false.”

The results in Table 4 show that men more often have a medium or a high level of knowledge about pipelines than women, whereas women more often have a low level of knowledge. Furthermore, respondents between 35 and 44 years as well as respondents between 45 and 54 years more often have a low level of knowledge about pipelines compared to the other age classes. Interviewees younger than 25 years, respondents between 25 and 34 years, and respondents who were at least 55 years old more often have a medium level of knowledge than the other age classes. Interviewees between 35 and 44 years less often have a high level of knowledge.

Table 4. Level of knowledge about pipelines according to gender, age and professional qualifications

	Level of knowledge about pipelines			Total
	Low	Medium	High	
Gender				
Male	35.7%	49.8%	14.5%	100.0%
Female	47.5%	42.8%	9.8%	100.0%
Total	41.7%	46.2%	12.1%	100.0%
Age				
< 25 years	40.7%	48.1%	11.1%	100.0%
25-34 years	37.2%	52.3%	10.5%	100.0%
35-44 years	51.8%	39.7%	8.5%	100.0%
45-54 years	51.4%	35.8%	12.8%	100.0%
> = 55 years	34.8%	51.3%	13.9%	100.0%
Total	41.7%	46.2%	12.1%	100.0%
Professional qualifications				
No professional qualifications	46.1%	44.7%	9.2%	100.0%
Certified vocational training	44.7%	45.2%	10.1%	100.0%
Training at a post-secondary vocational school	39.2%	46.8%	13.9%	100.0%
Degree from a university	26.9%	51.3%	21.8%	100.0%
Total	41.7%	46.2%	12.1%	100.0%

Data source: Survey “CCS Chances” 2013 (n=1000)

With regard to professional qualifications, the results in Table 4 illustrate that individuals with no professional qualifications and persons with certified vocational training more often have a low level of knowledge about pipelines, whereas respondents with a degree from a university more often have a medium or a high level of knowledge. The associations between gender, age, professional qualifications and level of knowledge are statistically significant (cf. Table 5).

Table 5. Associations between level of knowledge and gender, age and professional qualifications

	Gender	Age	Professional qualifications
Cramer's V	.125**	.116**	.116**

** Association is significant at the 0.01 level. Values of the nominal measure Cramer's V can range from 0 (= no association) to 1 (= perfect association).

3.2. Perceptions of personal and societal risks of CO₂ transport by pipeline

Previous studies on the acceptance of risks and technologies confirmed that the acceptance of technologies by the general public is greatly influenced by the intuitive perception of risks, as well as by the perception of benefits and trust [e.g. 4, 17, 18]. In our studies, we generally differentiate between the perception of personal risk, which means how risky respondents think an energy technology would be for themselves and their family, and the perception of societal risk, which means how risky respondents think an energy technology would be for society in general [cf. 15, 19]. The risk perceptions are specified on a seven-level Likert scale, ranging from 1 (= very low) to 7 (= very high).

The results in Table 6 show that the personal and societal risk of CO₂ transport by pipeline was assessed neutrally on average. However, a comparison of the means indicates that the societal risk of a CO₂ pipeline was assessed higher than the personal risk. Women perceived the personal and societal risk of CO₂ pipelines to be higher than men did.

Table 6. Risk perceptions of CO₂ transport via pipeline according to gender, age and professional qualifications

	Personal risk		Societal risk	
	Mean¹	SD²	Mean¹	SD²
Gender				
Male	3.4	1.7	3.8	1.7
Female	4.0	1.7	4.3	1.6
Total	3.7	1.8	4.1	1.6
Age				
< 25 years	3.1	1.3	3.8	1.4
25-34 years	3.2	1.5	3.8	1.4
35-44 years	4.0	1.8	4.3	1.6
45-54 years	3.9	1.8	4.1	1.7
> = 55 years	3.8	1.9	4.2	1.7
Total	3.7	1.8	4.1	1.6
Professional qualifications				
No professional qualifications	3.5	1.7	3.9	1.7
Certified vocational training	3.8	1.7	4.2	1.6
Training at a post-secondary vocational school	3.8	1.9	4.2	1.7
Degree from a university	3.2	1.8	3.6	1.6
Total	3.7	1.8	4.1	1.6

Data source: Survey "CCS Chances" 2013 (n=1000). ¹ Scale from 1 (= very low risk) to 7 (= very high risk). The higher the mean, the higher the personal/societal risk is assessed. ² SD = standard deviation. Question: "How risky do you think CO₂ transport via pipeline would be for you and your family/for society in general?"

Respondents below 35 years assessed the risks to be lower than respondents who were 35 years and older. Respondents between 35 and 54 years perceived the personal risks of CO₂ transport via pipeline to be higher than the other age groups and interviewees between 35 and 44 years assessed the societal risks higher. Interviewees without professional qualifications, with certified vocational training or training at a post-secondary vocational school perceived the personal and societal risk as higher than interviewees with a university degree. The differences in the risk perceptions according to gender, age and professional qualifications are statistically significant[‡] and are in line with the results of previous studies regarding different risk perceptions of CCS according to gender and professional qualifications [cf. e.g. 19, 20].

[‡] This was tested by means of the Mann-Whitney U test and Kruskal-Wallis test.

3.3. General attitude towards CO₂ transport by pipeline

The general attitude regarding CO₂ transport via pipeline was measured in our survey by asking the question “Overall, how do you assess the idea of CO₂ transport via pipeline?” The respondents specified their general attitude on a seven-level Likert scale, ranging from 1 (= very negative) to 7 (= very positive).

Table 7: General attitudes towards CO₂ transport via pipeline according to gender, age and professional qualifications

	Mean ¹	SD ²
Gender		
Male	4.1	1.7
Female	3.8	1.5
Total	3.9	1.6
Age		
< 25 years	4.5	1.4
25-34 years	4.2	1.3
35-44 years	3.9	1.5
45-54 years	3.7	1.7
> = 55 years	3.8	1.7
Total	3.9	1.6
Professional qualifications		
No professional qualifications	4.1	1.6
Certified vocational training	3.8	1.6
Training at a post-secondary vocational school	4.0	1.6
Degree from a university	4.2	1.6
Total	3.9	1.6

Data source: Survey “CCS Chances” 2013 (n=1000).¹ Scale from 1 (= very negative) to 7 (= very positive). The higher the mean, the more positive the assessment of CO₂ transport via pipeline. ² SD = standard deviation. Question: “Overall, how do you assess the idea of CO₂ transport via pipeline?”

The respondents’ general attitude towards a CO₂ pipeline was on average neutral (cf. Table 7). Women had a more negative general attitude compared to men, interviewees who were 35 years and older had a more negative attitude than respondents younger than 35 years, and respondents with certified vocational training had a more negative attitude compared to individuals with no or other professional qualifications. The differences in general attitudes according to gender, age and professional qualifications are statistically significant.[§]

3.4. Willingness to actively protest against a CO₂ pipeline close to one’s home

In order to measure the willingness of the citizens to actively protest against a CO₂ pipeline close to their home, the participants in our survey were asked to state on a seven-level Likert scale, ranging from 1 (= strongly disagree) to 7 (= strongly agree), to what extent they agreed with the following statement: “If CO₂ is transported in a pipeline near to my home, I would actively protest against it (e.g. taking part in a petition).”

On average, the willingness to actively protest against a CO₂ pipeline close to one’s own home was slightly above the neutral assessment (cf. Table 8). The willingness to protest against a CO₂ pipeline was statistically significantly higher amongst women compared to men and statistically significantly higher amongst interviewees who were 35 years and older compared to respondents younger than 35 years.^{**} The differences in the willingness to actively protest against a CO₂ pipeline close to one’s home according to professional qualifications were not statistically significant.

[§] This was tested by means of the Mann-Whitney U test and Kruskal-Wallis test.

^{**} This was tested by means of the Mann-Whitney U test and Kruskal-Wallis test.

Table 8: Willingness to actively protest against CO₂ pipeline close to one's home according to gender, age and professional qualifications

	Mean ¹	SD ²
Gender		
Male	4.3	2.0
Female	4.8	1.8
Total	4.6	1.9
Age		
< 25 years	4.0	1.7
25-34 years	4.4	1.8
35-44 years	4.7	1.8
45-54 years	4.7	2.0
> = 55 years	4.7	2.1
Total	4.6	1.9
Professional qualifications		
No professional qualifications	4.2	1.9
Certified vocational training	4.7	1.9
Training at a post-secondary vocational school	4.6	1.9
Degree from a university	4.5	2.1
Total	4.6	1.9

Data source: Survey "CCS Chances" 2013 (n=1000). ¹ Scale from 1 (= strongly disagree) to 7 (= strongly agree). The higher the mean, the higher the willingness to actively protest against a CO₂ pipeline close to one's home. ² SD = standard deviation. Question: "How much do you agree with the following statement? 'If CO₂ is transported in a pipeline near to my home, I would actively protest against it (e.g. taking part in a petition)'."

3.5. Factors for acceptance of a CO₂ pipeline close to one's home

In order to investigate whether factors can be identified which help to facilitate the acceptance of CO₂ transport via a pipeline close to one's home among the German public, the participants in our survey were asked to express on a seven-level Likert scale, ranging from 1 (= strongly disagree) to 7 (= strongly agree), the extent to which they agree with the following statements: "I would accept a pipeline in which CO₂ is transported near to my home, if...(a) I received financial compensation, (b) I had the opportunity to participate in the planning process, (c) I had the opportunity to participate financially in the pipeline and would obtain financial return from it, (d) the municipality in which I live would receive financial compensation, (e) environmental organizations were involved in the assessment of the safety and environmental compatibility of the pipeline, and (f) the safety concept of the pipeline operator was convincing (cf. Table 9).

A comparison of the means firstly revealed that the level of agreement varied visibly for the six acceptance factors. On average, the respondents' approval was highest for the involvement of environmental organizations in the assessment of the safety and environmental compatibility of the pipeline and for the convincing safety concept put forward by the pipeline operator. The opportunity to participate financially in the pipeline and obtain financial return from it as well as the opportunity to participate in the planning process received the lowest level of approval (cf. Table 9).

For men, the level of agreement was statically significantly higher compared to women for the acceptance of the factors of financial compensation for the respondent, participation in the planning process, financial participation/return and financial compensation for the municipality.^{††} For respondents younger than 35 years, the level of agreement for financial compensation for the respondent, financial participation/return, financial compensation for the municipality and the convincing safety concept was statically significantly higher than for respondents who were 35 years and older.^{‡‡} Interviewees without professional qualifications had a statically significantly higher level of agreement compared to respondents with professional qualifications for the acceptance factor of financial compensation for the respondent. Furthermore, interviewees without professional qualifications as well as persons with a degree from a university had a higher level of agreement for participation in the planning process, the involvement of environmental organizations in the assessment of the safety and environmental compatibility of the pipeline, and the convincing safety concept put forward by the pipeline operator.

^{††} This was tested by means of the Mann-Whitney U test.

^{‡‡} This was tested by means of the Kruskal-Wallis test.

Table 9: Level of agreement with factors of acceptance for a CO₂ pipeline close to one's home according to gender, age and professional qualifications

	Financial compensation for the respondent		Participation in the planning process		Financial participation/return		Financial compensation for the municipality		Involvement of environmental organizations		Convincing safety concept	
	M ¹	SD ²	M ¹	SD ²	M ¹	SD ²	M ¹	SD ²	M ¹	SD ²	M ¹	SD ²
Gender												
Male	3.9	2.1	3.6	2.0	3.1	2.0	3.7	2.0	4.9	1.9	4.8	2.0
Female	3.4	2.1	3.0	1.9	2.6	1.8	3.4	2.0	4.7	2.1	4.7	2.0
Total	3.7	2.1	3.3	2.0	2.8	1.9	3.5	2.0	4.8	2.0	4.8	2.0
Age												
< 25 years	4.6	1.8	3.7	1.7	3.7	1.9	4.0	1.7	5.1	1.7	5.2	1.8
25-34 years	4.3	2.0	3.3	1.9	3.2	1.8	3.8	2.0	4.8	1.8	5.1	1.8
35-44 years	4.0	2.0	3.3	1.9	3.0	1.9	3.5	1.9	5.0	1.9	4.8	2.0
45-54 years	3.5	2.2	3.3	2.0	2.9	2.0	3.3	2.1	4.6	2.1	4.5	2.1
> = 55 years	3.2	2.1	3.3	2.0	2.4	1.8	3.4	2.1	4.8	2.1	4.7	2.1
Total	3.7	2.1	3.3	2.0	2.8	1.9	3.5	2.0	4.8	2.0	4.8	2.0
Professional qualifications												
No professional qualifications	4.3	2.1	3.8	1.9	3.2	2.0	3.8	2.0	5.0	2.0	5.0	2.0
Certified vocational training	3.6	2.1	3.1	1.9	2.8	1.9	3.4	2.0	4.7	2.0	4.7	2.0
Training at a post-secondary vocational school	3.4	2.0	3.3	1.9	2.7	1.8	3.5	2.1	4.9	2.1	4.5	2.1
Degree from a university	3.5	2.1	3.6	2.1	2.9	2.0	3.5	2.0	5.1	1.9	5.0	2.0
Total	3.7	2.1	3.3	2.0	2.8	1.9	3.5	2.0	4.8	2.0	4.8	2.0

Data source: Survey "CCS Chances" 2013 (n=1000).¹ M=Mean; scale from 1 (= strongly disagree) to 7 (= strongly agree). The higher the mean, the higher the agreement with the acceptance factor.² SD = standard deviation.

4. Conclusions

As yet, the transportation aspect has received little attention in social science research on public perception of CCS. This study contributes to filling this gap by investigating the public perception of CO₂ pipelines among the German public. For this purpose, a representative survey was performed and analysed with descriptive and inductive statistics.

The results of the analysis revealed that on average CO₂ pipelines are perceived neutrally by the general public in Germany. This is illustrated by the neutral evaluation of the personal and societal risk of CO₂ transport by pipeline as well as by the general attitude towards CO₂ pipelines, which was also neutral on average. The willingness to protest actively against a CO₂ pipeline close to one's home was only slightly above the neutral assessment, suggesting that the potential to protest against CO₂ transport via pipeline is not very high among the general public in Germany.

However, previous studies have shown that CCS projects have been prevented because they were not accepted by the local public [cf. e.g. 21, 22, 23]. Therefore, this study also explored which factors would help to facilitate the acceptance of CO₂ transport via pipeline close to one's home. In contrast to common discussions in Germany, in which financial compensation and participation in the planning process are often seen as important instruments in order to gain public acceptance for large infrastructure projects [cf. e.g. 24], the results of our analysis revealed that with regard to the acceptance of CO₂ transport by pipeline close to one's home the factors "involvement of environmental organizations in the assessment of the safety and environmental compatibility of the pipeline" and a "convincing safety concept of the operator of the pipeline" are likely to be more effective than "financial participation/return for the respondent", "participation in the planning process" or "financial compensation".

Nonetheless, it cannot be said that the involvement of environmental organizations or convincing safety concepts guarantees the acceptance of CO₂ pipelines among the general or local public. This is due to the results of this study, which show that the level of agreement with the factors for acceptance of CO₂ transport by pipeline differs

according to sociodemographic characteristics. This also holds true for factual knowledge, risk perceptions, general attitude and willingness to protest against a CO₂ pipeline close to one's own home. These results complement the findings of previous studies which showed that factual knowledge, perceptions of personal and societal risks of CO₂ pipelines as well as general attitude towards CO₂ transport by pipelines vary according to region [15].

Thus, with respect to the siting of CO₂ infrastructure projects in Germany, it is necessary to take into account the specifics of the affected regions as well as the characteristics and perceptions of its inhabitants. For the siting of CO₂ infrastructure projects in other countries, it is crucial to assess the extent to which the results of our study are applicable. For this purpose, similar representative studies should be carried out. This would be particularly important for the construction and deployment of CO₂ pipelines across national borders as part of the development of a European CO₂ infrastructure as is the aim of the European Commission, Parliament and Council [25].

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