



British
Geological
Survey

Survey of research undertaken by European geoscience partners of GeoERA Groundwater on contaminants of emerging concern in groundwater

Environmental Change Adaptation and Resilience
External Report OR/20/060



BRITISH GEOLOGICAL SURVEY

ENVIRONMENTAL CHANGE ADAPTATION AND RESILIENCE

EXTERNAL REPORT OR/20/060

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No. 100021290 EUL.

Keywords

Report; emerging
contaminants, organic,
Europe, data, EOCs.

Front cover

Logos of GeoERA and
HOVER

Bibliographical reference

CRANE, E.J., LAPWORTH, D.J.,
BUNTING, S.Y. AND LOPEZ, B.
2020.

Survey of research
undertaken by European
geoscience partners of
GeoERA Groundwater on
contaminants of emerging
concern in groundwater.

*British Geological Survey
External Report, OR/20/060.*
44pp.

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Survey of research undertaken by European geoscience partners of GeoERA Groundwater on contaminants of emerging concern in groundwater

Crane, E.J., Lapworth, D.J., Bunting, S.Y. and Lopez, B.

BRITISH GEOLOGICAL SURVEY

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Acknowledgements

Gratitude is extended to all those who responded to the questionnaire which forms the basis of this survey. We thank colleagues, particularly Anna Kuczyńska (PGI) and Mariëlle E. van Vliet (TNO), for reviewing the draft report.

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Summary

This work was undertaken as part of the [HOVER](#) project, within the GeoERA programme of research. The purpose was to gain an overview of any work previously undertaken on organic compounds of emerging concern (CECs) in groundwater by members of the GeoERA HOVER project team. HOVER partners were asked to complete a brief questionnaire which covered their familiarity with the topic, whether their organisations held any relevant data and some more specific questions, e.g. about compounds studied.

The overall response rate from the 35 organisations contacted was 86%. The results showed a range of familiarity with the topic. Fourteen of the organisations contacted hold data on organic CECs. Eleven organisations reported that they had undertaken work in this field in collaboration with partner organisations, while just 5 reported such work without partners. The most common reason for undertaking such studies was for general background surveys. Some organisations have focussed on particular types of compound (e.g. pharmaceuticals) while others have analysed for a wide range of compound categories.

1 Introduction and aims

This work was undertaken as part of the Work Package 8 (WP8) “Effective monitoring of emerging contaminants: development and validation of new assessment methods” integrated in the “Hydrological processes and Geological settings over Europe controlling dissolved geogenic and anthropogenic elements in groundwater of relevance to human health and the status of dependent ecosystems” (HOVER) project. HOVER is one of 4 projects within the GeoERA programme of research, which was co-funded by the European Union's Horizon 2020 research and innovation programme.

The purpose of the work presented in this report was to gain an overview of studies previously undertaken on organic compounds of emerging concern (CECs) in groundwater by members of the GeoERA HOVER project team. It complements the report, “The current state of understanding of Emerging Organic Compounds in European groundwaters”, a previous output of the HOVER project (Bunting et al., 2020) which reviewed published data on EOCs in Europe since 2012.

2 Methods

2.1 QUESTIONNAIRE: NUMBER AND WORDING OF QUESTIONS

The wording of the questionnaire was drafted by the BGS team, then sent to the WP8 Coordinator for comment. It was agreed to keep it as short as possible, so that it would be quick to complete, and thus maximise participation rates. Constrained tick box list options enable participants to answer rapidly, and provide us with easily comparable data, while free text fields allow respondents who wish to provide more information to elaborate.

The questionnaire comprised 19 questions, but used logical routing to bypass irrelevant questions based on user response (Appendix 1). The questions were grouped to distinguish work done in collaboration with one or more partner organisations (“with partners”) from work done solely by the respondent organisation (“without partners”).

2.2 QUESTIONNAIRE SOFTWARE

Several online form options were considered. Google Forms would have required Google account sign-in (as we were collecting email addresses) which could have been a barrier for some people. Other possible platforms required a paid subscription before sensible data export (e.g. CSV) was possible. Microsoft Forms was deemed to be the best option as BGS had access to this and it offered export to Microsoft Excel. Microsoft Forms also enables logical skipping of irrelevant questions (‘branching’). Screenshots of the questionnaire are provided in Appendix 1.

2.3 DISTRIBUTION OF QUESTIONNAIRE

An email with a link to the questionnaire was sent to 59 email addresses provided by the WP8 Lead. These related to 34 organisations (33 HOVER-GeoERA partner organisations plus ARPA). OVF, Hungary was later contacted by recommendation of MBFSZ. A list of the organisations contacted is provided in Table 1.

Table 1 List of HOVER-GeoERA partner organisations and additional organisations invited to complete the questionnaire

Country	Full name of organisation	Acronym
Austria	Geologische Bundesanstalt - Geological Survey of Austria	GBA
Belgium	Institut Royal des Sciences Naturelles de Belgique (RBINS-GSB)	RBINS-GSB
Belgium	Flanders Environment Agency	VMM
Bosnia-Herzegovina	Federalnog Zavoda za Geologiju	FZZG
Croatia	Hrvatski Geološki Institut - Croatian Geological Survey	HGI-CGS
Cyprus	Cyprus Ministry of Agriculture, Rural Development and Environment - Geological Survey Department (GSD)	GSD
Czech Republic	Česká Geologická Služba - Czech Geological Survey	CGS
Denmark	De Nationale Geologiske Undersøgelser for Danmark og Grønland	GEUS
Estonia	Geological Survey of Estonia	EGT
Finland	Geologian Tutkimuskeskus (GTK) - Geological Survey of Finland	GTK
France	Bureau de Recherches Géologiques et Minières	BRGM
Germany	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	BGR
Germany	Landesamt für Bergbau, Energie und Geologie	LBEG
Germany	Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg (LBGR)	LBGR
Hungary	Mining and Geological Survey of Hungary (MBFSZ)	MBFSZ
Hungary	Országos Vízügyi Főigazgatóság	OVF
Iceland	Iceland Geosurvey	ISOR
Ireland	Geological Survey Ireland	GSI
Italy	Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)	ISPRA
Italy (Piedmont region)	Agenzia Regionale per la Protezione Ambientale of Piedmont	ARPA
Latvia	Latvijas Vides, Ģeoloģijas un Meteoroloģijas Centrs	LEGMC
Lithuania	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos (LGT)	LGT
Malta	Energy and Water Agency	EWA
Netherlands	Deltares	DLT
Netherlands	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	TNO
Poland	Polish Geological Institute	PGI
Portugal	Laboratório Nacional de Energia e Geologia	LNEG
Romania	Institutul Geologic al României (IGR)	IGR
Serbia	Geological Survey of Serbia	GSS (GZS)
Slovenia	Geološki zavod Slovenije angleško Ime: Geological Survey Of Slovenia	GeoZS
Spain	Institut Cartogràfic i Geològic de Catalunya	ICGC
Spain	Instituto Geológico y Minero de España (Spanish Geological Survey)	IGME
Sweden	Sveriges Geologiska Undersökning (Geological Survey of Sweden)	SGU
UK	British Geological Survey	NERC
Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine (GEOINFORM)	GEOINFORM

2.4 FOLLOW UP TO ORGANISATIONS WHO DID NOT RESPOND

The initial generic email (sent to all recipients simultaneously) asking HOVER partners to complete the questionnaire gave a deadline for responses. Organisations who had not responded were then contacted again: this time emails were tailored to each individual

personally in the hope of appealing more directly. This follow up greatly improved the overall response rate (Section 3.1.2).

2.5 EMAILS TO ADDITIONAL CONTACTS

Some HOVER partners were aware of other people within their organisations, or other organisations in their countries, who may have experience of monitoring organic CECs in groundwater, and either forwarded the initial email directly or passed information to us such that we were able to contact them.

2.6 NOTES ON SPATIAL PLOTS

2.6.1 Source of basemap

The European basemap was obtained from the data layer “UIA_World Countries Boundaries” obtained from ArcGIS.com (2019) and reprojected into [WGS84 Web Mercator \(Auxiliary Sphere\)](#). “World Countries (Generalized) is a generalized layer of country level boundaries which can be used at small to medium scales” (ArcGIS.com, 2019).

2.6.2 Exclusion of overseas territories

Overseas territories were not included in the spatial plots; hence we have not included Greenland (for which no data were available) or other territories which are not physically connected to the European landmass.

2.6.3 Method for dealing with multiple responses for a country

Where multiple organisations responded from one country, the most positive result was plotted. For example, for Question 6 (familiarity of the organisations with the topic of organic CECs in groundwater), we had two responses from organisations based in Belgium: RBINS-GSB who stated they had “Not heard about this topic before and is unlikely to be interested”; and VMM who were more positive and said they were “Familiar with the topic but not yet working in this area”. Only the VMM response is incorporated in the spatial plot for Belgium for this question.

2.7 QUESTIONNAIRE OUTPUT

The questionnaire responses were exported from Microsoft Forms in Excel format (the only output option). The resulting spreadsheet did not give the correct column headings and jumbled up the order of the questions, listing them in apparently random order rather than the questionnaire order, creating an unanticipated sorting exercise.

3 Results

3.1 QUESTIONNAIRE RESPONSE RATES

3.1.1 Email issues

Of the initial list provided, 3 of the email addresses bounced errors back. The email list already contained alternative contact details for people at the relevant organisations.

3.1.2 Responses by organisation

Of the 35 organisations contacted, at least 1 response was returned by 30 organisations. There were 2 responses from GTK, Finland. These were rationalised by using the most positive response.

3.1.3 Responses by country

The 35 organisations contacted relate to 29 countries or regions of countries (e.g. ARPA - The Regional Agency for the Protection of the Environment of Piedmont) (Table 1).

Six countries had multiple organisations in our list: five countries had two organisations, and Germany had three (BGR, LBEG and LBGR).

The only countries contacted for which no responses were received were Denmark and Ukraine.

3.1.4 Engagement with questionnaire

30 out of 35 organisations completed the questionnaire (86%). The response rate to individual questions was much lower as a result of the branching, whereby if respondents answered ‘no’ to Question 8, for example, they were not asked questions 9 to 11 as they were not relevant. Answering ‘no’ to Question 7, indicating that no work had been undertaken in the area, would take the respondent directly to Question 18.

Table 2 Response rate to individual questions (grey–shaded cells indicate follow-up questions), where 100% would mean responses were received from all 35 organisations contacted.

Question number	6	7	8	9	10	11	12	13	14	15	16	17	18
Response rate (%)	91	88	41	18	18	15	41	32	32	32	38	44	88

The diagram below the table shows two arrows indicating branching logic. One arrow starts from the 'No' response for Question 7 and points to Question 18. Another arrow starts from the 'No' response for Question 8 and points to Question 12.

3.2 MICROSOFT FORMS RESULTS OUTPUT

Screenshots of a summary of the questionnaire responses as reported by Microsoft Forms are provided in Appendix 2. There are 32 responses from 30 organisations. There are different reasons for duplicated responses: 2 responses from different respondents at GTK, Finland; 2 responses from PIG-PIB, Poland with some corrections; in the following analysis the initial response from Poland have been discounted, while the most positive response from GTK was included.

3.3 FREE TEXT ANSWERS

Responses to the free text parts of the questionnaire, where permission is given to share, are given in Appendix 3 and Appendix 4. Appendix 3 comprises the free text answers to Question 16 “Please share your work”, which people answered in different ways (12 responses); some people provided citations, others mentioned the existence of unpublished work which could be shared on request, or work currently documented in their country’s language. Appendix 4 comprises free text given in the final part of the questionnaire which provided a free text field for “anything else you would like to add”.

3.4 FAMILIARITY OF THE ORGANISATIONS WITH THE TOPIC OF ORGANIC CECS IN GROUNDWATER (QUESTION 6)

Of the 30 organisations who responded to the questionnaire, the vast majority (29) were already aware of the topic of organic CECs in groundwater, to a varying degree (Figure 1). The spatial distribution of responses to this question is shown in Figure 2: there is no discernible pattern.

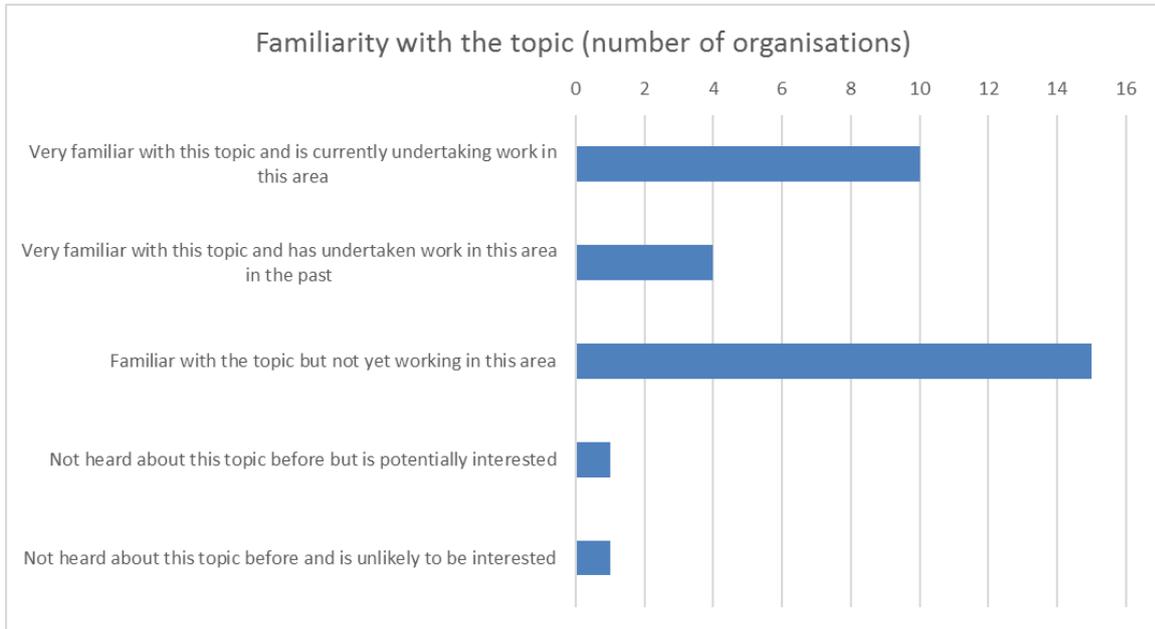


Figure 1 Familiarity with the topic of emerging CECs: number of organisations

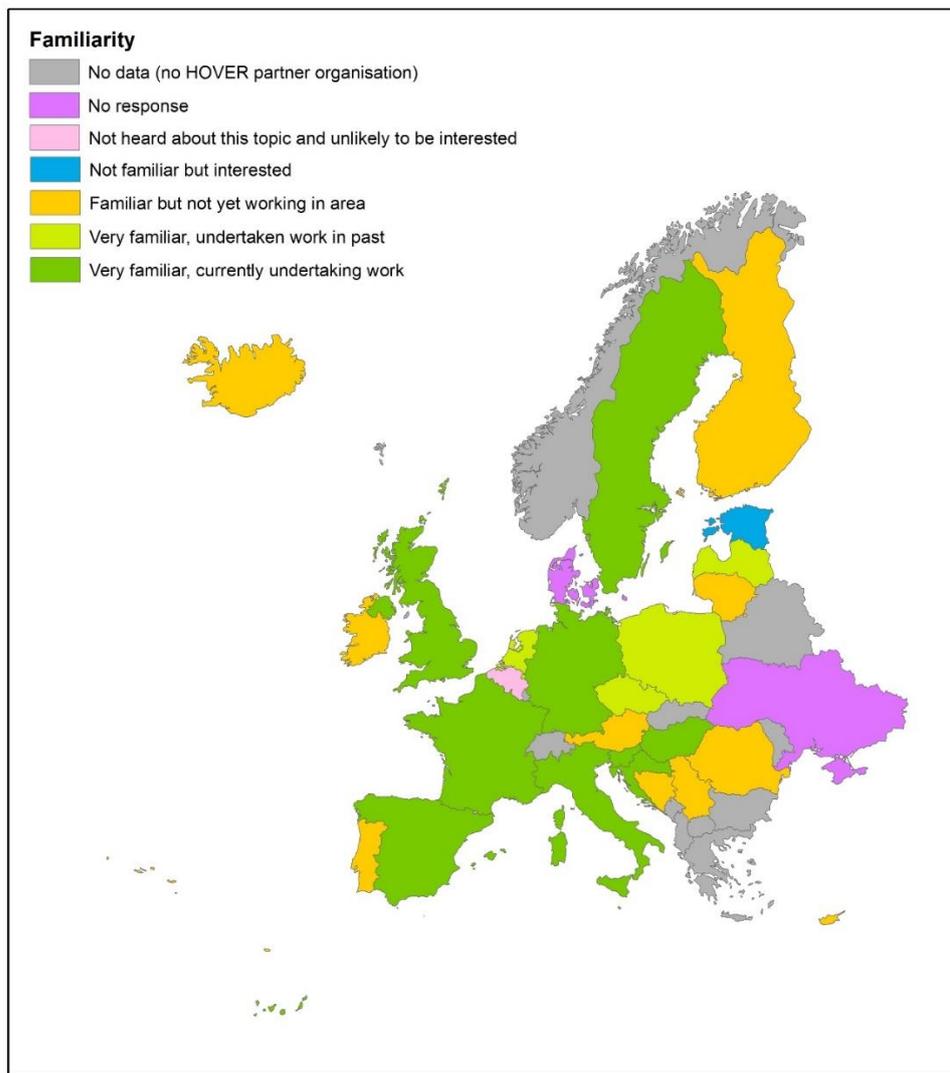


Figure 2 Familiarity with the topic of emerging CECs plotted as choropleth map

3.5 ORGANISATIONS THAT HOLD ORGANIC CEC DATA (QUESTION 7)

Fourteen of the organisations who responded to the questionnaire hold organic CEC data, while a further one has worked in the area with partner's data (Table 3). Fifteen organisations hold no such data, and five organisations did not respond to this question (Question 7).

The data from this question was plotted in a choropleth map (Figure 3), which shows the most positive response for countries for which we had multiple responses (Section 2.6.3).

Table 3 Organisations who hold organic CEC data

Category	Count
Yes	14
No, but we have worked in this area with partner's data	1
No	15
Nil response	5

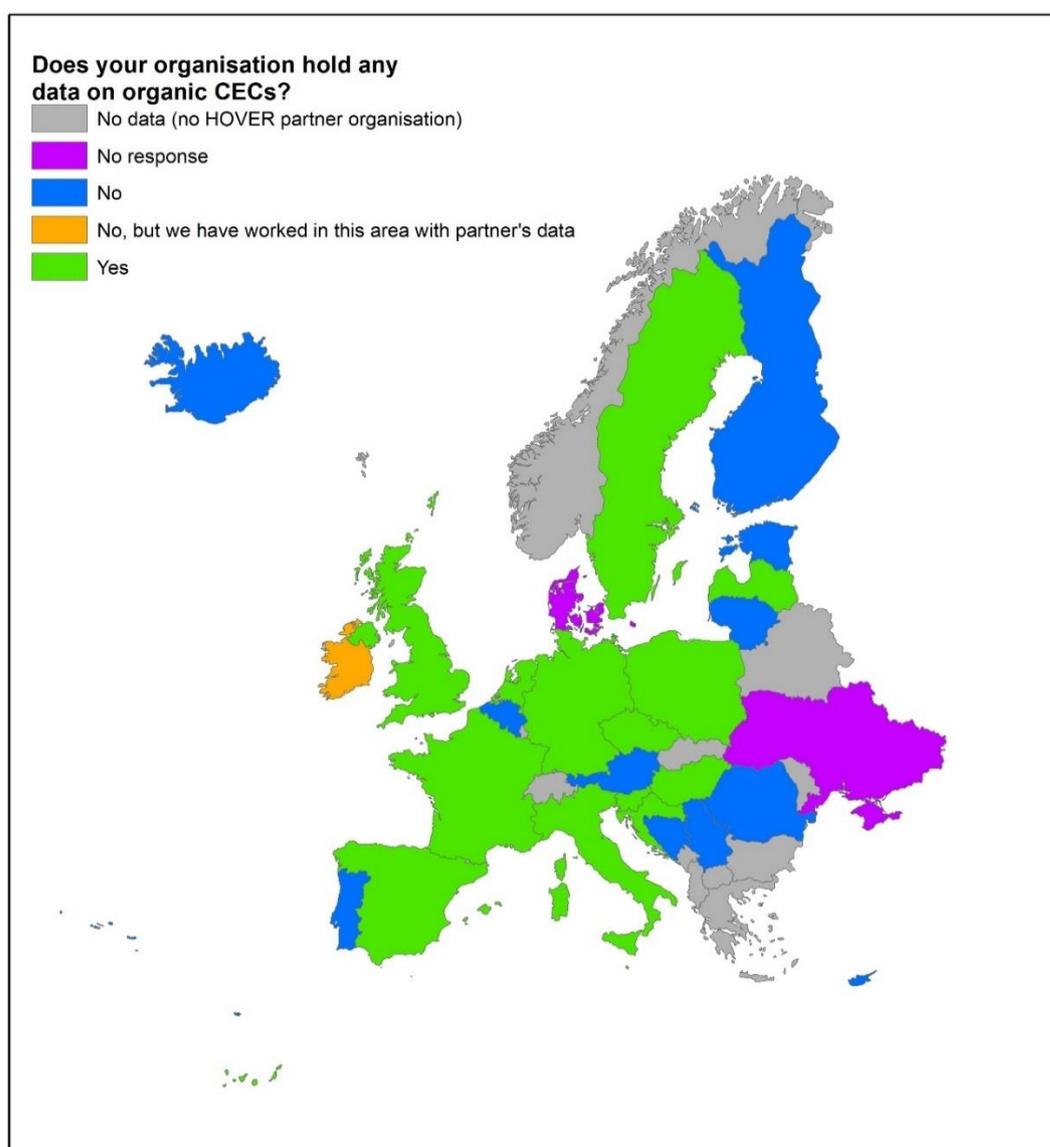


Figure 3 Countries that hold data on organic CECs

3.6 ORGANISATIONS THAT HAVE UNDERTAKEN STUDIES ON ORGANIC COMPOUNDS OF EMERGING CONCERN WITHOUT PARTNERS (QUESTION 8, ALSO 9-11)

Question 8 asked respondents whether their organisations had undertaken studies on organic compounds of emerging concern **without** partner organisations, i.e. solely the respondent organisation (not considering the involvement of external laboratories if they were purely engaged to undertake analysis). A clarification of “without partners” was given in the question: “i.e. studies which have been carried out solely by your own organisation”.

The bulk of respondents to the questionnaire did not complete this question, as those who responded “no” to Question 7 were not asked. Of the 14 who responded, 6 have undertaken work in this area without partners, while 8 have not. The spatial distribution of these responses is shown in Figure 4 (again, taking the highest response per country for instances of multiple organisations per country). There is no pattern to these responses.

The five countries who have undertaken work in this area without partners are: Czech Republic, France, Netherlands, Sweden, Poland and UK.

Questions 9 to 11 were follow-up questions to Question 8. There was a maximum of 6 responses to these questions, as they were only asked of organisations who responded ‘yes’ to Question 8. The reasons for undertaking such studies included general background survey (with dedicated monitoring sites away from known pollution) and point source survey (Table 4). Three of the respondent organisations had analysed for more than 50 substances, while the other 3 had analysed for between 10 and 50 substances (Table 5). The categories of substances which were analysed for are reported in Table 6.

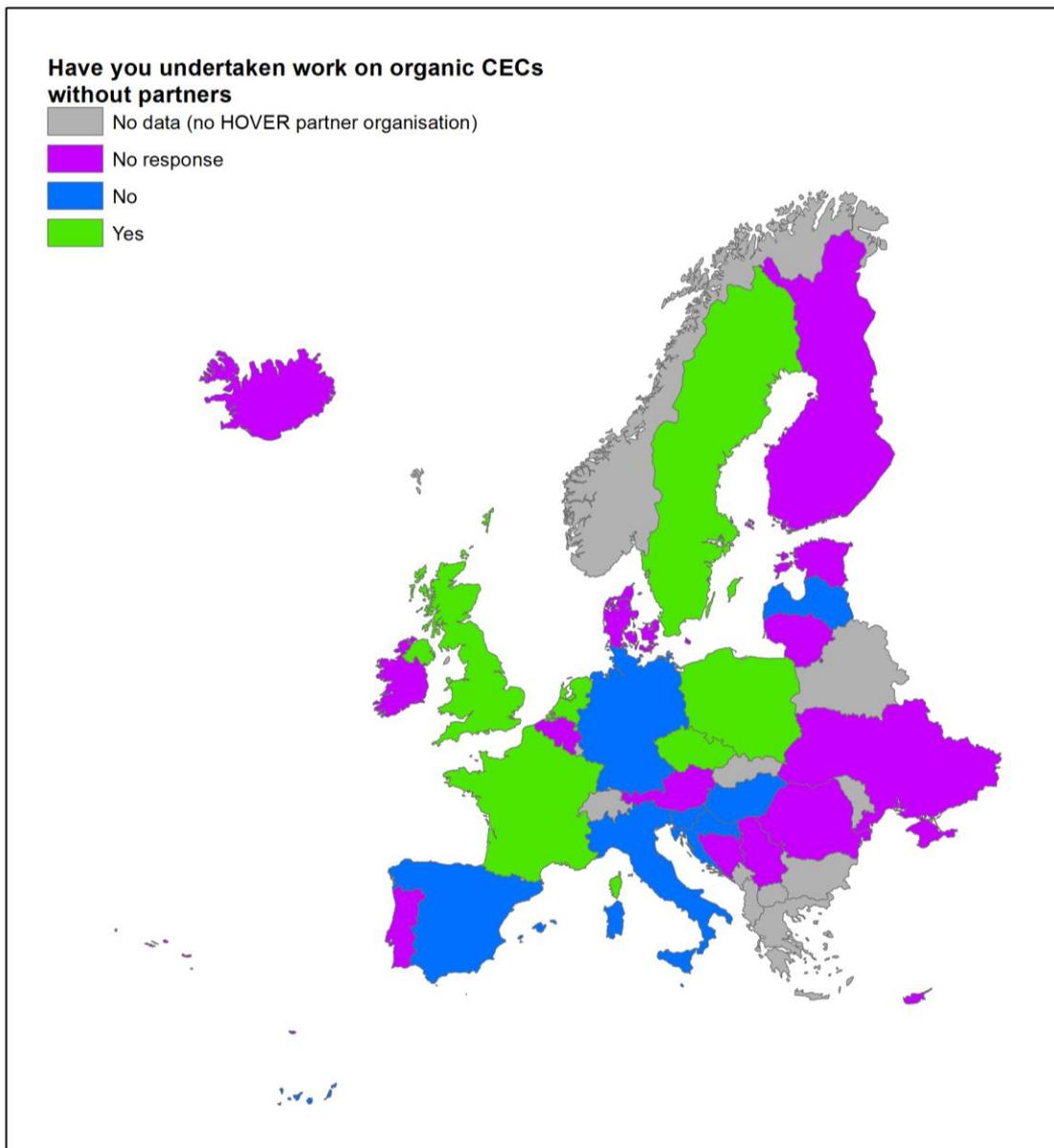


Figure 4 Countries which have undertaken work on organic CECs without partners (Question 8)

Table 4 Main reasons for undertaking studies without partners (Question 9)

*(dedicated monitoring sites away from known pollution)

Organisation	Country	Point source survey	General background survey *	Sampling method test	Analytical method test (e.g. interlab test)
BGS	UK	Y	Y	Y	
BRGM	France	Y	Y	Y	Y
CGS	Czech Republic		Y		
PGI	Poland		Y		
SGU	Sweden	Y	Y		
TNO	The Netherlands		Y		

Table 5 How many substances were analysed for, in studies without partners (Question 10)

Organisation	Country (e.g. UK)	How many substances did you analyse for?
BGS	UK	>50
BRGM	France	>50
CGS	Czech Republic	10-50
PGI	Poland	10-50
SGU	Sweden	>50
TNO	The Netherlands	10-50

Table 6 Which categories of substances were analysed for, in studies without partners (Question 11)

Organisation	Country	Pharmaceuticals	Veterinary compounds	Lifestyle products	Industrial compounds	Food additives	Perfluorinated compounds	Plasticisers	Biocides	Personal care products	Other
BGS	UK	Y	Y	Y	Y	Y	Y	Y	Y	Y	
BRGM	France	Y	Y	Y	Y		Y	Y		Y	perchlorate
CGS	Czech Republic	Y			Y		Y		Y		
PGI	Poland	Y		Y							
SGU	Sweden	Y			Y		Y	Y			
TNO	Netherlands		Y								
Count:		5	3	3	4	1	4	3	2	2	1

3.7 ORGANISATIONS THAT HAVE UNDERTAKEN STUDIES ON ORGANIC COMPOUNDS OF EMERGING CONCERN WITH PARTNERS (QUESTION 12, ALSO 13-15)

Question 12 asked respondents whether their organisations had undertaken studies on organic compounds of emerging concern **with** partner organisations. The response rate to Question 12 was similar to that of Question 8, but of the 15 who responded a much larger proportion (11 organisations) responded positively.

The spatial distribution of these responses is shown in Figure 5 (again, taking the highest response per country for instances of multiple responses). The eleven countries who have undertaken work in this area with partners are: Czech Republic, France, Germany, Hungary, Ireland, Latvia, Malta, Spain, Slovenia, Sweden and UK.

Questions 13 to 15 were follow-up questions to Question 12, providing greater detail regarding work undertaken with partners (see below).

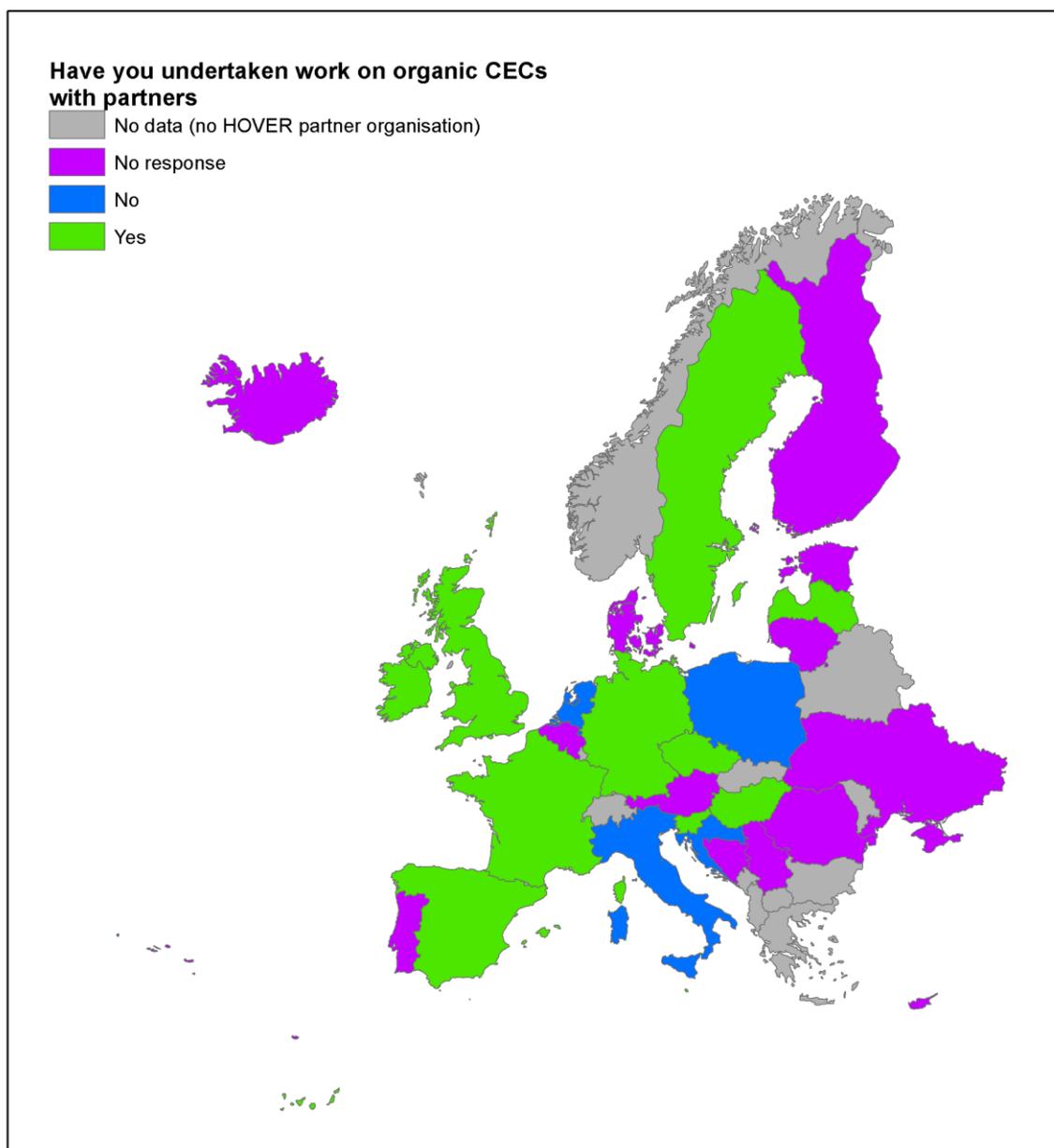


Figure 5 Countries that have undertaken work on organic CECs with partners (Question 12 responses)

3.7.1 Main reason for undertaking work with partners (Question 13)

Respondents who reported that they had undertaken work on organic CECs with partners were asked to describe the main reason for those studies. The majority (8) of the studies undertaken with partners were general background surveys, using dedicated monitoring sites away from known pollution (Figure 6 and Table 7). Of the other 3 studies described, one was a point source survey, one an analytical method test and the other for professional and legal reasons (Table 7).

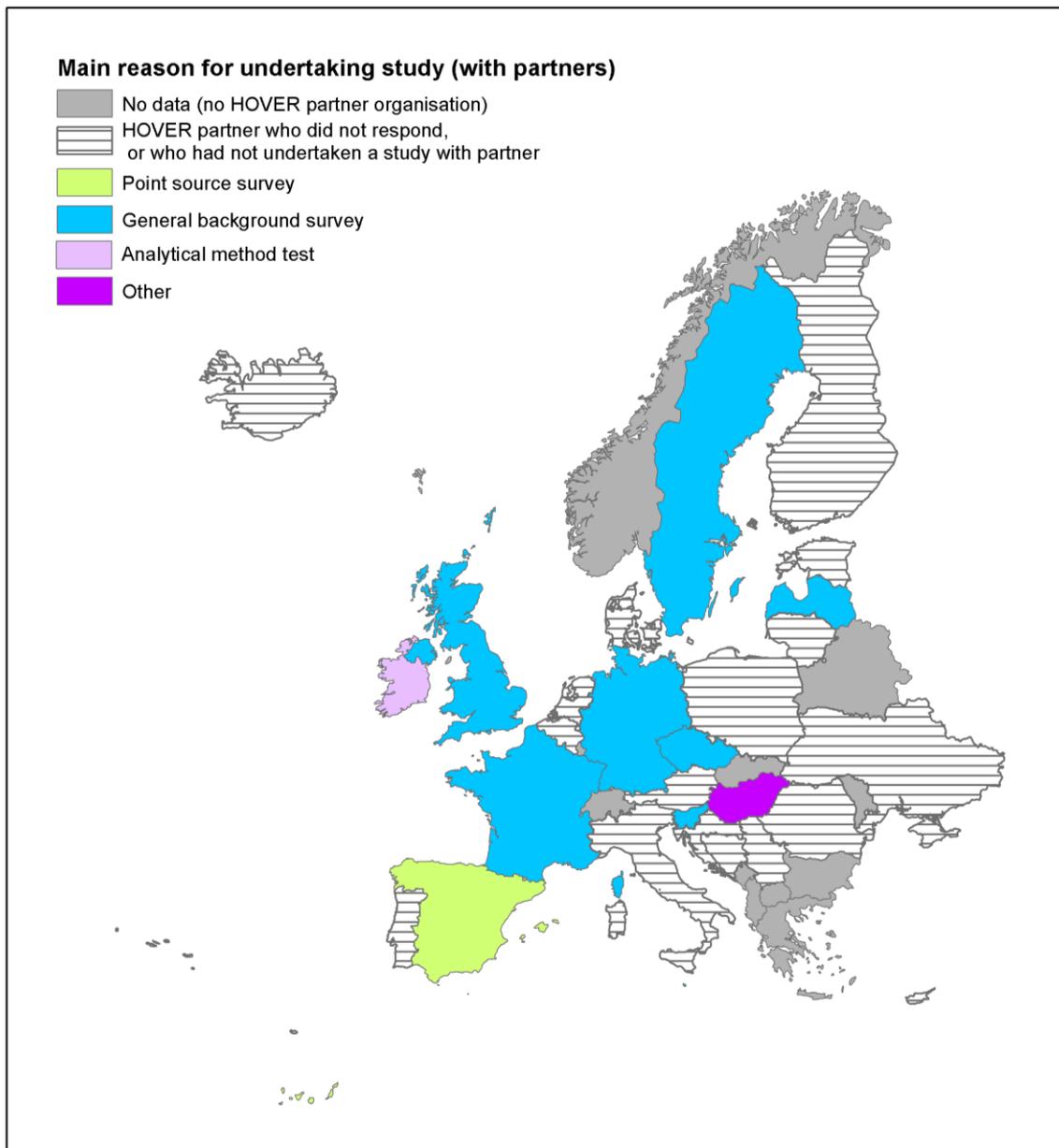


Figure 6 Choropleth map of main reason for undertaking CECs studies with partners (Question 13 responses)

Table 7 Main reason for undertaking studies with partners (Question 13 responses)

*monitoring sites away from known pollution

Organisation	Country (e.g. UK)	Point source survey	General background survey *	Analytical method test (e.g. interlab test)	Other
BGS	UK		Y		
BRGM	France		Y		
CGS	Czech Republic		Y		
EWA	Malta		Y		
GeoZS	Slovenia		Y		
GSI	Ireland			Y	
IGME	Spain	Y			
LBEG	Germany		Y		
LEGMC	Latvia		Y		
OVF	Hungary				Professional reasons, participation in legislation
SGU	Sweden		Y		

3.7.2 How many substances did you analyse for? (Question 14)

Respondents who reported that they had undertaken work on organic CECs in groundwater with partners were asked how many organic CEC substances their samples were analysed for, with possible answers in ranges. Two organisations had analysed for fewer than 10 substances, 4 organisations had analysed for 10 to 50 substances, and 5 organisations had analysed for more than 50 substances (Table 8).

Table 8 Number of substances analysed for, in studies with partners (Question 14 responses)

Organisation	Country (e.g. UK)	< 10	10 - 50	> 50
BGS	UK			Y
BRGM	France			Y
CGS	Czech Republic		Y	
EWA	Malta		Y	
GeoZS	Slovenia			Y
GSI	Ireland		Y	
IGME	Spain	Y		
LBEG	Germany			Y
LEGMC	Latvia	Y		
OVF	Hungary			Y
SGU	Sweden		Y	

3.7.3 Which categories of compounds have been studied, in studies with partners (Question 15)

Question 15 listed nine different categories of compound (by use) and asked respondents to tick all those which had been analysed for in studies that were undertaken with partners. There was also an 'other' option with a free text field. The responses tabulated in Table 9. Four organisations (from France, Malta, Slovenia and UK) have analysed groundwater samples for all these categories.

Table 9 Which categories of substances were analysed for, in studies with partners (Question 15)

Organisation	Country	Pharmaceuticals	Veterinary compounds	Lifestyle products	Industrial compounds	Food additives	Perfluorinated compounds	Plasticisers	Biocides	Personal care products	Other
BGS	UK	Y	Y	Y	Y	Y	Y	Y	Y	Y	
BRGM	France	Y	Y	Y	Y	Y	Y	Y	Y	Y	perchlorate
CGS	Czech Republic	Y	Y				Y		Y		
GeoZS	Slovenia	Y	Y	Y	Y	Y	Y	Y	Y	Y	
GSI	Ireland	Y									
IGME	Spain	Y		Y	Y						
LBEG	Germany	Y	Y				Y				
LEGMC	Latvia						Y			Y	
MTI	Malta	Y	Y	Y	Y	Y	Y	Y	Y	Y	
OVF	Hungary	Y		Y	Y		Y	Y		Y	
SGU	Sweden	Y			Y		Y	Y			
Count:		10	6	6	7	4	9	6	5	6	1
Colour in camembert:		purple	lilac	pink	mid blue	pale blue	green	yellow	orange	red	

3.8 SUMMARY OF CATEGORIES OF COMPOUNDS STUDIED

A summary of all reported categories of compounds studied by all respondents is presented in Figure 7, which combines the data provided in Table 6 and Table 9 (Questions 11 and 15).

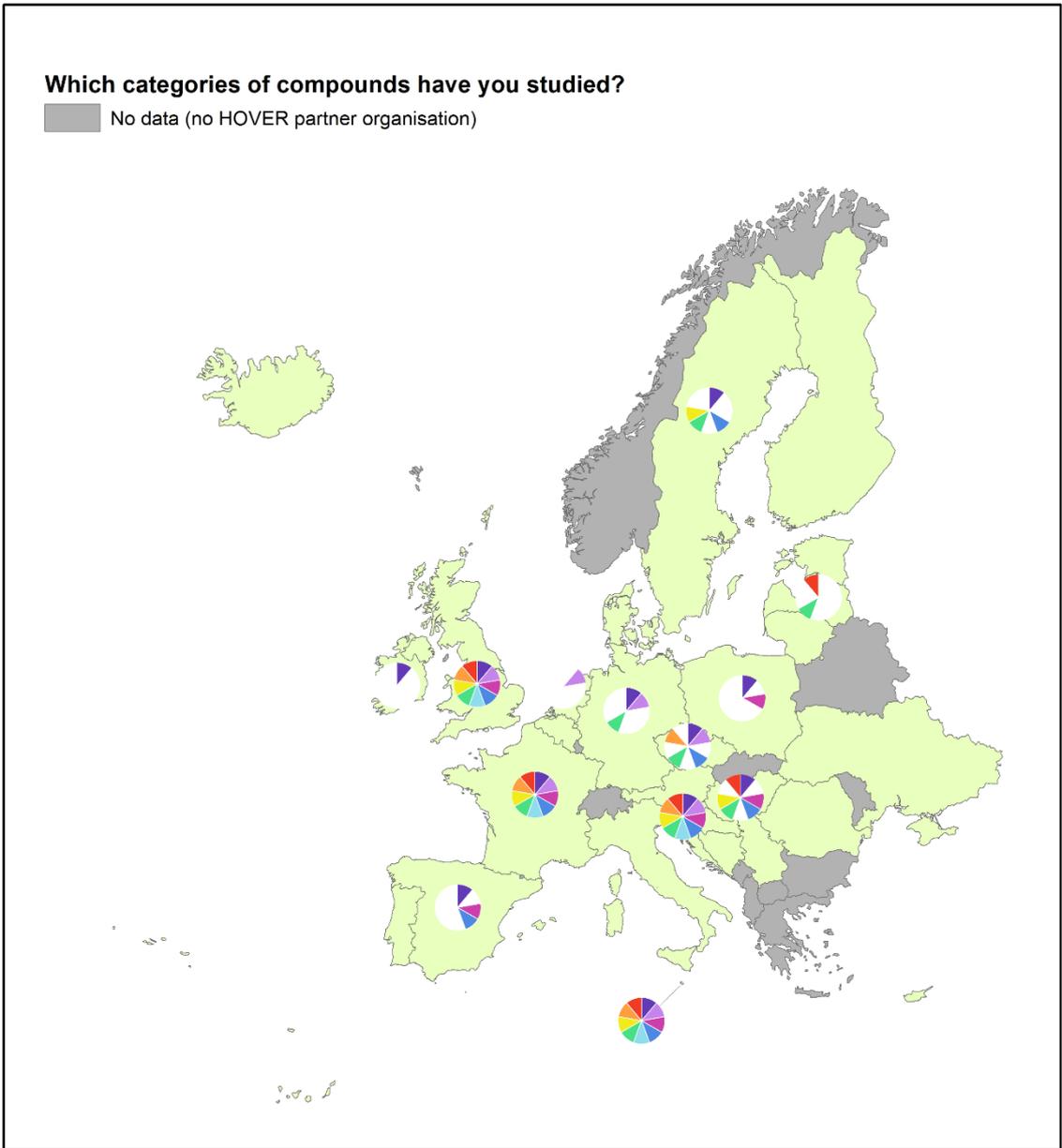


Figure 7 Plot showing which categories of compounds have been analysed for in countries that have organisations which responded to Questions 11 and 15 (combined data from Table 6 and Table 9)

3.9 SHARING WORK (QUESTION 16)

Question 16 was a free text field asking respondents to share their work. Responses are tabulated in Appendix 3

3.10 FOLLOW-UP INFORMATION ABOUT STUDIES UNDERTAKEN

At the request of the HOVER partners, a follow-up email was sent out to those who had completed the questionnaire and gave permission to be contacted again. This email requested:

We are interested in knowing which substances you have analysed for (whether or not they were detected) at more than 10 sites. Could you please send a list of CAS numbers for the substances that meet this criterion?

If you have used a screening method and cannot report the large number of possible substances, perhaps you could just send us a list of those which were detected.

An example would look like this:

CAS number	Number of sites
298-46-4	12
149-32-6	12
78-40-0	12

Seven responses were received; a summary of the information provided is given in Appendix 5.

4 Conclusions

This survey has identified that many organisations participating in the GeoERA HOVER project have undertaken work on organic CECs in groundwater. Even if they have not, all organisations except one are familiar or interested with the topic of emerging CECs in groundwater. The studies have been variable in terms of the number and types of substances analysed for. Pharmaceuticals and perfluorinated compounds are the most widely analysed categories of CECs at the European scale, while investigations of biocides and food additives have been more limited.

The questionnaire draws a picture of the current level of research on CECs in groundwater at European scale by participating European geological surveys and water agencies. It is now possible to identify organisations that hold unpublished data and which have agreed to share this for future studies. This pan-European view will help researchers to find potential partners with experience of studying CECs in groundwater, to build consortia in response to European calls. The gaps in investigation of different categories of substances in participating countries have also been revealed. It will be interesting to see how this field of research develops in coming years: we look forward to continued collaborations with our European colleagues.

Appendix 1 Screenshots of the HOVER WP8 Organic CECs questionnaire

The following images show screenshots of the questionnaire.



Organic contaminants of emerging concern (organic CECs) in groundwater



As part of GEOERA, WP8 is focussed on organic substances of emerging concern in groundwater. We are undertaking an assessment of ongoing and planned GEOERA participation in this topic. The aim of this short survey is to gather existing knowledge and experience on this topic within GEOERA members (not just those participating in WP8) and also those partner organisations that you work with as national Geological Surveys. This is important to inform future activities planned for WP8 and maximise the impact of WP8.

This is a short questionnaire and should take about 5 minutes to complete – your participation is very valuable, even if you have not started working on this topic yet, please complete the survey.

Thanks in advance!

1

Name of contact (e.g. John Patel) *

Enter your answer

2

Email address *

Enter your answer

3

Organisation (e.g. British Geological Survey) *

Enter your answer

4

Country (e.g. UK) *

Enter your answer

5

Region of country (e.g. Oxfordshire)

Enter your answer

6

Definition of organic substances of emerging concern in groundwater: ' Substances detected, or expected to be detected, but not included in groundwater resource protection regulations, whose fate, behaviour and toxicological effects are poorly understood'. Examples include pharmaceuticals, personal care products and perfluorinated compounds (e.g. PFOS/PFOA).

Would you say that your organisation is: *

- 1. Very familiar with this topic and is currently undertaking work in this area
- 2. Very familiar with this topic and has undertaken work in this area in the past
- 3. Familiar with the topic but not yet working in this area
- 4. Not heard about this topic before but is potentially interested
- 5. Not heard about this topic before and is unlikely to be interested

7

Does your organisation hold any data on organic compounds of emerging concern? *

- Yes
- No, but we have worked in this area with partner's data
- No

8

Work without partners

Have you undertaken studies on organic compounds of emerging concern *without* partners? *

i.e. studies which have been carried out solely by your own organisation

- Yes
- No

9

Work without partners

What was the main reason for undertaking these studies? *

- Point source survey
- General background survey (dedicated monitoring sites away from known pollution)
- Sampling method test
- Analytical method test (e.g. interlab test)
- Other

10

How many substances did you analyse for? *

Work without partners

- less than 10
- 10-50
- more than 50

11

Work without partners

Which categories of compounds have you studied? *

- Pharmaceuticals
- Veterinary compounds
- Lifestyle products (e.g. caffeine)
- Industrial compounds
- Food additives
- Perfluorinated compounds
- Plasticisers
- Biocides
- Personal care products
- Other

12

Work with partners

Have you undertaken studies on organic compounds of emerging concern **with** partner organisations? *

In the following questions please tell us about collaborative studies that you have participated in

- Yes
- No

13

Work with partners

What was the main reason for undertaking these studies? *

- Point source survey
- General background survey (dedicated monitoring sites away from known pollution)
- Sampling method test
- Analytical method test (e.g. interlab test)
-

14

How many substances did you analyse for? *

Work with partners

- less than 10
- 10-50
- more than 50

15

Which categories of compounds have you studied? *

- Pharmaceuticals
- Veterinary compounds
- Lifestyle products (e.g. caffeine)
- Industrial compounds
- Food additives
- Perfluorinated compounds
- Plasticisers
- Biocides
- Personal care products
- Other

16

Please share your work

Please provide any web links, document files or descriptions related to any of the work you have detailed above (both with or without partners). Documents can be emailed to ejwh@bgs.ac.uk

Enter your answer

17

Please can we contact you about your work on organic substances of emerging concern? *

- Yes
- No

18

Please can we share your information? *

As part of GEOERA we would like to share this information. This is for project purposes only and will not be shared with external parties.

Yes

No

19

Thank you very much for completing our survey

If there is anything else you would like to add please do so here, or email ejwh@bgs.ac.uk

Enter your answer

Appendix 2 Screenshots of the questionnaire response summary (Microsoft Forms)

Screenshots of the questionnaire responses as reported by Microsoft Forms online summary system. Thirty-two responses were submitted in total, one of which was a test and another a correction of an earlier response; one organisation had two respondents. To see the truncated text in full please refer to Appendix 1.

6. Definition of organic substances of emerging concern in groundwater: 'Substances detected, or expected to be detected, but not included in groundwater resource protection regulations, whose fate, behaviour and toxicological effects are poorly understood'. Examples include pharmaceuticals, personal care products and perfluorinated compounds (e.g. PFOS/PFOA). Would you say that your organisation is:

[More Details](#)

1. Very familiar with this topic ...	10
2. Very familiar with this topic ...	5
3. Familiar with the topic but n...	15
4. Not heard about this topic ...	1
5. Not heard about this topic ...	1



7. Does your organisation hold any data on organic compounds of emerging concern?

[More Details](#)

Yes	15
No, but we have worked in thi...	1
No	16



8. Have you undertaken studies on organic compounds of emerging concern *without* partners?

[More Details](#)

Yes	6
No	9



9. What was the main reason for undertaking these studies?

[More Details](#)

Point source survey	3
General background survey (d...	6
Sampling method test	2
Analytical method test (e.g. int...	1
Other	0



10. How many substances did you analyse for?

[More Details](#)

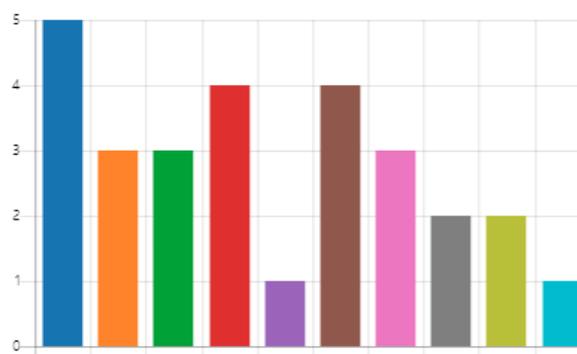
● less than 10	0
● 10-50	3
● more than 50	3



11. Which categories of compounds have you studied?

[More Details](#)

● Pharmaceuticals	5
● Veterinary compounds	3
● Lifestyle products (e.g. caffeine)	3
● Industrial compounds	4
● Food additives	1
● Perfluorinated compounds	4
● Plasticisers	3
● Biocides	2
● Personal care products	2
● Other	1



12. Have you undertaken studies on organic compounds of emerging concern *with* partner organisations?

[More Details](#)

● Yes	12
● No	4



13. What was the main reason for undertaking these studies?

[More Details](#)

● Point source survey	1
● General background survey (d...	8
● Sampling method test	0
● Analytical method test (e.g. int...	1
● Other	2



14. How many substances did you analyse for?

[More Details](#)

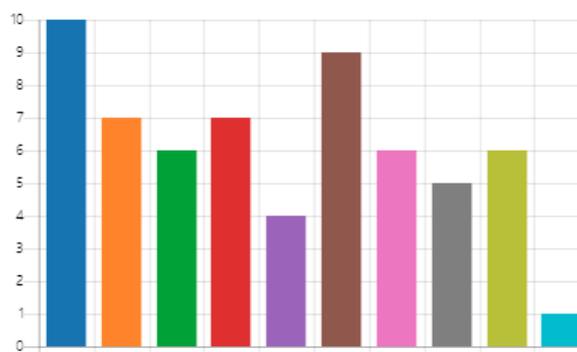
● less than 10	2
● 10-50	5
● more than 50	5



15. Which categories of compounds have you studied?

[More Details](#)

● Pharmaceuticals	10
● Veterinary compounds	7
● Lifestyle products (e.g. caffeine)	6
● Industrial compounds	7
● Food additives	4
● Perfluorinated compounds	9
● Plasticisers	6
● Biocides	5
● Personal care products	6
● Other	1



16. Please share your work

[More Details](#)

14
Responses

Latest Responses

- "Kuczyńska A. (2017) Results of a pilot study on the assessment of ph...
- "The General Directorate of Water Management is interested in the la...
- "Peer reviewed articles on EOCs in groundwater, including a few pape...

17. Please can we contact you about your work on organic substances of emerging concern?

[More Details](#)

● Yes	15
● No	1



18. Please can we share your information?

[More Details](#)

● Yes	28
● No	4



Appendix 3 Sharing work (Question 16)

Question 16 was a free text field asking for “any web links, document files or descriptions related to any of the work you have detailed above (both with or without partners)”. The information provided is shared here, where the respondents gave permission. Organisations which did not include anything in this field are omitted below.

GEOLOGICAL SURVEY OF SPAIN (SPAIN)

<https://www.sciencedirect.com/journal/journal-of-hydrology/vol/531/part/P3>

POLISH GEOLOGICAL INSTITUTE-NATIONAL RESEARCH INSTITUTE (POLAND)

Partial information is published in Polish. Publication in English shall available by the end of this year.

The pilot study on the content of pharmaceuticals in groundwater was undertaken during two sampling campaigns in year 2016-2017. In 2016 sampling was carried out on the occasion of the surveillance monitoring, which was carried out across the entire country, in all groundwater bodies (172). The total number of monitoring boreholes included in the study was 93. In 2017 sampling was carried out on the occasion of the operational and research monitoring. In total 67 samples were collected for the study in 2017. Locations of sampling points were carefully studied to reflect potential pollution sources associated with proximity to urban agglomerations or rural areas (poor sewage networks, manure spreading), or close proximity to documented outbreaks of pollution, eg a cemetery, a hospital, sewage treatment plants or a short distance from surface water courses. Depth to water bearing zone and borehole logs were analysed to ensure sampling locations could have been particularly exposed to the impact of municipal anthropogenic pressure due to the shallow occurrence of water bearing horizons, devoid of isolation.

Water samples were collected in accordance with accreditation rules for the collection of groundwater samples, held by the Polish Geological Institute-National Research Institute and certified by the AB 283 Accredited Laboratories Certificate. The scope of analytical tests included 34 active substances of the following groups of drugs:

1. Estrogenic hormones: estrone, estriol, 17 α -ethinylestradiol (EE2), 17 β -estradiol (E2), testosterone;
2. β -blockers (drugs for cardiovascular disease): nadolol (2016), atenolol (2017), metoprolol, pindolol, propranolol;
3. β -agonists (medicines for respiratory diseases): terbutaline, salbutamol;
4. Analgesics and anti-inflammatory drugs: diclofenac, ibuprofen, ketoprofen, naproxen, paracetamol, flurbiprofen;
5. Antidepressants: imipramine, clomipramine, doxepine (2016 only), amitriptyline (2017 only);
6. Antimicrobial agents (sulfonamides and antibiotics): sulfadiazine, sulfadimethoxine, sulfamerazine, sulfametazine, sulfamethoxazole, sulfapyridine and sulfathiazole, sulfachloropyridazine and trimethoprim, enrofloxacin;
7. Antiepileptics: carbamazepine
8. Caffeine (2017 only).

Chemical analyzes were carried out externally using gas and liquid chromatography. The sample preparation step included high-volume solid phase extraction using accelerated extraction disks. The final determinations were made using two techniques depending on the group of drugs. Estrogenic hormones, β -blockers, β -agonists, analgesics and tricyclic antidepressants were determined by gas chromatography coupled with mass spectrometry (GC/MS) in the mode of selected ion monitoring (SIM). Antimicrobial drugs, carbamazepine and caffeine were determined using high performance liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS) in the MRM recording mode.

GEOLOGICAL SURVEY OF SLOVENIA (SLOVENIA)

Data from national monitoring by the Slovenian Environment Agency is available.

MALI, Nina, CERAR, Sonja, KOROŠA, Anja, AUERSPERGER, Primož. Passive sampling as a tool for identifying micro-organic compounds in groundwater. *Science of the total environment*, 2017, vol. 593/594, str. 722-734, doi: 10.1016/j.scitotenv.2017.03.166.

CERAR, Sonja, MALI, Nina. Assessment of presence, origin and seasonal variations of persistent organic pollutants in groundwater by means of passive sampling and multivariate statistical analysis. *Journal of geochemical exploration*, ISSN 0375-6742. [Print ed.], 2016, vol. 170, str. 78-93, doi: 10.1016/j.gexplo.2016.08.016.

KOROŠA, Anja, AUERSPERGER, Primož, MALI, Nina. Determination of micro-organic contaminants in groundwater (Maribor, Slovenia). *Science of the total environment*, ISSN 0048-9697, 2016, vol. 571, str. 1419-1431, doi: 10.1016/j.scitotenv.2016.06.103.

TNO GEOLOGICAL SURVEY OF THE NETHERLANDS (NETHERLANDS)

TNO Geological Survey of the Netherlands. See Appendix A, Supplementary data in: <https://doi.org/10.1016/j.envpol.2018.05.085>

ENERGY AND WATER AGENCY (MALTA)

Data is available.

LANDESAMT FÜR BERGBAU, ENERGIE UND GEOLOGIE (GERMANY)

1)

http://www.nlwkn.niedersachsen.de/wasserwirtschaft/grundwasser/grundwasserbeschaffenheit/messergebnisse_landesweit/pflanzenschutzmittel/pflanzenschutzmittel-im-grundwasser-38697.html

2) internal reports

GEOLOGICAL SURVEY OF SWEDEN (SGU) (SWEDEN)

In Sweden, measurement of selected OECs is conducted (however, not always in a systematic way) within the Groundwater Monitoring Network (comprises time-series data), and data is also available for public water supply wells (no coordinates can be delivered due to national secrecy). Moreover, SGU has recently (2016-2017) conducted a national screening of environmental pollutants (including several OECs), focusing on municipal groundwater supplies in urban environments. The study included analyses of field and base parameters (physio-chemical parameters), metals and more than 200 organic pollutants including pesticides, PFASs (highly fluorinated substances), phenolics, phthalates, halogenated aliphates and BTEX (benzene, toluene, ethylbenzene and xylenes), PAHs (polycyclic aromatic hydrocarbons), organotin compounds, pharmaceuticals, dioxins and dioxin-like PCBs (polychlorinated biphenyls), brominated flame retardants and four other organic pollutants. Link to report (SGU2019:02, in Swedish with English summary): <http://resource.sgu.se/produkter/sgurapp/s1902-rapport.pdf>

Here you'll find some general information (in English) about groundwater maps, databases and groundwater chemistry at SGU:

<https://www.sgu.se/en/groundwater/geological-information-for-groundwater-management/>

And here some very short information regarding SGUs publications

<https://www.sgu.se/en/products/publications/>

SGU's map services comprise:

- a map viewer, presenting parts of our information, e.g. data on groundwater chemistry from national and regional groundwater monitoring. However, only few sites include data on OECs.

Data for specific sites can be downloaded to Excel. The information is however given in Swedish, translation to English needed.

<https://apps.sgu.se/kartvisare/kartvisare-miljoovervakning-grundvatten.html>

- a map generator, where users can generate their own maps (e.g. groundwater bodies, no groundwater chemistry), available in English -
http://apps.sgu.se/kartgenerator/maporder_en.html

LATVIAN ENVIRONMENT, GEOLOGY AND METEOROLOGY CENTRE (LATVIA)

Work is in Latvian and should be translated.

BRGM (FRANCE)

I can share raw materials and reports (in French) and articles in English about OECs screening in France including overseas territories.

- <https://doi.org/10.1016/j.scitotenv.2015.01.110>
- <https://doi.org/10.1016/j.scitotenv.2017.06.146>
- <https://hal.archives-ouvertes.fr/hal-00949271/>

REGIONAL AGENCY FOR THE PROTECTION OF THE ENVIRONMENT (AGENZIA REGIONALE PER LA PROTEZIONE AMBIENTALE - ARPA) OF PIEDMONT (ITALY)

http://www.arpa.piemonte.it/approfondimenti/temi-ambientali/acqua/acque-superficiali-laghi/Resocontoacquesuperficiali_anno2010.pdf/at_download/file

BRITISH GEOLOGICAL SURVEY (UK)

Peer reviewed articles on EOCs in groundwater, a few papers from overseas work included:

- <https://doi.org/10.1021/acs.est.8b04490>
- <https://doi.org/10.1088/1748-9326/aaf4d7>
- <https://doi.org/10.1016/j.scitotenv.2019.05.210>
- <https://doi.org/10.1016/j.envpol.2018.04.053>
- <https://doi.org/10.1016/j.scitotenv.2016.02.169>
- <https://doi.org/10.1016/j.scitotenv.2016.04.054>
- <https://doi.org/10.1016/j.scitotenv.2016.01.146>
- <https://doi.org/10.1016/j.scitotenv.2016.03.017>
- <https://doi.org/10.1016/j.watres.2014.08.002>
- <https://doi.org/10.1016/j.envpol.2015.02.030>
- <https://doi.org/10.1016/j.scitotenv.2013.08.042>
- <https://doi.org/10.1016/j.scitotenv.2011.11.072>
- <https://doi.org/10.1016/j.envpol.2011.12.034>
- Stuart, Marianne E.; Lapworth, Dan J.. 2014 Transformation products of emerging organic compounds as future groundwater and drinking water contaminants. In: Lambropoulou, Dimitra A.; Nollet, Leo M.L., (eds.) Transformation products of emerging contaminants in the environment: analysis, processes, occurrence, effects and risks. Wiley, 65-86. <http://nora.nerc.ac.uk/id/eprint/505077/>
- Stuart, Marianne; Lapworth, Dan. 2013 Emerging organic contaminants in groundwater. In: Mukhopadhyay, S.C.; Mason, A., (eds.) Smart Sensors for Real-Time Water Quality Monitoring. Berlin, Germany, Springer-Verlag, 259-284. (Smart Sensors, Measurement and Instrumentation). <http://nora.nerc.ac.uk/id/eprint/501510/>

Reports

- <http://nora.nerc.ac.uk/id/eprint/524322/>
- <http://nora.nerc.ac.uk/id/eprint/516710/>

GENERAL DIRECTORATE OF WATER MANAGEMENT (HUNGARY)

The General Directorate of Water Management is interested in the latest research results in this field and would welcome any statement with specific results. Of course we will share our results so far upon request.

Appendix 4 Additional information (Question 19)

The final part of the questionnaire thanked respondents for participating and provided a free text field for "anything else you would like to add". The information provided is shared here, where the respondents gave permission. Organisations which did not include anything in this field are omitted below.

TNO GEOLOGICAL SURVEY OF THE NETHERLANDS (THE NETHERLANDS)

In the Dutch pilot, we also use data from partners (provinces). I still have to collect and process this data. I'm going to do this soon.

NATIONAL LABORATORY OF ENERGY AND GEOLOGY (LNEG) (PORTUGAL)

Organic contaminants are not a work area in the LNEG

GEOLOGICAL SURVEY OF SWEDEN (SGU) (SWEDEN)

Note that SGU may also have limited data for categories of compounds other than those selected under point 11 and 15 above (both with or without partners). The categories of compounds selected under point 11 and 15 represent the ones that were in main focus of the monitoring/surveys.

LITHUANIAN GEOLOGICAL SURVEY (LITHUANIA)

We are planning investigation of PFOS/PFOA in groundwater as the part of National environmental monitoring program for year 2020.

We started investigative monitoring of short-lived plant protection products in groundwater and in 2017 and 2018 made screening for 75 different substances. We have found metabolites of metazachlor, dimetachlor, chloridazon, tritosulfuron and metalaxyl in concentrations above limit of quantification. "

CROATIAN GEOLOGICAL SURVEY (CROATIA)

This is our first touch with emerging contaminants, so we are not experts but are currently undertake work in this area.

Related to emerging contaminant data, we are conducting investigations at Croatian karst springs. There are 17 karstic springs in plan for sampling in two sampling campaign. We already finished first campaign but can't provide you with this data before we publish these data. I can send you data after publishing."

LANDESAMT FÜR BERGBAU, GEOLOGIE UND ROHSTOFFE BRANDENBURG (LBGR) (GERMANY)

In the federal state of Brandenburg, data on CECs are only available from the State Office of Environment (Landesamt fuer Umwelt Brandenburg). However, the LBGR itself has no data on CECs.

Appendix 5 Number of substances analysed and number of sampling locations

Organisation	Country	Number of substances	Number of sampling locations	Data provided, notes
HGI-CGS	Croatia	1518	17	CAS numbers
IGME	Spain	39		Substance names (in Spanish); No of sampling locations only attributed to 3 substances
LBEG	Germany	365	10 - 3788	CAS numbers and no of sampling locations
PGI	Poland	34	67-160	CAS numbers, no of sites and no of samples with detection
SGU	Sweden	357	10 - 3657	CAS numbers and no of sampling locations; Also give use categorisation
TNO	Netherlands	22	46	CAS numbers, no of sites and no of samples with detection
BGS	UK	>850 screened by GCMS		EA (and NRW) sites: 2465

Glossary

<i>CEC</i>	Compound of emerging concern – in this case it refers to organic compounds only
<i>OEC</i>	Organic emerging contaminant
<i>EOC</i>	Emerging organic contaminant
<i>HOVER</i>	Hydrological processes and Geological settings over Europe controlling dissolved geogenic and anthropogenic elements in groundwater of relevance to human health and the status of dependent ecosystems
<i>CAS</i>	Chemical Abstracts Service number
<i>PFOS</i>	Per-fluorooctanesulfonate
<i>PFAS</i>	Per-and polyfluoroalkyl substance
<i>GC/MS</i>	Gas chromatography mass spectroscopy

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: <https://envirolib.apps.nerc.ac.uk/olibcgi>.

ARCgis.COM 2019. UIA_World Countries Boundaries. Dataset (Feature Layer) obtained from:
<https://hub.arcgis.com/datasets/UIA::uia-world-countries-boundaries>

BUNTING, S.Y., LAPWORTH, D.J., CRANE, E.J., GRIMA-OLMEDO, J., KOROŠA, A., KUCZYŃSKA, A., MALI, N., ROSENQVIST, L., VAN VLIET, M.E., TOGOLA, A., LOPEZ, B. 2020. Emerging organic compounds in European groundwater. *Environmental Pollution*, 115945. <https://doi.org/10.1016/j.envpol.2020.115945>.