A changing home: a cross-sectional study on environmental degradation, resettlement and psychological distress in a Western German coal mining region

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Research Article

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Abstract

Background: Unwelcome changes to familiar home environments can provoke emotional and psychological distress, known as ‘solastalgia’. In Germany, the world's largest producer of brown coal, environments are being degradaded and villages resettled until today, to make way for mine developments. These environmental alterations may lead to solastalgia, though research is scarce. We therefore investigated, to which extend open-pit mining pose risks for solastalgia and psychological disorders, such as depression, generalized anxiety and somatization, on local communities.

Methods: A survey was carried out in June and July 2021 in the Rhenish mining region in Western Germany. Current and recently resettled residents of two open-pit mines (Garzweiler II and Hambach) were queried about perceived environmental stressors as well as personal, socioeconomic and health impacts of open-pit mining and resettlement, including feelings of change, place attachment and activities carried out in response. The questionnaire contained modules on depression, generalized anxiety and somatization of the Patient Health Questionnaire and items from the Environmental Distress Scale, including solastalgia.

Results: A total of 620 participants responded to the survey, including n = 181 resettlers, n = 114 persons from resettlement threathened villages and n = 325 persons from villages not threatened by relocation near an open-pit mine. All groups self-reported high levels of psychological distress, around twice to 7.5 times above population average. Moderate to severe somatization levels were stated by 52.7% of respondents from resettlement threathened villages, which applied for only 28% of resettlers ($p < .001$). Highest symptom levels of generalized anxiety (45.4%) and depression (34.3%) were also found in participants threatened by relocation. Dust was the most frequent observed environmental hazard (up to 73%), followed by noise and increased traffic.

Conclusion: The degradation and loss of home environments caused by open-pit mining are associated with an increased incidence of depressive, anxious and somatoform symptoms in local communities.

1. Background

Health and well-being deeply depend on the environment, the surrounding ecosystems and landscapes on which our natural livelihoods are built. In today’s globalized world, ecological disturbance is ubiquitous, whether due to resource extraction, infrastructural projects, population growth or climate change. How ecosystem integrity is vital for healthy human societies is also reflected in the recent holistic concept of planetary health (Whitmee et al., 2015).

The integrity of the direct home environment is a major key element for psychosocial health, contributing to our identity, security, culture, and sense of belonging (Clayton et al., 2021, Cunsolo Willox et al., 2012). Distress caused by the transformation and disruption of familiar places such as home is condensed under the concept ‘solastalgia‘. It describes a potential human reaction when valued physical and social environments are negatively transformed and deprived of their capacities to give solace (Albrecht et al., 2007, Eisenman et al., 2015). A central aspect of solastalgia that distinguish it from related concepts on ecosystem and human health relationships, like eco-anxiety or ecological grief (Comtesse et al., 2021), is its explicit focus on place: solastalgia is a “place-based lived experience“ (Galway et al., 2019).

The term was introduced by environmental philosopher Glenn Albrecht after fieldwork in an open-pit coal mining area in Western Australia (Albrecht, 2005, Connor et al., 2004). It has since found growing empirical application in contexts of resource extraction (Canu et al., 2017; Cordial et al., 2012, Elser et al., 2020, Hendryx and Innes-Wimsatt, 2013), natural disasters (Eisenman et al., 2015, Warsini et al., 2014) and climate change (Ellis and Albrecht, 2017, McNamara

and Westoby, 2011, Tschakert et al., 2013), showing that both acute and chronic factors can cause solastalgic distress.

While it is well documented that ecologic disturbance of the home environment can result into solastalgic feelings such as grief, desolation, loss of identity and powerlessness (Clayton et al., 2021, Connor et al., 2004, Tschakert et al., 2019), it is yet unclear to what extend those feelings can escalate into serious mental disorders such as depression or generalized anxiety disorder (Bunz and Mücke, 2017). However, solastalgia seems to be a promising approach to highlight the interdependence of environment integrity, place attachment and human health, which has been recently also acknowledged by the Lancet Commission on Health and Climate Change (Watts et al., 2015) and the American Psychological Association (Clayton et al., 2021).

Most industries in the world depend on minerals and mineral products, and for this reason mining is carried out in nearly every country (International Labour Organization, 2022), often leaving behind a range of environmental and social disturbances (London and Kisting, 2016). The scope, scale and systemic nature of resource extraction (e.g., mining) makes it difficult to comprehensively assess its overall impacts on nature, human health and societies (Parkes et al., 2019).

Wherever large-scale mining takes place, it may become necessary to remove landscapes, farmland, infrastructural facilities and even entire villages. Development projects are assumed to be the second largest cause of resettlement after disasters, displacing around fifteen million people annually (Cernea, 2006). At least one in ten cases of development-induced displacement and resettlement (DIDR) worldwide is due to mining, what is referred to as mining-induced displacement and resettlement (MIDR). Often presented as a problem specific to low- and middle-income countries, MIDR is yet a global phenomenon that also occurs on the European continent (Terminski, 2012).

Given its impactful and often irreversible nature, mining can be expected to disrupt both ecological and social environments with possible consequences on health and life quality. While there is a growing body of research on health and resource extraction, Brisbois and colleagues (2019) describe impacts on mental health and well-being as still “neglected topics“. Moreover, low research priority has been placed on affected communities, compared to workers (Brisbois et al., 2019). Especially in the context of DIDR/MIDR and mental health, there is only little research (Goessling, 2010), focusing predominantly on low- and middle-income counties (Owen and Kemp, 2015, Xi et al., 2013). Our study addresses these research gaps, exploring mental health impacts of environmental degradation and MIDR in Western Germany.

In 2018, Germany was the largest producer of lignite (also known as soft or brown coal) in the world, which has played an important role in shaping the country‘s economic and social structure for decades. It is used almost entirely for domestic power generation (Sandau et al., 2021). Due to political and economic reasons, there has been a slight decline in lignite use during the last years, with national gross electricity generation decreasing from 22.5% in 2018 (AG Energiebilanzen, 2018) to 18.7% in 2021 (AG Energiebilanzen, 2022). Currently, lignite is still mined in three German coal fields, the Rhenish (Rhineland, West Germany), Lusatian (Lusatia, East Germany) and Central German coal fields, in the form of open pits (Federal Ministry for Economic Affairs and Climate Action, 2022).

The climatic and environmental impacts of open-pit mining and coal combustion are regularly analyzed by the German Environment Agency (Umweltbundesamt): this includes high emissions of CO_2 (159 million tonnes/year) and other air pollutants such as dust, methane, mercury, sulphur and nitrogen dioxides, at risk of contaminating soil and water (Sandau et al., 2021). In order to maintain the open-pit mines, groundwater must be pumped out extensively, with far-reaching supraregional impacts on the water balance, water quality and drinking water supply. The land use

by open-pit mines, around 179,402 hectares in total in Germany to date, further impairs local natural and human habitats (Sandau et al., 2021).

The densely populated and intensively industrialized Rhineland is Germany's most important lignite region, covering an area of around 250,000 hectares west of Cologne. Today, three large-scale open-pit mines in the Rhenish region – named Hambach, Garzweiler II and Inden – are still operated (DEBRIV Bundesverband Braunkohle, 2022). Lignite mining in the Rhineland started in the 19th century with less large-scale open-pit mines. After the Second World War in the 1950s, industrial growth in the area has led to an expansion of open-pit mines, while fewer families depended on jobs in the lignite industry (Dickmann, 2011). The acceptance of mining among the local population dropped noticeably in this time. Many local residents were no longer willing to accept the pollution and loss of the highly fertile farmlands, forests, rivers and their homes (Dickmann, 2011). With the emergence of the environmental movement in Germany in the 1980s, this opposition encompassed broader sections of the population (Sandau et al., 2021). Especially in recent years, with a growing population-wide climate change awareness, the conflicts in the coal mining regions have gained new dimensions and stakeholders (Brock and Dunlap, 2018, Willms, 2018).

So far, lignite mining has contributed to the relocation of more than 300 villages (Michel, 2008) with about 120,000 inhabitants in Germany (Pao-Yu et al., 2019), of those 130 villages and 40,000 people in the Rhenish region alone since 1950 (Porada and Castro, 2020). The expropriation of land and property for mining purposes is enabled by the German Federal Mining Act in § 79, making it "admissible in individual cases if it serves the common good", e.g., when it secures the supply of lignite to the market and secures jobs in mining (Federal Ministry of Justice, 2017). The whole resettlement process of a community from the old to a newly built village ("joint resettlement") is supposed to take around 15 years, with 5 years of planning and 10 years of implementation (RWE, 2022c). This long period of time and the involvement of communities in the resettlement planning and process, as intended by the responsible authorities, allows for a certain degree of predictability and control. Willms (2018) describes the relocation process in more detail and explores the reasons for both pre-emptive resettlement and prolonged delay. However, it can be assumed that the socioeconomic, time, physical and mental efforts of relocation, which can involve protracted sales negotiations, the self-organised construction of a new house and leaving behind familiar structures, places and people, are causing considerable distress.

Though the German Bundestag (parliament) has decided in 2020 to phase-down lignite by 2038 at the latest (The Federal Government, 2022), six still partly inhabited villages in the Rhineland remained at risk of relocation for the expansion of existing open-pit mines (at the time of data collection for the present study, mid-2020). Other villages could soon find themselves in closer proximity to the approaching pit edge (MWIDE NRW, 2021).

While studies suggest that both local environmental degradation and forced relocation can contribute to an increase in mental health problems such as depressive disorders (Canu et al., 2017, Hendryx and Innes-Wimsatt, 2013; Speldewinde et al., 2009, Xi et al., 2013), the empirical evidence specific to open-pit mining in Germany has been largely missing. Also, there is a general lack of quantitative data in the area of solastalgia research (Galway et al., 2019). Therefore, the present study aimed to gather and analyze primary quantitative data documenting both possible environmental and resettlement distress due to the expansion of German open-pit mines. We characterized and compared three groups of participants differing in their type of affectedness due to their residential situation (environmental degradation in pit edge villages, additional threat of resettlement in old villages, experienced resettlement in new villages). We investigated to which extent environmental change and forced relocation might be risk factors for psychological distress, namely (i) depressive, (ii) anxious (iii) and somatic symptoms, and whether the concept of solastalgia is applicable to the mining-affected communities in Western Germany.

2. Methods

2.1 Study area and population

A cross-sectional study was conducted between June and July 2021. The study population included local residents of the two active open-pit mines Garzweiler II (further referred to as Garzweiler) and Hambach in the Rhenish lignite region. Study participants had to be at least 18 years old and were required to live or recently have lived (prior to resettlement) in the immediate vicinity of the Garzweiler or Hambach open-pit mine (< 7 km beeline, considered as high disturbance area). This included residents from (i) pit edge villages (not threatened with resettlement), (ii) resettlement threatened villages (further referred to as old villages), and (iii) new settlements (further referred to as new villages; see Fig. 1).

Since 2016, five villages at the Garzweiler open-pit mine (RWE, 2022b) and since 2012, one village at the Hambach open-pit mine (RWE, 2022a) have been resettled to make way for mine developments. The most recently surveyed population census of the relevant villages can be found in Table 1 (City of Erkelenz, 2021, City of Mönchengladbach, 2022), but is subject to constant fluctuation due to resettlements.

Figure 1. Garzweiler open-pit mine with relevant surrounding pit edge, old (framed) and new-built villages ©OpenStreetMap contributors (CC BY-SA 2.0), edited by the authors

2.2 Data collection

For data collection, both online and paper-based versions of the same questionnaire were used in order to reach a large number of the study population regardless of age and media use.

The online questionnaire was generated using SoSci Survey (Leiner, 2021) and was made available to users via www.soscisurvey.de. Participants were recruited via mailing lists and private chat groups (e.g., Facebook, WhatsApp) of village communities and associations as well as via local newspapers, with support from local key stakeholders who shared the study information and access link to the online questionnaire.

Self-administered paper-based questionnaires were distributed by drop-off method to all households in the five old villages and the corresponding five new villages as well as in the pit edge village of Wanlo at the Garzweiler open-pit mine in June 2021. Additionally, paper-based questionnaires were displayed in publicly accessible places in the pit edge villages of Kaulhausen/Venrath (bakery) and Holzweiler (gas station). At the Hambach open-pit mine no active recruitment took place. The questionnaires were mailed back via prepaid envelopes by the end of July.

2.3 Survey structure and development

The questionnaire contained 87 similar items for all respondents and an additional number of items that differed in quantity and content according to the respective residential situation (21 additional items for people in new villages, 20 for people in old villages, 5 for people in pit edge villages). The total 133 items included questions and statements about the following topics:

1. Sociodemographic characteristics: age, gender, level of education, marital status, (grand)children, residential situation (ownership of property, family heritage, ancestry)
2. Environmental hazards: dust, noise, vibration, nocturnal illumination, traffic (five-point Likert scale: nearly always to never); mining damages (yes/no)
3. Place attachment: emotional connection, responsibility for people, desire/duty to preserve the place (five-point Likert scale: strongly agree to strongly disagree)

4. Feelings about changes and solastalgia: general attitude to mining, life satisfaction, economic benefits, fear of illnesses, loss of flora and fauna, building damages, social divisions, powerlessness (five-point Likert scale: strongly agree to strongly disagree)
5. Resettlement process and distress: perceived social, financial, mental and physical impacts (five-point Likert scale: strongly agree to strongly disagree; yes/no)
6. Activities in response to mining or resettlement (yes/no)
7. Patient health questionnaire (PHQ-SADS): symptoms of depression, generalized anxiety and somatization

We extracted and translated into German suitable items from the Environmental Distress Scale (EDS). The EDS was developed and validated by Higginbotham and colleagues after qualitative fieldwork in an open-pit coal mining area in New South Wales, Australia, to monitor the “bio-psycho-social cost of ecosystem disturbance“ (Higginbotham et al., 2006), and has since been applied in further studies (Cunsolo Willox et al., 2012, Eisenman et al., 2015, Warsini et al., 2014). The original EDS contains a subscale measuring solastalgia with nine Likert-type items and explores feelings of grief, concern, longing and belonging in the context of damage to valued environment. We used only six (slightly modified) items due to different local and cultural conditions in Western Germany. We converted each item into a numeric score with responses reflecting the highest level of solastalgic distress coded as five and responses reflecting the lowest level of solastalgic distress coded as one (i.e., strongly agree = 5 and strongly disagree = 1), and only considered questionnaires with all six items answered. Thus, a higher total solastalgia score corresponds to a greater level of solastalgia.

The standard screening tool PHQ-SADS was used to detect levels of psychological distress. It contains a 15-item scale for somatic symptoms (PHQ-15) with a total score ranging from 0 to 30, a 7-item scale for generalized anxiety (GAD-7) with a total score ranging from 0 to 21, and a 9-item scale for depressive disorders (PHQ-9) with a total score ranging from 0 to 27 (Kroenke et al., 2010). Missing responses were coded with 0, assuming that the respective symptom did not occur or apply. Scores of ≥ 5, ≥10, ≥ 15 represent mild, moderate and severe levels of somatization, generalized anxiety or depressive disorders respectively. We classified participants into two groups depending on whether they had at most mild (score 0–9) or at least moderate symptom severity (≥ 10), as it is done in most diagnostic analyses in the use of this screening tool (Kroenke et al., 2010).

Further questions regarding the situation in the Rhenish lignite region were added based on initial site visits and interviews with local residents from all three study groups. For most questions regarding sociodemography, place attachment, felt impacts of change and resettlement, a dichotomization of the Likert scale was performed for analysis. Usually two answers (e.g., strongly agree and agree) were combined and compared with the other three (e.g., neither agree nor disagree, disagree and strongly disagree).

2.4 Analysis

Survey data were analyzed with SAS Software (SAS 9.4, SAS Institute Inc., Cary, NC, USA). After exclusion criteria were applied (n = 29 entries deleted due to no information on residential status, n = 19 entrys deleted due to residence outside the defined mining-affected area), questionnaires from a total of n = 620 participants were included in the analyses (n = 208 online, n = 412 paper-based).

Descriptive analyses were performed for all respondents and categorized by belonging to the group of new villages, old villages or pit edge villages. Chi-Square tests and Kruskal-Wallis H tests were used to describe the distribution of categorical and continuous variables between three study groups. Frequency tables were created for each variable in the Likert scales and dichotomous questions and the overall trends were examined. For associations between the PHQ

scores, solastalgia and the period of resettlement, Pearson correlation coefficient was used. All statistical tests were two-sided, and $p < .05$ was used as the level of significance.

3. Results

3.1 Sample overview

A total of 620 respondents were included in the analyses. Different numbers of questionnaires were returned from each study group: pit edge villages (n = 325), new villages (n = 181), old villages (n = 114). A large majority of 607 respondents (97.9%) originated from the Garzweiler open-pit mine. A more detailed grouping by villages can be seen in Table 1.

The period of time since completed resettlement for new villages' residents was on average 32.8 months (45.1 SD), with a median of 22 months (n = 175).

Table 1
Overview of study participants and population levels at Garzweiler open-pit mine

	study participants	**population levels #**
	n (% of overall population)	n
pit edge villages*	322	
Wanlo	195 (18)	1087
Kaulhausen/Venrath	76 (7)	1146
Holzweiler	48 (3)	1400
others	6	
old villages	112 (21)	540
(Keyenberg, Westrich**, Kuckum, Berverath)		
new villages***	170 (30)	574
(named like old villages with appendix 'neu')		
* respondents from pit edge villages were asked to specify their village to ensure they are located in the mining-affected inclusion area		
** occasionally referred to as two villages (Unterwestrich and Oberwestrich)		
*** including respondents that did not participate in the "joint settlement" to new-built villages but moved elsewhere (11.2%)		
# data from 30.06.2021 (City of Erkelenz 2021), for Wanlo from 31.12.2021 (City of Mönchengladbach 2022)		

3.2 Sociodemographic characteristics

Table 2 gives respondents' sociodemographic characteristics. Respondents from the three groups were similar concerning age, gender, university degree, property ownership, having children or grandchildren in the village, and whether they spent their entire life in this place. However, participants from old villages were less often married or in a partnership (67.6%, vs. 86.7% in new and 81.1% in pit edge villages; $p < .001$), had a longer ancestry (more generations)

in the region (73.6%, vs. 62% in new and 60.5% in pit edge villages; $p < .05$) and rather lived on old family property (63.7%, vs. 50% in new and 41.7% in pit edge villages; $p < .001$).

Table 2
Sociodemographic characteristics, Solastalgia and PHQ scores and correlations

	new villages	old villages	pit edge villages	*p*-Value *
	Sociodemographics			
	mean (SD)			
age	55.7 (15.7)	54.2 (18.1)	53.9 (15.3)	n.s. #
	n = 173	n = 104	n = 301	
	n (%)			
female gender	93 (52.0)	57 (51.4)	177 (55.7)	n.s.
	n = 179	n = 111	n = 318	
marriage or partnership	156 (86.7)	75 (67.6)	261 (81.1)	< .001
	n = 180	n = 111	n = 322	
university degree	32 (18.7)	26 (25.0)	69 (22.9)	n.s.
	n = 171	n = 104	n = 301	
children living in the village	85 (48.3)	53 (46.9)	130 (40.3)	n.s.
	n = 176	n = 113	n = 323	
grandchildren living in the village	27 (15.3)	9 (8.0)	31 (9.6)	n.s.
	n = 176	n = 113	n = 323	
former generations in the region	106 (62.0)	81 (73.6)	188 (60.5)	< .05
	n = 171	n = 110	n = 311	
living on old family property	86 (50.0)	72 (63.7)	131 (41.7)	< .001
	n = 172	n = 113	n = 314	
ownership of residence	158 (89.8)	98 (89.1)	267 (84.8)	n.s.
	n = 176	n = 110	n = 315	
spend entire life in the village	72 (40.9)	56 (50.0)	117 (37.1)	n.s.
	n = 176	n = 112	n = 315	
	Solastalgia (score)			
	mean (SD)			
	n = 170	n = 111	n = 312	
solastalgia	21.19 (7.51)	25.59 (5.81)	25.38 (4.97)	< .001 #
- male	20.09 (7.88)	25.85 (5.73)	24.35 (5.93)	< .001 #
- female	22.34 (6.94)	25.90 (5.27)	26.32 (3.73)	< .001 #

	new villages	old villages	pit edge villages	*p*-Value *
	Patient Health Questionnare (score)			
	mean (SD)			
somatization	6.07 (6.71)	10.28 (7.17)	10.05 (7.04)	< .001 #
- male	6.01 (6.56)	8.69 (6.98)	8.89 (6.86)	< .05 #
- female	6.09 (6.86)	11.98 (6.84)	11.16 (7.03)	< .001 #
generalized anxiety	4.60 (5.91)	8.92 (6.07)	7.32 (6.64)	< .001 #
- male	4.20 (5.24)	7.73 (6.23)	6.22 (5.33)	< .001 #
- female	4.99 (6.50)	10.19 (5.63)	8.37 (5.70)	< .001 #
depression	5.02 (6.48)	7.85 (5.86)	7.35 (6.03)	< .001 #
- male	4.78 (5.98)	7.10 (5.88)	6.50 (6.11)	< .05 #
- female	5.22 (6.96)	8.70 (5.68)	8.19 (5.87)	< .001 #
	Patient Health Questionnare (dichotomized score > 9)			
	n (%)			
somatization > 9	47 (28.0)	58 (52.7)	145 (46.5)	< .001
	n = 168	n = 110	n = 312	
- male	21 (26.3)	24 (46.2)	54 (39.7)	< 0.05
	n = 80	n = 52	n = 136	
- female	25 (29.1)	33 (60.0)	88 (52.4)	< .001
	n = 86	n = 55	n = 168	
generalized anxiety > 9	31 (18.6)	49 (45.4)	96 (31.2)	< .001
	n = 167	n = 108	n = 308	
- male	12 (15.2)	17 (33.3)	30 (22.4)	n.s.
	n = 79	n = 51	n = 134	
- female	19 (22.1)	31 (57.4)	65 (39.2)	< .001
	n = 86	n = 54	n = 166	
depression > 9	35 (20.8)	37 (34.3)	94 (30.3)	< 0.05
	n = 168	n = 108	n = 309	
- male	16 (20.0)	17 (33.3)	33 (24.3)	n.s.
	n = 80	n = 51	n = 135	
- female	18 (20.9)	19 (35.2)	60 (36.1)	< 0.05

	new villages	old villages	pit edge villages	*p*-Value *
	n = 86	n = 54	n = 166	
	Patient Health Questionnare and Solastalgia (correlations)			
	r (n)			
somatization and solastalgia	.54 (166)	.44 (109)	.42 (310)	< .001
generalized anxiety and solastalgia	.51 (165)	.49 (107)	.38 (306)	< .001
depression and solastalgia	.52 (166)	.45 (107)	.35 (307)	< .001
Respondents from new villages were asked to refer to their village prior to resettlement if necessary * chi-square or (#) Kruskal–Wallis H test; SD = standard deviation; n.s. = not significant; r = Pearson correlation coefficient				

Table 2. Sociodemographic characteristics, Solastalgia and PHQ scores and correlations

3.3 Solastalgia and the Patient Health Questionaire (PHQ)

The solastalgia scores (shown in Table 2) differed significantly among the three groups ($p < .001$), with people still living at the open-pit mine in either old villages (25.59, 5.81 SD) or pit edge villages (25.38, 4.97 SD) scoring higher than those already resettled to new villages (21.19, 7.51 SD). These effects remained when data was categorized for male and female ($p < .001$). Within all three groups, female respondents showed higher solastalgia levels than male respondents, while this difference was only marginal for old villages.

The PHQ scores (shown in Table 2) for the three scales of somatic, anxious and depressive symptoms also showed considerable differences between the three groups ($p < .001$), even when categorized by gender ($p < .001$ to $p < .05$). Scores for all three PHQ scales were highest in old villages, followed by pit edge and lastly new villages. This same trend was also found after dichotomization, based on the proportion of respondents with a moderate-to-severe symptom level: At least moderate levels were stated for somatic symptoms by 52.7% of respondents in old villages, 46.5% in pit edge villages and 28% in new villages, for generalized anxiety symptoms by 45.4%, 31.2% and 18.6%, respectively, and for depressive symptoms by 34.3%, 30.3% and 20.8%. Gender-specifically, this effect was only absent for males with at least moderate anxiety or depressive symptoms. Furthermore, proportions for females with at least moderate depressive symptoms were slightly higher in pit edge villages than in old villages. Within the three groups, female respondents presented higher symptom severity than male ones, although these differences were less prominent in the new villages.

Thus, people who still live at the open-pit mine showed higher degrees of mental health problems, namely somatic, depressive and generalized anxiety symptoms, than those who had already resettled.

We detected moderate positive correlations between solastalgia and symptoms of somatization (r = .54 to .43), generalized anxiety (r = .51 to .38) or depression (r = .52 to .35) respectively (all $p < .001$, see Table 2).

Also, the three PHQ symptom scales were highly intercorrelating in the three groups (r = .92 to .72, see suppl.), indicating comorbidity. For people in new villages, no significant correlations between period of time since completed resettlement and solastalgia levels, somatic, anxious or depressive symptoms could be found (r = − .02 to .07, see suppl.).

3.4 Environmental hazards

The frequencies of observed environmental hazards in both groups still living at the open-pit mine were comparatively similar (shown in Figs. 2 and 3). Dust was the most frequently observed hazard (73% of participants in old villages and 82.5% in pit edge villages observed it often to nearly always), followed by noise from the open-pit mine (65.1% and 52.8%) or increased traffic (56.4% and 61.8%). For vibration from the open-pit mine (61.2% in old villages and 43.7% in pit edge villages observed it sometimes to nearly always) and noise from resettlement activities (71.2% in old villages and 87.7% in pit edge villages observed it rarely or never), results varied more between the groups, with the latter being in general seldomly observed.

Moreover, n = 78 people in old villages (70.9%) and n = 137 in pit edge villages (44.5%) said they have experienced mining damages to their house or property.

Figure 2. Frequency of observed environmental hazards in old villages

Figure 3. Frequency of observed environmental hazards in pit edge villages

3.5 Place attachment

Place attachment (see Table 3) was measured in terms of connection to the place, responsibility for the people in the place, and sense of duty to preserve the place, whereby people in new villages were asked to refer to their old place of residence at the open-pit mine. While the majority of people who have not been relocated (yet) still felt deeply connected to their place (73.8% in old and 74.5% in pit edge villages), this feeling was considerably lower among those relocated (39.8%). The felt duty to preserve the place for future generations was higher in pit edge villages (79.1%), compared to old (56.6%) and new villages (16.5%). Noteworthy, responsibility for people in the place was rather low in the two sites affected by resettlement (23.7% in new and 39.8% in old villages), compared to the non-affected pit edge villages (79.1%).

Table 3
Place attachment and feelings about changes caused by open-pit mining

	new villages	old villages	pit edge villages
	n (%)*		
	Place attachment		
I feel a deep connection to that place	68 (39.8%)	79 (73.8%)	228 (74.5%)
	n = 171	n = 107	n = 306
I feel a sense of responsibility for the people in this place	40 (23.7%)	43 (39.8%)	209 (68.3%)
	n = 169	n = 108	n = 306
I feel it is my duty to preserve this place for future	28 (16.5%)	60 (56.6%)	242 (79.1%)
generations	n = 170	n = 106	n = 306
	Positive feelings		
I have understanding for the expansion of the open-pit mine	45 (26.3%)	14 (12.5%)	26 (8.1%)
	n = 171	n = 112	n = 320
Economic benefits of open-pit mining are important	68 (39.5%)	12 (11.0%)	38 (11.9%)
for the region	n = 172	n = 109	n = 320
Funding of community projects by the mining company	86 (50.9%)	23 (21.1%)	56 (17.7%)
is helpful for the region	n = 169	n = 109	n = 317
I am satisfied with efforts of authorities to monitor	47 (27.5%)	10 (9.2%)	24 (7.6%)
environmental impacts	n = 171	n = 109	n = 314
	Negative feelings		
I couldn't enjoy life as much as I would like to because of	51 (29.5%)	79 (70.5%)	159 (50.0%)
the open-pit mine	n = 173	n = 112	n = 318
My community is / was divided by disagreements over the	101 (58.4%)	76 (68.5%)	121 (38.2%)
open-pit mine	n = 173	n = 111	n = 317
My family is / was divided by disagreements over the	17 (9.8%)	20 (18.4%)	35 (10.9%)
open-pit mine	n = 173	n = 109	n = 320
I am upset at the destruction of historic buildings and	105 (61.0%)	97 (87.4%)	286 (89.4%)
landmarks	n = 173	n = 111	n = 320
I am upset at the destruction of natural habitats	114 (65.9%)	95 (85.6%)	293 (91.6%)
	n = 173	n = 111	n = 320
I am disturbed that future generations are not given a	84 (48.6%)	89 (80.2%)	267 (83.7%)
higher priority	n = 173	n = 111	n = 319

	new villages	old villages	pit edge villages
I am concerned that my health may be threatened	65 (38.0%)	79 (71.8%)	237 (75.7%)
	n = 171	n = 110	n = 313
I feel powerless against changes of my homeland	102 (60.0%)	89 (79.5%)	267 (85.0%)
	n = 170	n = 112	n = 314
Respondents from new villages were asked to refer to their village prior to resettlement if necessary * respondes who strongly agree or agree			

3.6 Feelings about changes

The felt impacts of changes caused by the open-pit mine are presented in Table 3.

In general, it can be observed that the understanding for the expansion of the open-pit mine was low in all three groups, but in comparison more than twice as high in new villages (26.3%) compared to old (12.5%) and pit edge villages (8.1%). In new villages, 39.5% agreed that economic benefits are important to the region, and about one in two (50.9%) considered the funding of community projects as helpful, while the latter was only agreed to by around one fifth in old villages (21.1%) and pit edge villages (17.7%). The open-pit mine also seemed to have least impact on life satisfaction in new villages, since only 29.5% reported that due to mining they could not enjoy life as much as they would have liked to, compared to 70.5% in old villages with highest impairment. While satisfaction with authorities to monitor environmental impacts were generally low, people in new villages reported highest satisfaction (27.5%, vs. 9.2% in old and 7.5% in pit edge villages).

However, 38% in new villages were still concerned about mining threatening their health, while this was the case for 71.8% in old villages and 75.7% in pit edge villages. A majority in new villages felt also powerless against changes of their homeland (60%), upset about the destruction of nature (65.9%) and historical sites (61%), while these feelings were even more prominent in the two groups still living at the open-pit mine (8 to 9 out of 10 people agreed on feeling this way).

Interestingly, all respondents seemed more disturbed that future generations are not given a higher priority in the expansion of the open-pit mine (48.6% in new villages, 80.2% in old villages, 83.7% in pit edge villages) than they felt a personal duty to preserve their place for them (see place attachment). Disagreements over mining dividing the community seemed to be most present in the two groups affected by resettlement (58.4% in new villages, 68.5% in old villages). Intra-family conflicts were indicated less often, with highest frequency in in old villages (18.4%).

The pit edge villages group was asked the additional questions of how their living situation was affected by open-pit mining and whether they would leave their village if they could. Interestingly, while 72% stated that their living situation was negatively affected, only 28% would leave the place.

3.7 Resettlement impacts

Regarding the experienced or expected impacts of resettlement, the two affected groups (new villages and old villages) differed in all queried aspects ($p < .001$ to .05; see Table 4), with generally more negative perceptions in old villages.

About one third of respondents in new villages felt physically (36.3%) or psychologically (33%) exhausted by the relocation process, while those numbers where even higher in the old villages (59.3% and 69.7%), especially with

regard to mental exhaustion. Only 8.3% of people in old villages felt well advised by authorities in the resettlement process, compared to 32.2% in new villages. Notably, 53.8% in new villages stated that their general living conditions had improved after relocation. Surprisingly, only 7% in new locations indicated that their professional situation had worsened, while in old locations 30.4% assumed this. Also, more people in old villages anticipated an additional financial burden (71%) than it was experienced by those already resettled (42.7%).

Noteworthily, 30 respondents in old villages had livestock, and only one of them affirmed that the livestock can be kept equally good in the new place. In the larger group of new villages (see 3.1 study overview), only n = 14 people reported having livestock, while four of them (28.6%) said holding conditions remained just as well.

Table 4. Experienced or expected impacts of resettlement

	new villages	**old villages**	p-**Value #**
	n (%)*		
feeling physically exhausted	62 (36.3%)	64 (59.3%)	< 0.05
	n = 171	n = 108	
feeling psychologically exhausted	56 (33.0%)	76 (69.7%)	< .0001
	n = 170	n = 109	
feeling well informed/advised by authorities	55 (32.2%)	9 (8.3%)	< .0001
	n = 171	n = 109	
(expectation of) better general living conditions	92 (53.8%)	18 (16.7%)	< .0001
	n = 171	n = 108	
(fear of) lost contact with cherished people	37 (21.6%)	55 (50.9%)	< .0001
	n = 171	n = 108	
(fear of) extra financial burden	73 (42.7%)	76 (71.0%)	< .0001
	n = 171	n = 107	
(fear of) worse professional situation	12 (7.0%)	31 (30.4%)	< .0001
	n = 170	n = 102	
my pets can be kept equally well	58 (73.4%)	23 (36.5%)	< 0.05
	n = 79	n = 63	
my livestock can be kept equally well	4 (28.6%)	1 (3.3%)	< .0001
	n = 14	n = 30	

* respondents who strongly agree or agree or, for the last two items (pets/livestock), who indicated yes

chi-square test

3.8 Activities

Activity levels (shown in Fig. 4) were highest in old villages, followed by pit edge villages and new villages. For example, more than half of the people in old (57%) and pit edge villages (53%) support citizens' initiatives against open-pit mining, while only one in five resettled persons (21%) stated doing so. Nevertheless, every third person in new villages (33%) had at least once taken part in a demonstration against open-pit mining. People attending village community meetings to discuss the open-pit mining impacts were frequent in all the groups (71% old, 67% pit edge and 61% new villages), while only one third of people in old villages (34%) to one fifth of people in pit edge (19%) and new villages (21%) sought contact with politicians.

Figure 4. Activities in response to open-pit mining

4. Discussion

This cross-sectional study aimed to record psychological distress, as well as solastalgic feelings, linked with open-pit mining in Western Germany. We found high levels of self-reported depressive, anxious and somatic symptoms in all three groups examined (old villages, new villages, pit edge villages) and particularly in female respondents, with participants from old villages being most impaired, followed by pit edge and new villages. To our knowledge, this is the first study to quantitatively assess the links between psychological distress and environmental degradation caused by open-pit mining in Germany.

The study has attracted considerable interest within the study population: Despite the survey length, nearly 95% of the participants reached the last page while almost one third added comments at the end, providing details about their personal situation, further aspects of distress or feedback to the questionnaire. The different numbers of returned questionnaires from our three groups may be caused by varying population levels: most of our potential study participants in the area live in a pit edge village, while the villages affected by resettlement (old and new villages) relate to smaller and more precise groups of people (see Table 1).

Respondents living at the open-pit mine reported high levels of depressive, anxious and somatoform symptoms, with participants from old villages scoring slightly higher compared to respondents from pit edge villages. These findings indicate that the gradual loss of social and community structures and one’s own home and the reconstruction of a new home can create an additional mental burden. However, people in new villages, who are not anymore directly exposed to the open-pit mine or involved in resettlement activities, still showed elevated symptom levels when comparing with general population norms: Whereas in the most recent German population-representative studies that used the PHQ as a screening tool, prevalences for at least moderate symptom severity were 5.6 or 8.1% for depression (Busch et al., 2013, Kocalevent et al., 2013a), 5.9% for generalized anxiety (Hinz et al., 2017a) and 14.9% for somatization (Hinz et al., 2017), we found remarkable levels around twice to 7.5 as high in the open-pit mining-affected communities (see Table 2). However, it can be assumed that up-to-date general population norms for depressive disorders might be higher, and discrepancies with our respondents thus lower, since German health insurance funds reported increases in diagnosed depressions in the past years (Steffen et al., 2020). Yet there is debate about whether this trend is attributable to overall prevalence or other factors, such as coding practice or patients’ help seeking behavior (Bretschneider et al., 2018, Steffen et al., 2020). Also, the COVID-19 pandemic may have contributed to a generally higher mental health burden nowadays. While somecross-sectional studies carried out in the initial pandemic phase in Germany in early 2020 have found an increase in depressive and anxiety-related symptoms, mainly or only in younger and female individuals and those with pre-existing psychiatric disorders (Bäuerle et al., 2020, Peters et al., 2020, Schelhorn et al., 2021), longitudinal research indicated that these effects were rather transient or related to small and already vulnerable groups (Ahrens et al., 2021, Mata et al., 2021). However, so far published research focus mainly on the first lockdown in early 2020, while reliable data on long-lasting mental health

impacts of the pandemic in Germany are yet scarce. Given that our data collection took place in June to July 2021, with very low regional incidences (RKI, 2021) and an ongoing European soccer championship, we consider impacts of COVID-19 on our results to be rather limited.

That female participants report higher depressive, anxious, or somatic symptoms in the PHQ are well-known phenomena from previous research, in the general population (Busch et al., 2013, Hinz et al., 2017, Hinz et al., 2017a, Kocalevent et al., 2013, Tibubos et al., 2021) as well as in the context of experienced environmental disturbances (Casey et al., 2018, Eisenman et al., 2015, Hendryx and Innes-Wimsatt, 2013). Regarding solastalgia research, gender is so far considered an understudied aspect (Galway et al., 2019). Nevertheless, Elser et al. (2020) observed higher solastalgia scores in female individuals, congruent with our findings.

The levels of depressive, anxious, and somatic symptoms should not be equated with prevalence of illness and do not serve as a substitute for accurate diagnostic interviews carried out by qualified professionals. Though scores of moderate symptom severity have shown good sensitivity and specificity in the diagnosis of major depression (Kroenke et al., 2010), more recent studies indicated that self-report screening questionnaires overestimate prevalences for both depression and generalized anxiety compared with diagnostic interviews (Jacobi et al., 2014, Levis et al., 2020). However, given that special barriers to seeking help and care for people with psychological problems exist in rural communities, like culture of self-reliance and lack of anonymity (Boyd and Parr, 2020, Parr and Philo, 2003), our results remain alarming.

Based on our questionnaire, including additional comments of respondents, we identified the following risk factors for psychological distress, without weighting their importance, claiming exhaustiveness or a direct causal relationship: environmental hazards such as dust and noise from open-pit mining operations and resettlement works, fear of ill health from those and other hazards/pollutants, solastalgia due to unwelcomed environmental change, loss of familiar places (home, land, property), negotiation and relocation related stress/workload, community and family divisions and erosions, future uncertainty, felt powerlessness, environmental injustice and political neglect, disturbances from activism, the press and curious public, nostalgia and uprooting. Similar themes of mental distress have been reported by local residents of open-pit mines in Australia, for example regarding personal health, damages to homes, properties, landscapes and community heritage, higher costs of living, changing neigbourhood structures, social pressure caused by mining companies as well as mistrust between supporters and opponents of mining (Albrecht, 2005).

While individual experiences, emotions and reactions are manifold, we observe a trend reflecting the high psychological distress in open-pit mining communities, whether affected by resettlement or not. The mental burden appears to be(come) lower for those that have distanced from the open-pit mine. This observation could be attributed to two different mechanisms. First, it could be based on exposure, ergo moving away from the open-pit mine would provide relief. Second, it could be due to the different characteristics of the two groups, also shedding light on rationales for early resettlement or prolonged stay.

Despite differences between the groups, it is conceivable that a greater day-to-day exposure to open-pit mining and its impacts is the most important driver of psychological distress and solastalgia. These assumptions align with prior published studies that describe adverse effects on the mental health and well-being of local communities exposed to open-pit coal mining (Canu et al., 2017, Hendryx and Innes-Wimsatt, 2013) or other developmental/industrial projects like oil and gas extraction sites (Casey et al., 2018, Hirsch et al., 2018, Mactaggart et al., 2018), petroleum refineries (Luginaah et al., 2002) or waste dumps (Elliott and McClure, 2009). For instance, Hendryx et al. (2013) found that residing in an area where mountaintop removal coal mining is practiced, poses a relative risk for mild and moderate (but not severe) depression, using the PHQ-8 (PHQ-9 with one item less) as a screening tool. A similar conclusion is

reached in the study by Canu et al. (2017), where residents of coal mining counties had about 37% higher odds of being diagnosed with a depressive disorder compared to those in non-mining counties, based on an emergency department database. In contrast to our research, no increased risk for anxiety disorders was found here. Furthermore, it is an inherent feature of the concept of solastalgia, that solastalgic feelings are strongest when people immediately experience the unwelcome change in their homeland (Higginbotham et al., 2006). Thus, solastalgia diminishes when one no longer witnesses how the valued place is negatively transformed, which is consistent with our findings.

Noteworthy, perceiving the open-pit mine as a health threat, what around three quarters of the people living in its vicinity do, and what additionally was very often echoed in the comments, can result in emotional reactions like fear or anxiety. According to the 5-stage stress-coping model from Higginbotham et al. (2006), the further threat appraisal can lead to action- or emotion-based copying and finally adapting. Importantly, this threat appraisal is iterative, so the threat is constantly reassessed and responses vary according to personal situations and resources (Luginaah et al., 2002), which may also explain the decreased threat appraisal of resettlers (i.e. moving away from the open-pit mine as a form of action-based copying). Importantly, the subjective threat appraisal is paramount in generating emotional or psychological distress, rather than the real health risk, which is why nocebo effects may occur, ergo the expectation of illness from mining could already trigger (mental) illness (Hahn, 1997).

Notably, though place of residence was the key distinguishing criterion among the three studied groups, further observed differences may be relevant: Participants from old villages seemed more anchored to their homeland, as measured by longer family roots in the region and rather living on old family property. A congruent observation was made in a coal mining community in Southeastern Australia, where environmental distress, including solastalgia, was related to having a long family heritage in the area and occupying a heritage family home (Higginbotham et al., 2006). Deeper familiar embeddedness may be also one reason why people in old villages apparently considered relocation more difficult by not having completed it yet or by not even having started negotiations. In line with this, more participants in old villages (exactly one in two) have spent their entire lives in their village, compared with respondents from new villages, although these differences were not significant. Moreover, participants from old villages were significantly less likely to be married or in a partnership, which was identified as a sociodemographic correlate for depression in previous research concerning both coal mining affected communities and the general (German) population (Hendryx and Innes-Wimsatt, 2013, Maske et al., 2016).

Perceived poor advisory services from responsible bodies and greater concerns about worse life conditions after resettlement, including financial, professional, and personal circumstances, could be other individual factors shedding light on why resettlement has been more difficult for respondents from old villages so far. Also, a remarkably high rate of participants from old villages claimed having livestock. It is recognized that compensating residents with livestock, and therefore often larger plots, is more challenging for the mining company, since available land is scarce (Morris, 2021).

Moreover, delaying resettlement can be considered as an “act of resistance against the normality of displacement” (Willms, 2018), likely to be “committed” by those who have a more negative perception of the open-pit mine and mining company, felt predominantly upset or disturbed about the destruction of their homeland, nature, buildings or future generations’ perspectives and are more often engaged in activities against mining. Community resistance to mining projects is known to occur more likely when experienced environmental impacts are large, while the level of participation and trust towards responsible institutions are low (Conde and Le Billon, 2017). Individual or collective activities could be coping mechanisms, strengthen self-efficacy and thereby undermine perceived powerlessness (Jenkins and Rondón, 2015, Lubell, 2002). However, it may also be that these activities place an additional time,

physical, and mental burden on involved respondents, and thus contribute to higher PHQ scores (Conner et al., 2021, Jenkins and Rondón, 2015).

Eventually, it is conceivable that resettling may improve community mental health by less exposure to the open-pit mine and its impacts. Conversely, keeping in mind empirical factors of vulnerability (e.g. people from old villages were less capable or willing to leave their homes so far), relocating residents from old villages may also result in persistence of symptoms or further psychosocial impairment. The cross-sectional design of this study does not allow to draw definitive conclusions on this. Given the fact that around half of respondents from new villages stated their living conditions had improved, we suggest that the overall resettlement outcome varies widely. This is further reflected by a majority of resettlement-affected participants (in old and new villages) reporting dividing disagreements over the open-pit mine in their communities.

While it is possible for old villages that resettlement distress contribute more to mental health problems than the mourning for environmental degradation (solastalgia) itself, findings from pit edge villages suggest otherwise: Though demolition of neighbouring villages could have a secondary impact on pit edge villages as well, the approxing open-pit mine and resulting environmental impacts seems to be the single biggest source of distress for them.

4.1 Limitations and future directions

Several limitations of this study should be taken into consideration, the first and foremost of which is its cross-sectional design, which does not allow for causal inference about the role of open-pit mining on the emergence or exacerbation of psychological disorders. A lack of pre-resettlement data makes relocated residents in particular vulnerable to recall and selection bias. Longitudinal surveys would be of interest to assess long-term psychosocial consequences of relocation, as well as of further mining developments, and to allow conclusions about cause-effect relationships.

Second, caution is advised when applying our results to the entire community. Since we could not test for non-response bias, more “environmentally aware“ residents or those disturbed by environmental hazards, mining-induced changes or resettlements, may have completed the long survey. Although we were able to make the questionnaire available to presumably all households in the old and newly-built villages at the Garzweiler open-pit mine, by using the drop-off method, we reached only few of those resettlers who did not participate in the “joint resettlement” but moved elsewhere (applies to approx. 40% of the resettlers; RWE, 2022b). Their perspective, which includes not only changing place of residency, but also leaving behind an entire known neighborhood and community, is underrepresented. Similarly, the views of underage and non-German speaking persons are not reflected in this study. Nevertheless, the high numbers of returned questionnaires allow at least for preliminary representation within the local context. There is a pressing need for more studies focusing on youth, which are in general highly underrepresented in solastalgia research (Galway et al., 2019), even despite evidence suggests that climate change puts a disproportionate psychological burden on younger generations (Hickman et al., 2021).

Third, our questionnaire contained more statements postulating negative than positive feelings about environmental changes and resettlement, hence there could be an acquiescence bias.

Forth, there is a lack of an appropriate control group in this study, without a local coal mining background, but that has comparable regional and socio-cultural characteristics. Thus, observed mining-specific risk factors for mental health remain preliminary.

Lastly, relevant themes may have been missed in our regular questionnaire, as to be assumed by some comments made from participants. Uncertainty about the future was a particularly frequent issue in all three groups. In old villages, respondents were particularly uncertain about whether their villages would be finally excavated or could be preserved, in the light of recent or expected political developments and power shifts. In new villages, a few participants expressed a desire to preserve their old villages, while many described the thought of strangers reoccupying their former homes as an enormous emotional burden, knowing that their resettlement would then have been unnecessary. The new German government's decision in November 2021 to preserve the old villages at the Garzweiler open-pit mine after all (The Federal Government, 2021) is thus likely to be a curse for some and a blessing for others. Beyond that, the feeling of being subject to environmental and political injustice cropped up in the comments. In new villages, benefits of relocation such as more age-appropriate and refurbished homes were further mentioned in the comments, but also burdens of living on a large construction site for many years, limited recreational activities and less access to green spaces. For the elderly, resettling was described as particularly stressful, given physical decline in later life, and familiarisation with the new village as disproportionally difficult, which is why an age-specific analysis of resettlement effects would be useful in future studies. Also, lacking safety due to burglaries in abandoned neighboring houses was mentioned in old villages. Perceived disturbances by the presence of activists, security forces, the press or curious onlookers (referred to as "ghost village tourists") in old villages were also commented on several times. Concerns about climate change and the perception that it is being fueled at one's doorstep were further described. The latter suggests that the proximate environmental changes are not the only source of worry, but rather accompanied by awareness for farther-reaching, global consequences of burning coal, possibly triggering eco-anxiety or ecological grief (Comtesse et al., 2021). Employment dependencies with the mining company or related corporates could have been moreover queried, since employees are less likely to criticize a project which is the direct or indirect source of their income (Willms, 2018). Also, inquiring about the precise progress of the resettlement process (e.g. no contact with the open-pit mining company yet vs. in sales negotiations vs. already acquired new land vs. building/arranging new home) could have further been revealing. Moreover, information about existing psychological diagnoses or substance use, known to be more frequent in mining than non-mining-communities (Canu et al., 2017), could provide a more detailed picture of mental health conditions in our study population. Those additional themes and characteristics could further contextualize the study findings and should therefore be focused on in future research.

5. Conclusions

Mining has displaced millions of people worldwide and created great tensions in local populations and throughout society. The findings of this study suggest, that both environmental degradation and (upcoming) resettlement pose risks for depressive, anxious and somatic disorders, on local communities in a Western German coal mining region.

Thus, the legitimacy of moving and altering villages for coal should not only be an environmental and climatic, but also a public mental health debate. Our data indicate a need to allocate targeted psychosocial support services for affected local communities. The links between environmental degradation and mental health are of particular interest to researchers and professionals in the environmental and psychosocial sector, given that this field is still emerging and only partially understood. Also, our findings could have policy implications, and stimulate changes in industry and government decision-making and priority setting, for the benefit of local residents. This study reveals many still unanswered questions, showing a pressing need for well designed prospective studies to describe and quantify the (mental) health harms related to coal mining and burning and the societal costs of these negative externalities.

Albeit drawing upon a German case study, we argue the present findings have international relevance, since large infrastructure projects continue to be implemented until today, disrupting natural and human habitats and causing

DIDR (Pearce, 2020), while the accelerating man-made climate change will presumably increase solastalgia worldwide.

Declarations

Author Contributions: Conceptualization, T.Kru. and A.K.; Methodology, T.Kru. and A.K.; Formal Analysis, T.Kru. and A.K.; Resources, T.Kru.; Writing - Original Draft Preparation, T.Kru.; Writing—Review & Editing, T.Kru, T.Kra. and A.K.; Supervision, A.K. All authors have read and agreed to the published version of the manuscript.

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Ethics approval and consent to participate: Ethical approval for the study was obtained from the local Human Research Ethics Committee of the RWTH Aachen University Faculty of Medicine (EK104-21). Informed consent was obtained from all subjects involved in the study. Information about where to seek psychological support should participation in the survey cause distress was provided to respondents.

Consent for publication: Not applicable.

Availability of data and material: The datasets used and analysed during the current study are available from the corresponding author upon request.

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References

1. AG Energiebilanzen, 2018. Gross electricity generation in Germany 2017. Retrieved January 24, 2022, from https://www.bmwi.de/Redaktion/DE/Downloads/I/Infografiken/bruttostromerzeugung
2. -in-deutschland.pdf
3. AG Energiebilanzen, 2022. Gross electricity production in Germany from 2019 to 2021. Retrieved January 24, 2022, from https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Energy/Production/Tables/gross-electricity-production.html
4. Ahrens, K., Neumann, R., Kollmann, B., Brokelmann, J., Von Werthern, N., Malyshau, A., Weichert, D., Lutz, B., Fiebach, C., Wessa, M., Kalisch, R., Plichta, M., Lieb, K., Tüscher, O., Reif, A., 2021. Impact of COVID-19 lockdown on mental health in Germany: longitudinal observation of different mental health trajectories and protective factors. Translational psychiatry, 11(1), 1–10. https://doi.org/10.1038/s41398-021-01508-2
5. Albrecht, G., 2005. 'Solastalgia'. A new concept in health and identity. PAN: Philosophy Activism Nature, 3, 41–55. Retrieved January 24, 2022, from https://search.informit.org/doi/abs/10.3316/informit.897723015186456
6. Albrecht, G., Sartore, G.-M., Connor, L., Higginbotham, N., Freeman, S., Kelly, B., Stain, H., Tonna, A., Pollard, G., 2007. Solastalgia: the distress caused by environmental change. Australasian psychiatry 15 (sup1), 95–98.

https://doi.org/10.1080/10398560701701288

7. Bäuerle, A., Teufel, M., Musche, V., Weismüller, B., Kohler, H., Hetkamp, M., Dörrie, N., Schweda, A., Skoda, E.-M., 2020. Increased generalized anxiety, depression and distress during the COVID-19 pandemic: a cross-sectional study in Germany. Journal of Public Health, 42(4), 672–678. https://doi.org.10.1093/pubmed/fdaa106
8. Boyd, C. P., Parr, H., 2020. Climate change and rural mental health: a social geographic perspective. Rural and Remote Health, 20(4), p. 6337. https://doi.org.10.22605/rrh6337
9. Bretschneider, J., Janitza, S., Jacobi, F., Thom, J., Hapke, U., Kurth, T., Maske, U. E., 2018. Time trends in depression prevalence and health-related correlates: results from population-based surveys in Germany 1997–1999 vs. 2009–2012. BMC psychiatry, 18(1), 1–13. https://doi.org/10.1186/s12888-018-1973-7
10. Brisbois, B. W., Reschny, J., Fyfe, T. M., Harder, H. G., Parkes, M. W., Allison, S., Buse, C. G., Fumerton, R., Oke, B., 2019. Mapping research on resource extraction and health: A scoping review. The Extractive Industries and Society, 6(1), 250–259. https://doi.org/10.1016/j.exis.2018.10.017
11. Brock, A., Dunlap, A., 2018. Normalising corporate counterinsurgency: Engineering consent, managing resistance and greening destruction around the Hambach coal mine and beyond. Political Geography, 62, 33–47. https://doi.org/10.1016/j.polgeo.2017.09.018
12. Bunz, M. Mücke, H.-G., 2017. Klimawandel – physische und psychische Folgen. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz, 60(6), 632–639. https://doi.org/10.1007/s00103-017-2548-3
13. Busch, M. A., Maske, U. E., Ryl, L., Schlack, R., Hapke, U., 2013. Prävalenz von depressiver Symptomatik und diagnostizierter Depression bei Erwachsenen in Deutschland. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz, 56(5–6), 733–739. https://doi.org/10.1007/s00103-013-1688-3
14. Canu, W. H., Jameson, J. P., Steele, E. H., Denslow, M., 2017. Mountaintop removal coal mining and emergent cases of psychological disorder in Kentucky. Community mental health journal, 53(7), 802–810. https://doi.org/10.1007/s10597-017-0122-y
15. Casey, J. A., Wilcox, H. C., Hirsch, A. G., Pollak, J., Schwartz, B. S., 2018. Associations of unconventional natural gas development with depression symptoms and disordered sleep in Pennsylvania. Scientific reports, 8(1), 1–10. https://doi.org/10.1038/s41598-018-29747-2
16. Cernea, M., 2006. Development-induced and conflict-induced IDPs: bridging the research divide. Forced Migration Review, 261, 25–27. Retrieved January 24, 2022, from https://www.fmreview.org/brookings/cernea
17. City of Erkelenz, 2021. Population development 2021 - Population status as of 30.06.2021. Retrieved January 24, 2022, from https://www.erkelenz.de/tourismus-kultur-sport-freizeit/stadtportrait/bevoelkerungsentwicklung
18. City of Mönchengladbach, 2022. Population structure - population by city districts and neighbourhoods on 31.12.2021. Retrieved January 24, 2022, from https://www.moenchengladbach.de/de/rathaus/buergerinfo-a-z/planen-bauen-mobilitaet-umwelt-dezernat-vi/fachbereich-stadtentwicklung-und-planung-61/abteilung-statistik-und-informationsmanagement-handlungsfeld-wohnen/statistik-und-informationsmanagement
19. Clayton, S., Manning, C., Krygsman, K., Speiser, M., 2021. Mental health and our changing climate: Impacts, implications, and guidance. Washington, DC: American Psychological Association and ecoAmerica. Retrieved January 24, 2022, from https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf
20. Comtesse, H., Ertl, V., Hengst, S. M. C., Rosner, R., Smid, G. E., 2021. Ecological Grief as a Response to Environmental Change: A Mental Health Risk or Functional Response?. International journal of environmental research and public health, 18(2), p. 734. https://doi.org/10.3390/ijerph18020734
21. Conde, M., Le Billon, P., 2017. Why do some communities resist mining projects while others do not?. The Extractive Industries and Society, 4(3), 681–697. https://doi.org/10.1016/j.exis.2017.04.009

22. Conner, J. O., Crawford, E., Galioto, M., 2021. The mental health effects of student activism: Persisting despite psychological costs. Journal of Adolescent Research, 07435584211006789. https://doi.org/10.1177/07435584211006789
23. Connor, L., Albrecht, G., Higginbotham, N., Freeman, S., Smith, W., 2004. Environmental change and human health in Upper Hunter communities of New South Wales, Australia. EcoHealth, 1(2), SU47-SU58. https://doi.org/10.1007/s10393-004-0053-2
24. Cordial, P., Riding-Malon, R., Lips, H., 2012. The effects of mountaintop removal coal mining on mental health, well-being, and community health in Central Appalachia. Ecopsychology, 4(3), 201–208. https://doi.org/10.1089/eco.2012.0032
25. Cunsolo Willox, A., Harper, S. L., Ford, J. D., Landman, K., Houle, K., Edge, V. L., 2012. "From this place and of this place:" Climate change, sense of place, and health in Nunatsiavut, Canada. Social science & medicine, 75(3), 538–547. https://doi.org/10.1016/j.socscimed.2012.03.043
26. DEBRIV Bundesverband Braunkohle, 2022. Overview and history of the mining districts. Retrieved January 24, 2022, from https://braunkohle.de/braunkohle-in-deutschland/uebersicht-und-geschichte-der-reviere
27. Dickmann, F., 2011. Reclamation conditions of opencast mining in the Rhenish Lignite-mining Region (Germany). Zeitschrift fur Geomorphologie, supplementary issues, 55(1), 15–24. https://doi.org/10.1127/0372-8854/2011/0055S1-0034
28. Eisenman, D., McCaffrey, S., Donatello, I., Marshal, G., 2015. An ecosystems and vulnerable populations perspective on solastalgia and psychological distress after a wildfire. EcoHealth, 12(4), 602–610. https://doi.org/10.1007/s10393-015-1052-1
29. Elliott, S. J., McClure, J., 2009. "There's just hope that no one's health is at risk": residents' reappraisal of a landfill siting. Journal of Environmental Planning and Management, 52(2), 237–255. https://doi.org/10.1080/09640560802666578
30. Ellis, N. R., Albrecht, G. A., 2017. Climate change threats to family farmers' sense of place and mental wellbeing: A case study from the Western Australian Wheatbelt. Social science & medicine, 175, 161–168. https://doi.org/10.1016/j.socscimed.2017.01.009
31. Elser, H., Goldman-Mellor, S., Morello-Frosch, R., Deziel, N. C., Ranjbar, K., Casey, J. A., 2020. Petro-riskscapes and environmental distress in West Texas: Community perceptions of environmental degradation, threats, and loss. Energy Research & Social Science, 70, 101798. https://doi.org/10.1016/j.erss.2020.101798
32. Federal Ministry for Economic Affairs and Climate Action, 2022. Coal. Retrieved January 24, 2022, from https://www.bmwi.de/Redaktion/EN/Artikel/Energy/coal.html
33. Federal Ministry of Justice, 2017. Federal Mining Act. Retrieved January 24, 2022 from https://www.gesetze-im-internet.de/englisch_bbergg/englisch_bbergg.html#p0278
34. Galway, L. P., Beery, T., Jones-Casey, K., Tasala, K., 2019. Mapping the solastalgia literature: A scoping review study. International journal of environmental research and public health, 16(15), 2662. https://doi.org/10.3390/ijerph16152662
35. Goessling, K. P., 2010. Mining Induced Displacement and Mental Health: A Call for Action. International Journal for the Advancement of Counselling, 32(3), 153–164. https://doi.org/10.1007/s10447-010-9096-y
36. Hahn, R. A., 1997. The nocebo phenomenon: concept, evidence, and implications for public health. Preventive medicine, 26(5), 607–611. https://doi.org/10.1006/pmed.1996.0124
37. Hendryx, M., Innes-Wimsatt, K. A., 2013. Increased risk of depression for people living in coal mining areas of central Appalachia. Ecopsychology, 5(3), 179–187. https://doi.org/10.1089/eco.2013.0029

38. Hickman, C., Marks, E., Pihkala, P., Clayton, S., Lewandowski, R. E., Mayall, E. E., Wray, B., Mellor, C., van Susteren, L., 2021. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. The Lancet Planetary Health, 5(12), e863-e873. https://doi.org/10.1016/S2542-5196(21)00278-3
39. Higginbotham, N., Connor, L., Albrecht, G., Freeman, S., Agho, K., 2006. Validation of an environmental distress scale. EcoHealth, 3(4), 245–254. https://doi.org/10.1007/s10393-006-0069-x
40. Hinz, A., Ernst, J., Glaesmer, H., Brähler, E., Rauscher, F. G., Petrowski, K., Kocalevent, R.-D., 2017. Frequency of somatic symptoms in the general population: Normative values for the Patient Health Questionnaire-15 (PHQ-15). Journal of psychosomatic research, 96, 27–31. https://doi.org/10.1016/j.jpsychores.2016.12.017
41. Hinz, A., Klein, A. M., Brähler, E., Glaesmer, H., Luck, T., Riedel-Heller, S. G., Wirkner, K., Hilbert, A., 2017a. Psychometric evaluation of the Generalized Anxiety Disorder Screener GAD-7, based on a large German general population sample. Journal of affective disorders, 210, 338–344. https://doi.org/10.1016/j.jad.2016.12.012
42. Hirsch, J. K., Smalley, K. B., Selby-Nelson, E. M., Hamel-Lambert, J. M., Rosmann, M. R., Barnes, T. A., Abrahamson, D., Meit, S. C., GreyWolf, I., Beckmann, S., 2018. Psychosocial impact of fracking: a review of the literature on the mental health consequences of hydraulic fracturing. International Journal of Mental Health and Addiction, 16(1), 1–15. https://doi.org/10.1007/s11469-017-9792-5
43. International Labour Organization, 2022. Mining (coal; other mining) sector. Retrieved January 24, 2022 from https://www.ilo.org/global/industries-and-sectors/mining/lang–en/index.htm
44. Jacobi, F., Höfler, M., Strehle, J., Mack, S., Gerschler, A., Scholl, L., Busch, M. A., Maske, U., Hapke, U., Gaebel, W., Maier, W., Wagner, M., Zielasek, J., Wittchen, H.-U., 2014. Psychische Störungen in der Allgemeinbevölkerung. Der Nervenarzt, 85(1), 77–87. https://doi.org/10.1007/s00115-013-3961-y
45. Jenkins, K., Rondón, G., 2015. 'Eventually the mine will come': women anti-mining activists' everyday resilience in opposing resource extraction in the Andes. Gender & Development, 23(3), 415–431. https://doi.org/10.1080/13552074.2015.1095560
46. Kocalevent, R.-D., Hinz, A., Brähler, E., 2013. Standardization of a screening instrument (PHQ-15) for somatization syndromes in the general population. BMC psychiatry, 13(1), 1–8. https://doi.org/10.1186/1471-244X-13-91
47. Kocalevent, R.-D., Hinz, A., Brähler, E., 2013a. Standardization of the depression screener patient health questionnaire (PHQ-9) in the general population. General hospital psychiatry, 35(5), 551–555. https://doi.org/10.1016/j.genhosppsych.2013.04.006
48. Kroenke, K., Spitzer, R. L., Williams, J. B., Löwe, B., 2010. The patient health questionnaire somatic, anxiety, and depressive symptom scales: a systematic review. General hospital psychiatry, 32(4), 345–359. https://doi.org/10.1016/j.genhosppsych.2010.03.006
49. Leiner, D. J., 2021. SoSci Survey (Version 3.2.32) [Computer software]. https://www.soscisurvey.de
50. Levis, B., Benedetti, A., Ioannidis, J. P., Sun, Y., Negeri, Z., He, C., Wu, Y., (… Thombs, B. D, 2020. Patient Health Questionnaire-9 scores do not accurately estimate depression prevalence: individual participant data meta-analysis. Journal of clinical epidemiology, 122, 115–128. https://doi.org/10.1016/j.jclinepi.2020.02.002
51. London, L., Kisting, S., 2016. The extractive industries: can we find new solutions to seemingly intractable problems?. NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 25(4), 421–430. https://doi.org/10.1177/1048291115622222
52. Lubell, M., 2002. Environmental activism as collective action. Environment and Behavior, 34(4), 431–454. https://doi.org/10.1177/00116502034004002

53. Luginaah, I. N., Taylor, S. M., Elliott, S. J., Eyles, J. D. 2002. Community reappraisal of the perceived health effects of a petroleum refinery. Soc Sci Med, 55(1), 47–61. https://doi.org/10.1016/S0277-9536(01)00206-4
54. Mactaggart, F., McDermott, L., Tynan, A., Gericke, C. A., 2018. Exploring the determinants of health and wellbeing in communities living in proximity to coal seam gas developments in regional Queensland. BMC public health, 18(1), 1–13. https://doi.org/10.1186/s12889-017-4568-1
55. Maske, U. E., Buttery, A. K., Beesdo-Baum, K., Riedel-Heller, S., Hapke, U., Busch, M. A., 2016. Prevalence and correlates of DSM-IV-TR major depressive disorder, self-reported diagnosed depression and current depressive symptoms among adults in Germany. Journal of affective disorders, 190, 167–177. https://doi.org/10.1016/j.jad.2015.10.006
56. Mata, J., Wenz, A., Rettig, T., Reifenscheid, M., Möhring, K., Krieger, U., Friedel, S., Fikel, M., Cornesse, C., Blom, A. G., Naumann, E., 2021. Health behaviors and mental health during the COVID-19 pandemic: A longitudinal population-based survey in Germany. Social science & medicine, 287, 114333. https://doi.org/10.1016/j.socscimed.2021.114333
57. McNamara, K. E., Westoby, R., 2011. Solastalgia and the gendered nature of climate change: An example from Erub Island, Torres Strait. EcoHealth, 8(2), 233–236. https://doi.org/10.1007/s10393-011-0698-6
58. Michel, J. H., 2008. Status and impacts of the German lignite industry. Swedish NGO Secretariat on Acid Rain, Air pollution and climate series, 18, 17. Retrieved January 24, 2022, from https://www.airclim.org/sites/default/files/documents/APC18SE.pdf
59. Morris, L., 2021. Germany portrays itself as a climate leader. But it's still razing villages for coal mines. Retrieved January 24, 2022, from https://www.washingtonpost.com/world/2021/10/23/germany-coal-climate-cop26
60. MWIDE NRW, 2021. Lead decision 2021: New perspectives for the Rhenish lignite mining region. Retrieved 24 January, 2022, from https://www.wirtschaft.nrw/sites/default/files/asset/document/leitentscheidung_2021_0.pdf
61. Owen, J. R., Kemp, D., 2015. Mining-induced displacement and resettlement: a critical appraisal. Journal of Cleaner Production, 87, 478–488. https://doi.org/10.1016/j.jclepro.2014.09.087
62. Pao-Yu, O., Brauers, H., Herpich, P., Hirschhausen, C. v., Prahl, A., Wehnert, T., (… Kemfert, C., 2019. Die Beendigung der energetischen Nutzung von Kohle in Deutschland: ein Überblick über Zusammenhänge, Herausforderungen und Lösungsoptionen. Retrieved January 24, 2022, from https://epub.wupperinst.org/frontdoor/index/index/docId/7231
63. Parkes, M. W., Allison, S., Harder, H. G., Hoogeveen, D., Kutzner, D., Aalhus, M., (… Vaillancourt, C., 2019. Addressing the Environmental, Community, and Health Impacts of Resource Development: Challenges across Scales, Sectors, and Sites. Challenges, 10(1), 22. https://doi.org/10.3390/challe10010022
64. Parr, H., Philo, C., 2003. Rural mental health and social geographies of caring. Social & Cultural Geography, 4(4), 471–488. https://doi.org/10.1080/1464936032000137911
65. Pearce, F., 2020. A Major Oil Pipeline Project Strikes Deep at the Heart of Africa. Retrieved 24 January, 2022, from https://e360.yale.edu/features/a-major-oil-pipeline-project-strikes-deep-at-the-heart-of-africa
66. Peters, A., Rospleszcz, S., Greiser, K. H., Dallavalle, M., Berger, K., 2020. The Impact of the COVID-19 Pandemic on Self-Reported Health: Early Evidence From the German National Cohort. Deutsches Ärzteblatt International, 117(50), 861–867. https://doi.org/10.3238/arztebl.2020.0861
67. Porada, H., Castro, P., 2020. Resettling Villages, Unsettling Lives. Green European Journal. Retrieved January 24, 2022, from https://www.greeneuropeanjournal.eu/resettling-villages-unsettling-lives

68. RKI, 2021. Daily situation report of the Robert Koch Institute on COVID-19 (page 4). Retrieved January 24, 2022, from https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/Jun_2021/2021-06-29-de.pdf?__blob=publicationFile
69. RWE, 2022a. Framework data of the resettlement site Manheim, City of Kerpen. Retrieved January 24, 2022, from https://www.rwe.com/nachbarschaft/rwe-vor-ort/umsiedlung/rahmendaten-manheim
70. RWE, 2022b. Framework data of the resettlement sites Keyenberg, Kuckum, Unter-/Oberwestrich and Berverath. Retrieved January 24, 2022, from https://www.rwe.com/nachbarschaft/rwe-vor-ort/umsiedlung/rahmendaten-keyenberg
71. RWE, 2022c. Planning and implementation of the resettlement. Retrieved January 24, 2022, from https://www.rwe.com/nachbarschaft/rwe-vor-ort/umsiedlung/planung-und-durchfuehrung
72. Sandau, F., Timme, S., Baumgarten, C., (… Wintermeyer, D., 2021. Facts and figures on lignite and hard coal: Status and prospects 2021. German Environment Agency (UBA), 28/2021. Retrieved January 24, 2022, from https://inis.iaea.org/collection/NCLCollectionStore/_Public/52/097/52097885.pdf
73. Schelhorn, I., Ecker, A., Lüdtke, M. N., Rehm, S., Tran, T., Bereznai, J. L., (… Shiban, Y., 2021. Psychological Burden During the COVID-19 Pandemic in Germany. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.640518
74. Speldewinde, P. C., Cook, A., Davies, P., Weinstein, P., 2009. A relationship between environmental degradation and mental health in rural Western Australia. Health & Place, 15(3), 880–887. https://doi.org/10.1016/j.healthplace.2009.02.011
75. Steffen, A., Thom, J., Jacobi, F., Holstiege, J., Bätzing, J., 2020. Trends in prevalence of depression in Germany between 2009 and 2017 based on nationwide ambulatory claims data. Journal of affective disorders, 271, 239–247. https://doi.org/10.1016/j.jad.2020.03.082
76. Terminski, B., 2012. Mining-induced displacement and resettlement: social problem and human rights issue. SSOAR. Retrieved January 24, 2022, from https://nbn-resolving.org/urn:nbn:de:0168-ssoar-327774
77. The Federal Government, 2021. Coalition Agreement 2021–2025 between the Social Democratic Party of Germany (SPD), Alliance 90/The Greens (BÜNDNIS 90 / DIE GRÜNEN) and the Free Democratic Party (FDP) (page 59). Retrieved January 24, 2022, from https://www.bundesregierung.de/resource/blob/974430/1990812/04221173eef9a6720059cc353d759a2b/2021-12-10-koav2021-data.pdf
78. The Federal Government, 2022. Ending coal-generated power. Retrieved January 24, 2022, from https://www.bundesregierung.de/breg-en/news/kohleausstiegsgesetz-1717014
79. Tibubos, A. N., Otten, D., Zöller, D., Binder, H., Wild, P. S., Fleischer, T., (… Beutel, M. E., 2021. Bidimensional structure and measurement equivalence of the Patient Health Questionnaire-9: sex-sensitive assessment of depressive symptoms in three representative German cohort studies. BMC psychiatry, 21(1), 1–13. https://doi.org/10.1186/s12888-021-03234-x
80. Tschakert, P., Ellis, N. R., Anderson, C., Kelly, A., Obeng, J., 2019. One thousand ways to experience loss: A systematic analysis of climate-related intangible harm from around the world. Global Environmental Change, 55, 58–72. https://doi.org/10.1016/j.gloenvcha.2018.11.006
81. Tschakert, P., Tutu, R., & Alcaro, A., 2013. Embodied experiences of environmental and climatic changes in landscapes of everyday life in Ghana. Emotion, Space and Society, 7, 13–25. https://doi.org/10.1016/j.emospa.2011.11.001
82. Warsini, S., Buettner, P., Mills, J., West, C., Usher, K., 2014. The psychosocial impact of the environmental damage caused by the MT Merapi eruption on survivors in Indonesia. EcoHealth, 11(4), 491–501.

https://doi.org/10.1007/s10393-014-0937-8

83. Watts, N., Adger, W. N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., (… Costello, A., 2015 Health and climate change: policy responses to protect public health. The Lancet, 386(10006), 1861–1914. https://doi.org/10.1016/S0140-6736(15)60854-6
84. Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., de Souza Dias, B. F., (… Yach, D., 2015. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. The Lancet, 386(10007), 1973–2028. https://doi.org/10.1016/S0140-6736(15)60901-1
85. Willms, A., 2018. Moving Villages for Coal: A German case study. The State of Environmental Migration 2018: A review of 2017, 163–188. Retrieved January 24, 2022, from http://labos.ulg.ac.be/hugo/wp-content/uploads/sites/38/2017/11/01-SEM2018_30oct_18h_HD_Final-version_compressed.pdf
86. Xi, J., Hwang, S.-S., Drentea, P., 2013. Experiencing a forced relocation at different life stages: the effects of China's three gorges project–induced relocation on depression. Society and Mental Health, 3(1), 59–76. https://doi.org/10.1177/2156869312458291

Figures

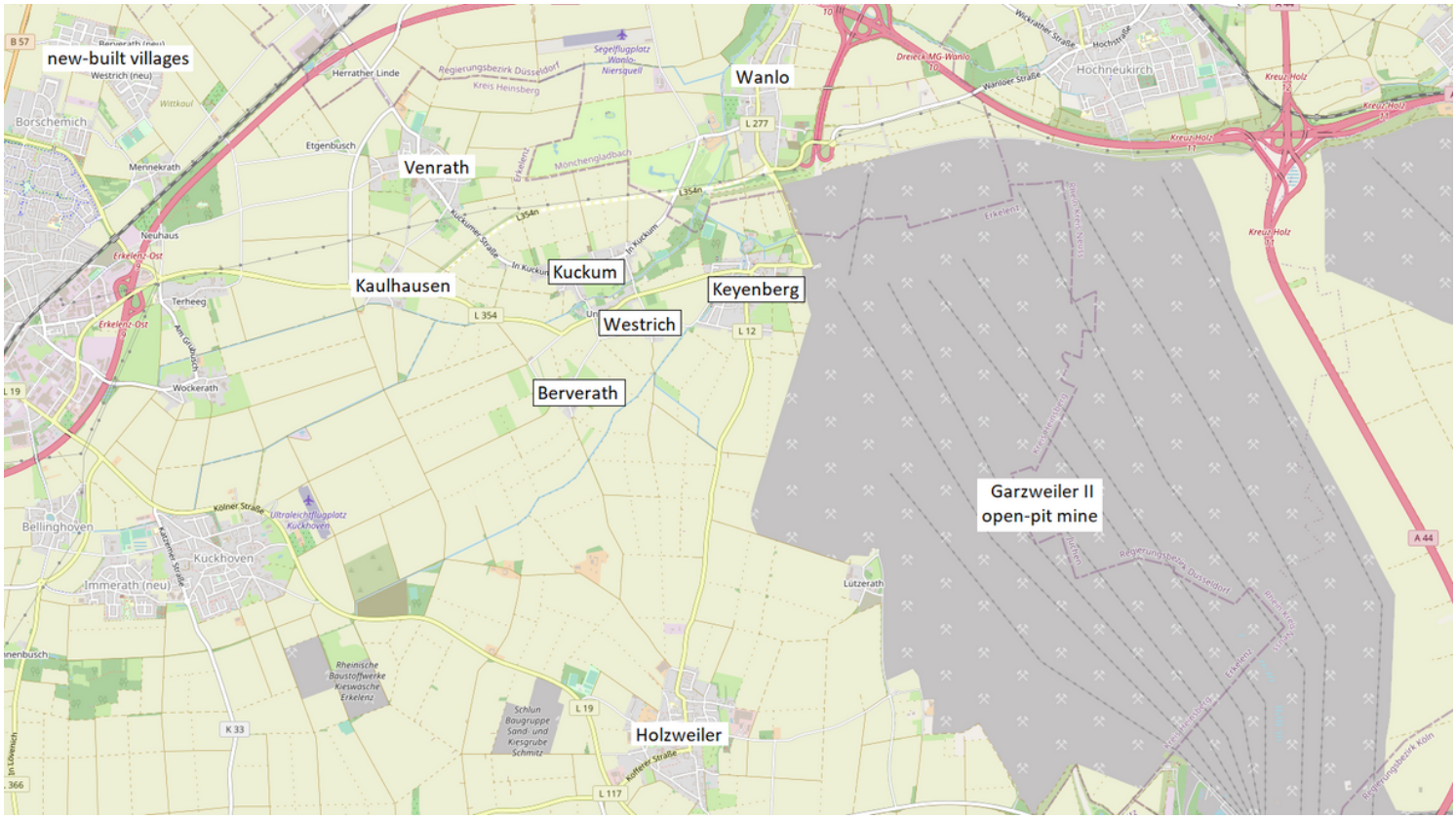

Figure 1

Garzweiler open-pit mine with relevant surrounding pit edge, old (framed) and new-built villages ©OpenStreetMap contributors (CC BY-SA 2.0), edited by the authors

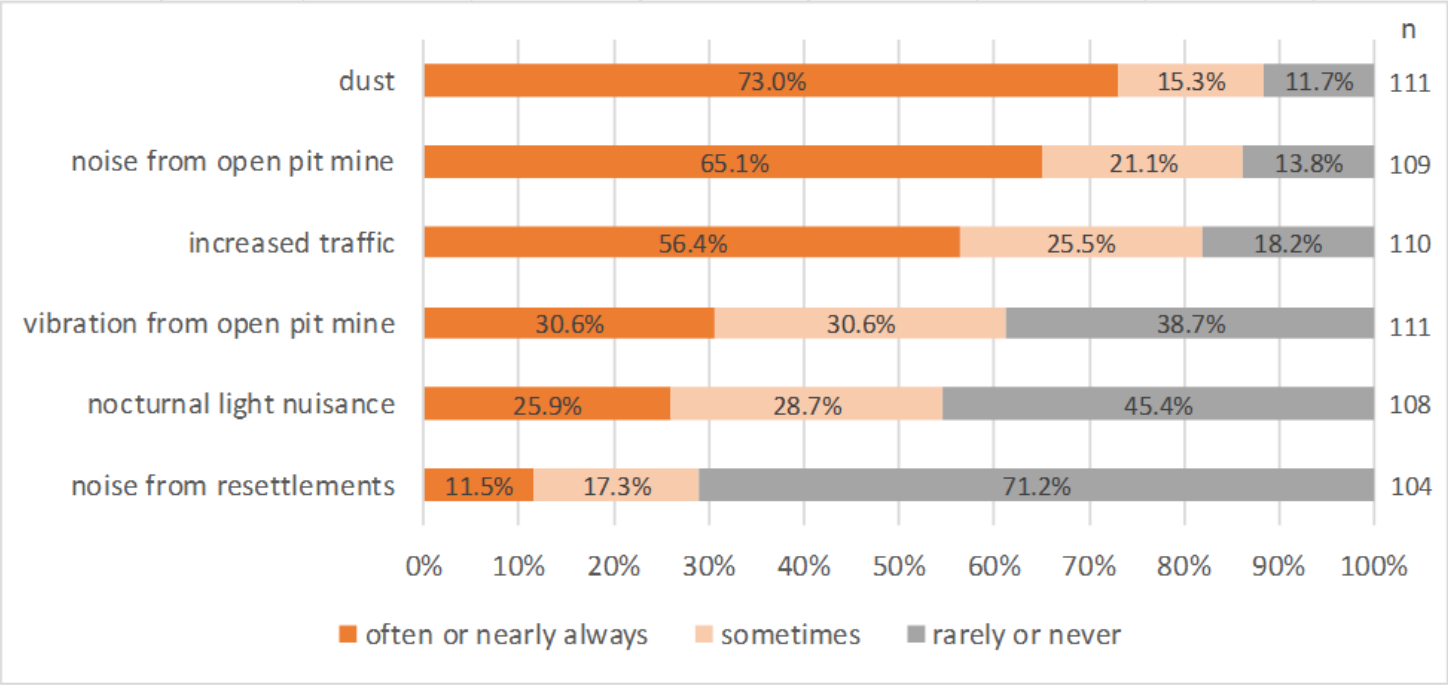

Figure 2

Frequency of observed environmental hazards in old villages

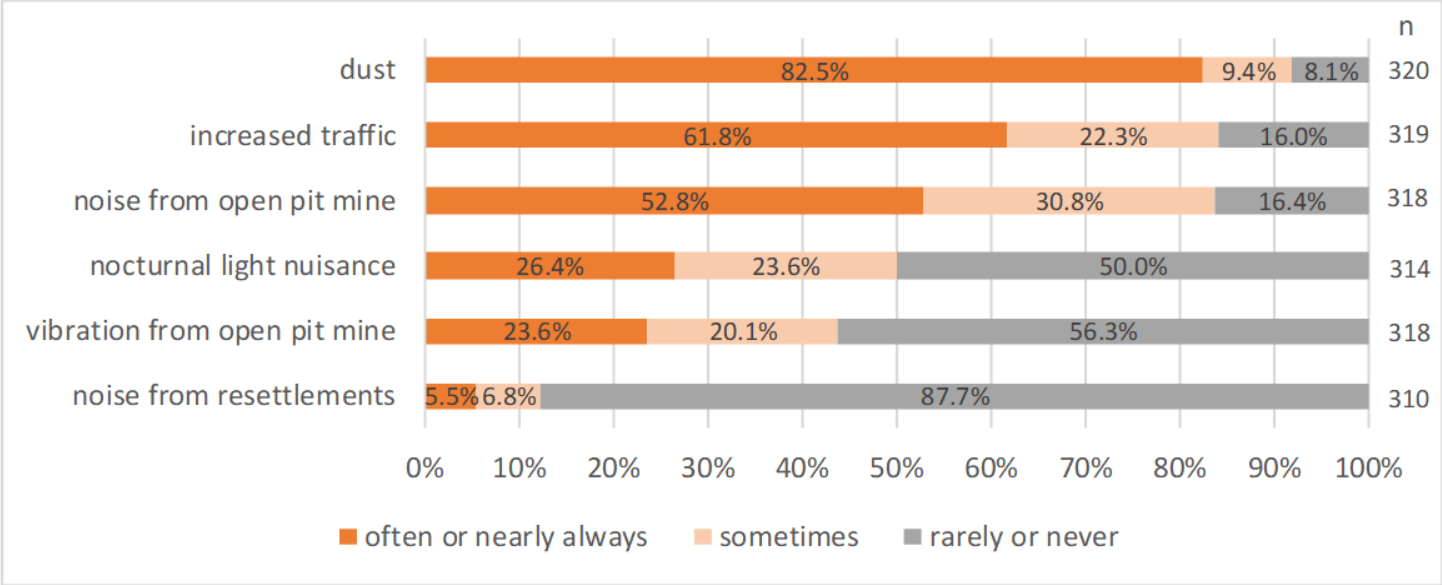

Figure 3

Frequency of observed environmental hazards in pit edge villages

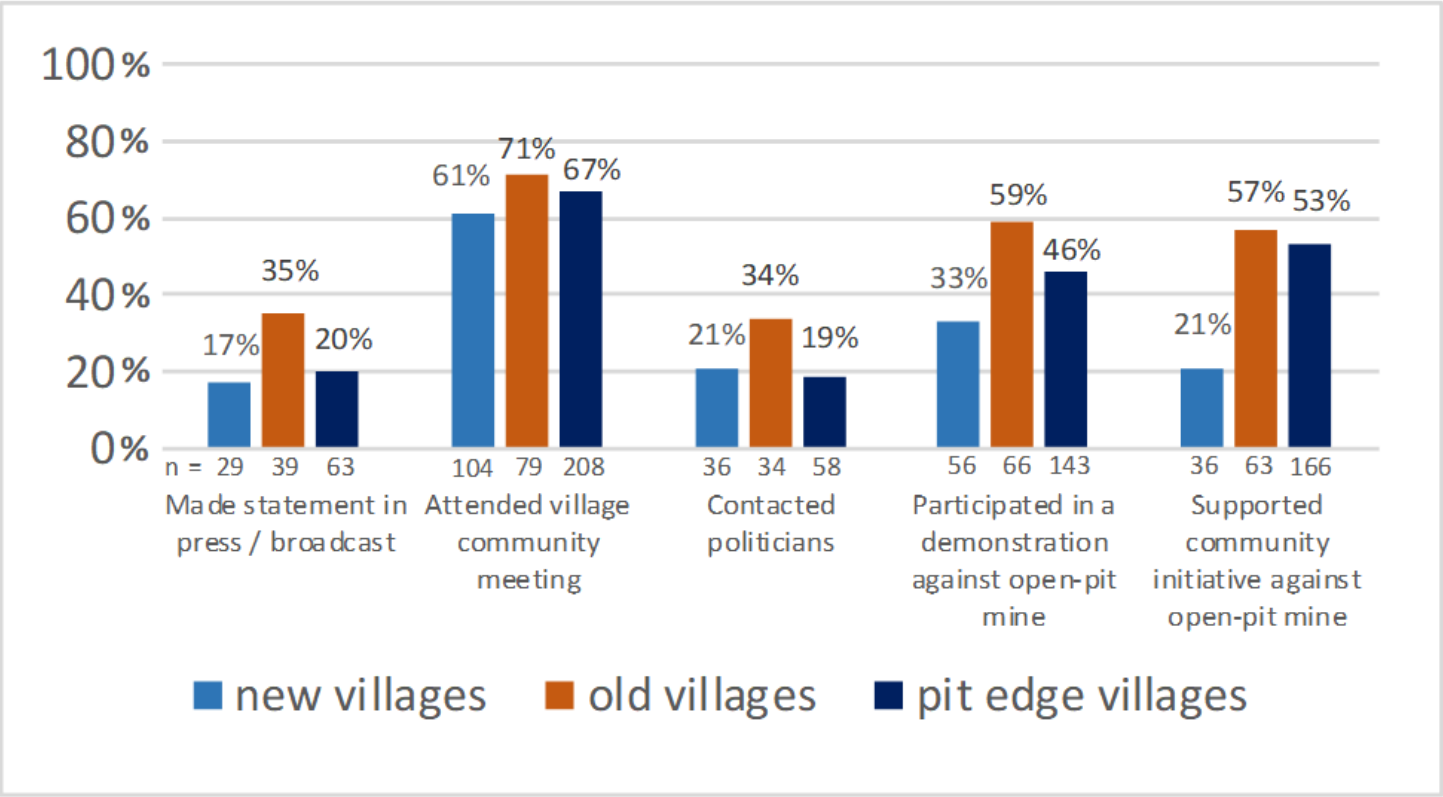

Figure 4

Activities in response to open-pit mining

Supplementary Files

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