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Supplement belonging to

Health effects of the 2021 flooding in Limburg

Anniek E. E. de Jong[1], Janko van Beek [2], Hans Korving [3], Marion Koopmans [4], Eline Boelee [5]

Supplementary materials 1 – water quality issues

By Astrid Fischer (Evides), Marie-Louise Geurts (WML Limburgs Drinkwater), Jaap Mos (Dunea), Anniek de Jong (Deltares), and Eline Boelee (Deltares)

Along the Meuse River three drinking water companies use the surface water to provide drinking water. These are from upstream to downstream: NV Waterleiding Maatschappij Limburg (WML), Dunea, and Evides (Figure S1). This supplement presents general descriptions of observations by the three companies during and immediately after the flooding.

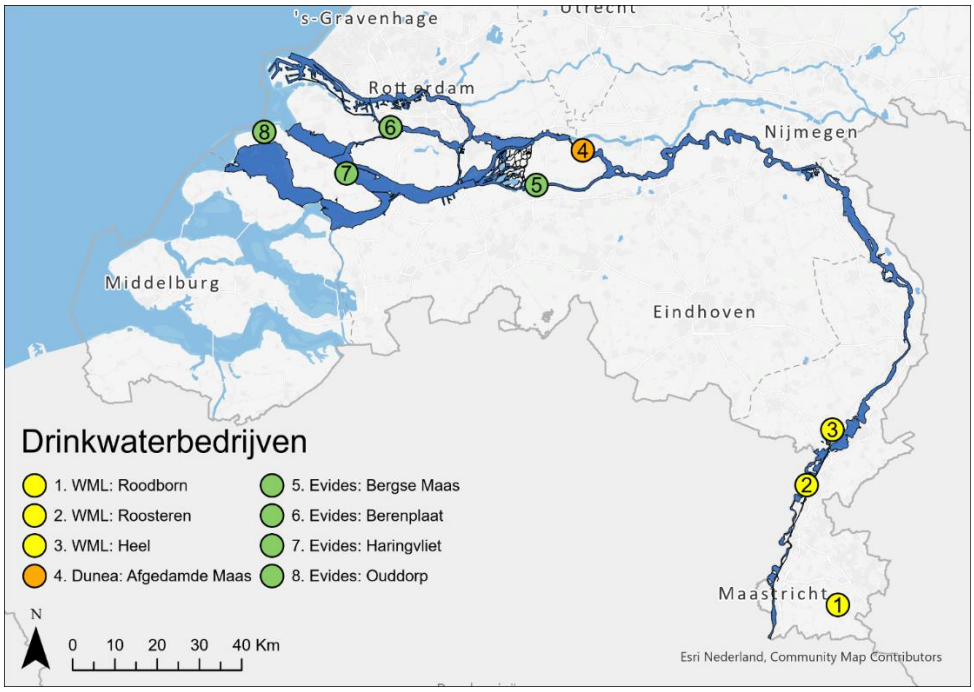


Figure S1. Map of the locations of the drinking water companies along the river Meuse

WML has intake points in the province of Limburg at Roodborn, Roosteren, and Heel. The location at Roosteren consists of a deep extraction and a shallow extraction (shore groundwater extraction) and contains 8% of the total capacity of WML. All three intake locations were flooded, and this company was most affected by the flooding. Parts of the extraction fields at Roodborn were flooded due to the overflown Eyserbeek. The pumping wells were temporarily out of use because they were microbiologically contaminated. Frequent sluicing removed the contaminations. The water intake at Roosteren was taken completely out of operation. Here, the water extraction location, the pump building and the clean water cellars were flooded with Meuse water. When the site was brought back into use, analyses of water samples showed contamination with faecal bacteria from the Meuse water not only in the pump building and the clean water cellars but also in the transport pipeline from Roosteren to Susteren and the shallow wells (including the radial well). The radial well in Roosteren, despite being built on a mound, was inundated by seepage water. Subsequently, as soon as it was possible, the infrastructure was cleaned with purified water. Drinking water production could not be resumed until the entire system was bacteriologically safe. Spraying and cleaning alone did not completely remove the bacteriological contamination, hence the system was disinfected with chlorine, after which it was flushed and drained again. The shallow extraction started after the infrastructure and wells were flushed with groundwater. WML also stopped the intake of Meuse water at Heel, prior to the flooding, for a period of two till three weeks. The intake pumping station was flooded by the Meuse, as a result the intake was temporarily out of operation. After the flood, it was necessary to replace the electrical wiring. The closure of the Roosteren site (about 8% of WML's total production) meant that the drinking water supply must be monitored closely. Extraction at all WML's other extraction sites had increased. Since it was a reasonably cool summer with low temperatures, the drinking water demand was relatively low, compared to previous hot dry summers. With

sufficient capacity at WML's other extraction sites, continuous high-quality drinking water supply could be guaranteed, also during the period that some locations were taken out of service. A hot summer might have created a capacity problem.

Dunea takes water from the Afgedamde Maas, a side river of the Meuse in the province of Brabant. It did not experience a reduction in water quality with flooding. During the high-water period, the waterboard Rivierenland used the Afgedamde Maas as storage basin to lower the flood wave. In the period just before the flood water arrived, the Afgedamde Maas was filled with relatively clean water. At its peak, the water was up to 2.5 m higher than usual in the Afgedamde Maas. The water level stayed 0.2 m below the critical point of 3.5 m above Amsterdam Ordnance Datum (Normaal Amsterdams Peil or NAP in Dutch) in the Afgedamde Maas so the stop lock at Heusden did not have to be closed. Turbidity and water quality were continuously monitored but the values allowed for continuous intake. When the river flow in the Meuse decreased, the stored water in the Afgedamde Maas was allowed to flow back into the Meuse. Thanks to this intervention, the lower quality water did not reach the intake point of Dunea, and there were no consequences for drinking water production at this location.

Evides takes water from the Bergsche Maas and has additional intake points downstream at the Biesbosch, Haringvliet (water from the river Meuse and Rhine) and Ouddorp, all in the province of Zuid Holland. Meuse water from the Biesbosch is stored in the Berenplaat reservoirs, which provides a water storage buffer of up to two months when the water intake from the Meuse must be temporarily halted, e.g., because of pollution. The dune area of Ouddorp is less flexible, because of its fragile nature, and here reserves and alternative management of Haringvliet must be mobilized within two weeks. Evides did not have any capacity problems during the high-water period. When turbidity increased because of flooding, Evides stopped taking water from the intake at Bergsche Maas (July 16th - 28th) and Haringvliet (July 20th - 28th). Figure S2 shows the difference in turbidity and colour of the flooded river and the drinking water reservoirs. The sampling campaign on July 20th showed low concentrations of many chemical substances such as drugs, sweeteners, complexing agents, benzotriazoles and thiazols. These substances mainly enter the surface water via the effluent of wastewater treatment plants and their concentration gets reduced through dilution with the increased amounts of water. Normal concentrations were found for caffeine, cotinine, melamine, and various (agricultural) pesticides. For some substances of unknown source, such as cyanuric acid and the metals chromium and lead, the concentrations were higher than usual. When the water resided and concentrations were back to normal, the intakes were opened again.

Figure S2. The flood water sludge coloured the water in the Oude Maas and the Spui brown, while the Berenplaat reservoir (Evides) remained clear blue (source Lianne Dijkhuizen, July 21st, 2021).

Summarizing, the floods in Limburg had a negative effect on the water quality of the Meuse, with increased levels of bacterial contamination and some metals. Of the three drinking water companies dependent on the Meuse, the one in the flooded area (WML) was most affected. Several parts of the operation sites were flooded by Meuse water, and extra

measures had to be taken to minimize health risks, such as temporary closure of certain water intake points. This affected the available drinking water capacity. However, due to the mild summer and therefore lower demand for drinking water, this did not lead to capacity problems. The other drinking water companies, Dunea and Evides, did not experience problems regarding water quality, because river water could be stored before arrival of the polluted flood water, and sufficient clean water was available from closed river arms and storage reservoirs, respectively. The water quality values could not all be explained, as some wastewater-effluent related substances were diluted with the increased amount of water, while others showed normal or higher concentrations. With high flows, normal concentrations of caffeine, cotinine, melamine (possibly also originating from effluents of wastewater treatment plants), and pesticides were detected, which indicate presence in higher amounts. Increased amounts of these substances might have been released during the high-water period. Higher concentrations of cyanuric acid, chromium and lead suggest that large quantities of these substances were present in the Meuse during the high-water; however, the source of these substances was unknown.

Supplementary materials 2 – questionnaire

By Eline Boelee (Deltares)

The questionnaire was sent out in Dutch. This translation was made afterwards, specifically for this publication. Questions marked with * were multiple choice questions.

Dear health worker,

Deltares, an independent institute for applied research in the field of water and subsurface, works on a better understanding of the health impacts of floods. The underlying idea is that if we can make the effects of floods on human health more visible, we could do more to prevent such health risks. Deltares conducts a lot of research and advises on dikes and other flood protection measures, but also on how to deal with floods once these occur, for instance in Bangladesh, Indonesia, and Mozambique. So far mainly health infrastructure has been taken into account into this disaster management (think of evacuation of hospitals) but we know very little about the prevention of health complaints.

Last July's floods in Limburg provide us with the opportunity to monitor which health effects occur, both immediately upon, and a few weeks after the floods. Your knowledge and experience -as a health worker- can help us to better put this information in a broader context. Therefore, we ask you to answer the questions below from your own perspective as general practitioner, occupational health physician or other health worker; much space has been provided for comments.

For questions and more information:

eline.boelee@deltares.nl

1. What is your profession?
2. Where do you work? (town, neighbourhood or postal code)
3. Did you (personally or professionally) experience any inconvenience due to the floods?
4. What are in your opinion the most important health impacts of the floods in Limburg, last month (July 2021)?
5. Did you see an increase in the following symptoms and diseases IMMEDIATELY after the floods?*

	Increase	**Decrease**	**No difference**	**Don't know**
Injuries				
Fear				
Stress and anxiety				
Depression				
Diarrhoea				
Other gastro-intestinal diseases				
COVID-19				
Other respiratory infections / complaints				
Fever				
Headache				
Skin irritation				
Eye irritation				
Throat, nose, ear complaints				
Poisoning symptoms				
Heart and vascular disease				

6. Did you see an increase in the following symptoms and diseases one MONTH after the floods?*

	Increase	**Decrease**	**No difference**	**Don't know**
Injuries				
Fear				
Stress and anxiety				
Depression				
Diarrhoea				
Other gastro-intestinal diseases				
COVID-19				
Other respiratory infections / complaints				
Fever				
Headache				
Skin irritation				
Eye irritation				
Throat, nose, ear complaints				
Poisoning symptoms				
Heart and vascular disease				

7. Do you see any other primary or secondary health impacts other than those mentioned above?

8. Do you expect more, possibly secondary, health impacts of the floods in future? If yes, please explain.

9. Did you observe work absenteeism through health complaints, related to the floods?*

Yes / No / Maybe

10. Do you have any idea about the length of this absenteeism?*

No idea / 1-5 working days / 6-10 working days / more than 10 working days / highly variable / other ….

11. Which health complaint (related to the floods) was the most important reason for absenteeism?*

	Yes
Injuries	
Fear	
Stress and anxiety	
Depression	
Diarrhoea	
Other gastro-intestinal diseases	
COVID-19	
Other respiratory infections / complaints	
Fever	
Headache	
Skin irritation	
Eye irritation	
Throat, nose, ear complaints	
Poisoning symptoms	
Heart and vascular disease	

Additional comments to absenteeism:

11a. Are systematic records kept of fore-mentioned health risks due these floods?

Yes / No / Don't know

11b.If yes, where are these records kept?

12. To what extent do you see differences between various groups of patients in their degree of health complaints after the floods?

13. In your opinion, which factors contribute to these differences?

14. To what extent have these floods, in your opinion, changed the vulnerability of specific groups, and with this, increased (or reduced) inequities?

15. Do you have any suggestions on how to deal with health impacts of floods, now or in the longer term?

16. Space for additional remarks:

Please leave your email address in case you want to be posted on the results of this study:

Supplementary materials 3 – additional figures and tables on SARS-CoV-2

By Hans Korving, Anniek de Jong, and Eline Boelee (all Deltares)

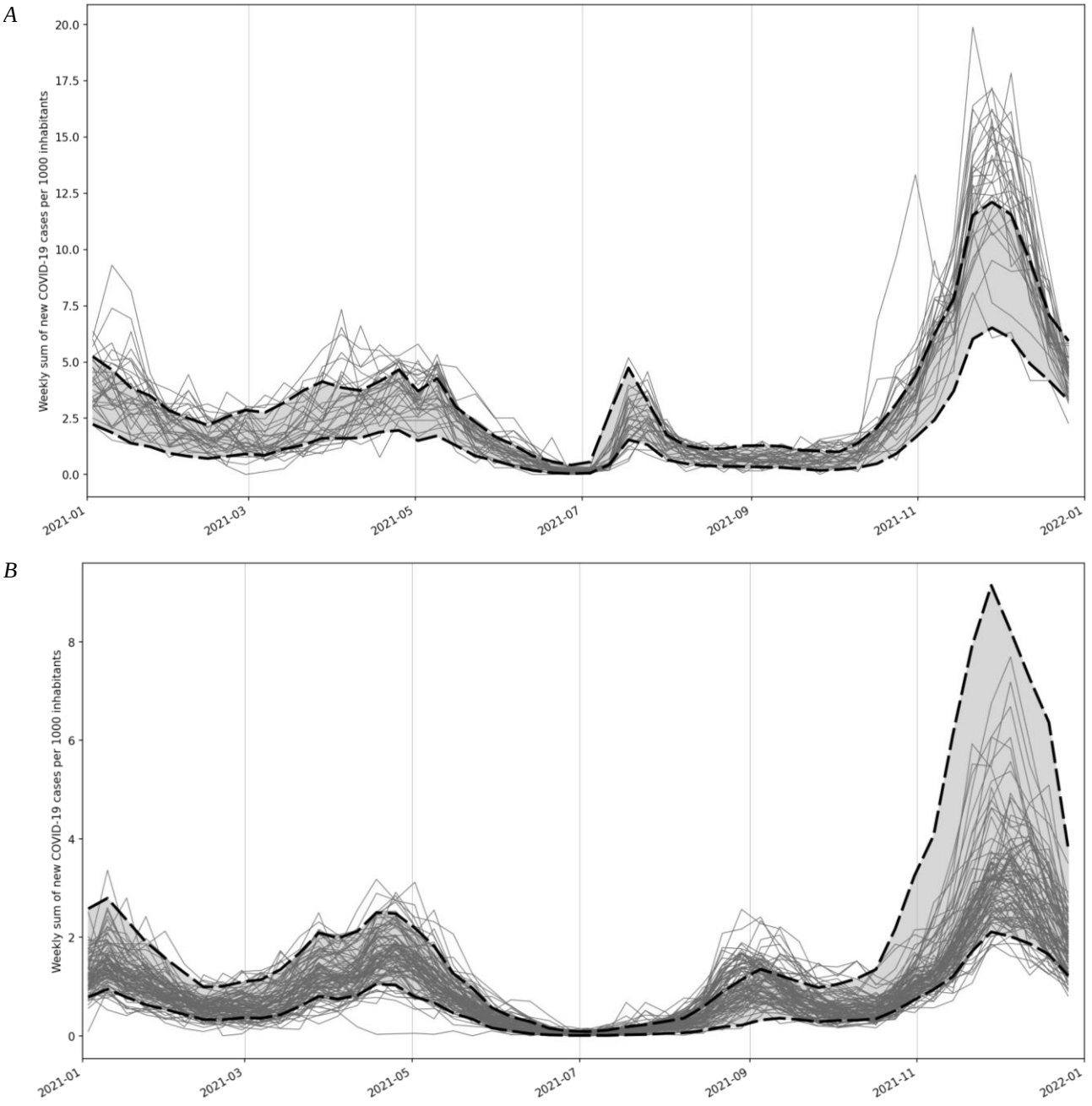


Figure S3. A) Overview of positive COVID-19 tests per week in 2021 in the Netherlands, based on https://data.rivm.nl/covid-19/COVID-19_aantallen_gemeente_per_dag_tm_03102021.csv. The incidence in the municipalities of Limburg is shown in grey lines and the background grey bar depicts the 75% interval of the COVID-19 incidence in the Netherlands. And B) positive COVID-19 test per week in 2021 in Germany with the incidence in the (city)counties of Nordrhein-Westfalen and Rheinland-Pfalz shown in grey lines and the background grey bar depicts the 75% interval of incidence in Germany, based on https://github.com/jgehrcke/covid-19-germany-gae/blob/master/cases-rki-by-ags.csv.

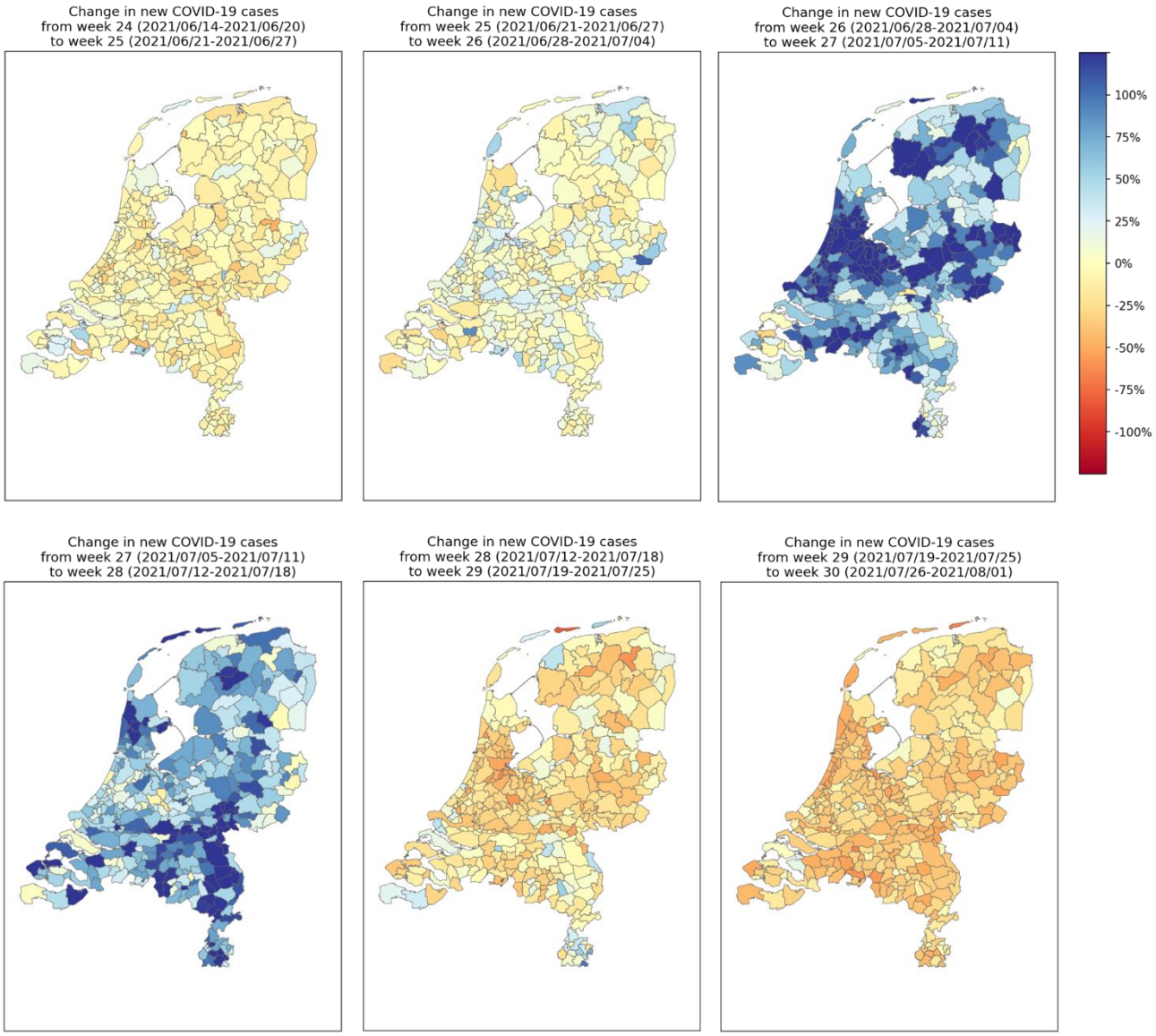


Figure S4. Weekly changes in COVID-19 cases in municipalities in the Netherlands between June 14 and August 1, 2021

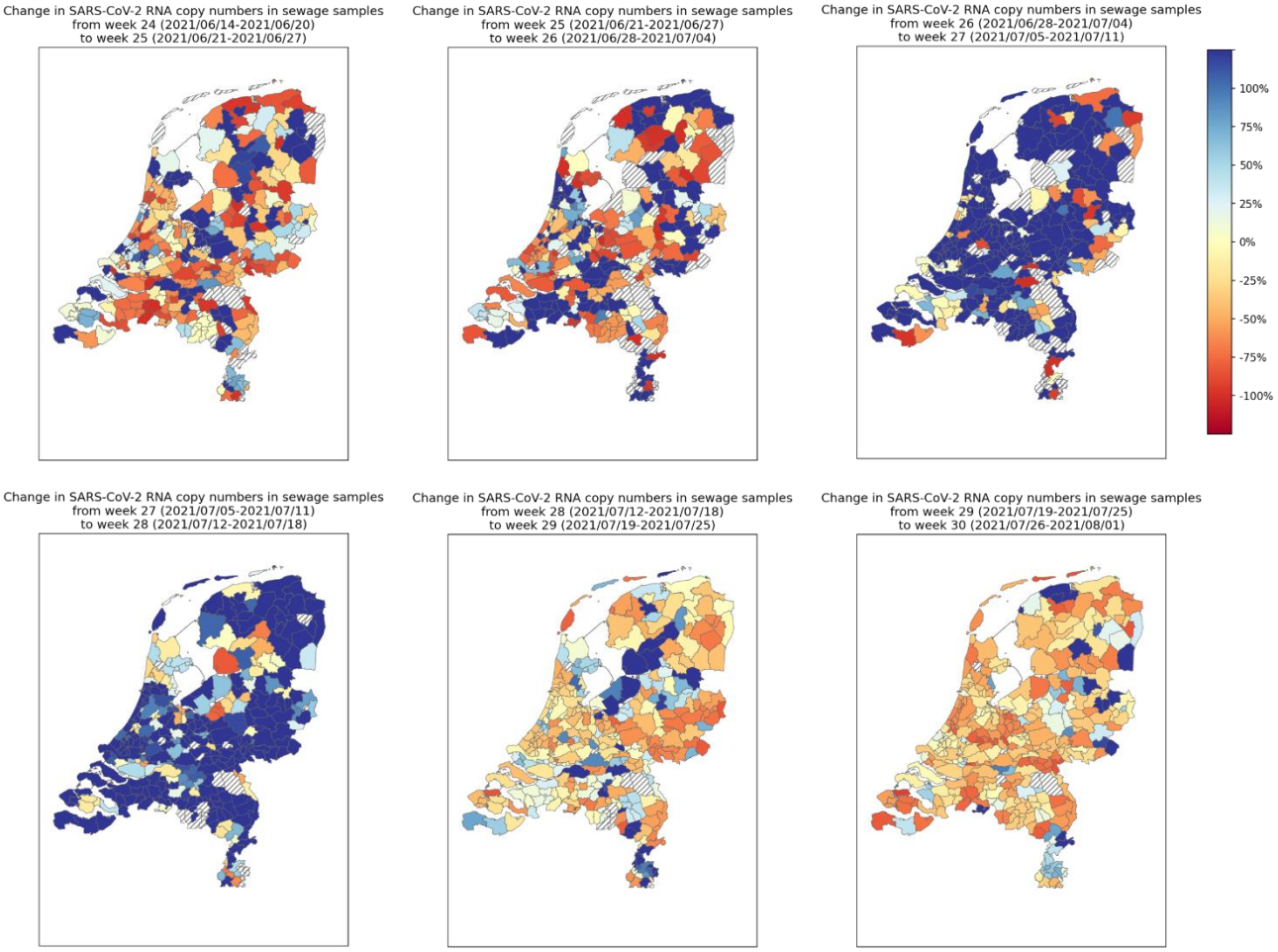


Figure S5. Weekly changes in SARS-CoV-2 RNA copy numbers in sewage samples in municipalities in the Netherlands between June 14 and August 1, 2021. The values in southern Limburg show a delay as compared to the other regions. Dashed areas denote missing data.

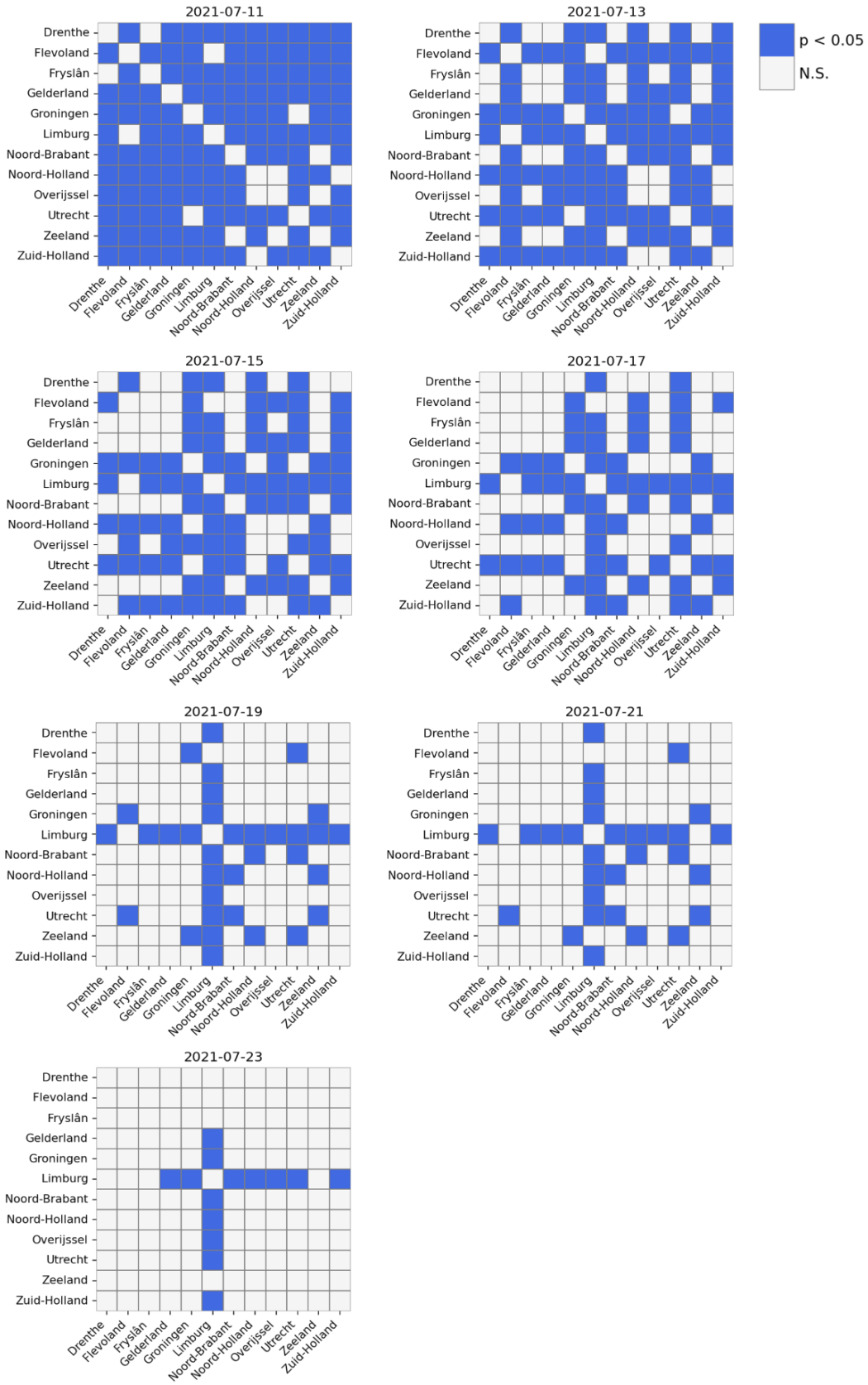
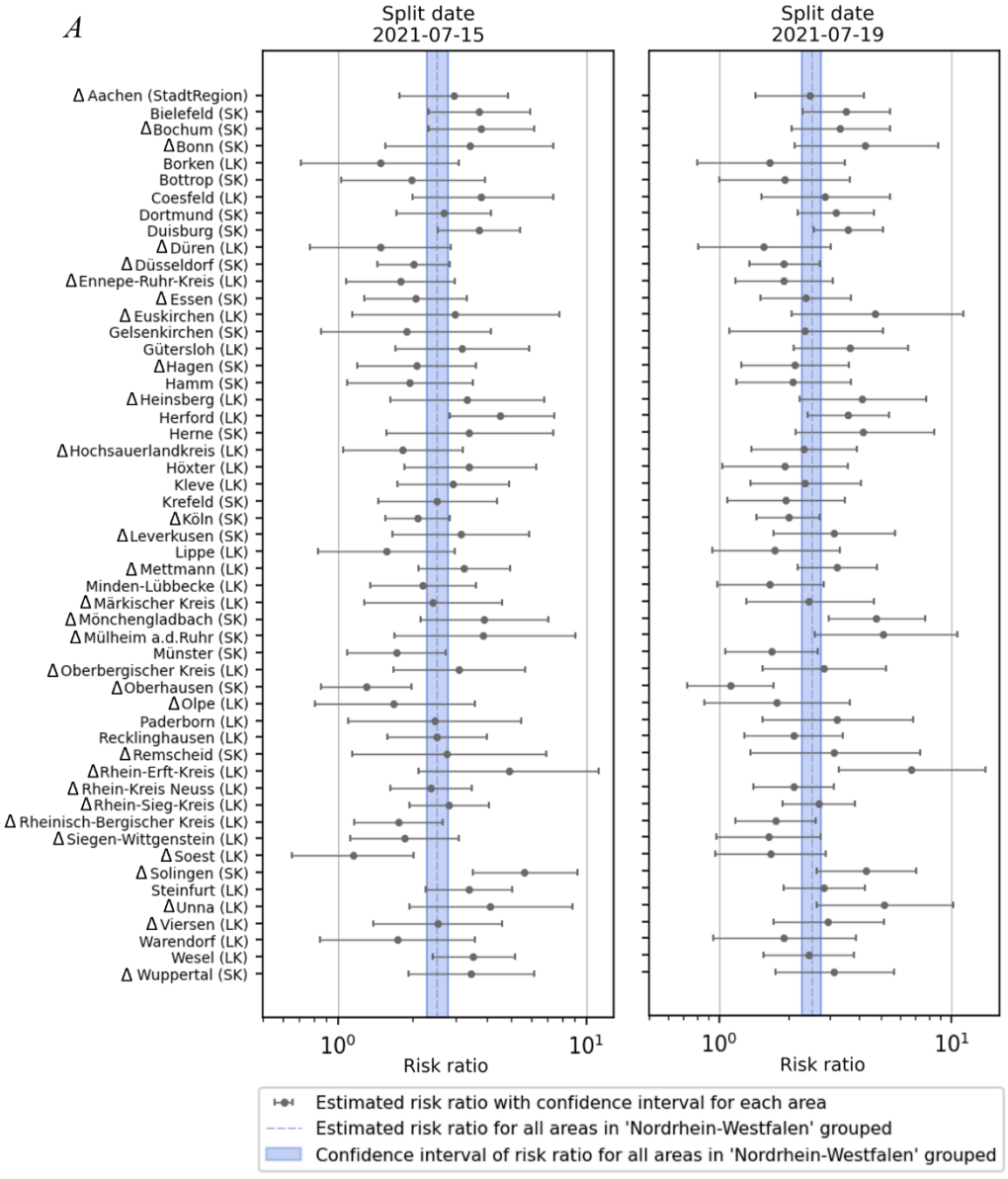


Figure S6. Pairwise comparison of differences in COVID-19 risk ratios between provinces in the Netherlands, according to the Benjamini-Yekutieli method, with different split dates. The graphs show that with later split days, Limburg stands out ever more clearly.

The pairwise test of differences in risk ratios between provinces in Figure S6 requires adjustment of p-values. We selected the Benjamini-Yekutieli method for the correction. This method provides improved control over the false discovery rate when the assumptions of independence or positive correlation are not strictly met. The false discovery rate balances the trade-off between reducing false positives and increasing the power to detect true positives (i.e., significant differences between provinces.



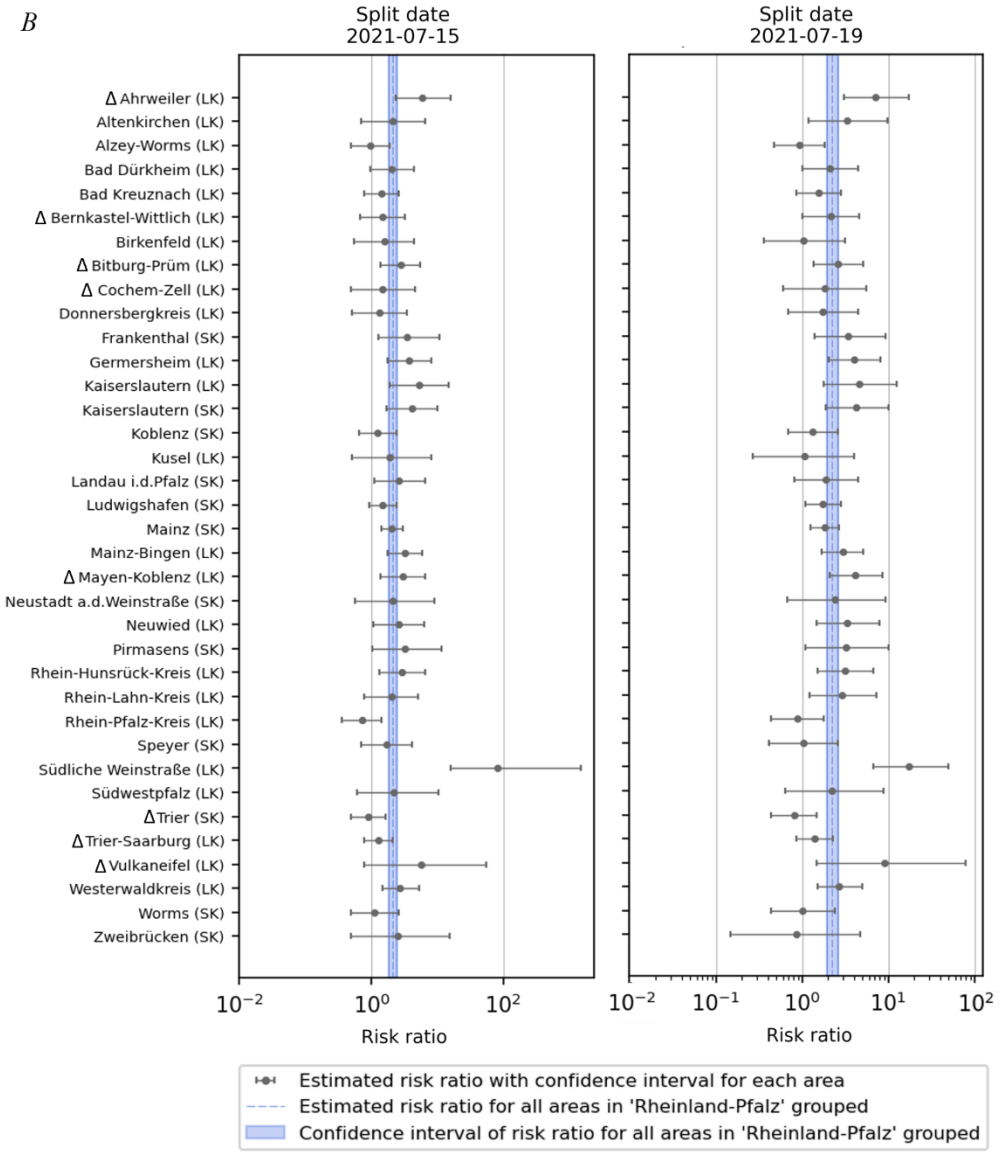


Figure S7. COVID-19 risk ratio in Germany in the federal state of A) Nordrhein-Westfalen and B) Rheinland-Pfalz with a split data of 15^{th} and 19^{th} of July. The Δ depicts the (city)counties that experienced flooding.

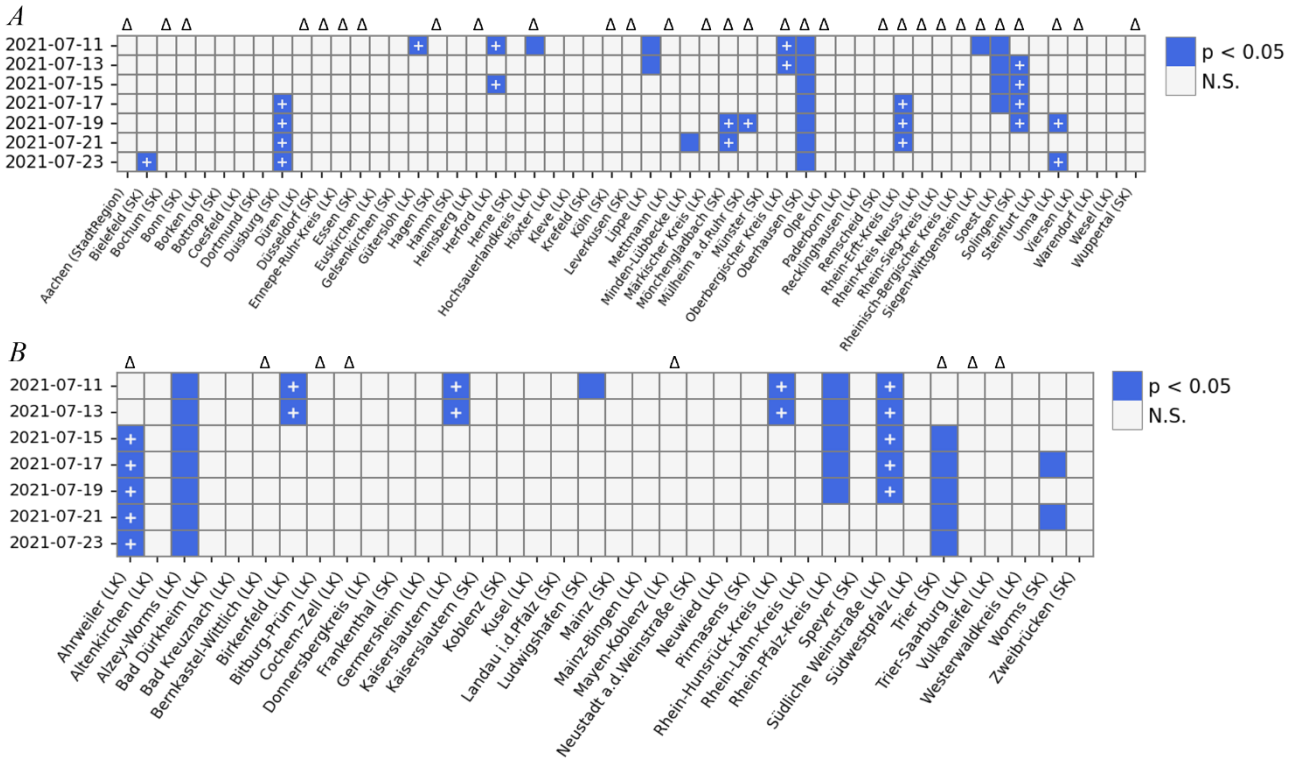


Figure S8. Difference between risk ratios of each area and average value for A) Nordrhein-Westfalen and B) Rheinland-Pfalz at several split dates. +: risk ratio of area (1) larger than risk ratio of areas grouped and (2) significantly different from risk ratio of areas grouped. Δ depicts the (city)countries that experienced flooding.

Table S1. Overview of municipalities that were flooded (noted with an X) and number of inhabitants that were evacuated.

Municipality	**Flooded**	**Number of evacuated inhabitants**
Beek		0
Beekdaelen	X	0
Beesel		0
Bergen (L)		1666
Brunssum		0
Echt-Susteren		1472
Eijsden-Margraten	X	405
Gennep		0
Gulpen-Wittem	X	0
Heerlen	X	0
Horst aan de Maas	X	10
Kerkrade	X	0
Landgraaf		0
Leudal	X	357
Maasgouw	X	3029
Maastricht	X	7053
Meerssen	X	2305
Mook en Middelaar		0
Nederweert		0
Peel en Maas		1492
Roerdalen	X	640
Roermond	X	1763
Simpelveld	X	0
Sittard-Geleen	X	10
Stein	X	1603
Vaals	X	0
Valkenburg aan de Geul	X	2902
Venlo		13330
Venray		0
Voerendaal	X	0