Supplementary material

Transmission risk of SARS-CoV-2 in the watershed triggered by domestic wastewater discharge

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S1 The statistical analysis of toilet usage frequency

Previous studies reported that people participating in regular working and educational activities usually experience varying degrees of psychological stress and physical fatigue due to commuting pressure, lack of autonomy, and unhealthy diet, which could lead to endocrine disorders and thereby experiencing reduced urination and defecation frequency and even defecation disorders (Clarke and James, 2003; Gideon et al., 2019; Palit et al., 2012; Rao et al., 2016). However, participation in working and educational activities through home-office patterns during lockdown relieves psychosocial stress and physical fatigue due to the reduced commuting stress, increased autonomy, and healthier diet (Giménez-Nadal José et al., 2019; Hornung and Glaser, 2009; Oakman et al., 2020; Tustin, 2014). As a result, the toilet usage frequency of home-office population during lockdown would increase to some extent compared to the normal situation and possibly increase the virus loads in daily excretions and spread risk in natural water.

The scenarios of toilet usage frequency were determined based on the statistical analysis of the urination and defecation frequency of the population. More explicitly, according to the investigation of people from different regions in the previous study (Heaton et al., 1992; Myo et al., 1994; Panigrahi et al., 2013; Sanjoaquin et al., 2004; Simons et al., 2010), the urination and defecation frequencies of people with different ages and genders were statistically analysed, the minimum, the maximum, and the average values were listed in Table S1. The analysis result demonstrated that although the urination and defecation frequencies varied greatly among age groups, the ratios of the maximum value to the average value were relatively stable, with the ranges of 1.09-1.15 and 1.92-2.08, respectively. According to the previous studies (Clarke and James, 2003; Gideon et al., 2019; Oakman et al., 2020; Palit et al., 2012; Rao et al., 2016), the average value was regarded as the normal scenario, and the maximum value was regarded as the increasing scenario. Based on the results of statistical analysis, the toilet usage frequency constant of the normal scenario was set as 1, and the toilet usage frequency constant of the increasing scenario was set as 1.13 for urination frequency and 1.96 for defecation frequency.

Supplementary Figures and Tables

Table S1 The statistical urination frequency and defecation frequency

Age (years)	Urination frequency (times / week)						Defecation frequency (times / week)						Reference
	Male			Female			Male			Female			
	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	
1-4	35	50.41	49	35	50.41	49	5.59	21	7	5.59	21	7	(Heaton et al., 1992; Myo et al., 1994; Panigrahi et al., 2013; Sanjoaquin et al., 2004; Simons et al., 2010)
20-39	35	53	46	35	53	47.6	3	21	12	3	21	10.5	
40-69	35	53	46.2	35	54	47.5	3	21	11.8	2	21	10	
>70	44	52	45.8	44	52	47.2	4	12	10.2	4	12	9.8	

Table S2 The parameter of the exponential dose-response models fitted to data sets on coronavirus infection

Virus	Host	1/k	k	Unit*	k (copies^{-1})	Reference
SARS-CoV	/	4.10E+02	2.44E-03	PFU^{-1}	3.16E-06	Watanabe et al. (2010)
SARS-CoV	Mice	[6.19E+04,7.28E+05]	[1.37E-06,1.62E-05]	Copies^{-1}	[1.37E-06,1.62E-05]	Zhang and Wang (2020)
SARS-CoV	Mice	/	2.97E-03	PFU^{-1}	3.84E-06	DeDiego et al. (2008)
SARS-CoV	Mice	/	2.14E-03	PFU^{-1}	2.77E-06	De Albuquerque et al. (2006)
HCoV-229E	Humans	1.85E+01	5.39E-02	TCID50^{-1}	7.70E-05	Bradburne et al. (1967)
HEV-67N	Mice	2.04E+03	4.91E-04	PFU^{-1}	6.35E-07	Hirano et al. (2001)
MERS-Cov	Mice	/	5.71E-03	TCID50^{-1}	8.16E-06	Lunn et al. (2019)

*The conversion of k's unit (PFU^{-1}, $TCID_{50}^{-1}$ and copies^{-1}) is based on the harmonization rules of 1 $TCID_{50}^{-1} \approx 1/700$ copies^{-1} (McBride et al., 2013) and 1 PFU^{-1}=773 copies^{-1} (Jonsson et al., 2009; Puig et al., 1994).

Table S3 The parameter of the exposure dose for population during recreational activities near waters

Activity	Exposure pathway	Exposure dose (mL/person/event)	Reference
Recreation	Skin, oral inhalation	100	Yang et al. (2020)
Farmland irrigation water	Oral, breath inhalation	10	
Canoeing	Ingestion	Norm (3.9, 4.03^2)	Dorevitch et al. (2011)
Fishing	Ingestion	Norm (3.6, 3.67^2)	
Kayaking	Ingestion	Norm (3.8, 3.98^2)	
Rowing	Ingestion	Norm (3.9, 4.03^2)	
Swimming	Ingestion	Norm (10, 12.65^2)	
Swimming	Ingestion	10-50	Dufour et al. (2017)
Swimming	Ingestion	Children: Gamma (0.64, 58) Men: Gamma (0.45, 60) Women: Gamma (0.51, 35)	Schets et al. (2011)
Swimming	Ingestion	50	Steyn et al. (2004)
Swimming	Ingestion	Children: 37 Men: 22 Women: 12	WHO (2006)

Table S4 The infection cases, population, and infection rate constant in different gender and age groups in Germany

Gender	Age	Infection case (RKI, 2021)	German population in 2020 (DESTATIS, 2020; UN, 2019)	Infection rate in the group (%)	Infection rate constant = Infection rate in the group/Average infection rate
Male	0-4	17,165	2,037,921	0.84	0.40
Female	0-4	16,128	1,933,933	0.83	0.40
Male	5-14	57,063	3,884,565	1.47	0.71
Female	5-14	52,261	3,623,511	1.44	0.69
Male	15-34	279,388	9,852,047	2.84	1.36
Female	15-34	283,274	9,089,283	3.12	1.50
Male	35-59	342,142	14,687,138	2.33	1.12
Female	35-59	384,156	14,500,188	2.65	1.27
Male	60-79	142,496	8,448,369	1.69	0.81
Female	60-79	145,309	9,418,632	1.54	0.74
Male	80-	60,527	2,177,822	2.78	1.34
Female	80-	122,101	3,537,147	3.45	1.66

Table S5 The domestic wastewater proportion in four German states and WWTPs with different capacity sizes (DESTATIS, 2016).

	1000-2000	2001-5000	5001-10000	10001-50000	50001-100000	>100000
Saxony	0.79	0.77	0.72	0.64	0.64	0.86
Saxony-Anhalt	0.89	0.86	0.8	0.71	0.78	0.54
Thuringia	0.81	0.78	0.8	0.68	0.7	0.61
Brandenburg	0.86	0.86	0.75	0.74	0.6	0.84

Table S6 The SARS-CoV-2 concentration in patients' stool and urine

Virus	Media	Variable	Min Concentration	Max Concentration	Unit	Reference
SARS-CoV-2	stool*	n_s	5.50×10^{2}	1.20×10^{5}	copies/mL	Pan et al. (2020)
SARS-CoV-2	stool*	n_s	6.00×10^{5}	7.00×10^{6}	copies/mL	Zang et al. (2020)
SARS-CoV-2	stool*	n_s	2.70×10^{7}	3.10×10^{8}	copies/mL	Kim et al. (2020)
SARS-CoV-2	stool*	n_s	5.0×10^{3}	3.98×10^{7}	copies/mL	Proplanta (2021)
SARS-CoV-2	stool*	n_s	1.00×10^{2}	1.00×10^{7}	copies/mL	Jones et al. (2020)
SARS-CoV-2	stool*	n_s	8.00×10^{6}		copies/mL	Jones et al. (2020)
SARS-CoV-2	stool*	n_s	1.55×10^{3}	6.46×10^{8}	copies/g	Wölfel et al. (2020)
SARS-CoV-2	urine	n_u	3.20×10^{2}	6.10×10^{5}	copies/mL	Jones et al. (2020); Peng et al. (2020); Yoon et al. (2020)
SARS-CoV-2	urine	n_u	3.89	1.23×10^{2}	copies/mL	Jeong et al. (2020)
SARS-CoV-2	urine	n_u	4.90×10^{7}	1.09×10^{8}	copies/mL	Kim et al. (2020)
SARS-CoV-2	urine	n_u	2.50×10		copies/mL	Yang et al. (2020)

*The density of stool is 1.06 g/mL (Brown et al., 1996; Penn et al., 2018)

Table S7 The average values and 95% confidence intervals of the total Sobol's sensitivity index of 7 model parameters

Category[*]	Total Sobol's sensitivity index, S_{Ti}[ǂ]																				
	k			m			γ			v_u			n_u			m_s			n_s		
	Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI	
N,Swm,M,5-14	1.01E+00	4.87E-01	1.79E+00	5.73E-01	2.86E-01	9.61E-01	3.29E-02	1.24E-02	6.76E-02	2.87E-01	9.75E-02	5.91E-01	4.81E-01	1.89E-01	8.92E-01	6.13E-03	2.32E-03	1.39E-02	4.32E-01	1.84E-01	7.54E-01
N,Swm,F,5-14	1.00E+00	4.97E-01	1.83E+00	5.84E-01	2.64E-01	1.00E+00	3.06E-02	1.26E-02	6.15E-02	2.80E-01	1.02E-01	6.60E-01	4.90E-01	1.86E-01	9.11E-01	5.91E-03	2.14E-03	1.25E-02	4.36E-01	1.80E-01	7.35E-01
N,Swm,M,15-34	9.76E-01	4.37E-01	1.72E+00	7.08E-01	2.91E-01	1.21E+00	3.08E-02	1.01E-02	6.43E-02	2.75E-01	7.66E-02	6.29E-01	5.17E-01	1.50E-01	9.80E-01	6.06E-03	1.74E-03	1.47E-02	4.31E-01	1.47E-01	8.12E-01
N,Swm,F,15-34	9.88E-01	4.41E-01	1.82E+00	7.19E-01	3.20E-01	1.29E+00	3.13E-02	1.17E-02	6.67E-02	2.90E-01	8.49E-02	6.78E-01	5.06E-01	1.61E-01	9.34E-01	6.24E-03	1.89E-03	1.36E-02	4.88E-01	1.66E-01	8.74E-01
N,Swm,M,35-59	9.87E-01	4.36E-01	1.65E+00	7.29E-01	3.08E-01	1.26E+00	3.11E-02	1.17E-02	6.37E-02	3.18E-01	8.39E-02	5.95E-01	5.06E-01	1.68E-01	1.09E+00	6.01E-03	1.86E-03	1.27E-02	4.27E-01	1.57E-01	7.62E-01
N,Swm,F,35-59	9.77E-01	4.23E-01	1.77E+00	7.20E-01	2.97E-01	1.27E+00	3.25E-02	1.12E-02	6.59E-02	2.73E-01	8.38E-02	6.46E-01	5.15E-01	1.64E-01	9.95E-01	6.22E-03	1.86E-03	1.47E-02	4.48E-01	1.62E-01	8.24E-01
N,Swm,M,60-79	9.51E-01	4.50E-01	1.72E+00	7.42E-01	3.16E-01	1.33E+00	3.22E-02	1.14E-02	6.67E-02	2.78E-01	8.60E-02	5.94E-01	5.17E-01	1.55E-01	9.71E-01	6.50E-03	1.99E-03	1.50E-02	4.34E-01	1.66E-01	8.12E-01
N,Swm,F,60-79	9.50E-01	4.16E-01	1.65E+00	7.15E-01	2.94E-01	1.38E+00	3.16E-02	1.07E-02	6.62E-02	2.89E-01	8.85E-02	5.69E-01	5.04E-01	1.66E-01	1.10E+00	6.19E-03	1.89E-03	1.40E-02	4.53E-01	1.53E-01	8.39E-01
I,Swm,M,5-14	9.38E-01	5.03E-01	1.55E+00	5.63E-01	2.94E-01	8.99E-01	3.10E-02	1.33E-02	5.96E-02	1.46E-01	4.98E-02	3.73E-01	2.55E-01	9.66E-02	5.29E-01	9.17E-03	3.70E-03	1.78E-02	6.38E-01	3.12E-01	1.05E+00
I,Swm,F,5-14	9.52E-01	5.04E-01	1.51E+00	5.70E-01	2.87E-01	9.34E-01	3.13E-02	1.33E-02	6.05E-02	1.48E-01	5.01E-02	3.31E-01	2.65E-01	9.49E-02	5.90E-01	9.06E-03	3.66E-03	1.81E-02	6.41E-01	3.10E-01	1.06E+00
I,Swm,M,15-34	9.43E-01	4.79E-01	1.65E+00	6.94E-01	3.53E-01	1.20E+00	3.32E-02	1.31E-02	6.65E-02	1.38E-01	4.41E-02	3.27E-01	2.57E-01	8.69E-02	5.75E-01	8.77E-03	3.40E-03	1.77E-02	6.46E-01	2.86E-01	1.09E+00
I,Swm,F,15-34	9.27E-01	4.52E-01	1.51E+00	7.13E-01	3.31E-01	1.27E+00	3.31E-02	1.23E-02	6.58E-02	1.48E-01	4.13E-02	3.59E-01	2.72E-01	8.43E-02	6.26E-01	9.04E-03	3.30E-03	1.89E-02	6.65E-01	2.83E-01	1.15E+00
I,Swm,M,35-59	9.57E-01	4.81E-01	1.55E+00	7.44E-01	3.60E-01	1.28E+00	3.15E-02	1.28E-02	6.19E-02	1.58E-01	4.25E-02	3.93E-01	2.73E-01	8.16E-02	6.21E-01	9.55E-03	3.56E-03	1.95E-02	6.75E-01	3.10E-01	1.15E+00
I,Swm,F,35-59	9.92E-01	4.21E-01	1.79E+00	6.98E-01	3.05E-01	1.17E+00	3.25E-02	1.12E-02	6.74E-02	1.81E-01	4.18E-02	4.17E-01	2.54E-01	7.93E-02	5.55E-01	8.82E-03	2.91E-03	1.78E-02	6.49E-01	2.53E-01	1.07E+00
I,Swm,M,60-79	9.44E-01	4.52E-01	1.68E+00	7.38E-01	3.18E-01	1.38E+00	3.06E-02	1.24E-02	5.78E-02	1.47E-01	4.10E-02	3.61E-01	2.85E-01	8.16E-02	6.30E-01	9.33E-03	3.29E-03	2.09E-02	6.43E-01	2.87E-01	1.10E+00
I,Swm,F,60-79	9.83E-01	4.97E-01	1.65E+00	7.08E-01	3.57E-01	1.27E+00	3.15E-02	1.33E-02	6.47E-02	1.52E-01	4.25E-02	3.75E-01	2.89E-01	9.04E-02	6.29E-01	9.73E-03	3.40E-03	2.16E-02	6.73E-01	2.97E-01	1.12E+00

*N: Normal toilet usage frequency; I: Possible increasing toilet usage frequency during lockdown; Swm: Swimming activities; M: Male; F: Female; number: age groups. ǂAve: Average; CI: Confidence interval

Table S8 The average values and 95% confidence intervals of Spearman’s rank correlations of 7 model parameters

Category*	Spearman’s rank correlation, ρ ‡																				
	k			m			γ			v_u			n_u			m_s			n_s		
	Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI		Ave	95% CI	
N,Swm,M,5-14	4.34E-01	4.30E-01	4.38E-01	4.06E-01	4.02E-01	4.10E-01	-5.54E-02	-6.07E-02	-5.04E-02	9.94E-02	9.43E-02	1.05E-01	3.64E-01	3.60E-01	3.68E-01	2.16E-02	1.64E-02	2.66E-02	5.62E-01	5.59E-01	5.66E-01
N,Swm,F,5-14	4.34E-01	4.30E-01	4.38E-01	4.06E-01	4.02E-01	4.10E-01	-5.53E-02	-6.02E-02	-5.02E-02	9.95E-02	9.46E-02	1.04E-01	3.65E-01	3.60E-01	3.69E-01	2.16E-02	1.66E-02	2.70E-02	5.62E-01	5.59E-01	5.66E-01
N,Swm,M,15-34	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.39E-01	5.45E-01	-5.01E-02	-5.53E-02	-4.52E-02	9.02E-02	8.48E-02	9.55E-02	3.29E-01	3.25E-01	3.34E-01	1.96E-02	1.43E-02	2.49E-02	5.07E-01	5.04E-01	5.11E-01
N,Swm,F,15-34	4.01E-01	3.97E-01	4.05E-01	5.20E-01	5.16E-01	5.23E-01	-5.13E-02	-5.68E-02	-4.61E-02	9.19E-02	8.66E-02	9.72E-02	3.36E-01	3.32E-01	3.41E-01	2.02E-02	1.49E-02	2.56E-02	5.17E-01	5.13E-01	5.21E-01
N,Swm,M,35-59	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.39E-01	5.45E-01	-5.01E-02	-5.54E-02	-4.48E-02	9.02E-02	8.53E-02	9.51E-02	3.29E-01	3.25E-01	3.34E-01	1.96E-02	1.45E-02	2.46E-02	5.07E-01	5.03E-01	5.11E-01
N,Swm,F,35-59	4.01E-01	3.97E-01	4.05E-01	5.20E-01	5.16E-01	5.23E-01	-5.09E-02	-5.62E-02	-4.55E-02	9.19E-02	8.66E-02	9.70E-02	3.36E-01	3.32E-01	3.41E-01	2.01E-02	1.46E-02	2.53E-02	5.17E-01	5.14E-01	5.21E-01
N,Swm,M,60-79	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.38E-01	5.45E-01	-5.01E-02	-5.51E-02	-4.51E-02	9.01E-02	8.46E-02	9.54E-02	3.30E-01	3.25E-01	3.34E-01	1.96E-02	1.39E-02	2.49E-02	5.07E-01	5.04E-01	5.11E-01
N,Swm,F,60-79	4.01E-01	3.97E-01	4.05E-01	5.20E-01	5.16E-01	5.23E-01	-5.11E-02	-5.64E-02	-4.61E-02	9.19E-02	8.65E-02	9.73E-02	3.36E-01	3.31E-01	3.41E-01	2.00E-02	1.43E-02	2.53E-02	5.17E-01	5.13E-01	5.21E-01
I,Swm,M,5-14	4.33E-01	4.29E-01	4.37E-01	4.06E-01	4.02E-01	4.10E-01	-5.54E-02	-6.03E-02	-4.99E-02	8.96E-02	8.46E-02	9.48E-02	3.21E-01	3.16E-01	3.26E-01	2.31E-02	1.76E-02	2.83E-02	5.98E-01	5.95E-01	6.02E-01
I,Swm,F,5-14	4.33E-01	4.29E-01	4.37E-01	4.06E-01	4.02E-01	4.10E-01	-5.52E-02	-6.02E-02	-5.00E-02	8.94E-02	8.44E-02	9.47E-02	3.21E-01	3.16E-01	3.25E-01	2.31E-02	1.81E-02	2.81E-02	5.98E-01	5.95E-01	6.02E-01
I,Swm,M,15-34	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.38E-01	5.45E-01	-5.00E-02	-5.53E-02	-4.49E-02	8.09E-02	7.54E-02	8.61E-02	2.90E-01	2.85E-01	2.94E-01	2.10E-02	1.61E-02	2.58E-02	5.40E-01	5.36E-01	5.44E-01
I,Swm,F,15-34	4.01E-01	3.96E-01	4.05E-01	5.19E-01	5.16E-01	5.23E-01	-5.12E-02	-5.65E-02	-4.58E-02	8.27E-02	7.78E-02	8.79E-02	2.96E-01	2.91E-01	3.00E-01	2.10E-02	1.61E-02	2.62E-02	5.51E-01	5.47E-01	5.55E-01
I,Swm,M,35-59	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.38E-01	5.45E-01	-5.00E-02	-5.47E-02	-4.53E-02	8.09E-02	7.55E-02	8.57E-02	2.90E-01	2.86E-01	2.94E-01	2.08E-02	1.55E-02	2.60E-02	5.40E-01	5.36E-01	5.43E-01
I,Swm,F,35-59	4.00E-01	3.96E-01	4.04E-01	5.19E-01	5.16E-01	5.23E-01	-5.11E-02	-5.60E-02	-4.57E-02	8.25E-02	7.74E-02	8.76E-02	2.96E-01	2.91E-01	3.00E-01	2.13E-02	1.62E-02	2.65E-02	5.51E-01	5.47E-01	5.55E-01
I,Swm,M,60-79	3.93E-01	3.89E-01	3.97E-01	5.42E-01	5.38E-01	5.45E-01	-4.99E-02	-5.47E-02	-4.48E-02	8.09E-02	7.58E-02	8.61E-02	2.90E-01	2.85E-01	2.94E-01	2.08E-02	1.56E-02	2.60E-02	5.40E-01	5.37E-01	5.44E-01
I,Swm,F,60-79	4.00E-01	3.96E-01	4.05E-01	5.19E-01	5.16E-01	5.23E-01	-5.12E-02	-5.67E-02	-4.59E-02	8.27E-02	7.77E-02	8.77E-02	2.96E-01	2.91E-01	3.00E-01	2.14E-02	1.61E-02	2.66E-02	5.51E-01	5.47E-01	5.54E-01

*N: Normal toilet usage frequency; I: Possible increasing toilet usage frequency during lockdown; Swm: Swimming activities; M: Male; F: Female; number: age groups. ‡Ave: Average; CI: Confidence interval

Table S9 The percentage of resident population connected to urban wastewater collecting system in 2016-2018 estimated by OECD (OECD, 2021)

Country	2016	2017	2018
Australia	92	93	93
Austria	95		100
Belgium	88	88	
Canada	86	86	
Chile	100	100	
Colombia	88	88	
Czech Republic	81	82	82
Denmark	92	92	92
Estonia	88	88	
Finland			85
France	82	82	81
Germany	97		
Greece	93		
Hungary	78	79	80
Iceland			
Ireland	94	94	
Israel	99	99	99
Japan	78	79	
Korea	93	94	94
Latvia	100	100	100
Lithuania	77	78	79
Luxembourg	99		
Mexico			
Netherlands	100	100	100
Norway	100	99	100
Poland	95	95	96
Portugal		92	
Slovak Republic	89	89	89
Slovenia	92	96	97
Spain			
Sweden	87	87	
Switzerland			
Turkey	71	74	74

Table S10 P values of Mann-Whitney U test of the sensitivity results of the parameters between the categorical factors (toilet usage frequency, gender, and age)

Category	Total Sobol's sensitivity index, S_{Ti}							Spearman's rank correlation, ρ						
	k	m	γ	v_u	n_u	m_s	n_s	k	m	γ	v_u	n_u	m_s	n_s
Toilet usage	3.43E-03	9.85E-01	8.38E-01	3.33E-09	3.33E-09	3.33E-09	3.33E-09	5.18E-01	4.36E-01	4.69E-01	2.48E-03	2.31E-03	1.47E-02	4.83E-02
Gender	1.10E-01	4.91E-01	1.84E-01	6.96E-01	8.67E-01	8.09E-01	7.80E-01	2.47E-01	7.11E-01	8.94E-01	8.49E-01	7.30E-01	8.35E-01	7.44E-01
Age	5.40E-12	5.40E-12	5.40E-12	5.40E-12	5.40E-12	5.40E-12	5.40E-12	4.27E-12	4.44E-12	5.07E-12	5.09E-12	4.88E-12	5.27E-12	4.87E-12

Fig. S1 The geographic distribution of the district-level of COVID-19 epidemic situation, estimated SARS-CoV-2 pRNA amount discharged from WWTPs, and the pRNA concentrations along the rivers of the study Elbe at lower 95% confidence interval boundary in **a)** Apr 2020, **b)** June 2020, **c)** October 2020 and **d)** January 2021. It included the COVID-19 active infection cases in 100,000 inhabitants (purple color shading), pRNA concentrations in surface water (red color shading), and the sum of pRNA WWTP-influent dose and untreated amount (white round label).

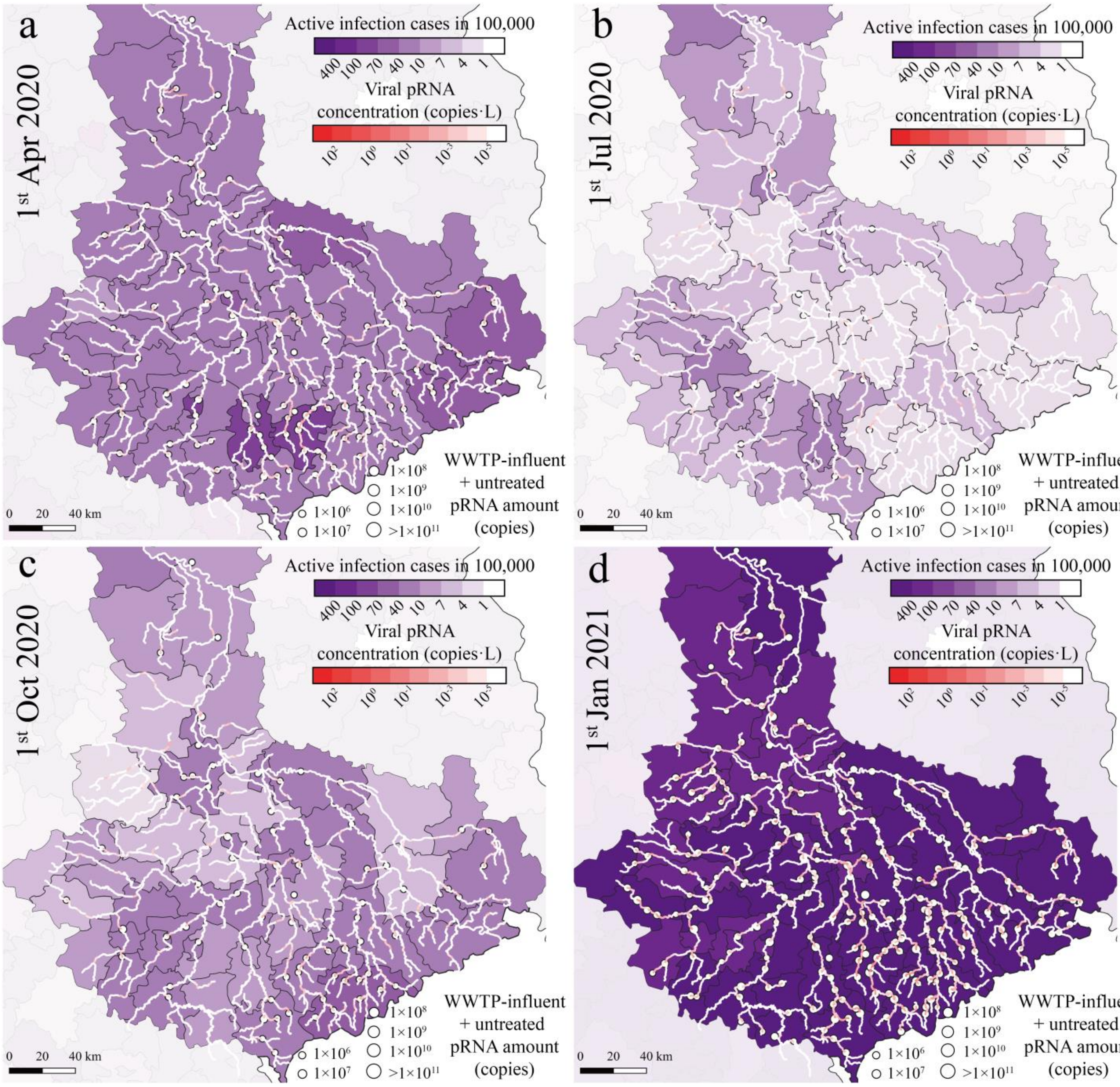


Fig. S2 The geographic distribution of the district-level of COVID-19 epidemic situation, estimated SARS-CoV-2 pRNA amount discharged from WWTPs, and the pRNA concentrations along the rivers of the study Elbe at upper 95% confidence interval boundary in **a)** Apr 2020, **b)** June 2020, **c)** October 2020 and **d)** January 2021. It included the COVID-19 active infection cases in 100,000 inhabitants (purple color shading), pRNA concentrations in surface water (red color shading), and the sum of pRNA WWTP-influent dose and untreated amount (white round label).

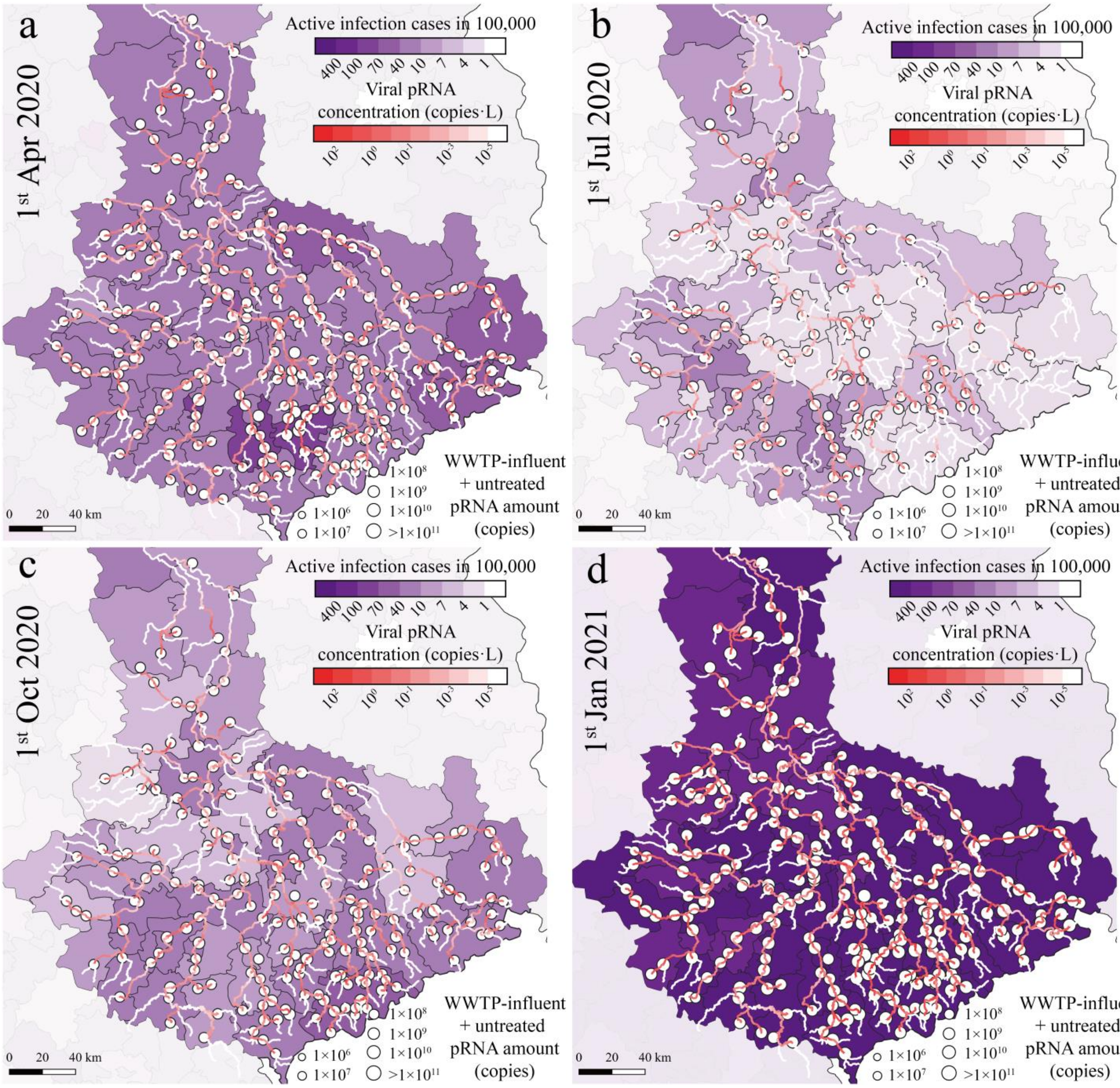


Fig. S3 The geographic distribution of the district-level of COVID-19 epidemic situation, estimated average SARS-CoV-2 pRNA amount discharged from WWTPs, and the average pRNA concentrations along the rivers of the study Elbe in **a)** Apr 2020, **b)** June 2020, **c)** October 2020, and **d)** January 2021. It included the COVID-19 active infection cases in 100,000 inhabitants (purple color shading), pRNA concentrations in surface water (red color shading), and the sum of pRNA WWTP-influent dose and untreated amount (white round label).

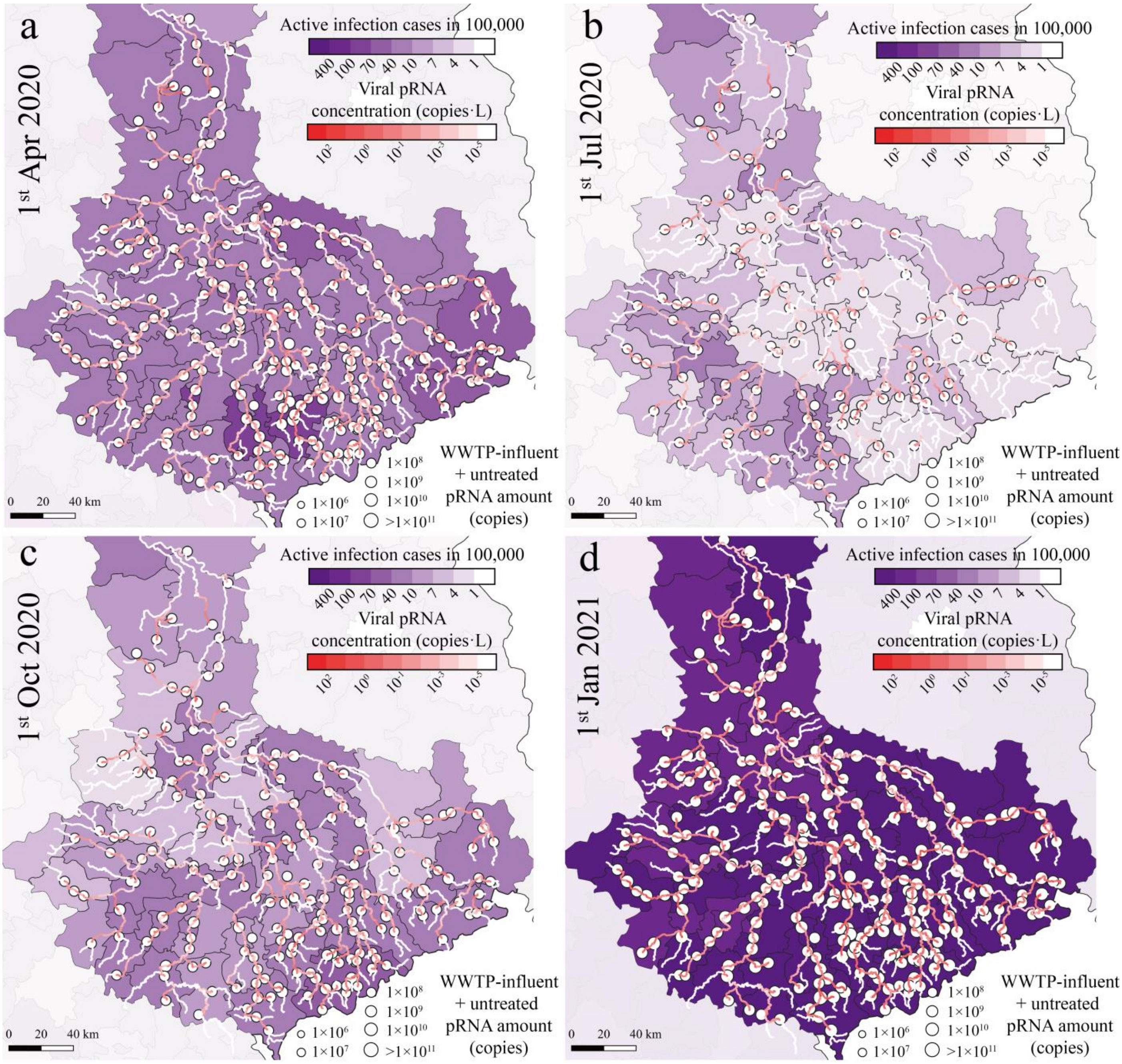
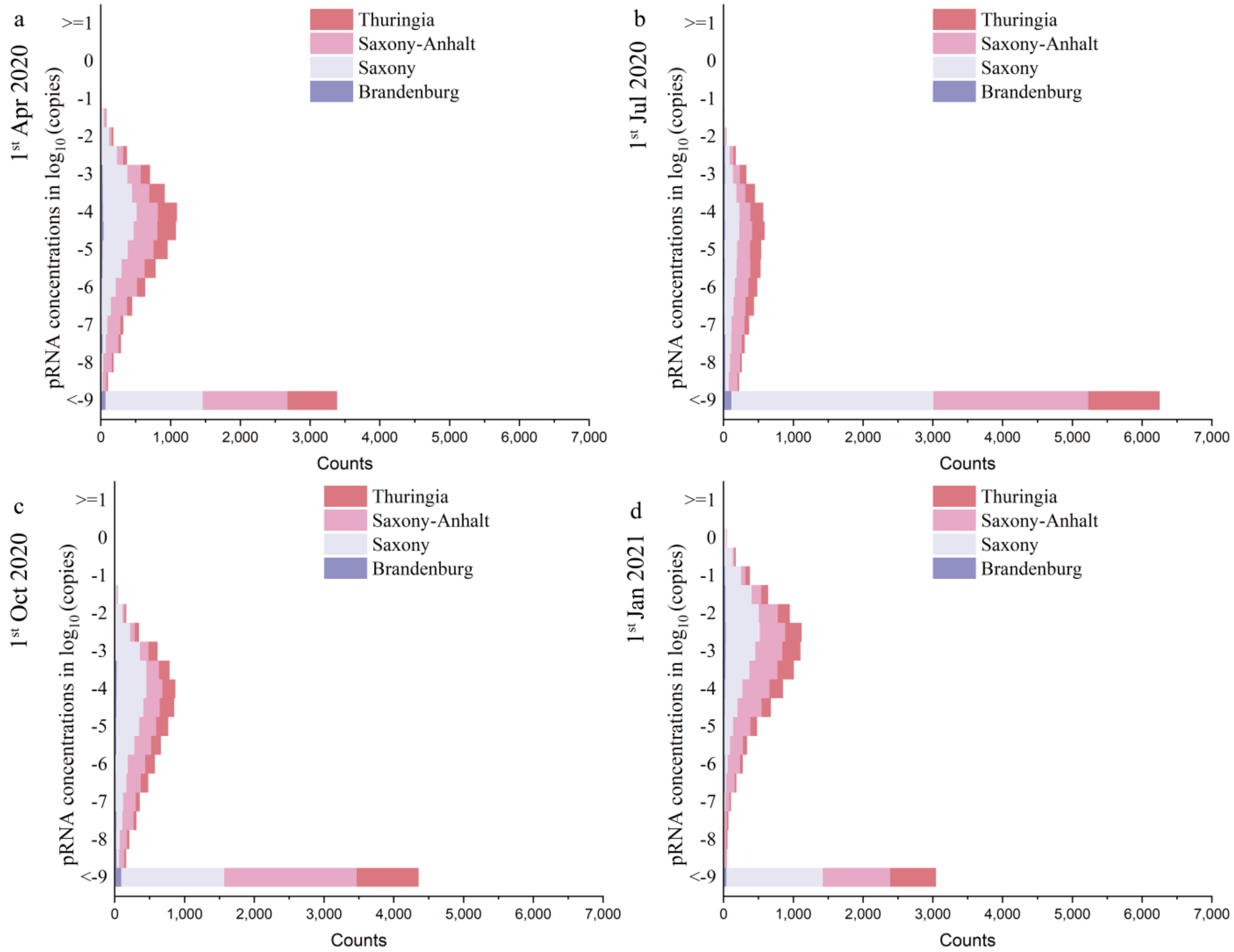


Fig. S4 Log_{10}-transformed distributions of median spatial pRNA concentrations in the state of Thuingia, Saxony-Anhalt, Saxony, and Brandenburg in **a)** Apr 2020, **b)** June 2020, **c)** October 2020 and **d)** January 2021



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