Supplementary Information

Global distribution of wastewater treatment plants and their released effluents into rivers and streams

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S1 National and regional wastewater treatment plant (WWTP) datasets

S1.1 Europe

The Urban Waste Water Treatment Directive (UWWTD; https://uwwtd.eu/) is concerned with the collection, organisation and management of data related to the treatment and discharge of urban wastewater. Version 6 of their WWTP database from 2017 contains 30,437 records from which we used 24,971. The excluded records were collection facilities (not connected to a discharge point) or records without point coordinates. The UWWTD database provides information on effluent load in terms of population equivalent and treatment level. In version 8 from 2020, wastewater discharge was included for 8,662 WWTPs. The countries included are: Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, French Guiana, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Monaco, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Saint-Martin, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.

S1.2 USA

The Clean Watersheds Needs Survey (CWNS; https://www.epa.gov/cwns) is an assessment conducted by the US Environmental Protection Agency (EPA) every four years to address water quality and its capital cost in the US territory. The latest version (2012) contains 27,016 records of publicly owned treatment works (POTW), i.e. wastewater collection and treatment facilities, stormwater and sewer overflows controls, nonpoint source pollution controls, and decentralized wastewater management facilities. For the purpose of compiling HydroWASTE, only WWTPs were selected, accounting for 14,819 facilities. The CWNS dataset contains information on population served, wastewater discharge, effluent quality, treatment level, in present conditions as well as planned projects for the future. The state of South Carolina did not participate in the 2012 campaign, thus the information used for this specific region is from 2008. The US government also provides wastewater information through the Enforcement and Compliance History Online (ECHO) system, which tracks the permit compliance and enforcement status of

facilities regulated by the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act (CWA). The ECHO dataset is updated on a weekly basis with records of POTW and non-POTW (private and industrial facilities), but it does not contain information on the number of people served or the treatment level for each WWTP. Since most records of POTW are found in both datasets, to avoid duplication, the CWNS dataset was chosen as the most complete WWTP dataset from the USA for our purposes.

S1.3 Brazil

The Atlas Esgotos (http://atlasesgotos.ana.gov.br/) was developed in 2017 by the Brazilian government through the Agência Nacional de Águas (ANA) to provide information on national sanitation conditions. The focus was to evaluate the impact of effluents on Brazil's water resources. It contains 2,820 records of WWTPs from 2013 which were all used in the compilation of HydroWASTE. The atlas includes information on population served, wastewater discharge and treatment type.

S1.4 Mexico

The Mexican WWTP dataset is provided by the Comisión Nacional del Agua (CONAGUA; https://sina.conagua.gob.mx/sina/), the government sector responsible for the management of water resources. It contains 2,540 records of WWTPs from 2018 which were all used in the compilation of HydroWASTE. The provided point coordinates of each WWTP indicate the center of the municipality in which the WWTP is located, rather than the exact location of the plant itself. The dataset includes information on the wastewater discharge and treatment level.

S1.5 China

The locations and characteristics of 2,739 WWTPs were provided in table format to Grill et al. (2018) by the Ministry of Environmental Protection for China. Grill et al. (2018) manually verified 2,486 WWTPs with flow rate higher than 1,000 m^3 d^{-1} using geolocation techniques and satellite imagery. These WWTPs contain information on population served, wastewater discharge and treatment level.

S1.6 Canada

The Canadian WWTP dataset is made available by Environment Canada under the Wastewater Systems Effluent Regulations (WSER; https://www.canada.ca/en/environment-climate-change/services/wastewater). It contains 2,064 records of WWTPs from 2017 which were all used in the compilation of HydroWASTE. The provided point coordinates indicate the discharge location of each WWTP. It does not contain the number of people served, but the treatment capacity is presented as daily effluent discharge. The dataset includes information on the treatment types performed in each facility, which were then used to estimate the treatment level. For example, if the treatment offered by the facility includes only physical processes such as screening, grit removal, or sedimentation, the treatment level is assumed to be primary; if the facility includes activated sludge, facultative lagoon or other biochemical processes, the treatment level is assumed to be secondary; finally, if the facility offers additional

treatments such as disinfection, the treatment level is assumed to be advanced. Other information provided in the dataset includes the name of the waterbody at the discharge location, the status (i.e., operational; construction completed; under construction; or non-operational), name and owner of the WWTP.

S1.7 Australia

The National Wastewater Treatment Facilities Database from Geoscience Australia (Hill et al., 2012) provides the point coordinates of WWTPs in the country, but it does not include any other information regarding size or treatment level. There are 1,234 records of WWTPs, last updated in 2016. All of them were included in the compilation of HydroWASTE.

S1.8 South Africa

We obtained the geographic location and wastewater discharge of 964 WWTPs in South Africa from the publicly accessible national data repository of the Department of Water and Sanitation (DWS) of South Africa (http://ws.dwa.gov.za/gsm/; accessed in October 2019).

S1.9 India

The Central Pollution Control Board of India (CPCB; https://cpcb.nic.in/water-pollution/) produced an inventory of sewage treatment plants in 2015. The inventory contains information for 816 WWTPs in 28 states of India, including installed capacity, treatment type, status (i.e., operational; construction completed; under construction; or non-operational). There are no point coordinates, but the inventory lists for each WWTP the name of the city or suburb where it is located. We thus manually assigned the WWTP position using satellite imagery and topographic maps (Google Maps). If the WWTP could not be reliably located, it was placed centrally inside the boundary of the reported spatial unit (city or suburb). We used all 816 records in the compilation of HydroWASTE.

S1.10 New Zealand

The New Zealand Wastewater Plant Inventory (https://www.waternz.org.nz/WWTPInventory) reports data about publicly owned WWTPs. It contains 323 records from which we used 317 in the compilation of HydroWASTE as the remaining 6 did not include point coordinates. The dataset provides information on treatment capacity, population served, wastewater discharge, and treatment level.

S1.11 Peru

The sanitation sector of the Peruvian government (SUNASS; https://geosunass.sunass.gob.pe/) provides information on WWTPs. It contains 186 records updated in 2018 from which we used 184 records in the compilation of HydroWASTE. The two excluded were considered unreliable given that they did not have any information besides point location and regional company responsible. All others include treatment capacity in volume of discharge.

S2 Georeferencing methods and thresholds

S2.1 Selection of reference subset

To test for the WWTPs geographic and topological location accuracy, a sample of each national dataset (approximately 10%) was selected randomly, at a total of 4,354 records. The dataset from China was excluded from this analysis since the location was already verified and corrected in a previous study (Grill et al., 2018), and the dataset from South Africa was acquired after the analysis was performed.

S2.2 Reported location accuracy

The reference subset had their location point evaluated using satellite imagery. The location was considered 'verified' if a building resembling a WWTP facility was located within 500 meters of the point coordinates. Each dataset had a different rate of successfully verified locations, 62% for Europe, 66% for the USA, 61% for Brazil, 5% for Mexico, 66% for Canada, 97% for Australia, 80% for India, 75% for New Zealand, 84% for Peru, and 85% for the remaining countries (Open Street Map). In Mexico's database, each WWTP record contains point coordinates, but the point only represents the center of the municipality where the WWTP is located.

There were 202 WWTPs that were located farther than 500 meters from the point, and the average distance was measured as 1.22 ± 0.79 km with a maximum of 5.19 km.

S2.3 Georeferencing accuracy

The georeferencing of all WWTPs to the estimated outfall location was performed using an automated algorithm (see main manuscript, section 2.1.3 for details on the georeferencing procedures). To evaluate the accuracy of the algorithm, each original WWTP point location from the reference subset was manually moved to a location on the river network that seemed most plausible based on satellite imagery; i.e. the location resembled a visible river or stream nearby but downstream of the original WWTP location. The distance between the WWTP location and the manually estimated outfall location was measured for each WWTP in the reference subset and resulted in an average adjustment distance of 1.00 ± 1.13 km, a maximum of 14.18 km, and a 99.9^{th} percentile of 8.23 km. Given these results for the reference subset, a 10 km georeferencing radius was chosen for the automated assignment procedure of all outfall locations in HydroWASTE (see main manuscript for more details). We chose this radius on the upper end of the manually assigned distance range in order to avoid that the outfall location is assigned to very small streams (in very close vicinity) which could lead to erroneously high wastewater concentrations and risk indicators in subsequent analyses; i.e. our chosen radius is intended to be conservative. Confirming this preferential assignment to larger rivers, a test showed that 99% of the reference subset was manually georeferenced to an equal or smaller river (in terms of river discharge) than when automatically georeferenced using the 10 km threshold.

S3 Estimation of missing attributes

S3.1 Population served: Approach A1

If wastewater discharge was reported in any of the national WWTP datasets, Eq. (1) (see main text) was used to estimate the population served. To test the validity of this approach, we investigated 28,497 WWTP records for which both wastewater discharge and population served was reported in the original national datasets (USA, Europe, Brazil, China, and New Zealand). We applied Eq. (1) to these WWTPs and then tested the correlation between reported and calculated values of population served. The resulting correlation coefficient, R^2, was found to be between 0.59 and 0.96, with an overall value of 0.75 (Table S1).

In addition, we investigated the uncertainty related to using reported country-level data of treated wastewater per capita (*U* in Eq. 1). For that, Table S1 shows a comparison between the average wastewater discharge per capita as calculated from the national datasets and the reported country-level values. Whereas the values agree reasonably well for USA, Europe, and Brazil, a more than twofold discrepancy was observed for New Zealand and China, which may in part explain the inferior R^2 value of China.

Table S1. Correlation coefficient (R^2) between reported and calculated values of population served for USA, Europe, Brazil, China, and New Zealand. Also, comparison of average wastewater discharge per capita as calculated from national WWTP datasets with reported country-level data of treated wastewater per capita (Jones et al., 2021).

WWTP dataset	Number of WWTPs used	R^2	Average wastewater discharge per capita (L day^{-1})	Country-level treated wastewater per capita (L day^{-1})
USA	14,490	0.72	504.3	477.0
Europe	8,415	0.79*	286.5*	256.6*
Brazil	2,815	0.95	182.8	159.1
China	2,486	0.59	215.8	105.6
New Zealand	291	0.96	615.1	234.2
Total	28,497	0.75		

*Average of the countries included at the national WWTP dataset weighted by population served (for list of countries see section S1.1)

S3.2 Population served: Approach A2 – without wastewater discharge available

One of the assumptions for estimating the population served is that the number of people served should be in the proximity of the WWTP. To evaluate this approach, a new subset of WWTPs was created, drawn from the reference subset (see section S2.1): 281 Records were selected where the WWTP (a) is the sole WWTP in a radius of 15 km, (b) could be manually verified, and (c) reports the population served in the original dataset. For these records, the number of people surrounding the WWTP was computed using a population grid (see main manuscript, section 2.1.2.c for description) within search radii ranging from 5 km to 15 km in increments of 1 km. Based on the 5 different goodness of fit criteria shown in Table S2, a radius of 11 km was found to deliver the overall best results (i.e., the next smaller radius showed a general deterioration in results while the next larger radius showed a deterioration in PBIAS and did not lead to substantial improvements in the other criteria). Figure S1 shows the

reported vs. estimated values of population served using the 11 km radius, conforming an overall good correlation with a slight bias towards overestimation.

Table S2. Goodness of fit (GOF) criteria for the selection of the radius size to estimate the population served. GOF criteria are: NRMSE (normalized root mean square error), PBIAS (percent bias), NSE (Nash-Sutcliffe efficiency) and KGE (Kling-Gupta efficiency).

Radius (km)	NRMSE	PBIAS	NSE	R^2	KGE
5	85.5	-55.7	0.27	0.61	0.01
6	77.8	-44.6	0.39	0.68	0.15
7	70.7	-34.9	0.5	0.72	0.28
8	64.3	-25.4	0.59	0.75	0.39
9	57.1	-16	0.67	0.78	0.52
10	51.4	-7.8	0.73	0.8	0.62
11	**47.2**	**1**	**0.78**	**0.8**	**0.72**
12	46.1	7.4	0.79	0.8	0.76
13	45.7	12.5	0.79	0.79	0.76
14	45.7	17	0.79	0.79	0.75
15	45.8	21.2	0.79	0.79	0.74

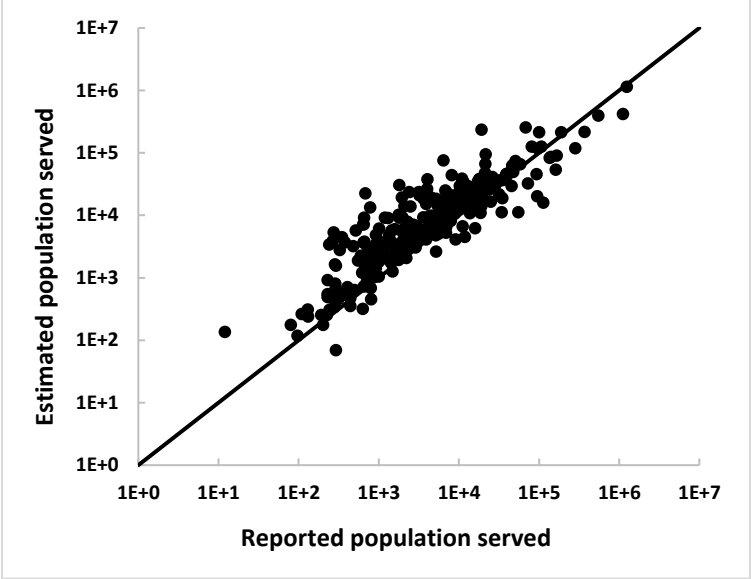

Figure S1. Population served estimated by aggregating all population inside a 11 km radius versus the reported population served value from the original WWTP datasets. The line represents the 1:1 line.

S3.3 Population served: Approach A2 – with wastewater discharge available

An alternative method was developed to derive an estimate of population served by analysing the population in the vicinity of the WWTP for cases in which information on wastewater discharge was available. This approach aims to avoid overestimations of the number of people served in cases where WWTPs are located in areas of low population

density but high wastewater discharge (e.g. industrial or mining related WWTPs). First, the wastewater discharge was used as described in Approach A1 (section S3.1) to estimate the general size category of the WWTP in terms of how many people could potentially be served. Next, this estimate was used to determine the search radius in which the number of existing people was aggregated; i.e., instead of using the optimized radius as found in section S3.2 above (11 km), a customized radius was used based on the size class of potentially served population.

In order to determine a customized radius per WWTP size category, the national dataset from India was used in the method developed by Shakya (2017). The WWTPs were first grouped into four size categories based on their capacity to serve populations: Group 1: ≥500,000 people; Group 2: 100,000–500,000 people; Group 3: 50,000–100,000 people; and Group 4: <50,000 people. Six radii ranging from 5 km to 30 km in 5 km increments were applied and the populations inside these search radii were aggregated. The mean bias and the standardized root mean square error (SRMSE) were used as goodness of fit criteria to select the smallest radius for each group that showed an acceptably low error and bias between reported and estimated values of population served (Table S3).

Table S3. Goodness of fit (GOF) criteria (mean bias and SRMSE) for estimated values of population served using different search radii, based on comparisons with national WWTP data of India. Best-fit results are shaded in green (Modified from Shakya (2017)).

Group	Population served	GOF criteria	Radius (km)					
			5	10	15	20	25	30
Group 1	≥500,000	Mean Bias (%)	46.32	14.89	6.65	2.87	0.47	-0.25
		SRMSE (%)	59.78	33.43	21.23	15.42	6.70	0.55
Group 2	100,000 - 500,000	Mean Bias (%)	29.06	12.65	9.66	6.93	5.44	2.53
		SRMSE (%)	48.38	33.09	29.79	24.83	23.66	17.78
Group 3	50,000 - 100,000	Mean Bias (%)	3.28	0.12	2.01	0.62	2.10	0.86
		SRMSE (%)	21.01	14.56	21.09	17.78	20.93	19.00
Group 4	<50,000	Mean Bias (%)	-14.95	-20.71	-26.46	-25.15	-35.91	-29.64
		SRMSE (%)	90.49	108.01	151.36	147.36	250.47	186.22

As a result, Group 1, Group 2, Group 3, and Group 4 were assigned a buffer size of 30 km, 20 km, 10 km, and 5 km, respectively. The lowest prediction quality was observed for Group 4 (i.e., smallest WWTPs) where negative bias values indicated a trend towards overestimating the number of people served.

S3.4 Level of treatment

To estimate the level of treatment, we investigated those national datasets for which this information was reported. Table S4 shows the percentage of WWTPs in each treatment level category (primary, secondary and advanced) for Brazil, China, India, Europe, New Zealand, and USA, grouped into income classes based on their Gross National Income (GNI).

Table S4. Breakdown of WWTP treatment level (in percent of total) for countries which reported this information.

GNI Group	Dataset	Number of WWTPs used	Primary (%)	Secondary (%)	Advanced (%)
Middle-income	Brazil	2,709	1	94	5
	China	2,486	0	100	0
	India	816	8	92	0
High-income	Europe	24,362	2	36	62
	New Zealand	260	19	45	36
	USA	14,771	0	62	37

Countries in the "middle-income" group showed secondary treatment for at least 92% of their WWTPs. Countries in the "high-income" group have a relatively equal distribution of WWTPs between secondary and advanced levels of treatment: around 53% of the WWTPs have advanced treatment, 46% have secondary treatment, and only 1% have primary treatment. Furthermore, within high income countries we observed a correlation between the level of treatment and the number of people served by the WWTP (Fig. S2) indicating that larger WWTPs have a higher likelihood of offering advanced treatment. As seen in Fig. S2, at a threshold of ~3,000 people served, the most likely level of treatment changes from secondary to advanced.

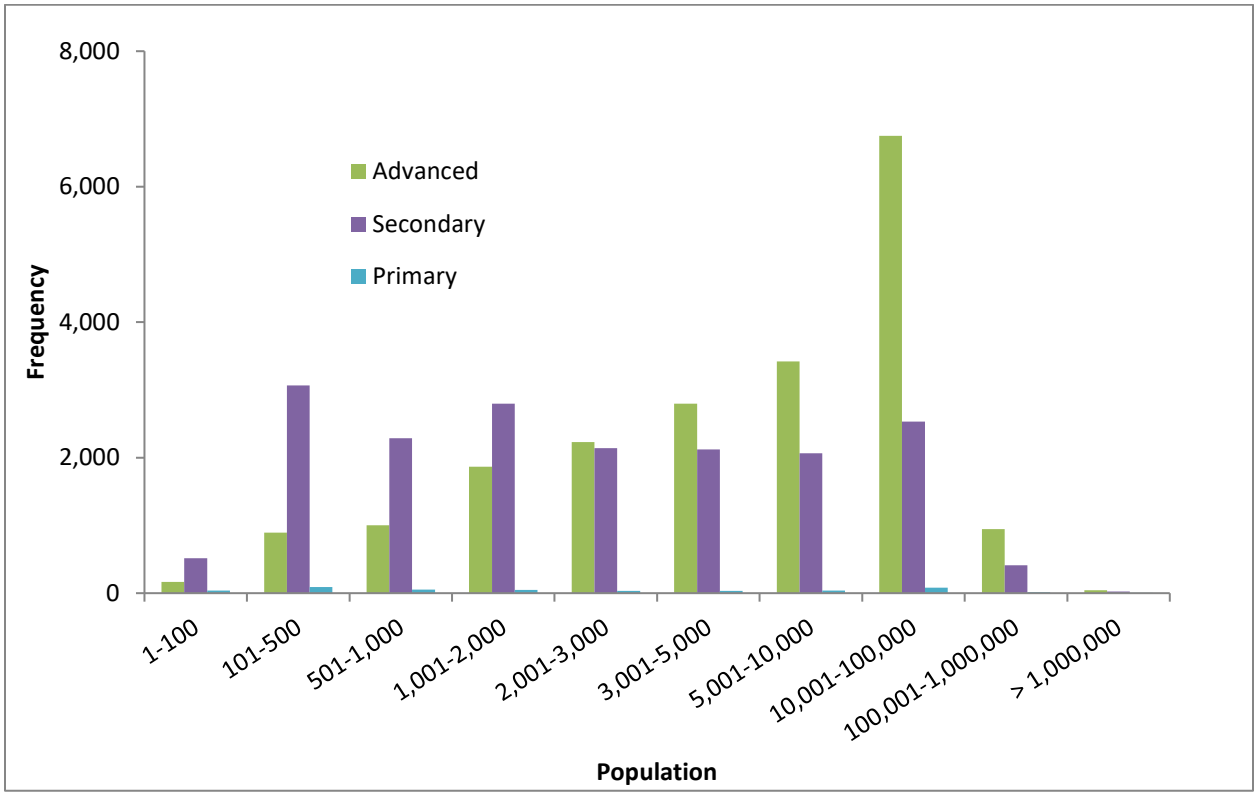

Figure S2. The distribution of the level of treatment in WWTP records for different ranges of population served in high-income countries (Europe, New Zealand, USA).

S4 Open Street Map validation

S4.1 Dataset completeness

We tested the level of comprehensiveness of the OSM dataset by comparing it against our national datasets based on number of WWTP records. For the USA, Canada, Australia, Brazil, Peru, India and China, the number of WWTP records in the OSM dataset range from 20% to 50% of the national datasets, with an average of 37%. For Mexico, only 7% of the WWTPs in the national dataset were also contained in OSM data. In contrast, for Europe, OSM includes more records than the UWWTD database (107%), possibly indicating that OSM data include also other types of wastewater facilities and/or smaller ones. Overall, we judge the OSM data completeness to be spatially uneven and rather incomplete for most regions of the world.

S4.2 Validation of estimated attributes for OSM data

Given that OSM data only offers WWTP point coordinates but no other attribute information, we tested the quality of our estimated wastewater discharge specifically for OSM data. For this, we were able to co-reference a subset of 145 OSM records in South Africa with corresponding records from the national dataset. Figure S3 shows that 86% of the estimated wastewater discharge values are within one order of magnitude of the reported values.

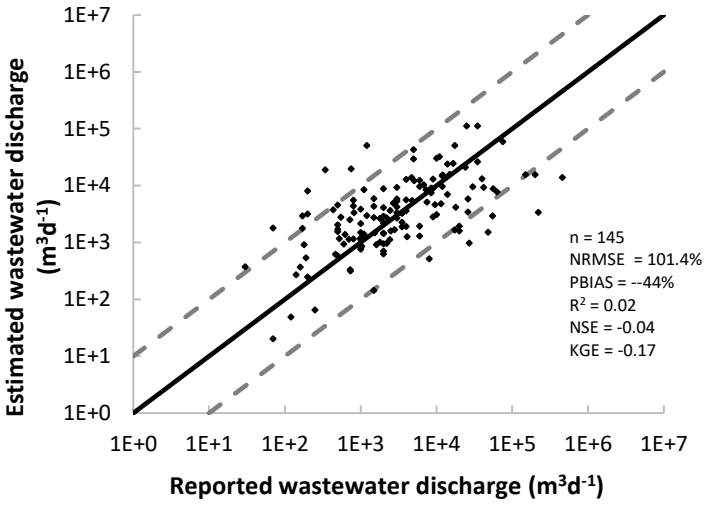

Figure S3. Reported (national dataset) versus estimated (Open Street Map) wastewater discharge (m^3 d^{-1}) for South Africa. Solid line represents the 1:1 correspondence line and the dashed lines represent the error of ±1 order of magnitude.

S5 Wastewater related country statistics derived from HydroWASTE

Table S4. Population served and wastewater discharge per country as provided by HydroWASTE. Also, for comparison, the country-level statistics for population served and wastewater discharge are listed as provided in the JMP database (Who and Unicef, 2017) and by Jones et al. (2021), respectively.

Country	Number of WWTPs in HydroWASTE	Population served (millions)			Wastewater discharge (million m^3day^{-1})		
		HydroWASTE	JMP	Under/ over-estimation	HydroWASTE	Jones et al. (2021)	Under/ over-estimation
Afghanistan	5	0.9	0.9	0.0%	0.0	0.0	
Aland	1	0.0	0.0	10.5%	0.0	0.0	
Albania	6	1.0	2.8	-63.4%	0.0	0.0	63.4%
Algeria	116	16.9	33.1	-48.9%	0.5	0.9	-48.9%
American Samoa	1	0.0	0.0	59.8%	0.0	0.0	59.8%

Angola	8	3.5	3.5	0.0%	0.0	0.0	0.0%
Antigua and Barbuda	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Argentina	143	19.1	24.6	-22.4%	0.7	1.0	-22.4%
Armenia	5	0.3	2.0	87.2%	0.0	0.0	87.2%
Aruba	3	0.0	0.0	0.0%	0.0	0.0	0.0%
Australia	1,234	16.0	21.1	-24.1%	4.1	5.5	-24.1%
Austria	634	13.8	8.0	72.7%	2.8	5.2	-46.0%
Azerbaijan	8	1.6	3.8	-56.2%	0.2	0.4	56.2%
Bahamas	3	0.1	0.1	0.0%	0.1	0.1	0.0%
Bahrain	2	1.2	1.2	0.0%	0.2	0.2	0.0%
Bangladesh	16	7.7	7.7	0.0%	0.0	0.0	0.0%
Barbados	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Belarus	348	6.0	8.5	-29.6%	1.5	2.1	-29.6%
Belgium	410	8.5	10.7	-20.7%	1.8	1.9	-5.1%
Belize	2	0.0	0.0	0.0%	0.0	0.0	0.0%
Bhutan	2	0.0	0.0	0.0%	0.0	0.0	0.0%
Bolivia	26	3.7	5.0	-27.3%	0.1	0.1	-27.3%
Bosnia and Herzegovina	13	0.7	1.9	-60.4%	0.1	0.1	60.4%
Botswana	5	0.0	0.0	0.0%	0.1	0.1	0.0%
Brazil	2,820	71.7	130.0	-44.8%	11.3	20.7	-45.4%
British Virgin Islands	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Brunei	2	0.1	0.4	62.5%	0.0	0.1	62.5%
Bulgaria	110	5.1	5.4	-6.6%	1.2	0.6	106.9%
Burkina Faso	1	0.2	0.2	0.0%	0.0	0.0	0.0%
Burundi	2	0.1	0.1	0.0%	0.0	0.0	
Cabo Verde	4	0.1	0.1	0.0%	0.0	0.0	0.0%
Cambodia	7	2.1	2.1	0.0%	0.2	0.0	
Cameroon	6	0.2	0.2	0.0%	0.0	0.0	
Canada	2,064	26.2	29.3	-10.6%	15.4	13.1	16.9%
Chad	2	0.1	0.1	64.0%	0.0	0.0	
Chile	46	5.2	15.7	-67.2%	0.9	2.6	-67.2%
China	2,486	480.9	810.1	-40.6%	93.9	85.6	9.7%
Colombia	63	23.6	36.3	-35.1%	0.4	0.6	-35.1%
Cook Islands	2	0.0	0.0	10.7%	0.0	0.0	
Costa Rica	21	1.2	1.2	0.0%	0.2	0.2	0.0%
Côte d'Ivoire	10	1.5	1.5	0.0%	0.2	0.0	
Croatia	83	0.0	2.4	98.8%	0.0	0.2	97.4%
Cuba	26	3.1	5.6	-44.8%	0.4	0.8	-44.8%
Curaçao	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Cyprus	17	0.7	0.6	22.6%	0.1	0.0	-106.0%
Czech Republic	663	9.3	9.4	-0.9%	1.9	2.4	-19.9%
Denmark	383	7.5	5.2	44.5%	1.7	1.0	63.4%
Dominican Republic	12	2.4	2.4	0.0%	0.1	0.1	0.0%
DR Congo	3	0.8	0.8	0.0%	0.0	0.0	
Ecuador	26	4.5	9.9	-54.3%	0.3	0.6	-54.3%
Egypt	132	39.1	58.1	-32.7%	11.8	17.6	-32.7%
El Salvador	6	1.7	2.5	-32.4%	0.0	0.0	32.4%
Equatorial Guinea	1	0.1	0.1	0.0%	0.0	0.0	0.0%
Estonia	68	1.2	1.2	3.5%	0.3	0.3	-3.5%
Ethiopia	4	1.1	1.1	0.0%	0.0	0.0	
Fiji	2	0.3	0.3	21.6%	0.0	0.0	21.6%
Finland	163	6.4	4.7	36.6%	1.0	0.8	36.6%
France	3,622	71.6	54.3	31.9%	12.8	9.7	31.9%
French Guiana	37	0.1	0.2	60.0%	0.0	0.0	
French Polynesia	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Gabon	1	0.0	0.7	99.0%	0.0	0.0	99.0%
Gambia	1	0.1	0.1	0.0%	0.0	0.0	
Georgia	5	0.2	1.9	89.9%	0.0	0.1	89.9%
Germany	4,257	110.6	78.9	40.3%	22.9	20.0	14.5%
Ghana	10	1.0	1.0	0.0%	0.1	0.1	0.0%
Greece	158	10.7	8.6	24.9%	3.6	2.9	24.9%
Guadeloupe	19	0.2	0.3	49.1%	0.0	0.0	
Guatemala	8	2.5	6.4	-60.9%	0.4	1.0	60.9%
Guinea	2	0.2	0.2	0.0%	0.0	0.0	
Haiti	10	0.1	0.1	0.0%	0.0	0.0	
Honduras	6	1.1	3.5	-69.6%	0.1	0.2	69.6%
Hong Kong	30	6.8	6.8	0.0%	1.6	1.6	0.0%
Hungary	749	9.7	7.7	25.8%	1.2	0.9	26.9%
Iceland	11	0.5	0.3	56.9%	0.2	0.1	-186.1%

India	816	132.1	132.1	0.0%	23.3	9.8	137.7%
Indonesia	38	28.1	29.4	-4.6%	10.8	11.3	-4.6%
Iran	134	17.7	20.8	-15.0%	1.3	1.5	-15.0%
Iraq	73	9.0	9.0	0.0%	0.6	0.6	0.0%
Ireland	166	5.0	3.1	63.0%	3.4	2.1	63.0%
Israel	37	6.0	8.3	-27.9%	1.0	1.5	-27.9%
Italy	4,090	70.5	56.9	23.9%	15.3	11.3	35.7%
Jamaica	13	0.6	0.6	0.0%	0.1	0.1	0.0%
Japan	378	85.2	94.5	-9.9%	21.3	23.6	-9.9%
Jordan	30	3.2	5.9	-46.4%	0.2	0.3	-46.4%
Kazakhstan	40	1.3	6.7	-80.1%	0.3	1.4	80.1%
Kenya	24	2.7	2.7	0.0%	0.3	0.0	
Kosovo	6	0.4	0.0		0.1	0.0	
Kuwait	7	1.8	3.8	-52.4%	0.3	0.7	52.4%
Kyrgyzstan	13	0.8	0.8	0.0%	0.0	0.0	0.0%
Laos	2	0.1	0.1	0.0%	0.1	0.1	0.0%
Latvia	89	1.3	1.8	-26.7%	0.2	0.3	31.6%
Lebanon	3	1.2	5.2	-77.6%	0.1	0.4	77.6%
Lesotho	15	0.0	0.0	0.0%	0.0	0.0	
Liberia	1	0.0	0.0	0.0%	0.0	0.0	
Libya	10	1.3	4.4	-70.7%	0.0	0.1	70.7%
Lithuania	74	2.5	2.7	-5.9%	0.4	0.4	-11.2%
Luxembourg	35	0.6	0.6	16.2%	0.2	0.1	-186.7%
Macao	5	0.4	0.4	0.0%	0.2	0.2	0.0%
Macedonia	3	0.0	1.5	97.1%	0.0	0.0	97.1%
Madagascar	2	0.1	0.3	77.3%	0.0	0.0	
Malaysia	484	21.4	23.0	-7.1%	2.5	2.7	-7.1%
Maldives	4	0.0	0.3	95.5%	0.0	0.0	95.5%
Mali	3	0.2	0.2	0.0%	0.0	0.0	
Malta	4	0.5	0.4	17.0%	0.1	0.1	36.6%
Marshall Islands	1	0.0	0.0	77.9%	0.0	0.0	77.9%
Martinique	45	0.3	0.3	-3.9%	0.1	0.0	
Mauritius	2	0.3	0.3	0.0%	0.0	0.0	0.0%
Mayotte	3	0.2	0.2	0.0%	0.0	0.0	
Mexico	2,540	57.7	94.9	-39.2%	11.9	9.0	32.5%
Micronesia	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Moldova	47	0.9	0.9	0.0%	0.0	0.0	0.0%
Monaco	1	0.0	0.0	79.6%	0.0	0.0	79.6%
Mongolia	2	0.6	0.6	-3.8%	0.1	0.1	3.8%
Montenegro	3	0.1	0.3	80.3%	0.0	0.0	80.3%
Montserrat	1	0.0	0.0	0.0%	0.0	0.0	
Morocco	27	7.4	18.8	-60.7%	0.3	0.8	-57.6%
Mozambique	3	0.3	0.3	0.0%	0.0	0.0	
Myanmar	2	0.5	0.5	0.0%	0.1	0.0	
N Mariana Islands	2	0.0	0.0	0.0%	0.0	0.0	0.0%
Namibia	18	0.2	0.8	74.1%	0.0	0.0	74.1%
Nepal	8	1.4	1.4	0.0%	0.0	0.0	
Netherlands	417	18.0	16.8	7.2%	5.2	4.8	7.2%
New Caledonia	12	0.0	0.0	0.0%	0.0	0.0	87.9%
New Zealand	317	3.7	3.8	-2.5%	1.4	0.9	55.3%
Nicaragua	7	1.5	1.5	0.0%	0.4	0.4	0.0%
Niger	3	0.1	0.2	41.8%	0.0	0.0	
Nigeria	3	2.7	16.8	-83.7%	0.0	0.2	-83.7%
North Korea	8	2.7	12.2	-77.8%	0.1	0.4	77.8%
Norway	330	6.6	4.3	53.4%	2.6	1.9	37.6%
Oman	18	0.4	0.4	0.0%	0.1	0.1	0.0%
Pakistan	25	23.5	49.0	-52.0%	0.6	1.2	-52.0%
Palau	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Palestine	21	2.2	2.2	0.0%	0.1	0.1	0.0%
Panama	8	1.3	1.4	-7.2%	0.2	0.2	7.2%
Papua New Guinea	2	0.3	0.3	19.0%	0.0	0.0	
Paraguay	9	0.6	0.6	0.0%	0.0	0.0	0.0%
Peru	184	21.1	21.1	0.0%	2.6	1.6	66.2%
Philippines	51	4.3	4.3	0.0%	0.1	0.1	0.0%
Poland	1,668	38.7	27.2	42.3%	5.5	3.9	42.5%
Portugal	500	6.6	6.6	0.0%	1.1	1.1	0.0%
Qatar	7	2.3	2.3	0.0%	0.7	0.7	0.0%
Romania	553	11.1	9.3	20.0%	2.3	2.1	8.7%
Russia	1,270	65.2	111.2	-41.4%	8.4	14.3	-41.4%
Rwanda	3	0.1	0.1	0.0%	0.0	0.0	

Saint Kitts and Nevis	2	0.0	0.0	56.8%	0.0	0.0	56.8%
Saint Lucia	3	0.0	0.0	0.0%	0.0	0.0	0.0%
Saint-Martin	2	0.0	0.0	25.4%	0.0	0.0	
Saudi Arabia	58	3.7	16.8	-77.7%	0.8	3.5	-77.7%
Senegal	9	1.2	1.2	0.0%	0.1	0.1	0.0%
Serbia	13	1.8	3.9	-54.9%	0.1	0.3	54.9%
Seychelles	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Sierra Leone	1	0.1	0.1	0.0%	0.0	0.0	
Singapore	4	3.2	5.5	-42.0%	0.9	1.5	-42.0%
Sint Maarten	1	0.0	0.0	0.0%	0.0	0.0	0.0%
Slovakia	322	3.7	3.8	-1.0%	0.9	0.8	15.2%
Slovenia	89	1.7	1.1	49.2%	0.4	0.2	-102.0%
South Africa	964	25.1	31.5	-20.2%	6.9	4.3	62.2%
South Korea	87	37.0	49.2	-24.7%	14.0	18.5	-24.7%
South Sudan	1	0.0	0.1	71.1%	0.0	0.0	
Spain	2,118	63.5	46.0	38.0%	11.6	8.3	39.7%
Sri Lanka	13	0.8	0.8	0.0%	0.0	0.0	0.0%
Sudan	2	0.4	0.4	0.0%	0.0	0.0	
Swaziland	3	0.1	0.1	0.0%	0.0	0.0	0.0%
Sweden	437	11.3	8.4	34.1%	2.4	1.3	81.1%
Switzerland	758	11.4	8.1	40.0%	5.1	3.7	38.6%
Syria	13	4.4	12.9	-65.7%	0.0	0.1	-65.7%
Taiwan	83	13.9	13.9	0.0%	0.8	0.8	0.0%
Tajikistan	5	1.2	1.2	0.0%	0.0	0.0	0.0%
Tanzania	10	0.5	0.5	0.0%	0.0	0.0	
Thailand	44	5.4	5.4	0.0%	2.5	2.5	0.0%
Togo	3	0.1	0.1	0.0%	0.0	0.0	
Tonga	2	0.0	0.0	0.0%	0.0	0.0	0.0%
Trinidad and Tobago	5	0.3	0.3	0.0%	0.0	0.0	0.0%
Tunisia	30	4.5	6.3	-28.5%	0.4	0.6	-28.5%
Turkey	320	36.2	65.0	-44.3%	4.0	7.2	-44.3%
Turkmenistan	3	0.1	1.5	90.9%	0.0	0.2	90.9%
UAE	34	3.8	8.3	-53.9%	0.7	1.4	-53.9%
Uganda	17	0.4	0.4	0.0%	0.0	0.0	
UK	1,887	70.4	63.1	11.5%	15.7	14.1	11.5%
Ukraine	312	18.4	23.0	-20.0%	1.5	1.9	-20.0%
United States	14,819	258.1	262.9	-1.9%	127.2	125.4	1.4%
Uruguay	22	1.8	2.0	-12.7%	0.1	0.1	12.7%
Uzbekistan	35	4.9	7.1	-31.0%	0.4	0.5	-31.0%
Venezuela	23	6.7	26.2	-74.2%	0.6	2.1	-74.2%
Vietnam	11	1.0	1.0	0.0%	0.6	0.6	0.0%
Yemen	2	0.7	7.6	-91.2%	0.0	0.0	
Zambia	13	1.5	1.5	0.0%	0.0	0.0	0.0%
Zimbabwe	42	2.6	3.6	-28.1%	0.3	0.0	
Global	**58,497**	**2,291.2**	**2,959.6**	**-22.6%**	**520.7**	**514.4**	**1.2%**

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Table S5. Total length of rivers downstream of WWTPs, by country.

Country	Total length of rivers dowsntream of WWTPs (km)	Percentage of rivers downstream of WWTPs containing more than x% of wastewater			
		x = 1%	x = 5%	x = 10%	x = 50%
Afghanistan	1,839	2.4%	1.2%	0.0%	0.0%
Albania	292	3.6%	0.0%	0.0%	0.0%
Algeria	5,471	38.3%	15.8%	8.1%	0.8%
Angola	1,231	4.4%	2.7%	0.0%	0.0%
Argentina	17,933	6.9%	1.6%	0.9%	0.0%
Armenia	273	8.5%	4.2%	4.2%	0.0%
Australia	57,263	18.3%	3.4%	1.6%	0.0%
Austria	5,295	41.9%	2.2%	0.2%	0.0%
Azerbaijan	1,093	9.9%	1.8%	0.0%	0.0%
Bangladesh	1,459	0.0%	0.0%	0.0%	0.0%
Belarus	8,547	42.7%	7.5%	4.2%	0.0%
Belgium	2,235	57.1%	16.2%	1.6%	0.0%
Benin	39	0.0%	0.0%	0.0%	0.0%
Bhutan	100	0.0%	0.0%	0.0%	0.0%
Bolivia	6,012	1.7%	0.5%	0.0%	0.0%
Bosnia and Herzegovina	879	4.4%	0.0%	0.0%	0.0%
Botswana	2,413	34.6%	24.0%	18.3%	2.1%

Brazil	88,604	9.9%	1.9%	0.4%	0.0%
Bulgaria	3,536	70.6%	10.8%	3.5%	0.0%
Burkina Faso	193	11.8%	5.2%	0.0%	0.0%
Burundi	13	0.0%	0.0%	0.0%	0.0%
Cambodia	915	6.1%	0.0%	0.0%	0.0%
Cameroon	1,083	3.0%	0.0%	0.0%	0.0%
Canada	54,694	18.6%	4.3%	1.5%	0.2%
Caspian Sea	43	0.0%	0.0%	0.0%	0.0%
Chad	130	0.0%	0.0%	0.0%	0.0%
Chile	2,206	24.9%	18.4%	6.8%	0.0%
China	104,698	52.8%	27.9%	20.2%	4.1%
Colombia	6,314	3.4%	0.0%	0.0%	0.0%
Costa Rica	462	17.5%	0.6%	0.0%	0.0%
Cote d'Ivoire	765	3.4%	3.4%	2.6%	0.0%
Croatia	1,145	51.3%	0.0%	0.0%	0.0%
Cuba	404	63.7%	13.3%	10.5%	0.0%
Cyprus	192	69.9%	52.5%	42.4%	0.0%
Czech Republic	5,641	74.7%	7.7%	1.4%	0.0%
Denmark	1,590	51.8%	2.8%	0.5%	0.0%
Dominican Republic	302	2.1%	0.0%	0.0%	0.0%
DR Congo	3,570	1.0%	0.0%	0.0%	0.0%
Ecuador	2,467	5.0%	0.6%	0.6%	0.0%
Egypt	2,434	65.8%	40.2%	33.9%	9.0%
El Salvador	259	3.0%	0.0%	0.0%	0.0%
Estonia	1,133	11.8%	0.5%	0.0%	0.0%
Ethiopia	978	7.2%	2.4%	1.0%	0.0%
Finland	3,953	13.7%	2.1%	0.9%	0.0%
France	30,248	29.7%	2.9%	0.7%	0.0%
French Guiana	26	0.0%	0.0%	0.0%	0.0%
Gabon	176	0.0%	0.0%	0.0%	0.0%
Georgia	372	0.0%	0.0%	0.0%	0.0%
Germany	28,206	80.8%	30.9%	8.5%	0.1%
Ghana	965	12.4%	3.3%	0.9%	0.0%
Greece	1,647	31.6%	8.9%	4.2%	0.7%
Guatemala	921	31.7%	11.6%	4.4%	0.0%
Haiti	14	0.0%	0.0%	0.0%	0.0%
Honduras	741	2.4%	0.0%	0.0%	0.0%
Hungary	7,731	62.9%	12.1%	4.7%	0.1%
Iceland	68	0.0%	0.0%	0.0%	0.0%
India	33,425	53.7%	26.2%	18.4%	4.2%
Indonesia	1,490	38.9%	11.7%	10.6%	0.9%
Iran	9,019	28.6%	10.9%	6.6%	0.0%
Iraq	4,752	16.2%	8.2%	5.2%	0.0%
Ireland	1,932	25.0%	2.0%	0.0%	0.0%
Israel	543	91.5%	48.1%	27.6%	0.0%
Italy	19,177	53.9%	12.0%	4.8%	0.2%
Japan	3,008	39.1%	17.5%	8.1%	0.5%
Jordan	600	87.0%	60.3%	51.4%	2.4%
Kazakhstan	10,115	24.9%	5.9%	3.2%	0.0%
Kenya	3,194	23.5%	6.8%	2.7%	0.0%
Kosovo	211	68.6%	4.8%	2.4%	0.0%
Kyrgyzstan	636	4.7%	4.3%	4.3%	0.0%
Laos	1,590	0.0%	0.0%	0.0%	0.0%
Latvia	2,585	4.3%	0.0%	0.0%	0.0%
Lebanon	113	100.0%	0.0%	0.0%	0.0%
Lesotho	696	13.9%	0.0%	0.0%	0.0%
Libya	256	40.7%	34.9%	34.1%	0.0%
Liechtenstein	13	100.0%	0.0%	0.0%	0.0%
Lithuania	2,444	34.2%	3.7%	2.4%	0.0%
Luxembourg	246	67.7%	27.7%	14.4%	0.0%
Macedonia	340	3.3%	0.0%	0.0%	0.0%
Malaysia	2,896	18.3%	3.8%	0.1%	0.0%
Mali	2,330	0.0%	0.0%	0.0%	0.0%
Mauritania	11	0.0%	0.0%	0.0%	0.0%
Mexico	43,657	37.9%	18.4%	11.5%	1.8%
Moldova	1,401	7.3%	0.9%	0.0%	0.0%
Mongolia	1,108	67.9%	31.9%	7.8%	0.0%
Montenegro	61	0.0%	0.0%	0.0%	0.0%
Morocco	2,009	19.4%	3.0%	2.7%	0.0%
Mozambique	2,916	26.0%	18.8%	9.9%	0.0%

Myanmar	3,170	0.1%	0.1%	0.1%	0.0%
Namibia	2,112	35.2%	17.4%	2.0%	0.0%
Nepal	779	4.1%	0.0%	0.0%	0.0%
Netherlands	2,892	94.5%	50.3%	21.4%	0.1%
New Zealand	4,245	0.9%	0.0%	0.0%	0.0%
Nicaragua	651	11.0%	0.0%	0.0%	0.0%
Niger	1,029	10.0%	4.9%	1.2%	0.0%
Nigeria	1,613	0.2%	0.2%	0.0%	0.0%
North Korea	361	0.0%	0.0%	0.0%	0.0%
Norway	3,202	2.6%	0.3%	0.0%	0.0%
Oman	816	63.9%	18.5%	11.0%	0.0%
Pakistan	6,879	29.8%	9.3%	4.1%	0.7%
Palestina	194	100.0%	58.0%	43.9%	0.0%
Panama	25	69.2%	0.0%	0.0%	0.0%
Papua New Guinea	634	0.9%	0.0%	0.0%	0.0%
Paraguay	2,119	0.2%	0.0%	0.0%	0.0%
Peru	9,349	9.8%	4.4%	2.8%	0.3%
Philippines	229	0.0%	0.0%	0.0%	0.0%
Poland	20,539	56.9%	13.3%	3.9%	0.0%
Portugal	4,367	32.0%	5.4%	1.0%	0.0%
Puerto Rico	239	48.6%	3.4%	0.0%	0.0%
Qatar	16	100.0%	100.0%	100.0%	100.0%
Republic of Congo	577	0.0%	0.0%	0.0%	0.0%
Romania	11,458	35.8%	3.9%	1.8%	0.0%
Russia	85,406	16.0%	2.5%	1.0%	0.0%
Rwanda	211	0.0%	0.0%	0.0%	0.0%
Saudi Arabia	2,499	46.0%	24.2%	20.3%	3.6%
Senegal	37	2.6%	2.6%	2.6%	2.6%
Serbia	2,100	44.4%	2.9%	1.3%	0.0%
Slovakia	3,015	58.0%	7.3%	3.5%	1.0%
Slovenia	931	38.3%	0.6%	0.0%	0.0%
Somalia	299	0.0%	0.0%	0.0%	0.0%
South Africa	32,951	57.6%	27.2%	16.3%	3.5%
South Korea	1,000	61.0%	40.7%	18.4%	6.7%
South Sudan	2,371	0.0%	0.0%	0.0%	0.0%
Spain	22,858	63.2%	17.0%	6.5%	0.2%
Sri Lanka	454	0.0%	0.0%	0.0%	0.0%
Sudan	2,375	0.0%	0.0%	0.0%	0.0%
Swaziland	621	0.0%	0.0%	0.0%	0.0%
Sweden	8,663	7.5%	0.5%	0.0%	0.0%
Switzerland	2,736	53.1%	4.6%	1.9%	0.0%
Syria	1,253	7.1%	4.8%	4.1%	0.0%
Taiwan	402	21.1%	0.0%	0.0%	0.0%
Tajikistan	517	3.8%	0.0%	0.0%	0.0%
Tanzania	1,702	1.0%	0.0%	0.0%	0.0%
Thailand	1,837	23.1%	6.7%	3.1%	0.6%
Togo	61	0.0%	0.0%	0.0%	0.0%
Tunisia	598	35.9%	9.8%	4.5%	0.0%
Turkey	7,949	43.4%	11.6%	5.1%	0.0%
Turkmenistan	1,987	18.3%	16.3%	4.8%	0.0%
UAE	197	100.0%	61.2%	61.2%	55.1%
Uganda	1,539	2.1%	0.0%	0.0%	0.0%
Ukraine	12,698	33.7%	5.8%	2.5%	0.0%
United Kingdom	10,358	55.3%	23.2%	11.2%	0.0%
United States	287,395	33.5%	9.6%	5.0%	0.6%
Uruguay	1,561	0.0%	0.0%	0.0%	0.0%
Uzbekistan	2,499	23.0%	9.6%	8.8%	0.0%
Venezuela	3,177	13.9%	7.0%	3.3%	0.0%
Vietnam	1,553	3.1%	0.8%	0.8%	0.0%
Yemen	129	100.0%	100.0%	35.7%	0.0%
Zambia	1,954	0.0%	0.0%	0.0%	0.0%
Zimbabwe	4,987	38.3%	16.4%	8.0%	0.0%
Global	**1,214,362**	**32.8%**	**10.9%**	**5.9%**	**0.9%**

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