Pharmaceuticals in the environment
- The global perspective –

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(IWW Water Centre, Germany)

GGHH Webinar Series – May 31st, 2016

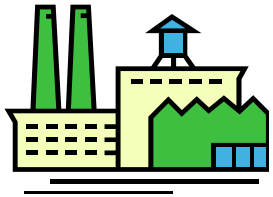
Safer Pharma:

How healthcare can reduce pharmaceutical pollution

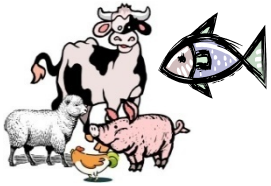
How do pharmaceuticals enter the environment?

Consumer

Pharmaceutical Industry



Hospital



Agriculture/Aquaculture

How do pharmaceuticals enter the environment?

Waste water treatment plants (WWTP)

Waste / Wastewater

Sludge / Manure

How do pharmaceuticals enter the environment?

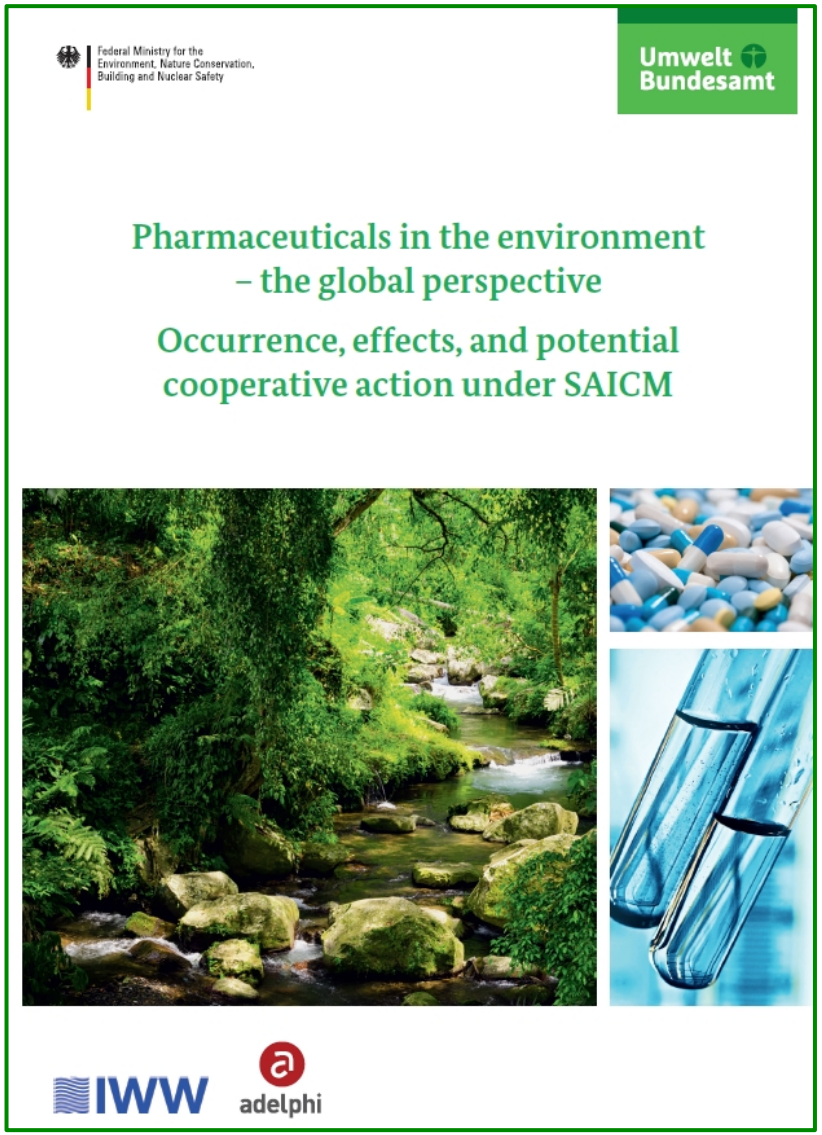
Drinking water

Surface and Groundwater

Agricultural soil

Motivation

- Multiple studies have shown that pharmaceuticals are occurring ubiquitarily in the environment of industrialized countries.
- In developing and emerging countries?
- IWW Water Centre and adelphi are conducting a study to determine the state of knowledge on the global scale.



Literature Compilation

Endnote© database:

- **1016 publications reporting MECs of pharmaceuticals in various countries (plus 139 review articles)**
- **Publications collected by**
  - **Database search** (ISI Web of Knowledge™, library catalogues, etc.)
  - **Internet**
  - **Contacting of stakeholders (41 in 18 countries)**
  - **Research projects (NORMAN, KNAPPE, FATE-SEES included)**
- **Types of publication**
  - **Mostly English-language scientific papers**
  - **Relative little governmental reports**
  - **German-, Chinese-, French-, Russian-, Slovenian-, Portuguese-, Dutch-, Swedish- and Spanish-language publications evaluated**

MEC Database (measured environmental concentrations)

- **123,761 MEC entries from 1016 publications**

	Count	Matrix_English
49.330	1.891	Sewage urban (untreated)
	729	Sewage industrial (untreated)
	2.889	Sewage hospital (untreated)
	351	Sewage hospital (treated)
	13.219	WWTP inflow (untreated)
	27.579	WWTP effluent (treated)
	2.672	WWTP sludge
67.987	3.245	Surface Water - unspecific
	50.686	Surface Water - River/Stream
	1.711	Surface Water - Lake
	1.420	Surface Water - Sea or Ocean
	467	Surface Water - Aquaculture
	743	Surface Water - Estuary
	485	Riverbank filtration
	3.304	Groundwater
	1.713	Well Water (untreated)
	382	Tap water
	3.831	Drinking Water

	Count	Matrix_English
3.070	283	Sediment - unspecific
	1.247	Sediment - River/Stream
	612	Sediment - Lake
	55	Sediment - Sea or Ocean
	184	Sediment - Aquaculture
	155	Sediment - Estuary
	9	Suspended particulate matter - unspecific
	5	Suspended particulate matter - Estuary
	146	Suspended particulate matter - Sewage
	12	Suspended particulate matter - Sea or Ocean
	362	Suspended particulate matter - River/Stream
3.374	15	Rain
	1.295	Soil
	372	Soil Water
	999	Manure - liquid
	580	Manure - dung
	18	Dust
	95	Unknown

MEC: measured environmental concentration

Database Analyses

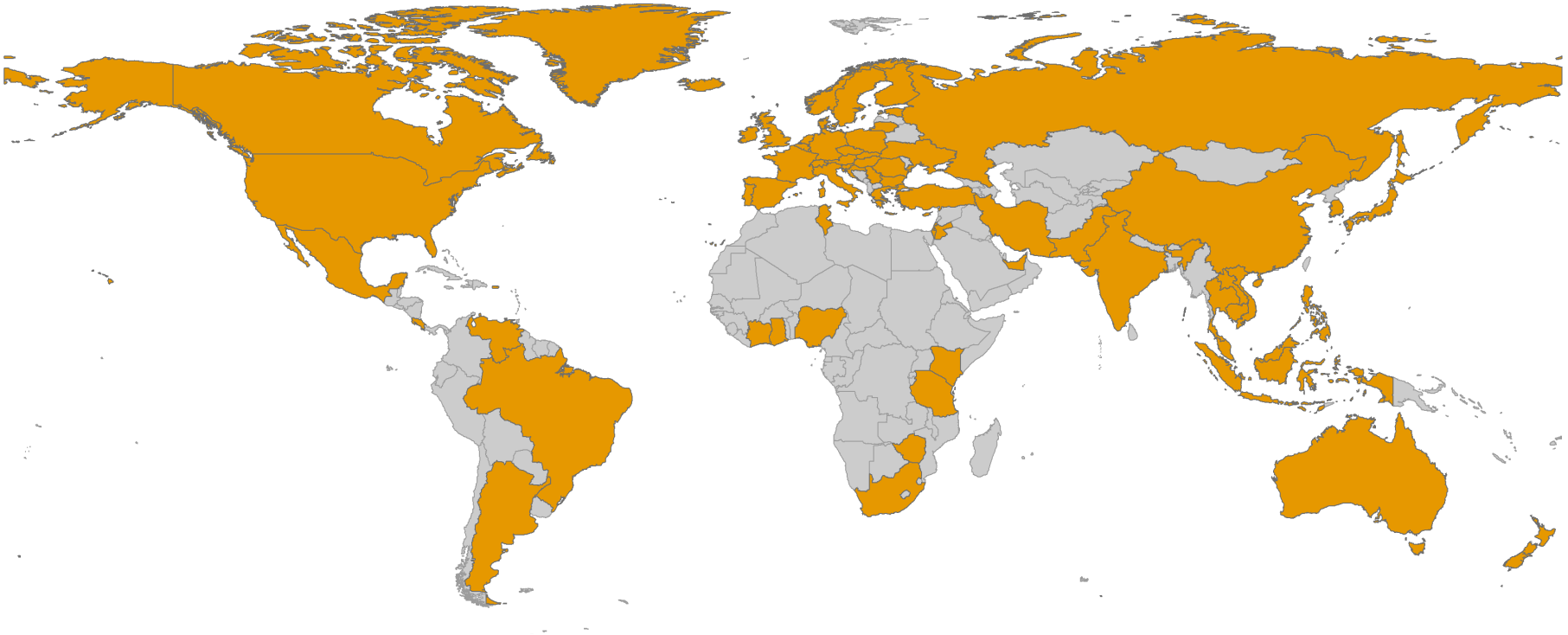
Questions to be answered:

- On a global scale, where have pharmaceuticals been found in the environment ?
- How many and what kind of pharmaceuticals have been found ?
- Are the same pharmaceuticals detected in each UN regional group?
- What is the source of the pharmaceuticals found ?
- At which concentrations are pharmaceuticals found in the environment?
- Can pharmaceuticals have ecotoxicological effects at these concentrations?

Data Analyses

In which countries have pharmaceuticals been found in the environment?

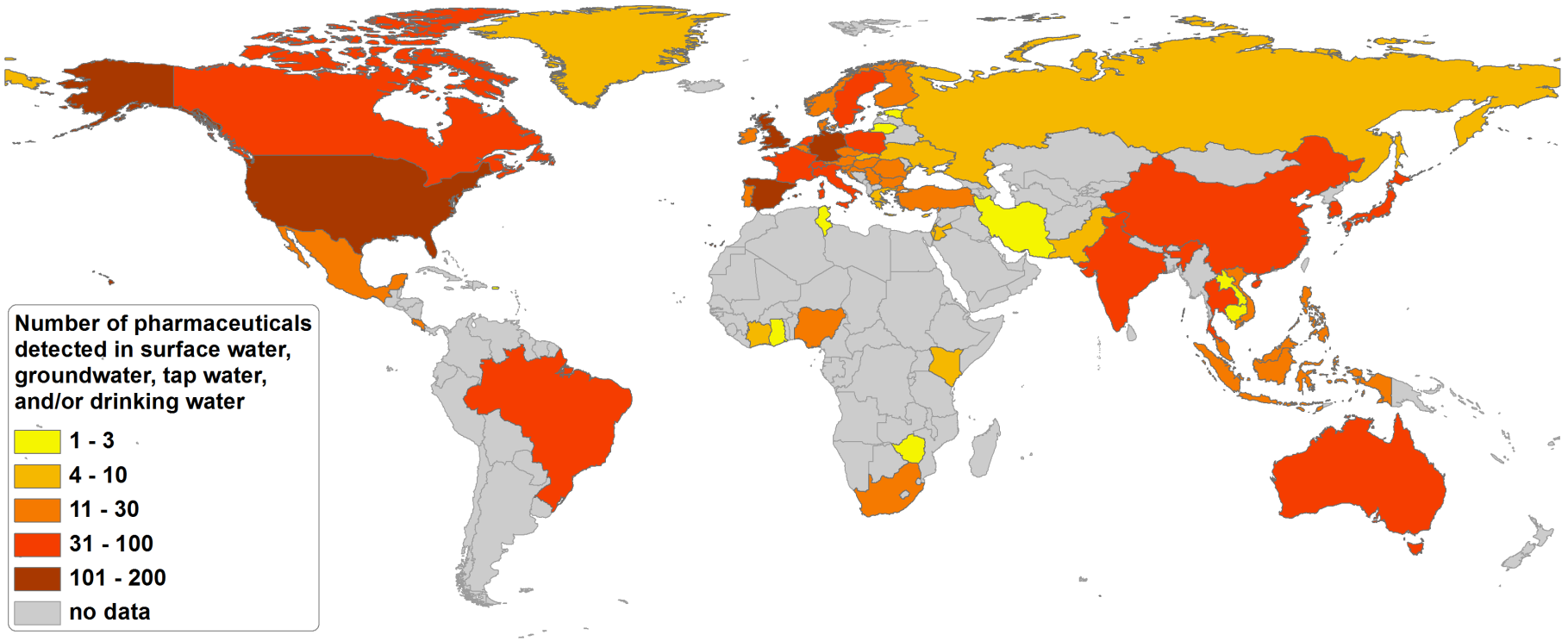
- **In 71 countries (covering all 5 UN regional groups), pharmaceuticals have been detected in the environment.**
  (concentration of at least one MEC in one matrix > detection limit)



Data Analyses

How many pharmaceuticals have been found in each UN regional group?

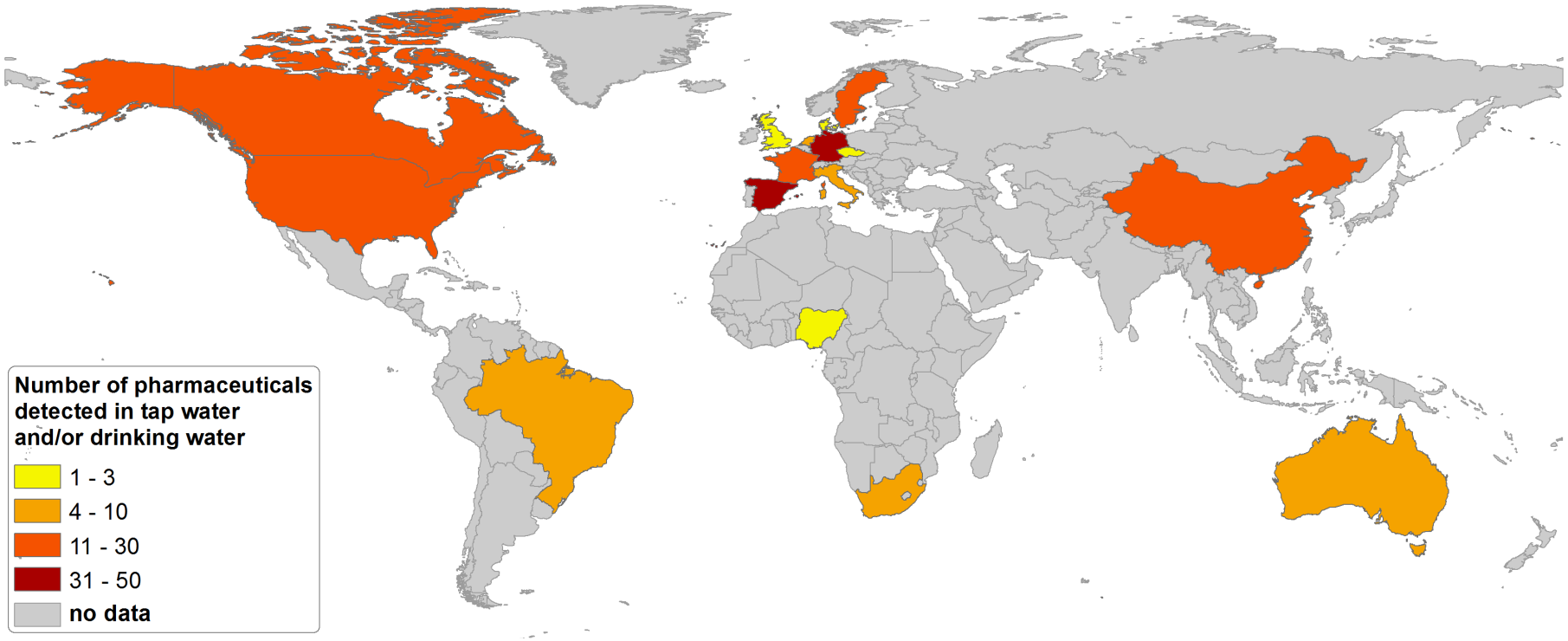
- **In each UN regional group,**
  ≥ 38 different pharmaceuticals have been found in surface water / groundwater / drinking water / tap water.



Data Analyses

Have pharmaceuticals been detected in drinking water or tap water?

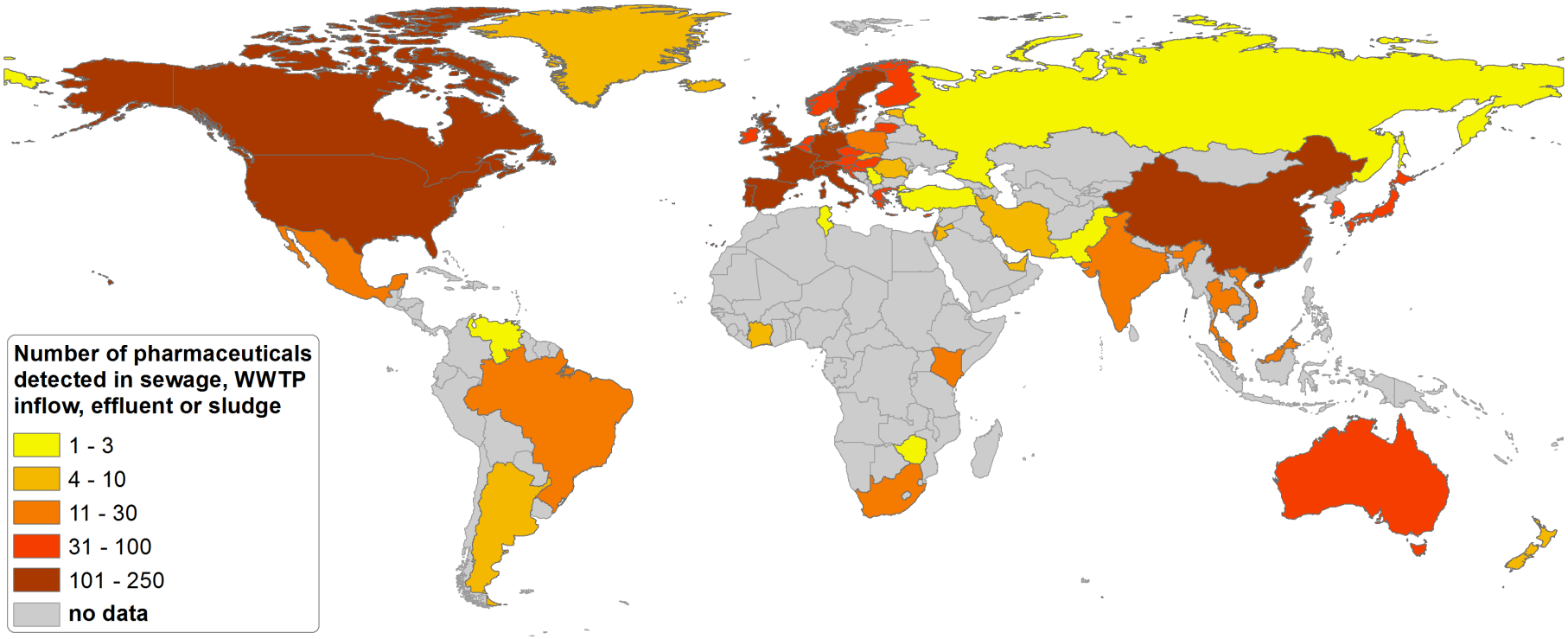
- **In every UN regional group, pharmaceuticals have been found in <u>drinking water / tap water.</u>**



Data Analyses

How many pharmaceuticals are found in sewage or WWTP influent/effluent/sludge?

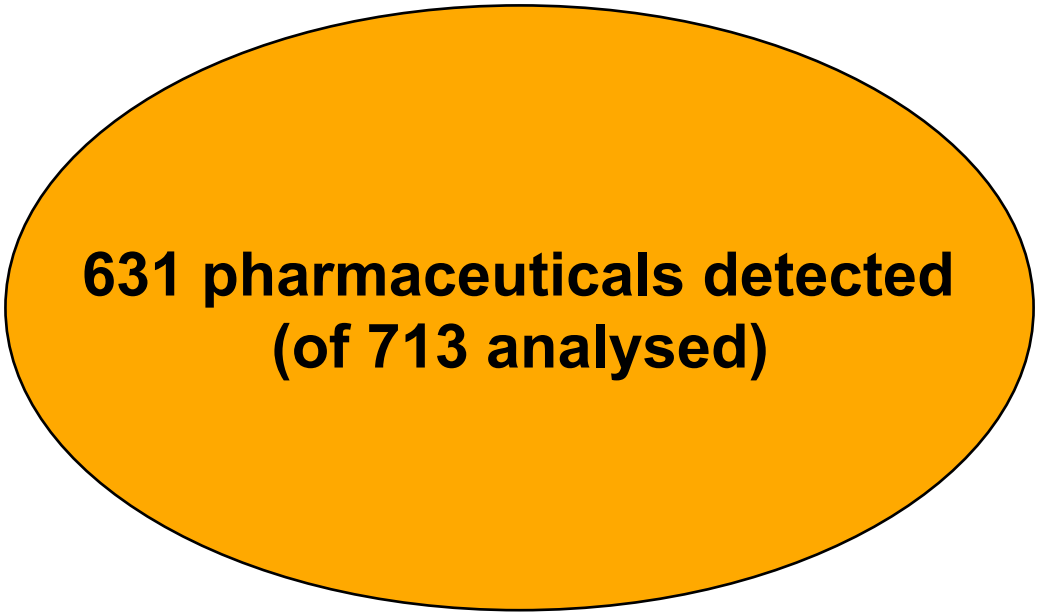
- **Worldwide, 559 pharmaceuticals or their transformation products have been found in sewage or WWTP influent/effluent/sludge.**



Data Analyses

How many pharmaceuticals have been found in the environment?

- **713 pharmaceuticals have been analysed (of which 142 are transformation products).**
- **631 have been found above their detection limits in the environment (of which 127 are transformation products).**



Data Analyses

Are the same pharmaceuticals detected in each UN regional group?

126 (205)
in EEC

249 (313)
in Asia-Pacific

574 (646)
in WEOC

55 (84)
in GRULAC

40 (59)
in Africa

Data Analyses

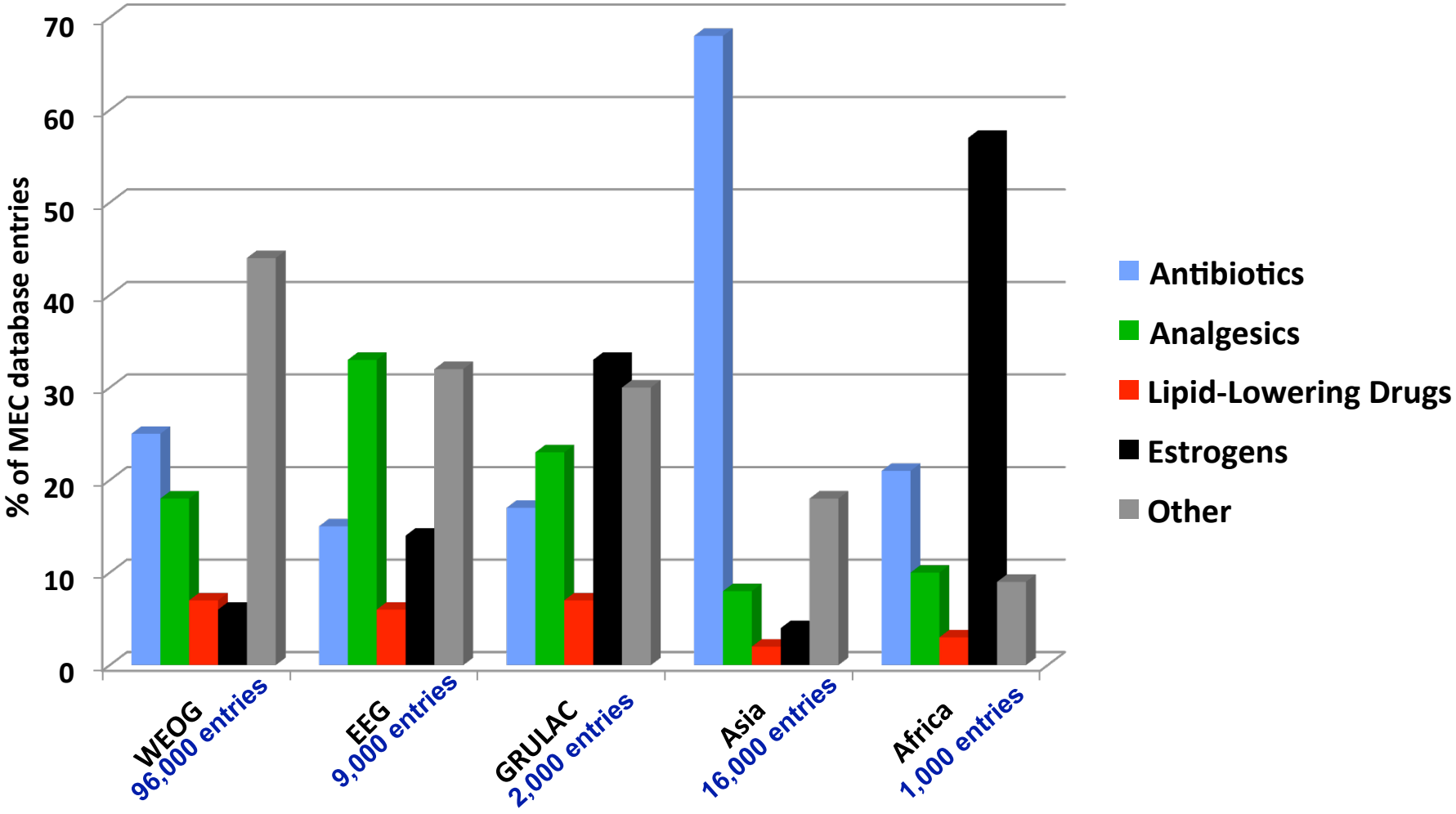
Are the same pharmaceuticals detected in each UN regional group?

- **16 pharmaceuticals were found in surface water / groundwater / drinking / tap water in each of the five UN regional groups**

Name	Therapy Group	Number of Countries with Positive Detection in Surface Water, Groundwater, Drinking Water					
		African Group	Asia Pacific Group	EEG	GRULAC	WEOG	global
Diclofenac	Analgesics	3	8	13	3	23	50
Carbamazepine	Antiepileptic drugs	3	6	13	2	24	48
Ibuprofen	Analgesics	3	8	10	2	24	47
Sulfamethoxazole	Antibiotics	5	9	10	2	21	47
Naproxen	Analgesics	2	8	10	2	23	45
Estrone	Estrogen	1	10	6	2	16	35
17-beta-Estradiol	Estrogen	2	9	4	2	17	34
17-alpha-Ethinylestradiol	Estrogen	1	8	3	2	17	31
Trimethoprim	Antibiotics	2	9	3	2	13	29
Paracetamol	Analgesics	1	6	4	3	15	29
Clofibric acid	Lipid-lowering drugs	1	3	5	2	12	23
Ciprofloxacin	Antibiotics	1	5	1	2	11	20
Ofloxacin	Antibiotics	1	4	1	1	9	16
Estriol	Estrogen	1	1	2	1	10	15
Norfloxacin	Antibiotics	1	4	1	2	7	15
Acetylsalicylic acid	Analgesics	1	4	1	2	7	15

Data Analyses

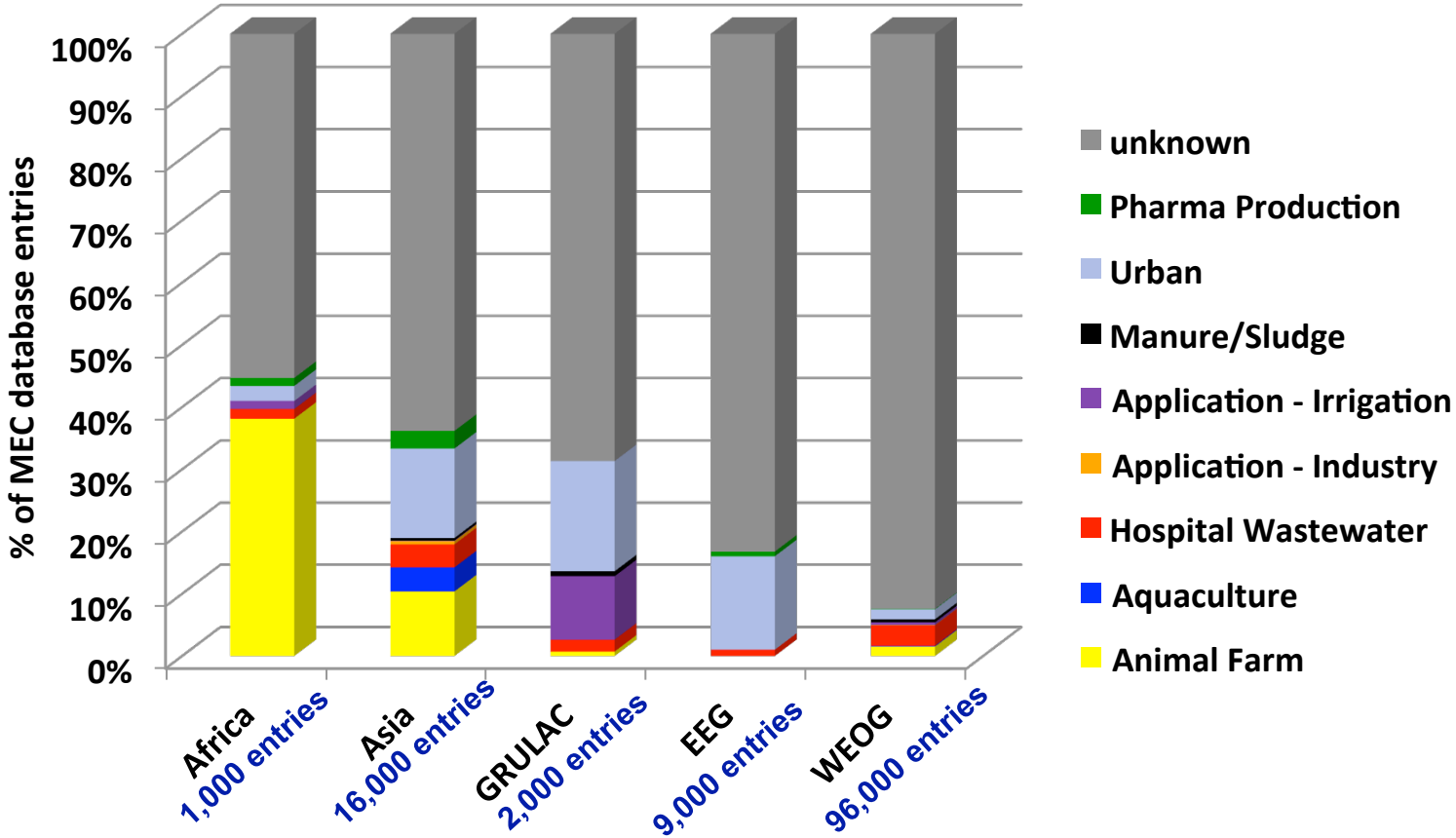
What kind of pharmaceuticals have been found in each UN groups?



Data Analyses

What is the source of the pharmaceuticals found in the environment?

- Urban areas are a major contributor.
- Discharge from manufacturing, animal husbandry, and aquaculture are important regionally.



Effects of human medicines in the environment – case studies

17α-Ethinylestradiol
Synthetic estrogen
Fathead minnow (*Pimephales promelas*)
Population collapse due to feminization of male fish
Whole-lake experiment
Kidd et al. 2007

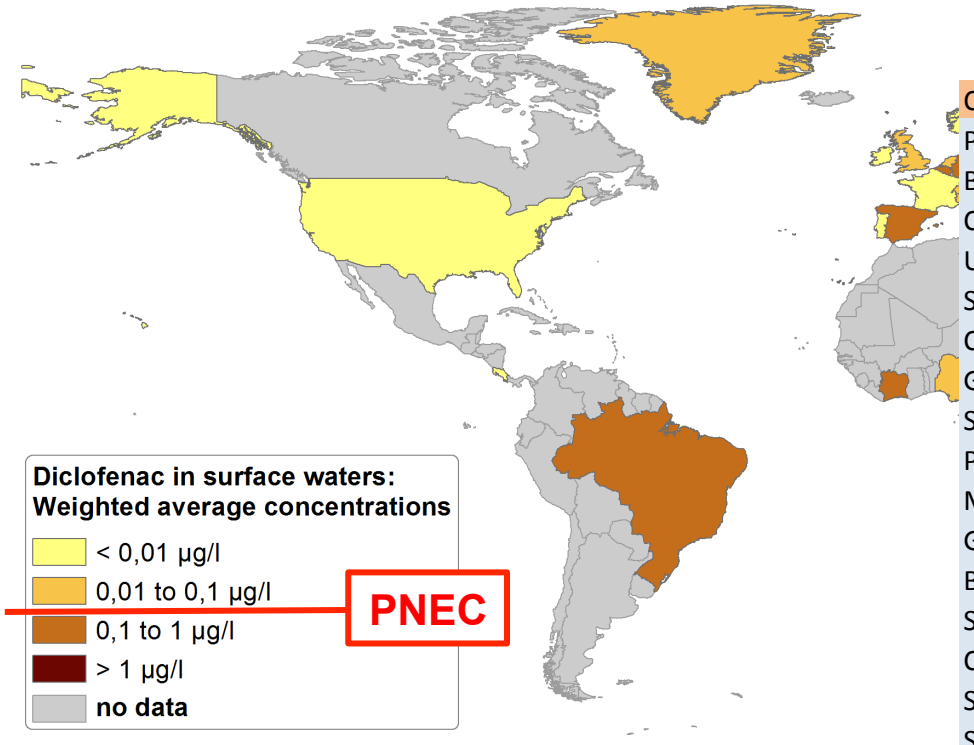
Fluoxetine
Antidepressant
Leopard Frog (*Rana pipiens*)
Delayed tadpole development
Laboratory
Foster et al. 2010

Enrofloxacin, Ciprofloxacin
Antibiotics
Cyanobacterium (*Anabaena flosaquae*) Duckweed (*Lemna minor*)
Growth inhibition
Laboratory
Ebert et al. 2011

Data Analyses

Can pharmaceuticals have ecotoxicological effects at these concentrations?

- **Average Diclofenac concentration in surface waters**
  (only monitoring campaigns in which “single values” or “average values” with known sample size n are reported)

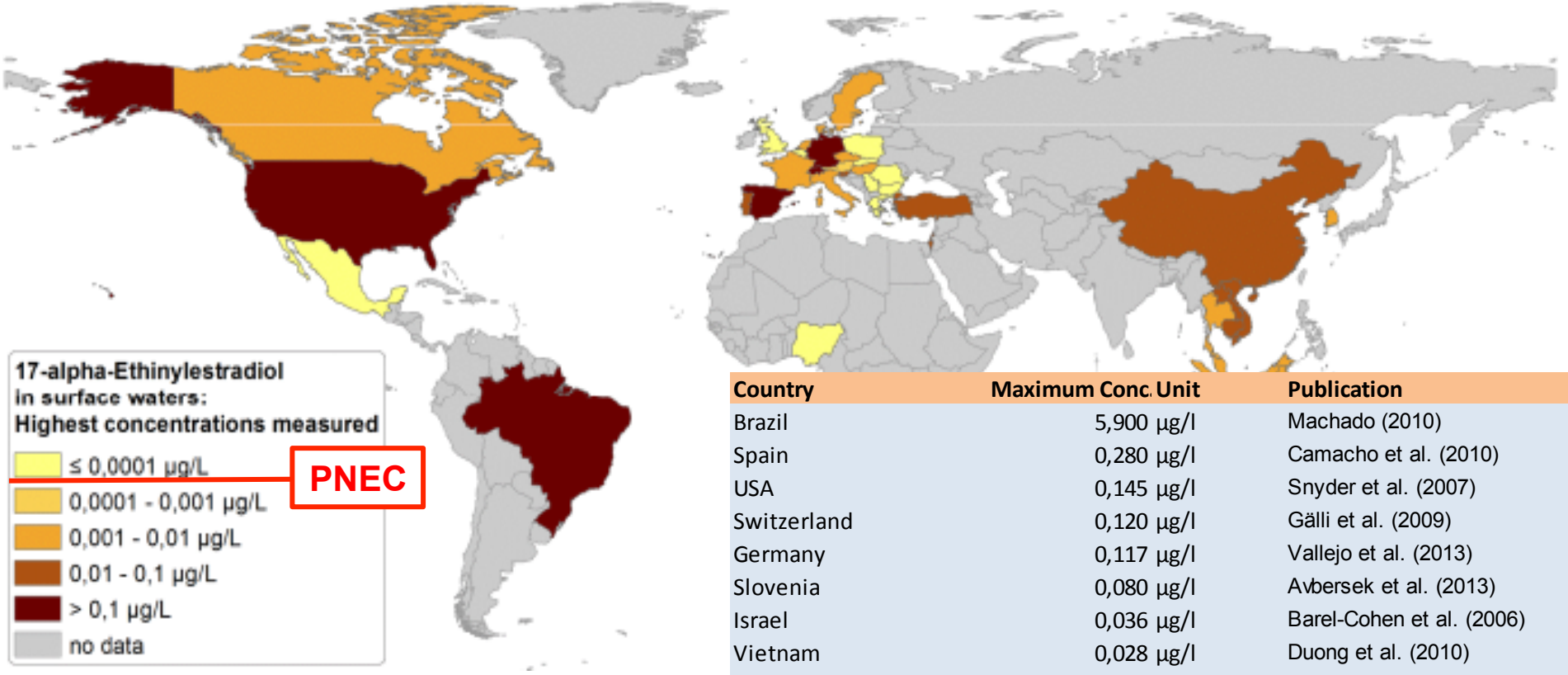


Country	Average (weighted)	Unit	Samples (n)
Pakistan	1,550	µg/l	8
Brazil	0,707	µg/l	44
Côte d'Ivoire	0,540	µg/l	6
Ukraine	0,438	µg/l	8
Spain	0,268	µg/l	204
Czech Republic	0,200	µg/l	68
Germany	0,164	µg/l	4137
Slovakia	0,152	µg/l	134
Poland	0,126	µg/l	40
Malaysia	0,117	µg/l	2
Greece	0,104	µg/l	25
Belgium	0,103	µg/l	14
Sweden	0,090	µg/l	113
Cyprus	0,088	µg/l	2
South Africa	0,085	µg/l	2
Switzerland	0,077	µg/l	183
…	…	…	…

Data Analyses

At which concentration are pharmaceuticals found in the environment?

- **Maximum 17-α-Ethinylestradiol (EE2, birth control pill) concentrations in surface waters**

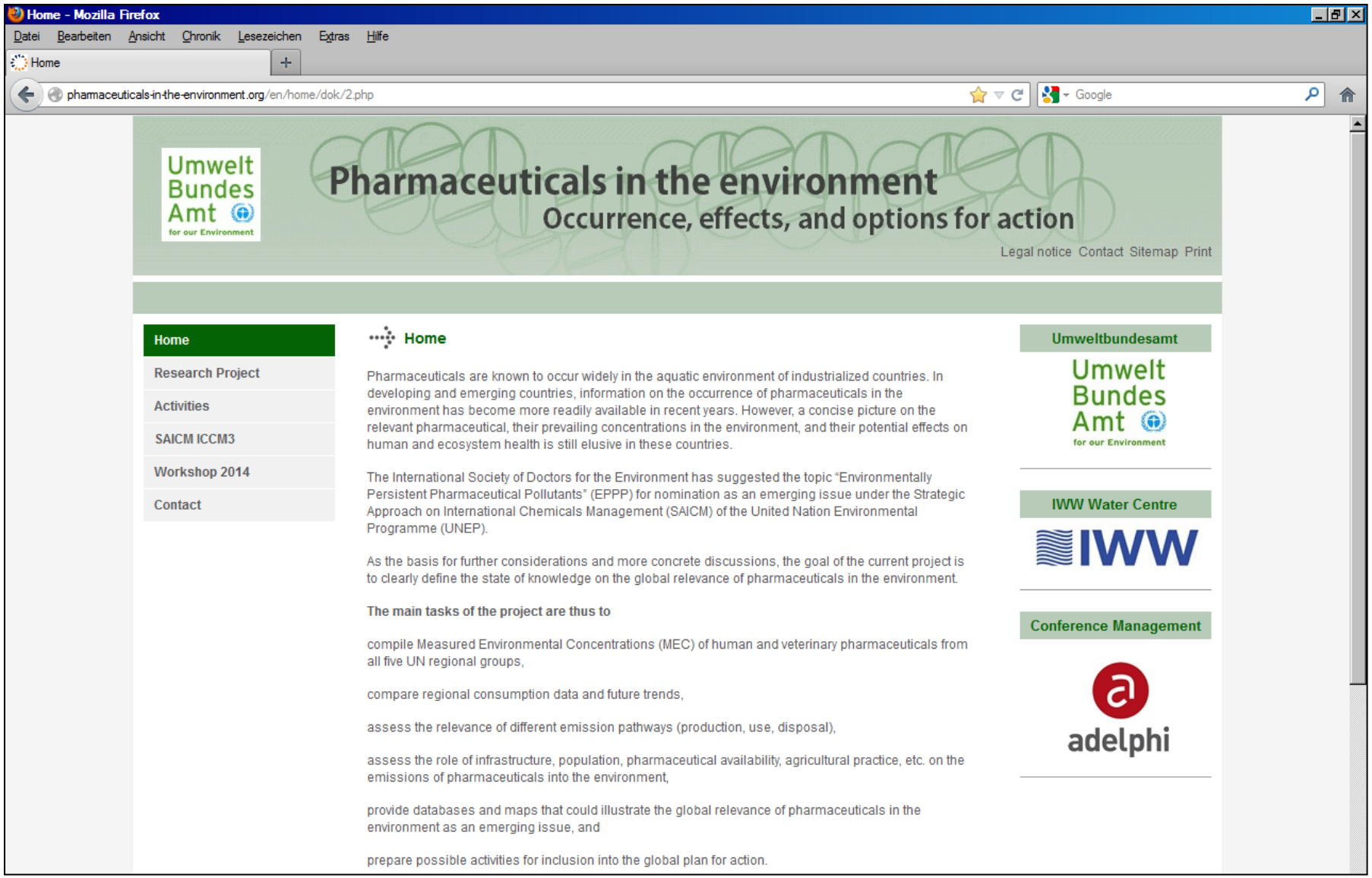


Country	Maximum Conc.	Unit	Publication
Brazil	5,900	µg/l	Machado (2010)
Spain	0,280	µg/l	Camacho et al. (2010)
USA	0,145	µg/l	Snyder et al. (2007)
Switzerland	0,120	µg/l	Gälli et al. (2009)
Germany	0,117	µg/l	Vallejo et al. (2013)
Slovenia	0,080	µg/l	Avbersek et al. (2013)
Israel	0,036	µg/l	Barel-Cohen et al. (2006)
Vietnam	0,028	µg/l	Duong et al. (2010)
China	0,027	µg/l	Chen et al. (2007)
...	...	...	...

Conclusions

- Pharmaceuticals occur globally in the environment (not just in industrialized countries):
  - Detected in 71 countries covering all 5 UN regional groups
  - Data availability for emerging and developing countries increasing, but still lower than in western countries
- In most countries, certain pharmaceuticals prevail at concentrations above PNEC in surface waters, suggesting adverse ecotoxicological effects in these locations.
- Different pharmaceutical groups have been in focus of monitoring in different UN regions, e.g. antibiotics in Asia and estrogens in Africa.
- Urban wastewater discharge is the dominant emission pathway, while discharge from manufacturing, animal husbandry and aquaculture are important regionally.
- Available data on production/consumption not sufficient for regional analysis of relevant pharmaceuticals.

www.pharmaceuticals-in-the-environment.org



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PHARMACEUTICALS IN THE ENVIRONMENT—GLOBAL OCCURRENCES AND PERSPECTIVES

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(Submitted 27 February 2015; Returned for Revision 3 July 2015; Accepted 11 December 2015)

Abstract: Pharmaceuticals are known to occur widely in the environment of industrialized countries. In developing countries, more monitoring results have recently become available, but a concise picture of measured environmental concentrations (MECs) is still elusive. Through a comprehensive literature review of 1016 original publications and 150 review articles, the authors collected MECs for human and veterinary pharmaceutical substances reported worldwide in surface water, groundwater, tap/drinking water, manure, soil, and other environmental matrices in a comprehensive database. Due to the heterogeneity of the data sources, a simplified data quality assessment was conducted. The database reveals that pharmaceuticals or their transformation products have been detected in the

Acknowledgement

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Umwelt Bundesamt

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  - Adelphi: G. Gruettner, A. Carius

- The data base and the full report will soon be available at www.uba.de free of charge.

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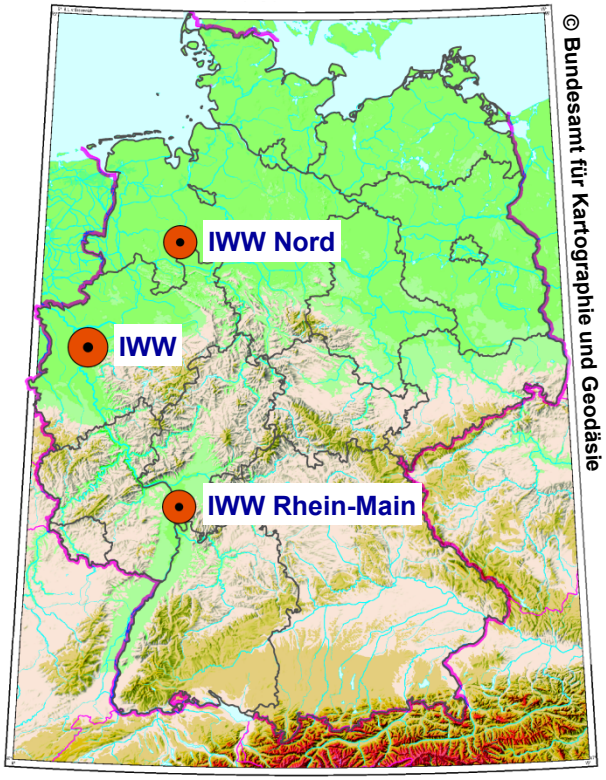

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