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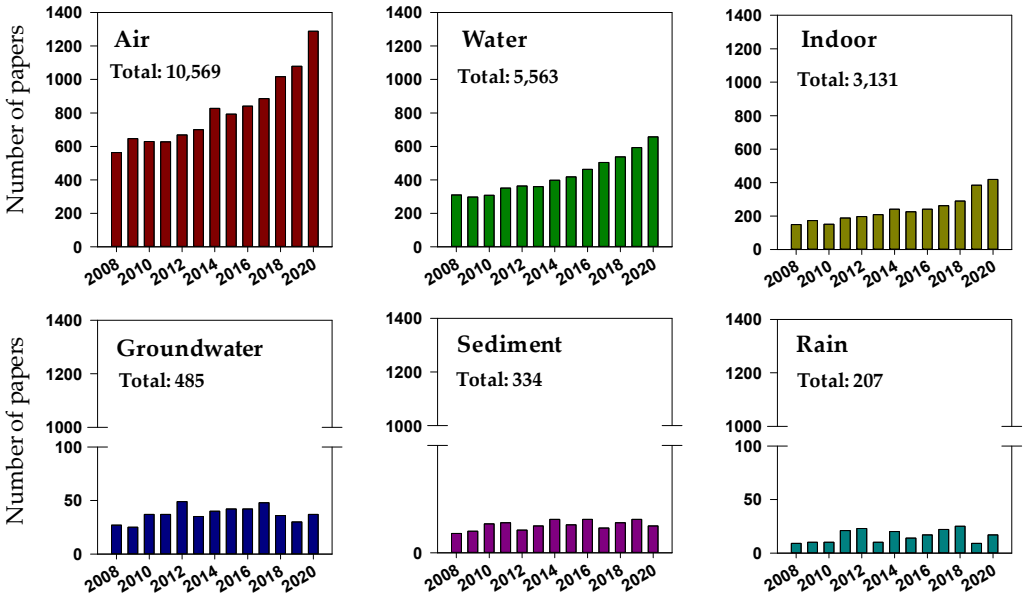


Figure S1. Published articles in various environmental media researched from Web of Science.

Table S1. Physiochemical properties of target VOCs.

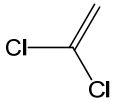
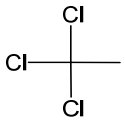
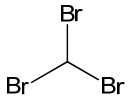
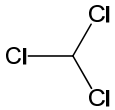
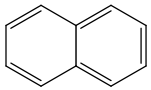
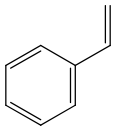
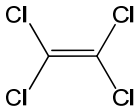
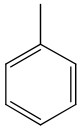
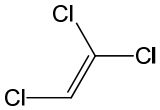
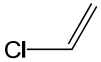
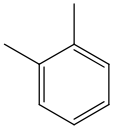
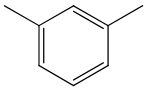
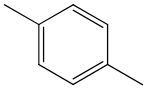
Compound (Abb.)	CAS no.	Molecular formula	Molecular weight (g/mol)	Structure	Density at 20°C (g/cm^3)	Solubility in water at 25°C (mg/L)	Vapor pressure at 25°C (mmHg)	Henrys law constant ($atm\text{-}m^3/mol$)
1,1-Dichloroethylene (1,1-DCE)	75-35-4	$C_2H_2Cl_2$	96.9		1.213	2420	600	0.03
1,1,1-Trichloroethane (1,1,1-TCA)	71-55-6	$C_2H_3Cl_3$	133.4		1.338	1290	124	0.02
Bromoform	75-25-2	$CHBr_3$	252.7		2.891	3100	5.4	0.00054
Chloroform	67-66-3	$CHCl_3$	119.4		1.483	7950	197	0.00
Naphthalene	91-20-3	$C_{10}H_8$	128.2		1.162	31	0.085	0.00044
Styrene	100-42-5	C_8H_8	104.2		0.906	300	6.4	0.00
Tetrachloroethylene (PCE)	127-18-4	C_2Cl_4	165.8		1.623	206	18.5	0.02

Table S1. (continued)

Compound (Abb.)	CAS no.	Molecular formula	Molecular weight (g/mol)	Structure	Density at 20°C (g/cm^3)	Solubility in water at 25°C (mg/L)	Vapor pressure at 25°C (mmHg)	Henrys law constant ($atm\text{-}m^3/mol$)
Toluene	108-88-3	C_7H_8	92.1		0.862	526	28.4	0.01
Trichloroethylene (TCE)	79-01-6	C_2HCl_3	131.4		1.464	1280	69	0.01
Vinyl chloride	75-01-4	C_2H_3Cl	62.5		0.911	2700	2980	0.03
o-Xylene	95-47-6	C_8H_{10}	106.2		0.880	180	6.7	0.01
m-Xylene	108-38-3	C_8H_{10}	106.2		0.870	160	8.3	0.01
p-Xylene	106-42-3	C_8H_{10}	106.2		0.861	165	8.8	0.01

Source: PubChem (https://pubchem.ncbi.nlm.nih.gov/).

Table S2. Information of sampling sites and its coordinates

Area	Sampling sites	Location		Land use
		Longitude	Latitude	
South Han River	S-1	127˚55'06.98"	37˚24'35.58"	Rural
	S-2	127˚45'07.95"	37˚14'11.08"	Rural
	S-3	127˚18'46.51"	37˚25'19.79"	Rural
	S-4	127˚32'21.92"	37˚19'54.24"	Rural
	S-5	127˚31'55.39"	37˚27'37.69"	Rural
	S-6	128˚27'35.38"	37˚09'56.03"	Rural
	S-7	127˚53'59.44"	36˚26'29.43"	Rural
North Han River	N-1	127˚42'49.94"	37˚52'12.22"	Rural
	N-2	127˚31'17.13"	37˚49'33.15"	Rural
	N-3	127˚35'34.94"	37˚43'12.09"	Rural
	N-4	127˚25'08.08"	37˚43'41"	Rural
	N-5	128˚11'13.69"	38˚04'58.72"	Rural
Imjin-Hantan River	I-1	127˚03'28.98"	38˚00'21.86"	Rural
	I-2	127˚04'50.89"	38˚00'09.46"	Rural
	I-3	127˚02'06.78"	38˚03'12.79"	Rural
	I-4	126˚55'12.39"	37˚59'01.39"	Rural
	I-5	127˚14'38.56"	37˚57'55.80"	Rural; industrial complex
	I-6	127˚12'50.42"	38˚00'36.57"	Rural; industrial complex
	I-7	127˚14'49.53"	38˚00'46.21"	Rural; industrial complex
	I-8	127˚01'19.19"	37˚52'09.34"	Rural; industrial complex
	I-9	126˚59'51.92"	37˚52'16.13"	Rural; industrial complex
	I-10	127˚03'40.27"	37˚57'27.87"	Rural; industrial complex
	I-11	127˚03'31.84"	37˚56'48.70"	Rural; industrial complex
	I-12	126˚44'40.88"	37˚49'17.09"	Rural; industrial complex
Han River mainstream	H-1	127˚10'04.98"	37˚34‘58.67"	Urban
	H-2	127˚04'14.24"	37˚30'36.75"	Urban
	H-3	127˚03'19.63"	37˚32'57.56"	Urban
	H-4	127˚02'51.73"	37˚32'51.76"	Urban
	H-5	126˚52'51.39"	37˚32'52.21"	Urban
	H-6	126˚46'37.24"	37˚34'10.39"	Urban
	H-7	126˚44'18.74"	37˚45'05.37"	Urban
	H-8	126˚50'06.88"	37˚35'35.59"	Urban
Anseong Stream	A-1	127˚14'23.35"	37˚00'21.68"	Rural; industrial complex
	A-2	127˚11'23.02"	36˚58'31.44"	Rural; industrial complex
	A-3	127˚04'15.07"	37˚01'48.60"	Rural; industrial complex
	A-4	126˚58'51.08"	36˚56'56.01"	Rural

Table S3. Information of municipal/industrial wastewater treatment plants.

MWTP/IWTP			Capacity (m^3/day)	Discharge (m^3/day)	Treatment processes	Notes
MWTP	1	Wonju STP	156,000	127,800	NPR	South Han River
	2	Munmak STP	7,000	5,153	BNR	
	3	Gwangju STP	25,000	24,177	HBR, SBAF	
	4	Konjiam STP	23,000	21,415	SBF	
	5	Yangbeol STP	20,000	10,871	SBAF	
	6	Samri STP	5,000	4,549	SBAF	
	7	Icheon STP	43,000	40,828	DeNiPho	
	8	Danwol STP (Icheon)	4,000	1,608	MSBR	
	9	Yongmun STP	4,700	2,968	MBR	
	10	Danwol STP (Yangpyeong)	1,700	1,461	KNR	
	11	Inje Bukmyeon STP	2,000	1,474	SBR	North Han River
	12	Cheongsan STP	2,100	1,198	MSBR	Imjin-Hantaan River
	13	Dongducheon STP	86,000	68,255	CNR	
	14	Guri STP	160,000	139,468	MLE	Han River mainstream
	15	Jingeon STP	100,000	93,431	CSBR	
	16	Tancheon STP	900,000	758,962	MLE	
	17	Gwacheon STP	30,000	17,652	DeNiPho	
	18	Seongnam STP	507,000	365,638	CAS	
	19	Jungnang STP	1,590,000	1,336,827	CAS, MLE, SBAF	
	20	Anyang Bakdal STP	250,000	162,013	CSBR	
	21	Seoksu STP	300,000	190,983	MLE	
	22	Gulpo STP	900,000	700,772	DeNiPho	
	23	Geumchon STP	27,000	24,522	MBR, HDF	
	24	Samsong STP	16,000	7,910	CSBR	
	25	Pyeongtaek Songtan WWTP	11,000	7,283	-	Anseong Stream
	26	Anseong 2nd WWTP	6,200	3,845	-	
	27	Paju LCD WWTP	185,000	144,304	-	Imjin-Hantaan River
	28	Yangju Hongjuk WWTP	1,000	456	-	
	29	Yangju Geomjun WWTP	23,000	10,412	-	
	30	Pocheon Yangmun WWTP	14,000	9,728	-	
	31	Pocheon Jangja WWTP	18,750	4,999	-	

Source: South Korea Ministry of Environment, 2016 Sewerage statistics and 2016 Operation status of wastewater treatment plants.

Table S4. Water quality at the sampling sites.

Sampling sites	Water temp. (°C)	pH	DO (mg/L)	Cond. (μS/cm)
S-1	15.6	7.6	7.9	540
S-2	15.0	9.3	16.6	343
S-3	14.9	7.7	10.7	434
S-4	16.5	7.4	8.1	932
S-5	13.9	7.8	12.1	198
S-6	14.7	8.2	9.4	260
S-7	16.1	9.5	15.3	247
N-1	12.2	7.6	11.0	136
N-2	11.5	7.6	11.6	109
N-3	13.3	8.1	10.6	179
N-4	11.9	7.9	12.0	192
N-5	9.8	7.8	10.9	84
I-1	13.8	8.0	9.0	386
I-2	15.9	7.9	9.4	2,000
I-3	13.3	7.7	10.2	264
I-4	14.2	8.3	10.3	491
I-5	15.7	8.5	10.8	604
I-6	14.1	7.9	8.7	81
I-7	13.6	8.4	8.3	229
I-8	14.7	7.5	2.9	1,697
I-9	16.2	7.4	4.6	1,613
I-10	17.6	7.5	7.7	1,815
I-11	20.5	7.6	6.6	2,290
I-12	24.6	7.6	6.2	1,311
H-1	18.0	7.1	7.5	610
H-2	17.4	7.3	7.2	587
H-3	13.0	8.2	10.0	320
H-4	17.8	7.3	7.0	590
H-5	15.9	7.5	7.2	721
H-6	14.7	7.8	8.6	309
H-7	15.1	7.3	3.7	669
H-8	13.8	7.6	7.6	614
A-1	18.3	9.3	18.3	356
A-2	15.6	7.8	11.3	486
A-3	18.1	7.6	5.9	689
A-4	14.2	8.0	10.8	730

Table S5. Water quality standards for VOCs at each country.

Compound	Ambient water (μg/L)					Drinking water (μg/L)				
	EU		South Korea	USA		EU	South Korea	USA		WHO
	AA-EQS[1)]	MAC-EQS[2)]		W+O[3)]	O only[4)]	DWQS	DWQS	MCLG[5)]	MCL[6)]	HBGV
1,1-Dichloroethylene (1,1-DCE)	-	-	-	300	20,000	-	30	7	7	-
1,1,1-Trichloroethane (1,1,1-TCA)	-	-	-	10,000	200,000	-	100	200	200	-
Bromoform	-	-	-	7	120	-	100(R)	0	-	100
Chloroform	2.5	not applicable	80	60	2,000	-	80	70	-	300
Naphthalene	2	130	-	-	-	-	-	-	-	-
Styrene	-	-	-	-	-	-	20(R)	100	100	20
Tetrachloroethylene (PCE)	10	not applicable	40	10	29	10(S)	10	0	5	40
Toluene	-	-	-	57	520	-	700	1,000	1,000	700
Trichloroethylene (TCE)	10	not applicable	-	0.6	7	10(S)	30	0	5	20(P)
Vinyl chloride	-	-	-	0.022	1.6	0.5	2(R)	0	2	0.3
Xylenes-total	-	-	-	-	-	-	500	10,000	10,000	500

AA-EQS: Annual Average-Environmental Quality Standards; MAC-EQS: Maximum Allowable Concentration-Environmental Quality Standards;

DWQS: Drinking water quality standards; MCLG: Maximum contaminant level goal; MCL: Maximum contaminant level; HBGV: Health-based guideline value.

(S) Sum of PCE and TCE; (R) Recommendation criteria for drinking water quality; (P) Provisional guideline value because of uncertainties in the health database.

Source:

- EU: Environmental quality standards (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013L0039), Drinking water directive (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01998L0083-20151027).
  - South Korea: Water Quality Standards (Water Environment Conservation Act (Act No. 16605) > Administrative Rules: Ministry of Environment (MoE) Notice No. 2018-6 (https://www.law.go.kr/LSW/admRulInfoP.do?admRulSeq=2100000111712),

  (a) Water Supply and Waterworks Installation Act (Act No. 17178) (https://www.law.go.kr/LSW/lsInfoP.do?lsiSeq=212567&lsId=007134&efYd=20191220&chrClsCd=010102&viewCls=lsInfoP&ancYnChk=#J8823815)

  (b) Drinking Water Management Act (Act No. 17326) (https://law.go.kr/LSW/admRulLsInfoP.do?chrClsCd=&admRulSeq=2100000178074#J1996368)
- USA: Water Quality Criteria (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table), National primary drinking water regulations (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#one).
- WHO: Drinking water quality guidelines (https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/water-safety-and-quality/drinking-water-quality-guidelines).

Table S6. Concentration of VOCs detected at each site.

Sites	Mean Conc. (μg/L)	Min Conc. (μg/L)	Max Conc. (μg/L)	Total Conc. (μg/L)	Frequency detected (%)
S-1	NA	NA	NA	NA	NA
S-2	0.0033 ± 0.0081	0.0000	0.0250	0.0400	16.7
S-3	NA	NA	NA	NA	NA
S-4	0.0020 ± 0.0069	0.0000	0.0240	0.0240	8.3
S-5	0.0013 ± 0.0046	0.0000	0.0160	0.0160	8.3
S-6	0.0011 ± 0.0038	0.0000	0.0130	0.0130	8.3
S-7	NA	NA	NA	NA	NA
N-1	NA	NA	NA	NA	NA
N-2	0.0042 ± 0.0089	0.0000	0.0290	0.0500	25.0
N-3	0.0026 ± 0.0060	0.0000	0.0160	0.0310	16.7
N-4	0.0075 ±0.0122	0.0000	0.0340	0.0900	41.7
N-5	0.0062 ± 0.0123	0.0000	0.0330	0.0740	25.0
I-1	0.0025 ± 0.0087	0.0000	0.0300	0.0300	8.3
I-2	0.0070 ± 0.0105	0.0000	0.0240	0.0840	33.3
I-3	0.0053 ± 0.0126	0.0000	0.0370	0.0640	16.7
I-4	0.0023 ± 0.0081	0.0000	0.0280	0.0280	8.3
I-5	0.0349 ± 0.0988	0.0000	0.3440	0.4190	25.0
I-6	0.0049 ± 0.0152	0.0000	0.0530	0.0590	16.7
I-7	0.0017 ± 0.0058	0.0000	0.0200	0.0200	8.3
I-8	0.0173 ± 0.0385	0.0000	0.1300	0.2080	25.0
I-9	0.0497 ± 0.1201	0.0000	0.4150	0.5960	33.3
I-10	0.0298 ± 0.0794	0.0000	0.2790	0.3570	33.3
I-11	0.0309 ± 0.1043	0.0000	0.3620	0.3710	16.7
I-12	0.0568 ± 0.1703	0.0000	0.5940	0.6820	25.0
H-1	0.0017 ± 0.0580	0.0000	0.0200	0.0200	8.3
H-2	0.0014 ± 0.0049	0.0000	0.0170	0.0170	8.3
H-3	NA	NA	NA	NA	NA
H-4	NA	NA	NA	NA	NA
H-5	0.0007 ± 0.0023	0.0000	0.0080	0.0080	8.3
H-6	0.0016 ± 0.0055	0.0000	0.0190	0.0190	8.3
H-7	0.0021 ± 0.0072	0.0000	0.0250	0.0250	8.3
H-8	0.0023 ± 0.0078	0.0000	0.0270	0.0270	8.3
A-1	0.0193 ± 0.0538	0.0000	0.1880	0.2310	25.0
A-2	0.0012 ± 0.0040	0.0000	0.0140	0.0140	8.3
A-3	0.0226 ± 0.0601	0.0000	0.2030	0.2710	16.7
A-4	NA	NA	NA	NA	NA

*NA: Not Applicable