Innovations in Water-Pollution Monitoring Based on Global Patent Trends (TRL 4–5): Toward Cleaner Environment and Smarter Technologies

SUPPLEMENTARY MATERIAL

TABLES

Table S1. Patent search scopes.

Focus	Parameter	Usage	No Pats	Search
Water pollution	Ammonia	na	69	(((AMMONIA OR AZANE OR NH3 OR AQUEOUS AMMONIA OR AMMONIUM)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Chlorophyll	na	9	(((CHLOROPHYLL OR THYLAKOID PIGMENT OR PHYLL PIGMENT OR PHOTOSYNTHETIC PIGMENT OR PHOTOSYNTHESIS PIGMENT OR LEAF GREEN OR CHLOROPLAST PIGMENT OR CHLOROPHYLLOUS COMPOUND OR CHLOROPHYLLIN)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	conductivity		13	(((CONDICTIVITY OR IONIC CONDUCTIVITY OR ELECTRICAL CONDUCTIVITY OR CONDUCTANCE OR CHARGE TRANSPORT)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Conductivity	na	321	(((CONDICTIVITY OR IONIC CONDUCTIVITY OR ELECTRICAL CONDUCTIVITY OR CONDUCTANCE OR CHARGE TRANSPORT)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))

Table S1. Patent search scopes.

Focus	Parameter	Usage	No Pats	Search
Water pollution	Dissolved oxygen		134	(((DISSOLVED OXYGEN OR WATER OXYGEN CONTENT OR OXYGEN IN WATER OR LIQUID PHASE OXYGEN OR DISSOLVED O2 OR AQUEOUS OXYGEN OR AQUATIC OXYGEN LEVEL)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Dissolved oxygen		1960	(((DISSOLVED OXYGEN OR WATER OXYGEN CONTENT OR OXYGEN IN WATER OR LIQUID PHASE OXYGEN OR DISSOLVED O2 OR AQUEOUS OXYGEN OR AQUATIC OXYGEN LEVEL)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((G01N-033/18)/IPC AND (EPRD=2004-01-01:2023-12-31))
Water quality	Heavy metals (Cu, Zn, Pb, Cd, Hg)		287	(((heavy metals OR toxic metals OR metal pollutants)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Heavy metals (Cu, Zn, Pb, Cd, Hg)		23	(((heavy metals OR toxic metals OR metal pollutants)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Nitrate		229	(((nitrate OR azotate)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Nitrate		13	(((nitrate OR azotate)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Oxidation-reduction potential (ORP)		384	(((Oxidation-reduction potential OR ORP)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))

Table S1. Patent search scopes.

Focus	Parameter	Usage	No Pats	Search
Water pollution	Oxidation-reduction potential (ORP)		28	(((Oxidation-reduction potential OR ORP)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Oil in water, PAHs		1	(((pahs OR fused ring aromatic systems OR multiring aromatic compounds OR polycyclic aromatic hydrocarbons OR condensed aromatic hydrocarbons OR aromatic hydrocarbon compounds)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Oil in water, PAHs		10	(((pahs OR fused ring aromatic systems OR multiring aromatic compounds OR polycyclic aromatic hydrocarbons OR condensed aromatic hydrocarbons OR aromatic hydrocarbon compounds)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Phosphorus		650	(((Phosphorus OR phosphate)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Phosphorus		46	(((Phosphorus OR phosphate)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water quality	Temperature		3895	(((temperature OR thermal measurement OR thermal level)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))
Water pollution	Temperature		206	(((temperature OR thermal measurement OR thermal level)/TI/AB/OBJ/ADB/ICLM AND (SENSOR OR PROBE OR MONITOR OR MEASURING DEVICE OR MEASUREMENT UNIT OR GAUGE OR DETECTOR OR ANALYZER)/TI/AB/OBJ/ADB/ICLM)) AND ((((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)))

Table S1. Patent search scopes.

Focus	Parameter	Usage	No Pats	Search
Water pollution	na	na	2146	(((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31))
Water pollution (exportation)	na	na	69	(((WATER POLLUTION)/TI/AB/OBJ/ADB/ICLM AND (G01N-033/18)/IPC) AND (EPRD=2004-01-01:2023-12-31)) AND NBPC>1
Water quality	na	na	40469	((G01N-033/18)/IPC AND (EPRD=2004-01-01:2023-12-31))

Table S2. Number of patents referring to combinations of the four most frequently monitored parameters: (A) water quality; (B) water pollution.

(A) Water Quality	pH	Temperature	Turbidity	Dissolved oxygen
pH	3,761			
Temperature	1660	3895		
Turbidity	1,128	775	1,872	
Dissolved oxygen	1158	968	583	1960

(B) Water Pollution	pH	Temperature	Turbidity	Dissolved oxygen
pH	233			
Temperature	117	206		
Turbidity	98	68	137	
Dissolved oxygen	94	76	53	134

Table S3. First-priority countries of all patents (TRLs 4–5).

Country or Region	Patents
China	1936
South Korea	102
India	44
Russia	13
USA	12
Japan	11
Ukraine	4
World Intellectual Property Organization (WIPO)	4
Taiwan	3
United Kingdom	2
Italy	2
Sweden	2
Vietnam	2
Australia	1
Canada	1
European Patent Office (EPO)	1
Spain	1
Iran	1
Peru	1
Poland	1
Romania	1
Turkey	1

Table S4. First-priority countries of active patents—those pending examination or granted (TRLs 4–5).

Country or Region	Patents
China	889
South Korea	75
India	44
USA	8
Russia	4
Japan	3
Taiwan	3
Italy	2
Sweden	2
European Patent Office	1
Iran	1
Peru	1
Romania	1
Turkey	1
Vietnam	1
World Intellectual Property Organization	1

Table S5. Countries where patents have been filed beyond the first priority, indicating potential commercial markets (TRL 9).

Country or Region	Patents
China	1951
South Korea	104
India	51
USA	48
World Intellectual Property Organization	40
Japan	20
Russia	15
European Patent Office	12
Australia	8
Canada	8
Taiwan	6
Spain	5
Ukraine	4
United Kingdom	3
Sweden	3
Vietnam	3
South Africa	3
Brazil	2
Hong Kong	2
Italy	2
Netherlands	2
Thailand	2
Argentina	1
Chile	1
Germany	1
Denmark	1
Eurasian Patent Organization	1
Israel	1
Morocco	1
Malaysia	1
Norway	1
Peru	1
Poland	1
Portugal	1
Romania	1
Turkey	1

Table S6. Countries where active patents have been filed beyond the first priority, indicating potential commercial markets for export (TRL 9).

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Country or Region	Patents
China	40
USA	34
World Intellectual Property Organization	30
South Korea	12
European Patent Office	9
India	9
Japan	9
Australia	5
Canada	5
Taiwan	5
Spain	4
Sweden	3
South Africa	3
Hong Kong	2
Italy	2
Netherlands	2

Country or Region	Patents
Russia	2
Thailand	2
Vietnam	2
Argentina	1
Brazil	1
Chile	1
Germany	1
Denmark	1
United Kingdom	1
Israel	1
Morocco	1
Malaysia	1
Portugal	1
Turkey	1

Table S7. Number and percentage distribution of patents by technological domain: all patents and active export-oriented patents.

Technology domain	All patents		Active exportation patents	
	Patents	Percentage	Patents	Percentage
Analysis of Biological Materials	2146	100.0%	56	100.0%
Measurement	24	1.1%	18	32.1%
Environmental Technology	179	8.3%	16	28.6%
Chemical Engineering	153	7.1%	8	14.3%
Computer Technology	120	5.6%	8	14.3%
Control	151	7.0%	6	10.7%
Biotechnology	26	1.2%	4	7.1%
Civil Engineering	57	2.7%	4	7.1%
Other Special Machines	47	2.2%	4	7.1%
Telecommunications	203	9.5%	4	7.1%
IT Methods for Management	136	6.3%	3	5.4%
Basic Materials Chemistry	2	0.1%	1	1.8%
Digital Communication	57	2.7%	1	1.8%
Electrical Machinery Apparatus Energy	59	2.7%	1	1.8%
Engines Pumps Turbines	13	0.6%	1	1.8%
Furniture Games	8	0.4%	1	1.8%
Medical Technology	8	0.4%	1	1.8%
Other Consumer Goods	5	0.2%	1	1.8%
Semiconductors	1	0.0%	1	1.8%
Surface Technology Coating	1	0.0%	1	1.8%
Transport	192	8.9%	1	1.8%
Audio-Visual Technology	24	1.1%	0	0.0%
Basic Communication Processes	1	0.0%	0	0.0%
Food Chemistry	1	0.0%	0	0.0%
Handling	31	1.4%	0	0.0%
Machine Tools	8	0.4%	0	0.0%
Macromolecular Chemistry Polymers	1	0.0%	0	0.0%
Materials Metallurgy	8	0.4%	0	0.0%
Mechanical Elements	47	2.2%	0	0.0%
Micro-Structure and Nano-Technology	2	0.1%	0	0.0%
Optics	1	0.0%	0	0.0%

Table S8. List of patents cited.

AU2021103878	CN111126768	CN120351964	CN218174768	TWI695982
CN102478532	CN112114107	CN202648999	CN219031910	US11097813
CN1036614	CN112162017	CN203396770	CN219201564	US12105075
CN103743876	CN113859451	CN204719035	CN220795207	US12339228
CN104217040	CN113959990	CN205449970	CN221726005	US20080116908
CN104457712	CN115009418	CN207380025	EP4578834	US20250044272
CN105445431	CN115211391	CN207742191	IT201700046831	US7691329
CN105866364	CN115762669	CN208076506	JP7351046	US8569045
CN106290759	CN116087455	CN209432812	KR10-1328026	WO2009/020709
CN106560709	CN116125027	CN209707494	KR10-13280260	WO2020/010836
CN107340375	CN116451142	CN210764447	KR10-2025-0002073	WO2021/205223
CN108318651	CN116879520	CN213210117	KR10-2025-0088929	WO2022/011399
CN108362846	CN117706053	CN216559088	KR10-2254774	WO2022/217734
CN110057992	CN117805208	CN217278299	KR10-2592931	WO2024/161846
CN110456016	CN119026955	CN217384845	KR10-2622449	
CN110988282	CN119624228	CN217820337	KR10-2746153	
CN111122816	CN119783371	CN217901718	KR20-0474046	

Innovations in Water-Pollution Monitoring Based on Global Patent Trends (TRL 4–5): Toward Cleaner Environment and Smarter Technologies

SUPPLEMENTARY MATERIAL

FIGURES

(A) All patents

(B) Active patents



Figure S1. Technological domains of patents: (A) all patents; (B) active patents.