Toward Cleaner and Smarter Ports: Systematic Review of Water Pollution Alert Technologies from Global Patents (TRL4-5) and Scientific Analyses (TRL 3)

SUPPLEMENTARY MATERIAL

TABLES

Table S1. Search scopes for articles and patents.

Record type	TRL	Database	Search
Articles	3	PubMed	"water qualit*" (Topic) and 2004-2025 (Year Published) and SEAWATER* OR "salt water*" OR OCEAN* OR marine* OR maritim* OR estuar* (Topic) and ALARM* OR EMERGENC* OR SAFET* OR alert* OR warn* OR disaster* OR hazard* (Topic) and HARBOR* OR harbour* OR PORT* OR MARINA* OR HARBORAGE* OR DOCK* OR BERTH* OR ANCHORAGE* OR QUAY* OR pier* OR SEAPORT* (Topic) and Journal Article (Publication Type)
Articles	3	Scopus	(TITLE-ABS-KEY ("water qualit*")) AND (TITLE-ABS-KEY (SEAWATER* OR "salt water*" OR OCEAN* OR marine* OR maritim* OR estuar*)) AND (TITLE-ABS-KEY (ALARM* OR EMERGENC* OR SAFET* OR alert* OR warn* OR disaster* OR hazard*)) AND (TITLE-ABS-KEY (HARBOR* OR harbour* OR PORT* OR MARINA* OR HARBORAGE* OR DOCK* OR BERTH* OR ANCHORAGE* OR QUAY* OR pier* OR SEAPORT*)) AND PUBYEAR > 2003 AND PUBYEAR < 2027 AND (LIMIT-TO (DOCTYPE , "ar"))
Articles	3	Web of Science	"water qualit*" (Topic) and 2004-2025 (Year Published) and SEAWATER* OR "salt water*" OR OCEAN* OR marine* OR maritim* OR estuar* (Topic) and ALARM* OR EMERGENC* OR SAFET* OR alert* OR warn* OR disaster* OR hazard* (Topic) and HARBOR* OR harbour* OR PORT* OR MARINA* OR HARBORAGE* OR DOCK* OR BERTH* OR ANCHORAGE* OR QUAY* OR pier* OR SEAPORT* (Topic) AND Journal Article (Publication Type)

Record type	TRL	Database	Search
Patents	4-5	Derwent	G01N-033/18 (International Patent Classification) and "WATER POLLUT*" OR "TOXIC WATER SUBSTANC*" OR "SURFACE WATER POLLUT*" OR "MARINE POLLUT*" OR "FRESHWATER DEGRADAT*" OR "CHEMICAL POLLUTION IN WATER*" OR "AQUATIC CONTAMINAT*" (Topic) and HARBOR* OR PORT* OR MARINA* OR HARBORAGE* OR DOCK* OR BERTH* OR ANCHORAGE* OR HARBOUR* OR QUAY* OR PIER* OR SEAPORT* (Topic) and ALARM* OR "EMERGENCY NOTIFICATION*" OR "SAFETY ANNOUNCEMENT*" OR "URGENT ALERT SYSTEM*" OR "REAL-TIME WARNING SYSTEM*" OR "INSTANT NOTIFICATION SYSTEM*" OR "DISASTER NOTIFICATION SYSTEM*" OR "CRITICAL WARNING SYSTEM*" OR "RISK ALERTING*" OR "HAZARD NOTIFICATION*" OR "DISASTER WARNING*" OR "EMERGENCY INDICATOR*" OR "DISTRESS CALL*" OR WARNING* OR "EMERGENCY NOTICE*" OR ALERT* (Topic) and SEA* OR SEAWATER* OR SALTWATER* OR OCEAN* OR MARITIME* OR MARINE* OR OCEANIC* OR ESTUAR* OR "COASTAL LAGOON*" OR BAY* OR WATERCOURSE* (Topic)
Patents	4-5	Lens	Patents (23) = (IPC G01N33/18)
Patents	4-5	Patentscope	FP:(G01N 33/18) AND EN_CL:("WATER POLLUT*" OR "TOXIC WATER SUBSTANC*" OR "SURFACE WATER POLLUT*" OR "MARINE POLLUT*") AND PD:([01.01.2004 TO 31.12.2023])
Patents	4-5	Worldwide Espacenet (ORBIT)	((ALARM OR EMERGENCY NOTIFICATION OR SAFETY ANNOUNCEMENT OR URGENT ALERT SYSTEM OR REAL-TIME WARNING SYSTEM OR INSTANT NOTIFICATION SYSTEM OR DISASTER NOTIFICATION SYSTEM OR CRITICAL WARNING SYSTEM OR RISK ALERTING OR HAZARD NOTIFICATION OR DISASTER WARNING OR EMERGENCY INDICATOR OR DISTRESS CALL OR WARNING OR EMERGENCY NOTICE OR ALERT)/TI/AB/OBJ/ADB/ICLM AND ((SEA OR SEAWATER OR SALTWATER OR OCEAN OR MARITIME OR MARINE OR OCEANIC OR ESTUARY OR COASTAL LAGOON OR BAY OR WATERCOURSE)/TI/AB/OBJ/ADB/ICLM AND ((HARBOR OR PORT OR MARINA OR HARBORAGE OR DOCK OR BERTH OR ANCHORAGE OR HARBOUR OR QUAY OR PIER OR SEAPORT)/TI/AB/OBJ/ADB/ICLM AND (EPD=2004-01-01:2023-12-31)) AND ((G01N-033/18)/IPC

Table S2. Number of published articles by country.

Country	Articles
China	25
United States	22
Portugal	21
Spain	10
Hong Kong	8
Australia	6
Canada	6
Italy	6
Egypt	5
France	5
India	5
South Korea	5
United Kingdom	5
Belgium	4
Germany	4
Brazil	3
Indonesia	3
Iran	3
Japan	3
Malaysia	3
Saudi Arabia	3
Croatia	2
Cyprus	2
Denmark	2
Greece	2
Haiti	2
Morocco	2
Netherlands	2
Norway	2
Poland	2
Russian Federation	2
Serbia	2
South Africa	2
Taiwan	2
Thailand	2
Chile	1
Colombia	1
Czech Republic	1
Hungary	1
Iraq	1
Kuwait	1
Libya	1
Mexico	1
Montenegro	1
New Zealand	1
Peru	1
Qatar	1
Sri Lanka	1
Sweden	1
Tunisia	1
Turkey	1
Undefined	1

Table S3. Number of published articles by organization.

Affiliation	Articles
UNIVERSIDADE DO PORTO	22
THE UNIVERSITY OF HONG KONG	15
KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH	14
OCEAN UNIVERSITY OF CHINA	13
UNIVERSITY OF CALIFORNIA	13
UNIVERSITY OF COIMBRA	13
SCHOOL OF BASIC MEDICAL SCIENCES	11
IHCANTABRIA - INSTITUTO DE HIDRÁULICA AMBIENTAL DE LA UNIVERSIDAD DE CANTABRIA	10
AARHUS UNIVERSITET	8
CIIMAR - INTERDISCIPLINARY CENTRE OF MARINE AND ENVIRONMENTAL RESEARCH	8
NATIONAL INSTITUTE OF OCEANOGRAPHY AND FISHERIES	8
UNIVERSIDADE DO ALGARVE	8
UNIVERSIDADE FEDERAL DO RIO DE JANEIRO	8
UNIVERSITY OF ÉVORA	8
ANNAMALAI UNIVERSITY	7
COLLEGE OF THE ENVIRONMENT AND ECOLOGY	7
CSIC - INSTITUTO DE DIAGNOSTICO AMBIENTAL Y ESTUDIOS DEL AGUA (IDAEA)	7
HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY	7
KOREA INSTITUTE OF OCEAN SCIENCE AND TECHNOLOGY	7
KOREA UNIVERSITY	7
NANJING NORMAL UNIVERSITY	7
POLITÉCNICO E UNIVERSITÁRIO	7
YANCHENG INSTITUTE OF TECHNOLOGY	7
DALIAN MARITIME UNIVERSITY	6
GDYNIA MARITIME UNIVERSITY	6
INSTITUTE OF OCEANOLOGY OF THE POLISH ACADEMY OF SCIENCES	6
NOVA SOUTHEASTERN UNIVERSITY	6
SAPIENZA UNIVERSITÀ DI ROMA	6
UNIVERSIDAD SAN SEBASTIÁN	6
ZHEJIANG OCEAN UNIVERSITY	6
FACULTY OF VETERINARY MEDICINE	5
INSTITUTE OF REMOTE SENSING AND DIGITAL EARTH	5
INSTITUTO PORTUGUES DO MAR E ATMOSFERA	5
INSTITUTO SUPERIOR TÉCNICO	5
JAMES COOK UNIVERSITY	5
STATE KEY LABORATORY OF ESTUARINE AND COASTAL RESEARCH	5
UNIVERSIDADE ESTADUAL DO NORTE FLUMINENSE	5
UNIVERSIDADE FEDERAL FLUMINENSE	5
UNIVERSITI MALAYSIA TERENGGANU	5
UNIVERSITI PUTRA MALAYSIA	5
UNIVERSITY OF CHINESE ACADEMY OF SCIENCES	5
UNIVERSITY OF FLORIDA COLLEGE OF MEDICINE	5
UNIVERSITY OF SRI JAYEWARDENEPURA	5
UNIVERSITY OF WINDSOR	5
BRAWIJAYA UNIVERSITY	4
CENTRO DE INVESTIGACAO MARINHA E AMBIENTAL	4
CHULALONGKORN UNIVERSITY	4
COLLEGE OF CHARLESTON	4
INSTITUTE OF MARINE BIOLOGY	4
IPB UNIVERSITY	4
'ISTITUTO PER L'AMBIENTE MARINO COSTIERO DEL CONSIGLIO NAZIONALE DELLE RICERCHE (IAMC-CNR)	4
KENT STATE UNIVERSITY	4
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG	4
NATIONAL CHUNG CHENG UNIVERSITY	4

Affiliation	Articles
NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH	4
NELSON MANDELA UNIVERSITY	4
TIANJIN UNIVERSITY	4
UNIVERSITÀ POLITECNICA DELLE MARCHE	4
UNIVERSITÉ MOHAMMED PREMIER OUJDA	4
UNIVERSITEIT ANTWERPEN	4
UNIVERSITY OF THESSALY	4
COLLEGE OF ENGINEERING AND COMPUTER SCIENCE	3
CYPRUS UNIVERSITY OF TECHNOLOGY	3
EUROPEAN UNIVERSITY CYPRUS	3
INSTITUTE OF GEOGRAPHIC SCIENCES AND NATURAL RESOURCES RESEARCH	3
INSTITUTO UNIVERSITÁRIO DE CIÊNCIAS DA SAÚDE (IUCS)	3
ISFAHAN UNIVERSITY OF MEDICAL SCIENCES	3
JADAVPUR UNIVERSITY	3
MUSTANSIRIYAH UNIVERSITY	3
OKLAHOMA STATE UNIVERSITY	3
RESEARCH CENTER FOR ECO-ENVIRONMENTAL SCIENCES CHINESE ACADEMY OF SCIENCES	3
SHANDONG GEOLOGY AND MINERAL EXPLORATION AND DEVELOPMENT BUREAU	3
SYDNEY INSTITUTE OF MARINE SCIENCE	3
UNIVERSIDAD DE LA COSTA	3
UNIVERSIDADE DE AVEIRO	3
UNIVERSITAS RIAU	3
UNIVERSITAT POLITÈCNICA DE CATALUNYA	3
UNIVERSITÉ QUISQUEYA	3
UNIVERSITY OF NEVADA	3
UNIVERSITY OF SOUTH FLORIDA	3
WATER SCIENCE AND TECHNOLOGY DIRECTORATE	3
AMIRKABIR UNIVERSITY OF TECHNOLOGY	2
BEIJING NORMAL UNIVERSITY	2
CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL INSTITUTO POLITÉCNICO NACIONAL	2
CHINESE ACADEMY OF SCIENCES	2
CHONNAM NATIONAL UNIVERSITY	2
COLLEGE OF ARTS AND SCIENCES	2
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION	2
CONCORDIA UNIVERSITY	2
DIVISION OF WATER RESOURCES AND ARID LAND	2
EVOLUTION AND ECOLOGY RESEARCH CENTRE	2
FACULTY OF EARTH SCIENCE	2
FLINDERS UNIVERSITY	2
FLORIDA ATLANTIC UNIVERSITY	2
FLORIDA STATE UNIVERSITY	2
GDAŃSK UNIVERSITY OF TECHNOLOGY	2
GUANGDONG INSTITUTE FOR DRUG CONTROL	2
HONG KONG BAPTIST UNIVERSITY	2
INSTITUTE OF ENVIRONMENTAL MANAGEMENT	2
INSTITUTO POLITÉCNICO DE BEJA	2
KWANGWOON UNIVERSITY	2
MARINE ECOLOGICAL RESTORATION AND SMART OCEAN ENGINEERING RESEARCH CENTER OF HEBEI PROVINCE	2
MIE UNIVERSITY	2
NANJING UNIVERSITY OF POST AND TELECOMMUNICATIONS	2
NATIONAL MARINE ENVIRONMENTAL MONITORING CENTER	2
SCHOOL OF MEDICINE	2
SCIENCE SYSTEMS AND APPLICATIONS	2
SWANSEA UNIVERSITY	2
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (GUANGZHOU)	2
UNIVERSIDAD DEL BIO BIO	2
UNIVERSIDADE DO MINHO	2

Affiliation	Articles
UNIVERSIDADE FEDERAL DA PARAÍBA	2
UNIVERSITÀ DEGLI STUDI DI MILANO	2
UNIVERSITAT DE BARCELONA	2
UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE	2
UNIVERSITY OF NEW ENGLAND AUSTRALIA	2
UNIVERSITY OF NEW SOUTH WALES AT AUSTRALIAN DEFENCE FORCE ACADEMY	2
UNIVERSITY OF SPLIT	2
UNIVERSITY OF TRIPOLI	2
XIAMEN UNIVERSITY	2
ASSOCIAÇÃO AMBIENTAL VOZ DA NATUREZA	1
BEDFORD INSTITUTE OF OCEANOGRAPHY	1
BHARATHIDASAN UNIVERSITY	1
CALIFORNIA NANOSYSTEMS INSTITUTE	1
CENTRO OCEANOLOGICO MEDITERRANEO	1
CHENG SHIU UNIVERSITY	1
CHIAYI CHRISTIAN HOSPITAL	1
CHULABHORN ROYAL ACADEMY	1
COLLEGE OF PHARMACY	1
CURTIN UNIVERSITY	1
DELFT UNIVERSITY OF TECHNOLOGY	1
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING	1
DEPARTMENT OF ENVIRONMENTAL ENGINEERING	1
DIRKSEN-FISCHER	1
DIVISION INFRASTRUCTURES ET EXPLOITATION RÉGIONALE	1
DR. KIRAN C. PATEL COLLEGE OF OSTEOPATHIC MEDICINE	1
EASTERN RESEARCH GROUP	1
ECOLE NATIONALE DES SCIENCES APPLIQUÉES - AGADIR	1
ECOLE NATIONALE DES TRAVAUX PUBLICS DE L'ETAT	1
E-DA HOSPITAL	1
ENVIRONMENTAL AND WATER STUDIES	1
FACULTÉ DES SCIENCES D'OUJDA	1

Affiliation	Articles
FACULTY OF SCIENCE	1
FEDERAL PUBLIC SERVICE HEALTH	1
FIRST INSTITUTE OF OCEANOGRAPHY	1
GÖTEBORGS UNIVERSITET	1
GREENWICH MARITIME INSTITUTE	1
GUANGDONG UNIVERSITY OF TECHNOLOGY	1
GUANGZHOU INSTITUTE OF GEOGRAPHY	1
HAFENCITY UNIVERSITY HAMBURG	1
HANYANG UNIVERSITY	1
HIROSHIMA UNIVERSITY	1
HOHAI UNIVERSITY	1
HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY	1
ICAR - CENTRAL MARINE FISHERIES RESEARCH INSTITUTE	1
IMAM MOHAMMAD IBN SAUD ISLAMIC UNIVERSITY	1
INTERNATIONAL HELLENIC UNIVERSITY	1
IRANIAN NATIONAL INSTITUTE FOR OCEANOGRAPHY AND ATMOSPHERIC SCIENCE	1
I-SHOU UNIVERSITY	1
JAWAHARLAL NEHRU UNIVERSITY	1
JINAN	1
KAGOSHIMA UNIVERSITY	1
KING'S COLLEGE LONDON	1
KØBENHAVNS UNIVERSITET	1
L'ECOLE NATIONALE DE COMMERCE ET DE GESTION D'AGADIR	1
LABORATOIRE D'AUTOMATIQUE	1
MALEK ASHTAR UNIVERSITY OF TECHNOLOGY	1
MARINE RESEARCH DIVISION	1
MIE PREFECTURE FISHERIES RESEARCH INSTITUTE	1
MINISTRY OF ENVIRONMENT KOREA	1
MINISTRY OF HEALTH	1
MONTCLAIR STATE UNIVERSITY	1
NANKAI UNIVERSITY	1
NASA GODDARD SPACE FLIGHT CENTER	1

Affiliation	Articles
NATIONAL INSTITUTE OF ADVANCED STUDIES	1
NATIONAL INSTITUTE OF OCEANOGRAPHY INDIA	1
NATIONAL KAOHSIUNG UNIVERSITY OF SCIENCE AND TECHNOLOGY	1
NOTREPORTED	1
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	1
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	1
QATAR UNIVERSITY	1
QINGDAO UNIVERSITY OF SCIENCE AND TECHNOLOGY	1
RUTGERS UNIVERSITY–NEW BRUNSWICK	1
SAINT PETERSBURG STATE UNIVERSITY	1
SCHLESWIG-HOLSTEIN	1
SCHMITZ	1
SCHOOL OF ENGINEERING AND APPLIED SCIENCE	1
SCHOOL OF VETERINARY MEDICINE	1
SCIENTIFIC RESEARCH CENTER FOR ECOLOGICAL SAFETY OF THE RUSSIAN ACADEMY OF SCIENCES	1
SHANDONG UNIVERSITY	1
SHANGHAI MEDICAL UNIVERSITY	1
SHANGHAI OCEAN UNIVERSITY	1
SHELUQUN ENVIRONMENTAL CONSULTING	1
SHENYANG ACADEMY OF ENVIRONMENTAL SCIENCES	1
SOUTH CHINA NORMAL UNIVERSITY	1
SOUTHERN ILLINOIS UNIVERSITY CARBONDALE	1
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY	1
STANFORD UNIVERSITY	1
STOCKHOLMS UNIVERSITET	1
TAIF UNIVERSITY	1
TEXAS AANDM UNIVERSITY	1
THAINES AND BODAH CENTER FOR EDUCATION AND DEVELOPMENT	1
THE UNIVERSITY OF HONG KONG LI KA SHING FACULTY OF MEDICINE	1
TIERÄRZTLICHE HOCHSCHULE HANNOVER	1
UNIVERSIDAD CATOLICA DE LA SANTISIMA CONCEPCION	1
UNIVERSIDAD DE LIMA	1
UNIVERSIDAD DE TARAPACÁ	1
UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO	1
UNIVERSITÀ DEGLI STUDI DI MESSINA	1
UNIVERSITAS GADJAH MADA	1
UNIVERSITAT ROVIRA I VIRGILI	1
UNIVERSITÉ DE LIÈGE	1
UNIVERSITI MALAYA	1
UNIVERSITY OF CALGARY	1
UNIVERSITY OF EXETER	1
UNIVERSITY OF HAFR AL-BATIN	1
UNIVERSITY OF LOUISIANA AT LAFAYETTE	1
UNIVERSITY OF NOVI SAD	1
UNIVERSITY OF OTTAWA	1
UNIVERSITY OF WATERLOO	1
UNIVERSITY OF ZADAR	1
YAKIMA VALLEY COMMUNITY COLLEGE	1
YANCHENG LUMING ROAD JUNIOR HIGH SCHOOL	1

Table S4. List of cited patent documents.

CN103605308	CN114088902	CN201320087769	CN201921557098	CN203222101
CN106116076	CN114088905	CN201510775831	CN201922331101	CN206594154
CN106596193	CN114216902	CN201610950214	CN202110114400	CN207192906
CN108614085	CN114428156	CN201720302259	CN202111037623	CN2095899060
CN110456013	CN114428156	CN201721321894	CN202111161510	CN211122814
CN111310976	CN115356455	CN201811046616	CN202111400707	CN212275732
CN112881635	CN115902137	CN201811387175	CN202111572813	CN220207580
CN113053086	CN200910155282	CN201910127288	CN202221978328	US10852287
CN113311129	CN201020611593	CN201910488129	CN202222431524	US10852287
CN114062625	CN201310581499	CN201910808768	CN202310054164	WO2018/032826

Toward Cleaner and Smarter Ports: Systematic Review of Water Pollution Alert Technologies from Global Patents (TRL4-5) and Scientific Analyses (TRL 3)

SUPPLEMENTARY MATERIAL

FIGURES

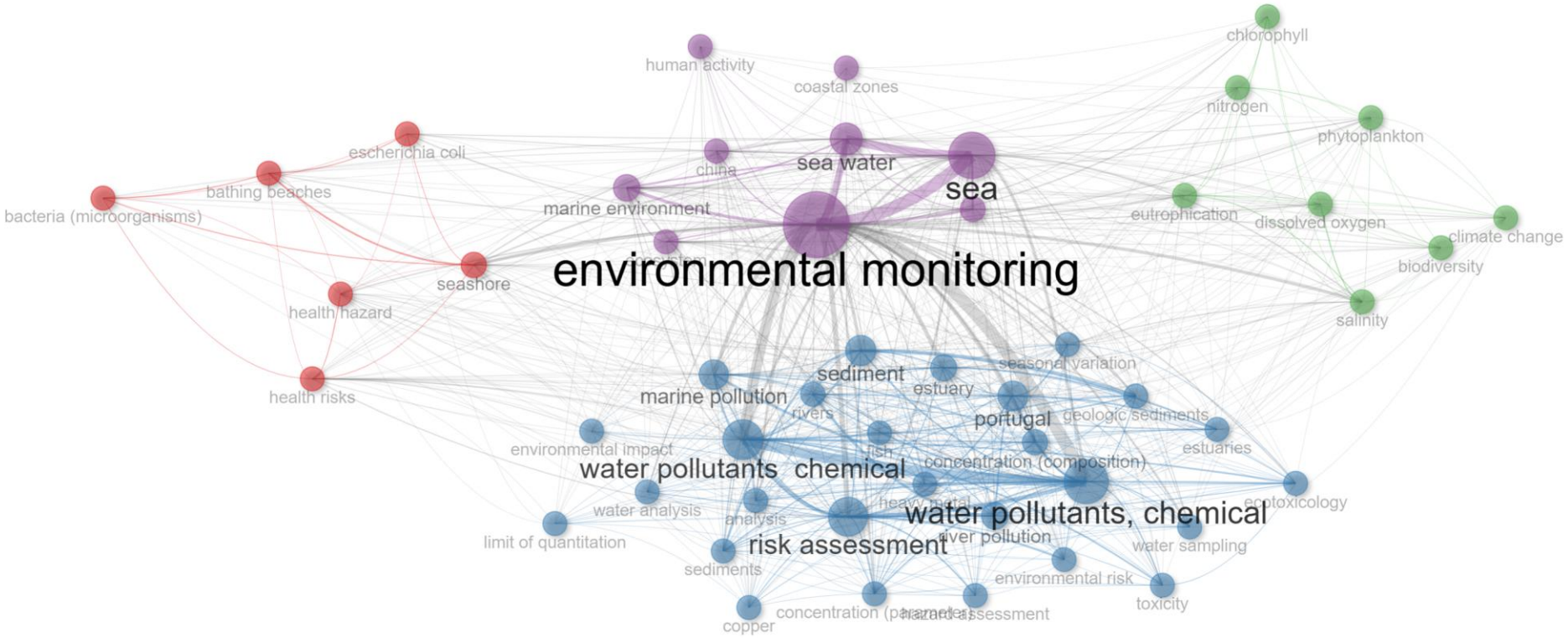


Figure S1. Co-occurrence network of article keywords showing four clusters: Environmental Monitoring, Chemical Water Pollutants, Seashore Hazards, and Eutrophication.

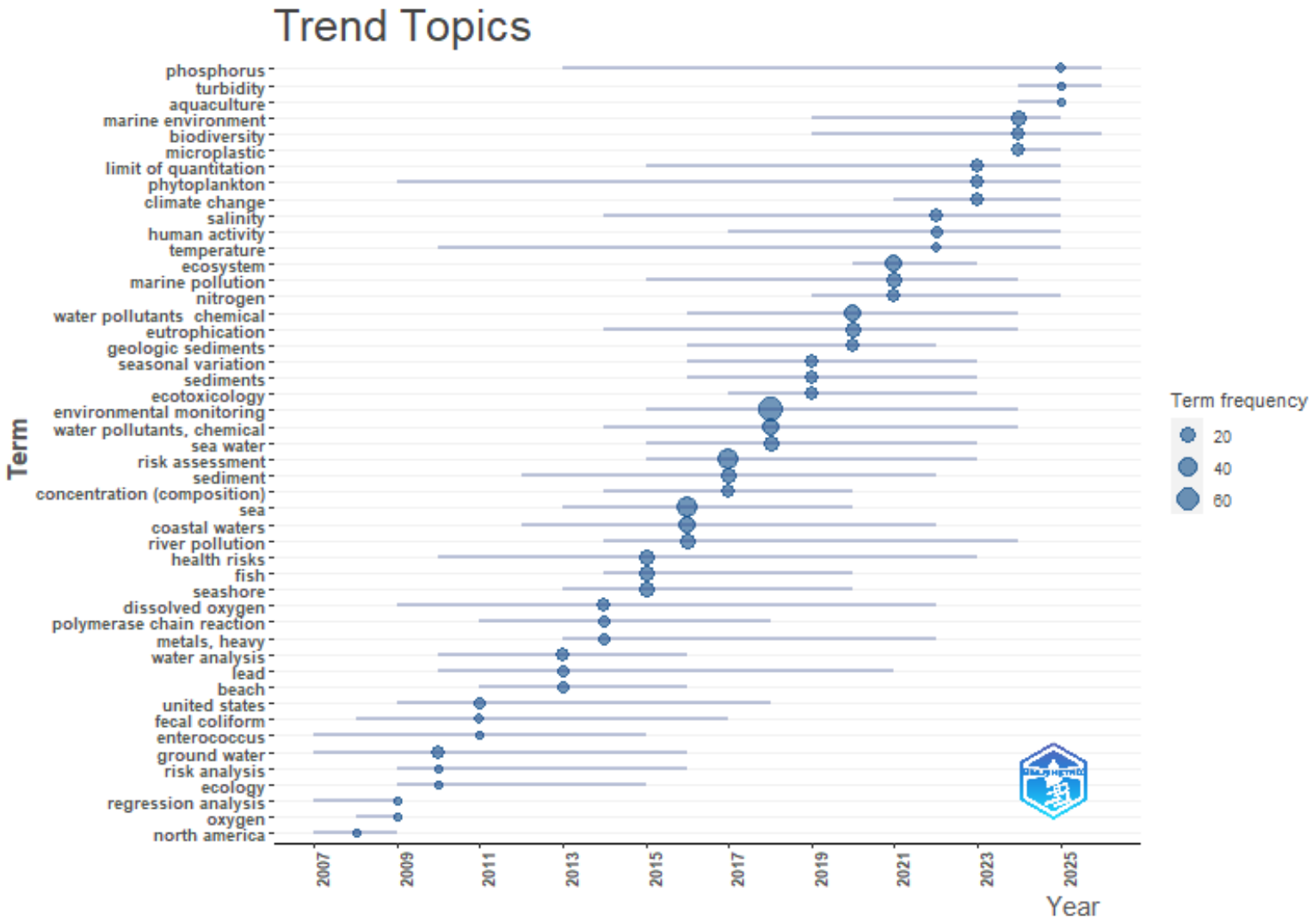


Figure S2. Trend topics showing their initial year, final year, and median year.