VI. Environmental and Light Textile Engineering

1 Engineering research fronts

1.1 Trends in Top 10 engineering research fronts

The Top 10 engineering research fronts in the field of environmental and light textile engineering include the subfields of environmental science, meteorological science, marine science, food science, textile science, and light industry science. The citation statistics for these research fronts and the number of core papers published annually for each research front between 2017 and 2022 are summarized in Tables 1.1.1 and 1.1.2, respectively.

(1) Environmental risks of emerging contaminants in soil

Emerging contaminants are toxic and harmful chemicals that feature biological toxicity, environmental persistence, and bioaccumulation. These contaminants pose a significant risk to both the ecological environment and human health. However, they have not been adequately addressed in current environmental management practices or regulations. Currently, emerging contaminants of concern globally include persistent organic pollutants regulated by international conventions, endocrine disruptors, antibiotics, microplastics, among others.

Emerging contaminants in soil come from a wide range of sources and varieties, and the soil matrix is complex. Therefore, the research and development of high-throughput screening technology with high sensitivity and multiple targets and the early establishment of standard methods are of great significance for determining emerging contaminants rapidly and efficiently, ensuring the accuracy of research results and completing environmental risk assessment.

Many research scholars have assessed individual emerging contaminants without considering the possibility of combined or

Table 1.1.1 Top 10 engineering research fronts in environmental and light textile engineering

No.	Engineering research front	Core papers	Citations	Citations per paper	Mean year
1	Environmental risks of emerging contaminants in soil	86	4 632	53.86	2021.1
2	Non-CO_2 greenhouse gas emission reduction and utilization	255	4 976	19.51	2020.3
3	Technologies for prevention and remediation of micro-pollution of drinking water sources and safe utilization of micro-polluted water	85	10 560	124.24	2018.6
4	Frontier interpretation of greenhouse gas emissions from aquaculture	33	1 502	45.52	2019.9
5	Neural network-based ensemble prediction method	50	5 016	100.32	2020.4
6	Research on the impact of urbanization on hourly extreme precipitation	47	743	15.81	2020.4
7	Estimation of global air–sea carbon dioxide flux and its regulation mechanism	48	2 293	47.77	2018.3
8	Research on the precision nutrition and healthy engineering	246	25 780	104.80	2018.7
9	Research and development of biomass textile materials for low-carbon environmental protection	101	7 362	72.89	2019.2
10	Research on whole component utilization of bulk biomass	50	697	13.94	2021.4

Table 1.1.2 Annual number of core papers published for the Top 10 engineering research fronts in environmental and light textile engineering

No.	Engineering research front	2017	2018	2019	2020	2021	2022
1	Environmental risks of emerging contaminants in soil	0	1	1	11	51	22
2	Non-CO_2 greenhouse gas emission reduction and utilization	23	24	23	51	54	80
3	Technologies for prevention and remediation of micro-pollution of drinking water sources and safe utilization of micro-polluted water	22	18	24	14	5	1
4	Frontier interpretation of greenhouse gas emissions from aquaculture	1	8	3	8	7	6
5	Neural network-based ensemble prediction method	0	0	0	32	14	4
6	Research on the impact of urbanization on hourly extreme precipitation	3	3	4	15	8	14
7	Estimation of global air–sea carbon dioxide flux and its regulation mechanism	19	9	11	6	3	0
8	Research on the precision nutrition and healthy engineering	57	56	62	46	21	4
9	Research and development of biomass textile materials for low-carbon environmental protection	13	21	21	27	15	4
10	Research on whole component utilization of bulk biomass	0	0	0	8	14	28

synergistic effects. However, multiple contaminants always coexist in soil; besides, a large number of factors may affect the toxicity of contaminant mixtures, making the risk assessment of mixed contaminants a complex task. Therefore, mixture toxicology should be given more attention in future studies. In addition, microplastics in soil can also affect the adsorption, degradation and migration behavior of other contaminants, which is also a hot research topic in recent years.

(2) Non-CO_2 greenhouse gas emission reduction and utilization

Greenhouse gases refer to gases in the atmosphere that can absorb long-wave radiation reflected from the Earth's surface and re-emit radiation, leading to an increase in surface temperature. They mainly include carbon dioxide, methane, nitrous oxide, nitric oxide, sulfur dioxide, carbon monoxide, fluorocarbons, and hydrofluorocarbons. Non-CO_2 greenhouse gas emission reduction and resource utilization mainly refers to measures taken to reduce greenhouse gas emissions and convert waste or by-products into reusable resources, thereby reducing environmental pollution and further reducing resource consumption. Currently, most greenhouse gas utilization schemes focus on carbon dioxide, such as capturing carbon dioxide for enhanced oil recovery and synthetic fuel production.

The concentration of non-CO_2 greenhouse gases in the atmosphere is much lower than that of carbon dioxide, but their global warming potential (GWP) is much higher that of carbon dioxide. There have been some explorations in the resource utilization of non-CO_2 greenhouse gases. Methane can be captured and converted into syngas for the production of synthetic fuels and chemicals such as synthetic natural gas, synthetic oil, synthetic plastics, turning waste gas into higher value-added products. Nitrous oxide can be captured from industrial processes or wastewater treatment through absorption, adsorption, catalytic reduction, etc., and catalytically converted into nitrates for use as agricultural fertilizers or for the production of styrene. Catalytic decomposition of perfluorocarbons can produce decomposition products such as hydrogen fluoride for use in chemical basic products, etc. The reduction and resource utilization of non-CO_2 greenhouse gases are of great significance in promoting pollution reduction, carbon reduction, and comprehensive air pollution control, and it is also one of the frontier research hotspots in environmental science and engineering.

(3) Technologies for prevention and remediation of micro-pollution of drinking water sources and safe utilization of micro-polluted water

The micro-pollution of drinking water sources featuring emergence of trace organic pollutants has become a global environmental concern. Recently, the proposal of the concept of emerging contaminants and the action of emerging contaminant control have put forward higher requirements for the prevention and control of micro-pollution in drinking water sources, and it is urgent to develop technologies for prevention and control and safe utilization of micro-polluted water.

According to different types of treatment technology, this research frontier mainly includes: ① advanced oxidation technologies for the treatment of organic micro-pollutants, including ozone oxidation, Fenton-like oxidation, and electrocatalytic oxidation; ② membrane technologies for treatment of micro-pollution in water sources, including reverse osmosis, forward osmosis, and nanofiltration; ③ research on adsorbents for micro-pollutants, mainly focusing on carbonaceous materials, particularly activated carbon; and ④ biochemical treatment technologies for micro-pollution in water sources, such as biological aerated filter. Among the various micro-pollutants of concern, the treatment methods for per- and polyfluoralkyl substances, medicines and personal care products, disinfection by-products, and microcystins have attracted considerable attention.

A promising field of research in the future is the development of selective advanced oxidation technologies for target micro-pollutants in micro-polluted water sources in light of the substantially lower concentration of the micro-pollutants compared to the coexisting substrates. Currently, this research frontier mainly focuses on the treatment technology of micro-pollutants, while there are few studies on the risk control of water quality of drinking water sources. Hence, it is promising to develop technologies for safe utilization of micro-polluted water based on risk control of water quality.

(4) Frontier interpretation of greenhouse gas emissions from aquaculture

China's marine fisheries economy has advanced stably, with surging carbon emissions from marine fisheries. To integrate the concept of green and low-carbon development into the whole process of marine fisheries development, it is necessary to understand the status quo and development trend of carbon emissions from marine fisheries.

Frontier studies in recent years have used system dynamics methods, decoupled index models and other methods to establish a dynamic model of carbon emissions from marine fisheries, and to study the relationship between carbon emissions and economic output, and the key influencing factors of carbon emissions from China's marine capture fisheries.

It is found that rapid economic development has a significant impact on increasing carbon emissions from marine fisheries, and both fishery carbon emissions and carbon sinks show an increasing trend while net carbon emissions a decreasing one; there are differences in the performance of carbon emissions, carbon sinks and net carbon emissions in different provinces, and the adjustment of the energy and industrial structure can help control carbon emissions from marine fisheries. The decoupling status of all coastal regions has improved in recent years, and the study recommends strengthening the implementation of carbon tax policies, establishing compensation mechanisms for farmers, and promoting carbon emissions trading and international blue carbon trading.

(5) Neural network-based ensemble prediction method

With the development of science and technology, weather forecasting technology has been constantly improved. Since the 1990s, ensemble forecasting, as an important means of reducing prediction uncertainty and improving prediction skills, has become the mainstream method for numerical weather and climate prediction in the world. The core operational logic of ensemble forecasting is to obtain a set of initial numerical forecast values with certain distribution characteristics of probability density function within a range of initial value error by using some certain mathematical methods, and then integrate each initial value with a numerical model to obtain a set of forecast results. From the set of forecast results, the probability density distribution information of future weather states, such as ensemble mean, probability, dispersion, extreme values, is estimated. In recent years, the application of artificial intelligence in the field of meteorology has attracted more and more attention, and neural network is an important branch of it. The main feature of neural network is that the input data can be mapped to the output data through any degree of nonlinearity, and it has a strong ability in learning and fitting highly nonlinear functions. By layer and layer feature transformation, the feature representation of the sample in the original space is transformed into a new feature space, so as to improve the accuracy of classification or prediction. Therefore, the ensemble forecasting method based on intelligent algorithm can fully take advantage of various numerical forecasting models and has a promising prospect of popularization and application in meteorological operations.

(6) Research on the impact of urbanization on hourly extreme precipitation

The occurrence of extreme precipitation often leads to water accumulation and flooding, and even causes landslides, mudslides and other geological disasters, threatening the safety of people's lives and property. Different from long-term extreme precipitation, extreme hourly precipitation can generate a large amount of precipitation in a short period of time, which has more serious impacts on people's lives and economic development. With the development of global urbanization, more and more attention has been paid to the relationship between extreme precipitation changes and urbanization. In urban areas, the factors that affect hourly extreme precipitation changes are very complex, and each factor even has a mutually cancelling effect. Urban heat island effect, aerosol emissions, frictional effect on urban underlying surfaces, and blocking effect of buildings can all affect the original distribution of precipitation in the local area where the city is located. Unlike the impact on temperature, the major centers of the impact may not be concentrated in the urban center, but may vary according to different geographical characteristics and meteorological circulation backgrounds. Therefore, further research on the relationship between extreme hourly precipitation and urbanization is beneficial for better urban engineering design and infrastructure planning. On the other hand, due to the characteristics of small spatial scale, rapid development and great difficulty in forecasting of convective systems that form extreme hourly precipitation, in-depth understanding and correct prediction of such systems are not only the key to improving refined meteorological services, but also helpful to enhance the ability of meteorological disaster prevention and reduction.

(7) Estimation of global air–sea carbon dioxide flux and its regulation mechanism

The ocean is the largest carbon pool in the Earth's system, regulating the amount of carbon in the atmosphere by absorbing and releasing carbon dioxide. The ocean carbon cycle is an important part of the global carbon cycle. In the context of global warming, accurate estimation of the air–sea carbon dioxide flux is an important part of the global carbon cycle and the key part of the global quantitative assessment of the ocean carbon budget and its spatio-temporal pattern of the source-sink. Further clarification of its regulatory mechanism is of great significance for understanding, predicting, and evaluating the global carbon cycle, climate change, and marine ecosystem health, and also provides a scientific basis for protecting the ocean and responding to climate change.

The current methods for studying the air–sea carbon dioxide flux include setting buoys in the ocean to measure the concentration of carbon dioxide in seawater; using satellite remote sensing technology to monitor the partial pressure of carbon dioxide on the ocean surface and estimating the air–sea carbon dioxide flux; on-site sampling and observation by ships and submersibles; laboratory research by radioisotope tracer. However, current data are few, the spatio-temporal distribution is extremely uneven, and the uncertainty of flux estimation is large. In the future, it is necessary to carry out further research on long-term, continuous, and wide-coverage carbon dioxide concentration monitoring, strengthen the development of more accurate means of estimating the air–sea carbon dioxide flux, and deeply explore the factors that regulate the air–sea carbon dioxide flux. Accurate assessment of carbon dioxide flux and a comprehensive analysis of its regulation mechanism are of great practical significance for predicting the ocean's ability to absorb carbon dioxide emitted by humans in the future.

(8) Research on the precision nutrition and healthy engineering

Translating the growing findings of basic nutrition science into clinically beneficial dietary guidance is one of the main challenges in the field of nutrition and health research today. The latest standardized dietary analysis results indicate that there are still huge differences in people's reactions to consuming the same food. This indicates that nutritional interventions need to consider factors such as dietary habits, food behavior, and physical activity/exercise. Precision nutrition aims to identify metabolic heterogeneity factors in individuals through multiple omics methods such as genetics, epigenetics, microbiome, metabolomics, and environmental exposure. In addition, based on methods such as molecular biology and molecular nutrition, precision nutrition conducts screening of biomarkers related to nutritional metabolism, studies the molecular and pathological processes of diseases, identifies precise targets for different health problems, and identifies the precise needs of different populations. Ultimately, precise nutritional stratification standards for populations are established, so as to achieve better dietary guidance and intervention and realize the goal of reversing chronic diseases and maintaining healthy homeostasis.

(9) Research and development of biomass textile materials for low-carbon environmental protection

Biomass materials consist of organic macromolecules obtained from living things, including plants, animals, and microbes. These materials are generally composed of carbon, hydrogen, and oxygen. In their original form, these materials undergo biodegradation easily due to the presence of natural microbial agents in the environment. This process results in the production of water, carbon dioxide, and other small molecular byproducts, allowing for their reintegration into the natural cycle. The unique characteristic of biomass materials grants them considerable benefits, making them intrinsically equipped with notable capacities for both regeneration and biodegradation. The common biomass materials are lignin and its derivatives, modified starch, chitin and its derivatives, tea saponin and its derivatives, fat peptide matter, etc., which have broad application prospects in the fields of textile slurry, textile functional finishing, textile printing and dyeing wastewater treatment.

The growing consumer expectations have led to a heightened focus on the usability of textile materials, specifically intelligent textile goods. Traditional textile materials have, during their manufacturing process, utilized significant amounts of natural resources, resulting in excessive carbon emissions. The increasing scarcity of conventional textile raw materials, such as chemical fibers and wool, has led to a growing interest in biomass materials. These materials are attractive due to their abundant availability, lower costs, and desirable physical-chemical stability, mechanical properties, and environmental compatibility. The endeavor to produce biomass textile materials that are low in carbon emissions and ecologically benign is crucial to tackle resource constraint in the textile industry and promote sustainable development. Therefore, the scientific importance of these materials is substantial.

The development and application of biomass materials face challenges due to their diverse sources and intricate composition. These factors impede the progress in utilizing biomass materials. Consequently, there is a need to explore low-carbon and environment-friendly methods for efficient purification. Additionally, chemical or physical modifications can be employed to align biomass materials with societal requirements. Furthermore, there is a growing interest in investigating the broader utilization of biomass materials in the textile industry, making it a prominent area of current research.

(10) Research on whole component utilization of bulk biomass

The entire life cycle of industrial production is usually accompanied by carbon emission issues, in which the mass production and usage of industrial raw materials such as iron and steel, cement as well as petroleum-based polymer materials account for a considerable proportion of the total carbon emissions. Therefore, the industrial feedstock substitution has become a key technology in the field of resource carbon neutrality. According to the International Energy Agency (IEA), biomass refers to a variety of organisms formed using photosynthesis to sequester carbon, which is a typically renewable carbon-neutral resource. Therefore, it is strategically important for achieving the goal of carbon neutrality through utilizing biomass as a full or partial replacement of feedstock for heavy carbon industries. Biomass has a complex composition, and there are large differences in the physical structure and chemical properties of various components. Hence, the conventional technological strategies for biomass utilization usually require the separation of biomass components, followed by utilization in a graded and qualitative manner. However, it is difficult to efficiently separate various biomass components since it requires harsh experimental conditions and consumes large quantities of chemicals, which further leads to the carbon emission problem. In addition, the components of biomass feedstock that cannot be utilized after separation also cause resource waste and environmental pollution problems. Therefore, the efficient utilization of all components of bulk biomass in industrial production is expected to further solve the problem of carbon emissions. In the future, it is necessary to focus on the research and development of pre-treatment technologies as well as processing and molding technologies that are universally applicable to various types of bulk biomass, so as to meet the needs of practical production while realizing the goal of resource carbon neutrality.

1.2 Interpretations for three key engineering research fronts

1.2.1 Environmental risks of emerging contaminants in soil

Emerging contaminants are toxic and harmful chemicals generated in human activities such as production and daily life, mainly including endocrine disruptors (EDs), pharmaceuticals and personal care products (PPCPs), perfluorinated compounds (PFCs), brominated flame retardants (BRPs), disinfection by-products of drinking water, nanomaterials, and microplastics. Emerging contaminants have characteristics such as persistence, high harm, and wide distribution. Its concentration in soil is generally low, but it poses serious harm to the ecosystem and has a significant impact on human health.

Soil is a huge "sink" of emerging contaminants in terrestrial ecosystems. For example, the amount of microplastics released into the soil every year is 4–23 times more than that released into the ocean. Only in Europe and North America do microplastics accumulate in the soil every year 7×10^5 tons, far exceeding the total amount of microplastics in the global ocean (9.3×10^4–2.3×10^5 tons). After entering the soil, some emerging contaminants remain in the soil or accumulate in plants and soil animals, while the other part enters surface water and groundwater through horizontal and vertical migration, which may eventually be exposed to humans. Therefore, soil is the "source" of emerging contaminants in the ecosystem.

Emerging contaminants affect the cycling of soil nutrients by altering soil physicochemical properties, reducing soil fertility, and interfering with the functional and structural diversity of soil microbial communities. In addition, certain toxic effects of emerging contaminants on soil animals, plants, and microorganisms, such as oxidative stress, DNA damage, and reduced metabolic function, will further threaten human health and life through the food chain. Research reports indicate that microplastics can lead to oxidative stress and inflammatory reactions upon entry into the human body, as well as their persistent presence in the body that may lead to chronic inflammation and increase the risk of tumor development.

Microplastics and antibiotics are research hotspots in the environmental risks of soil emerging contaminants. The dynamics and fate of emerging contaminants entering the soil, as well as the bioavailability of emerging contaminants in the soil environment, are currently the main issues of concern.

It can be seen from Table 1.2.1 that the main output countries of the core papers in this research direction are China, Iran, Turkey, Peru, and India. Among them, China ranks first in the number of core papers, accounting for 33.72%; Iran came second, accounting for 27.91%. The total number of core papers from the above two countries accounts for nearly 60% of the global total. According to Table 1.2.2, the institutions with a large number of core papers produced in this front are Hunan University, Quchan University of Technology, Akdeniz University, Universidad San Ignacio de Loyola, Hunan University of Chinese Medicine, Shiraz University of Medical Sciences, and Bushehr University of Medical Sciences. The number of core papers from these institutions has exceeded 8.

It can be seen from Figure 1.2.1 that China, Iran, Turkey, India, Malaysia, the USA, and Egypt pay more attention to cooperation among countries in this research field. China has the largest number of published papers, mainly in cooperation with Iran and Turkey. From Figure 1.2.2, it can be seen that institutions such as Quchan University of Technology, Akdeniz University, Shiraz University of Medical Sciences, University of Electronic Science and Technology of China, and Ankara University have established cooperative relationships.

In Table 1.2.3, the country with the highest output of citing papers is China, with a high percentage of citing papers 39.39%; India came second at 11.31%; Iran ranks third at 10.78%. In Table 1.2.4, the institution that produces the most citing papers is the Chinese Academy of Sciences, with 18.20% of the citing papers, and Quchan University of Technology has 14.82% of the citing papers.

Based on the above data analysis results, it can be seen that China ranks among the world's top in terms of core paper output and citation quantity in terms of environmental risks of new pollutants in soil, with a relatively large number of core papers cited by Chinese research institutions. Figure 1.2.3 shows the roadmap of the engineering research front of "environmental risks of emerging contaminants in soil".

Table 1.2.1 Countries with the greatest output of core papers on “environmental risks of emerging contaminants in soil”

No.	Country	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	China	29	33.72	2 276	78.48	2020.8
2	Iran	24	27.91	1 192	49.67	2021.5
3	Turkey	17	19.77	994	58.47	2021.5
4	Peru	13	15.12	376	28.92	2021.5
5	India	12	13.95	436	36.33	2021.3
6	Malaysia	11	12.79	603	54.82	2020.8
7	USA	8	9.30	446	55.75	2020.9
8	Egypt	8	9.30	327	40.88	2021.0
9	Germany	8	9.30	211	26.38	2021.2
10	Saudi Arabia	7	8.14	136	19.43	2021.4

Table 1.2.2 Institutions with the greatest output of core papers on “environmental risks of emerging contaminants in soil”

No.	Institution	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	Hunan University	15	17.44	923	61.53	2020.7
2	Quchan University of Technology	12	13.95	906	75.50	2021.7
3	Akdeniz University	10	11.63	870	87.00	2021.5
4	Universidad San Ignacio de Loyola	9	10.47	311	34.56	2021.3
5	Hunan University of Chinese Medicine	8	9.30	503	62.88	2020.6
6	Shiraz University of Medical Sciences	8	9.30	479	59.88	2021.5
7	Bushehr University of Medical Sciences	8	9.30	205	25.62	2021.2
8	University of Electronic Science and Technology of China	7	8.14	746	106.57	2021.7
9	Universiti Teknologi Malaysia	7	8.14	317	45.29	2020.9
10	Ankara University	7	8.14	230	32.86	2021.3

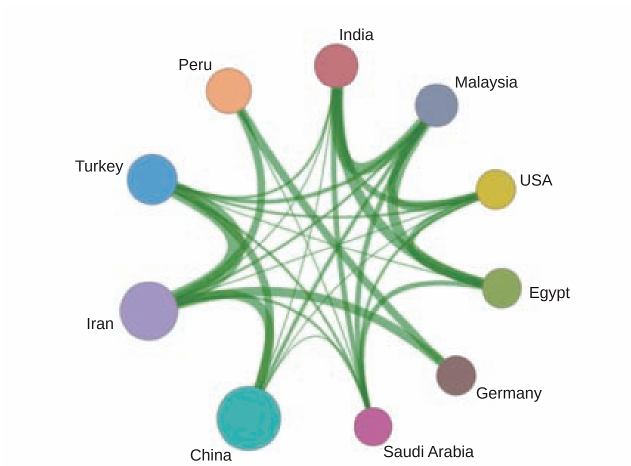

Figure 1.2.1 Collaboration network among major countries in the engineering research front of “environmental risks of emerging contaminants in soil”

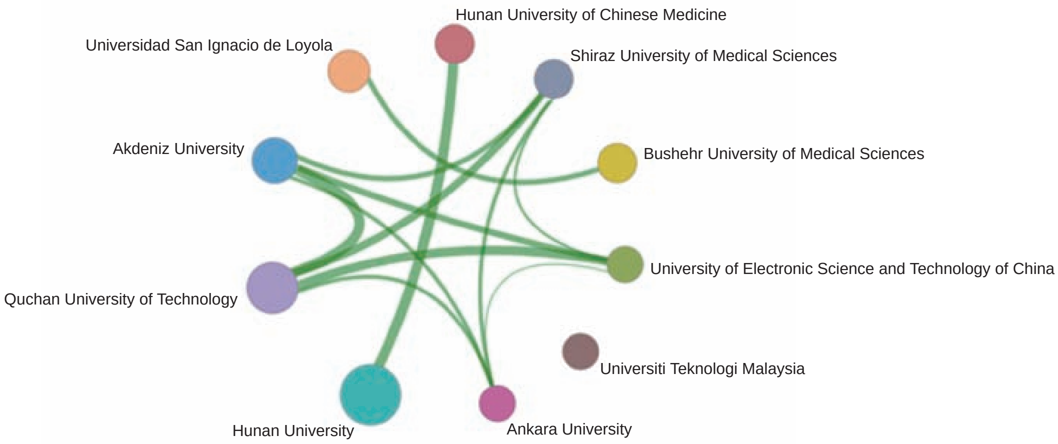

Figure 1.2.2 Collaboration network among major institutions in the engineering research front of "environmental risks of emerging contaminants in soil"

Table 1.2.3 Countries with the greatest output of citing papers on "environmental risks of emerging contaminants in soil"

No.	Country	Citing papers	Percentage of citing papers/%	Mean year
1	China	1 125	39.39	2021.6
2	India	323	11.31	2021.7
3	Iran	308	10.78	2021.8
4	USA	226	7.91	2021.5
5	Republic of Korea	169	5.92	2021.7
6	Turkey	142	4.97	2021.8
7	Saudi Arabia	135	4.73	2021.6
8	Canada	116	4.06	2021.5
9	UK	110	3.85	2021.4
10	Malaysia	103	3.61	2021.5

Table 1.2.4 Institutions with the greatest output of citing core papers on "environmental risks of emerging contaminants in soil"

No.	Institution	Citing papers	Percentage of citing papers/%	Mean year
1	Chinese Academy of Sciences	97	18.20	2021.5
2	Quchan University of Technology	79	14.82	2021.9
3	Hunan University	51	9.57	2021.2
4	Islamic Azad University	50	9.38	2021.8
5	King Saud University	50	9.38	2021.8
6	University of Johannesburg	41	7.69	2021.8
7	University of Electronic Science and Technology of China	40	7.50	2021.7
8	University of Tabriz	36	6.75	2021.9
9	Shenzhen University	31	5.82	2020.7
10	Akdeniz University	30	5.63	2021.8

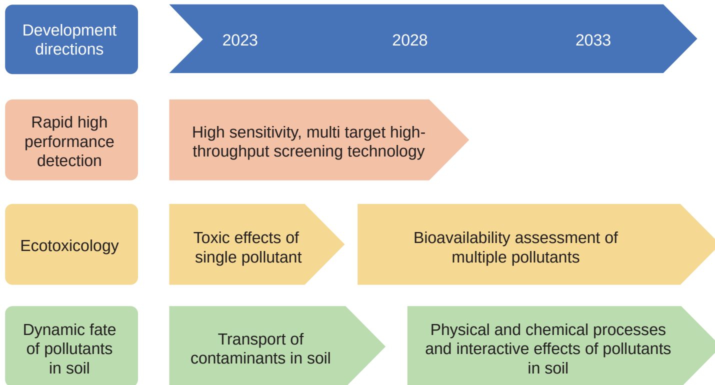

Figure 1.2.3 Roadmap of the engineering research front of "environmental risks of emerging contaminants in soil"

1.2.2 Neural network-based ensemble prediction method

Ensemble forecasting is an important way to reduce forecasting uncertainty and improve forecasting skills. Since the 1990s, ensemble forecasting has become the mainstream method for numerical weather forecast and climate prediction in the world. The concept of ensemble prediction is to generate a set of prediction results for a specific target. Its core is to make repeated forecasts through multiple initial sets with little difference without changing the existing forecast model, so as to increase the reliability of the forecast results. Its ultimate goal is to quantitatively predict the probability distribution of variable states in the future. Neural networks have a strong ability to deal with nonlinear problems, mainly using big data to learn features and being able to depict the rich internal information of data. However, current ensemble prediction methods based on neural networks often predict a specific meteorological data, which has limitations and cannot utilize the correlation between multiple types of weather data for prediction, resulting in low prediction efficiency.

The main countries with the greatest output of core papers on "neural network-based ensemble prediction method" are shown in Table 1.2.5. It can be found that China ranks first in both the proportion of papers and citations, and there is a big gap between other countries and China, which shows that China has a strong research advantage in this field. The USA ranks second in the number of core papers, and Iran ranks third. From the perspective of the citations per paper, China ranks low; and the number of core papers in Australia is small, but the citations in Australia ranks first, which also shows the importance of publishing high-level core papers recognized by peers. As shown in Figure 1.2.4, China has shown close cooperation with the USA, but the cooperation with other countries should be strengthened. Table 1.2.6 shows the main output institutions for core papers in this engineering research front. In terms of the number of core papers, the No.1 institution is Duy Tan University. As shown in Figure 1.2.5, the institutions in the same country has worked in cooperation, but there's very little cooperation among these 10 institutions.

In the rankings of countries with the greatest output of citing papers, China, the USA, and India rank the top three (Table 1.2.7). Chinese Academy of Sciences ranks first among the institutions, followed by North China Electric Power University and Huazhong University of Science and Technology (Table 1.2.8). It can be seen that China is ahead of the rest of the world in the study of "neural network-based ensemble prediction method". Meanwhile, the Chinese Academy of Sciences is also in a leading position among the research institutions in this field, and should continue to maintain a relevant research focus on this front. In addition, the cooperation with other countries should be strengthened.

Figure 1.2.6 shows the roadmap of the engineering research front of "neural network-based ensemble prediction method". It can be seen that there are two key development stages that this research front will experience in the next 5–10 years. The first is to set different model parameters for different meteorological data on the basis of obtaining sufficient training data, and perform multiple rounds of iterations to obtain better prediction accuracy. The second stage is to apply neural network methods to ensemble forecasting research to obtain more reliable results.

Table 1.2.5 Countries with the greatest output of core papers on “neural network-based ensemble prediction method”

No.	Country	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	China	22	44.00	1 978	89.91	2020.5
2	USA	9	18.00	756	84.00	2020.4
3	Iran	7	14.00	758	108.29	2020.3
4	Italy	5	10.00	610	122.00	2020.4
5	India	5	10.00	557	111.40	2020.8
6	UK	5	10.00	444	88.80	2020.6
7	Vietnam	4	8.00	512	128.00	2020.8
8	Australia	3	6.00	516	172.00	2020.3
9	France	3	6.00	436	145.33	2020.7
10	Germany	3	6.00	239	79.67	2021.0

Figure 1.2.4 Collaboration network among major countries in the engineering research front of “neural network-based ensemble prediction method”

Table 1.2.6 Institutions with the greatest output of core papers on “neural network-based ensemble prediction method”

No.	Institution	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	Duy Tan University	3	6.00	412	137.33	2020.3
2	Ton Duc Thang University	2	4.00	323	161.50	2020.5
3	Huazhong University of Science and Technology	2	4.00	288	144.00	2020.0
4	Graduate University of Advanced Technology	2	4.00	228	114.00	2020.0
5	Xi’an Jiaotong University	2	4.00	206	103.00	2021.0
6	North China Electric Power University	2	4.00	156	78.00	2020.0
7	Peking University	2	4.00	153	76.50	2020.5
8	University of Electronic Science and Technology of China	2	4.00	137	68.50	2020.5
9	Tsinghua University	2	4.00	132	66.00	2020.0
10	International University of Business Agriculture and Technology	1	2.00	328	328.00	2020.0

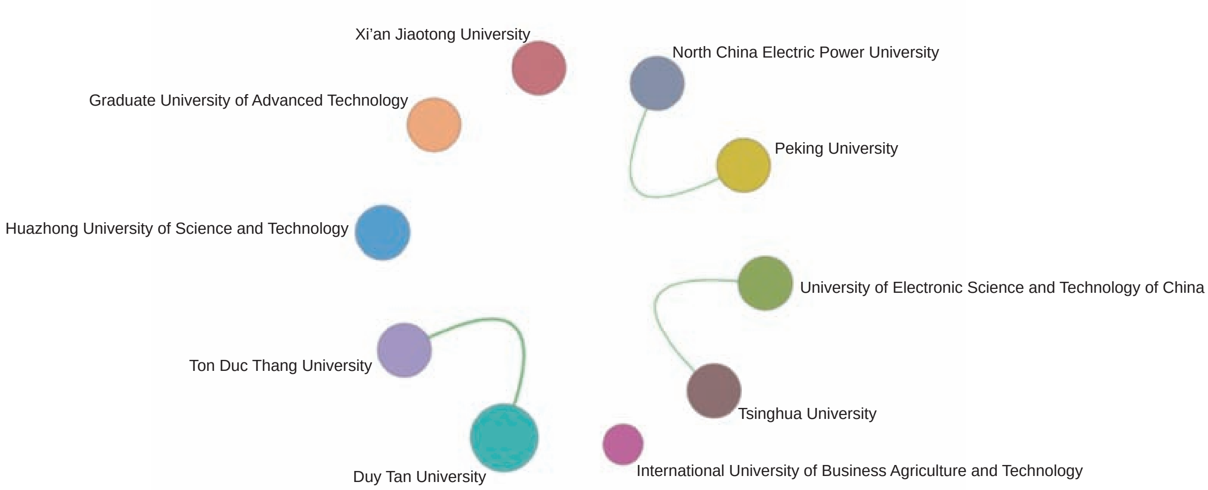

Figure 1.2.5 Collaboration network among major institutions in the engineering research front of "neural network-based ensemble prediction method"

Table 1.2.7 Countries with the greatest output of citing papers on "neural network-based ensemble prediction method"

No.	Country	Citing papers	Percentage of citing papers/%	Mean year
1	China	6 972	47.92	2021.0
2	USA	1 636	11.24	2020.9
3	India	1 094	7.52	2021.3
4	Iran	937	6.44	2020.9
5	UK	735	5.05	2020.9
6	Australia	634	4.36	2020.9
7	Republic of Korea	632	4.34	2021.1
8	Saudi Arabia	554	3.81	2021.4
9	Canada	520	3.57	2021.0
10	Spain	433	2.98	2020.8

Table 1.2.8 Institutions with the greatest output of citing papers on "neural network-based ensemble prediction method"

No.	Institution	Citing papers	Percentage of citing papers/%	Mean year
1	Chinese Academy of Sciences	404	17.71	2021.1
2	North China Electric Power University	331	14.51	2020.5
3	Huazhong University of Science and Technology	206	9.03	2020.5
4	Tsinghua University	202	8.86	2021.0
5	Wuhan University	188	8.24	2021.1
6	Hohai University	176	7.72	2021.1
7	Tianjin University	161	7.06	2020.8
8	Duy Tan University	161	7.06	2020.3
9	Islamic Azad University	152	6.66	2020.9
10	Central South University	151	6.62	2021.2

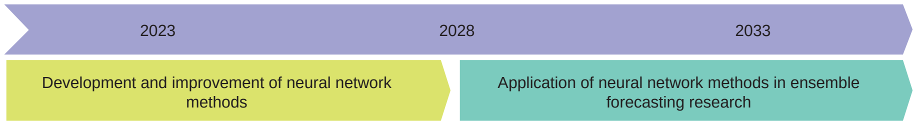

Figure 1.2.6 Roadmap of the engineering research front of "neural network-based ensemble prediction method"

1.2.3 Research on the precision nutrition and healthy engineering

Translating the growing findings of basic nutrition science into clinically beneficial dietary guidance is one of the main challenges in the field of nutrition and health research today. The latest standardized dietary analysis results indicate that even when consuming the same food, there are still significant differences in people's reactions. This indicates that nutritional interventions need to consider such factors as dietary habits, food behavior, and physical activity/exercise.

Therefore, the frontier path for the intelligent implementation of precision nutrition and shaping the paradigm of nutritional life lies in exploring the interaction between the intake of different nutritional factors, different metabolic characteristics, and different individual environments, and forming precision nutrition intervention methods with wearable devices as a lifestyle, which is achieved by combining deep phenotypes such as nutrigenomics, metabolomics, and microflora with the blood indicators (such as blood oxygen, blood pressure, blood sugar.) before and after diet, as well as physiological phenotypes such as faecal flora and dietary behavior rules, personal activities/exercise, and other life factors, leveraging the advantages of big data analysis and machine learning, techniques such as regression, classification, recommendation and clustering can also be employed. For example, recent research on obesity phenotypes has revealed that genetic variation, microbial metabolites, and epigenetic factors are crucial for obesity phenotypes. The epigenetic factors include variations in genes such as FTO, MC4R, PPAR, apoA, and fads, DNA methylation in the CpG island region, and specific miRNAs and microbial species such as Firmicut, Bacteriodes, and Clostridies. Additionally, microbial metabolites, folic acid, B-vitamins, and short-chain fatty acids interact with miRNAs, further affecting the obesity phenotype, which highlights the comprehensive nature of nutrient metabolism imbalance influenced by multi-dimensional biological factors. Therefore, it is crucial to integrate genomics, proteomics, metabolomics, microbiology, and other techniques to explore deep molecular indicators and biomarkers of diseases related to nutritional imbalance, and to establish a predictive analysis and clustering basis for abnormal metabolic indicators in the population from a multi-omics perspective. Such an approach can guide the preventive intervention of precision nutrition for chronic diseases and metabolic disorders, which is also the inevitable direction of clinical development in the field of precision nutrition.

Precision nutrition aims to identify metabolic heterogeneity factors in individuals through multiple omics methods such as genetics, epigenetics, microbiome, metabolomics, and environmental exposure. In addition, based on methods such as molecular biology and molecular nutrition, precision nutrition conducts screening of biomarkers related to nutritional metabolism, studies the molecular and pathological processes of diseases, identifies precise targets for different health problems and the targeted needs of populations. Ultimately, precise nutritional stratification standards for populations are established, so as to achieve better dietary guidance and intervention and realize the goal of reversing chronic diseases and maintaining healthy homeostasis.

Table 1.2.9 shows the countries with the greatest output of core papers on "research on the precision nutrition and healthy engineering". Among them, China ranks sixth with 11.79% core papers and 2 556 citations. There is still a gap compared to other countries, indicating that China needs to strengthen its research advantages in this area. Canada has fewer core papers, but it ranks first in terms of citations per paper. This indirectly illustrates the importance of publishing high-quality core papers recognized by peers. Table 1.2.10 shows the institutions with the greatest output of core papers on "research on the precision nutrition and healthy engineering". None of the Top 10 institutions are from China. Harvard University ranks first with 25 core papers. According to Figure 1.2.7, the countries that prioritize cooperation in this research field are the USA, the UK, Germany, and New Zealand. Figure 1.2.8 shows there is significant cooperation between Harvard University and Brigham and Women's Hospital. Table 1.2.11 indicates that the country with the greatest output of citing papers is the USA, accounting for a significant proportion of 23.61%. China ranks second with 20.54%. In Table 1.2.12, Harvard University is the institution with the largest output of citing papers, with

Table 1.2.9 Countries with the greatest output of core papers on "research on the precision nutrition and healthy engineering"

No.	Country	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	USA	97	39.43	10 192	105.07	2018.7
2	Italy	42	17.07	6 707	159.69	2018.9
3	UK	40	16.26	5 676	141.90	2018.5
4	Spain	34	13.82	3 559	104.68	2018.6
5	Germany	29	11.79	5 245	180.86	2018.7
6	China	29	11.79	2 556	88.14	2018.5
7	Netherlands	26	10.57	4 290	165.00	2018.6
8	France	23	9.35	4 097	178.13	2018.7
9	Canada	22	8.94	4 120	187.27	2018.3
10	Australia	20	8.13	3 301	165.05	2018.2

Table 1.2.10 Institutions with the greatest output of core papers on "research on the precision nutrition and healthy engineering"

No.	Institution	Core papers	Percentage of core papers/%	Citations	Citations per paper	Mean year
1	Harvard University	25	10.16	3 841	153.64	2018.8
2	Tufts University	11	4.47	1 235	112.27	2018.8
3	University of Navarra	10	4.07	1 436	143.60	2018.0
4	Brigham and Women's Hospital	10	4.07	1 091	109.10	2019.4
5	Carlos III Health Institute	9	3.66	821	91.22	2018.1
6	Newcastle University	9	3.66	732	81.33	2017.4
7	University of Oxford	8	3.25	1 414	176.75	2019.5
8	University of Copenhagen	8	3.25	487	60.88	2018.1
9	University of Milan	7	2.85	1 807	258.14	2019.0
10	Maastricht University	7	2.85	569	81.29	2017.4

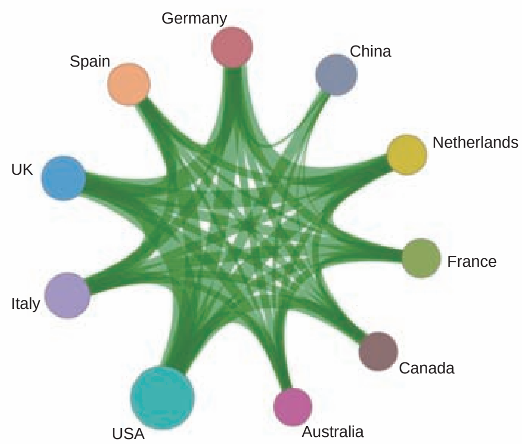

Figure 1.2.7 Collaboration network among major countries in the engineering research front of "research on the precision nutrition and healthy engineering"

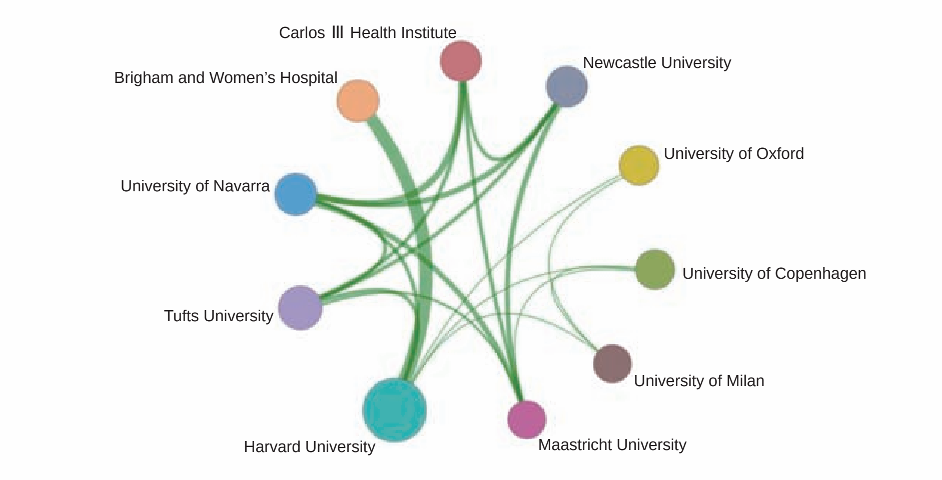

Figure 1.2.8 Collaboration network among major institutions in the engineering research front of “research on the precision nutrition and healthy engineering”

Table 1.2.11 Countries with the greatest output of citing papers on “research on the precision nutrition and healthy engineering”

No.	Country	Citing papers	Percentage of citing papers/%	Mean year
1	USA	5 160	23.61	2020.9
2	China	4 489	20.54	2021.2
3	Italy	2 209	10.11	2020.9
4	UK	1 900	8.69	2020.8
5	Spain	1 716	7.85	2020.9
6	Germany	1 484	6.79	2020.9
7	Australia	1 228	5.62	2020.8
8	Canada	1 034	4.73	2020.9
9	France	905	4.14	2020.9
10	Netherlands	898	4.11	2020.8

Table 1.2.12 Institutions with the greatest output of citing papers on “research on the precision nutrition and healthy engineering”

No.	Institution	Citing papers	Percentage of citing papers/%	Mean year
1	Harvard University	615	21.39	2020.9
2	Chinese Academy of Sciences	405	14.09	2021.2
3	University of Milan	279	9.70	2021.0
4	University of Queensland	216	7.51	2020.6
5	University of Sao Paulo	211	7.34	2020.8
6	University of Copenhagen	209	7.27	2020.7
7	Zhejiang University	201	6.99	2021.3
8	University of Toronto	187	6.50	2021.0
9	University of Naples Federico II	187	6.50	2020.8
10	Carlos III Health Institute	184	6.40	2020.6

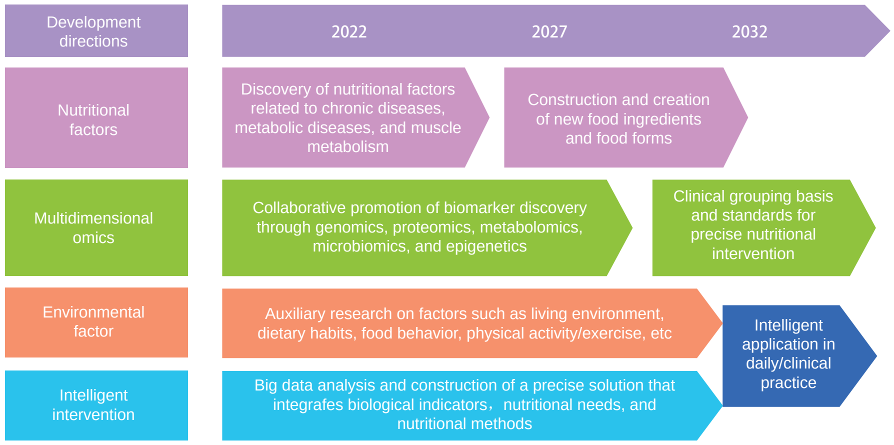

Figure 1.2.9 Roadmap of the engineering research front of “research on the precision nutrition and healthy engineering”

a proportion of 21.39%. It is followed by Chinese Academy of Sciences, with a proportion of 14.09%.

Based on the above data analysis, it can be concluded that among the top countries in terms of citations of core papers on “research on the precision nutrition and healthy engineering”, China ranks second only to the USA. However, there is still a significant gap between China and other countries like the USA in terms of core paper output.

2 Engineering development fronts

2.1 Trends in Top 10 engineering development fronts

The Top 10 engineering development fronts in the field of environmental and light textile engineering are summarized in Table 2.1.1, covering the subfields of environmental science, meteorological science, marine science, food science, textile science, and light industry science. The number of patents related to these individual topics between 2017 and 2022 is presented in Table 2.1.2.

(1) Low-carbon source wastewater denitrification technology

Nitrogen pollution is a typical global environmental issue that has long posed a threat to human health and aquatic ecosystem safety. Increasingly stringent standards on sewage discharge have raised higher requirements for nitrogen emissions from wastewater. In traditional nitrate removal processes based on heterotrophic denitrification, microorganisms utilize organic carbon sources as electron donors to convert nitrates into harmless nitrogen gas. During this process, denitrification performance strongly depends on the concentration of organic carbon sources in water. However, there is a widespread shortage of carbon sources in urban wastewater treatment plants, which adversely affects total nitrogen removal and results in unstable effluent compliance. Therefore, the development of new low-carbon nitrogen removal technologies for wastewater has become a research hotspot.

In recent years, with the deepening understanding of the biological denitrification mechanism, novel denitrification processes such as sulfur-based autotrophic denitrification, shortcut nitrification-denitrification, simultaneous nitrification-denitrification, and anaerobic ammonia oxidation have been developed. These processes focus on shortening the denitrification pathway to achieve deep denitrification while reducing carbon source requirements and operational costs. Although these corresponding processes have been pilot-tested in hundreds of wastewater treatment plants worldwide, research on these new denitrification technologies is still in its infancy. Their practical application in engineering requires further development and exploration. The key factors influencing the processes and future research directions encompass two primary elements. Firstly, in comparison to conventional heterotrophic denitrifying bacteria, autotrophic bacteria exhibit slow growth rates, resulting in extended startup times. Therefore,

Table 2.1.1 Top 10 engineering development fronts in environmental and light textile engineering

No.	Engineering development front	Published patents	Citations	Citations per patent	Mean year
1	Low-carbon source wastewater denitrification technology	941	2 933	3.12	2020.0
2	River and lake eutrophication ecological management technology and equipment	463	802	1.73	2019.7
3	Cross media collaborative prevention and control technology for emerging and traditional pollutants	1 000	4 957	4.96	2019.7
4	Integrated soil pollution reduction and carbon emission control technologies for chemical industrial park	942	2 947	3.13	2020.3
5	Laser detection technology of bio-optical profile in upper ocean water	431	1 393	3.23	2019.7
6	Development of a regional earth system model with convective resolution scale	9	7	0.78	2020.9
7	Construction technology of large-scale aquaculture platform in deep sea	72	108	1.5	2020.5
8	Antimicrobial textile derived from cellulose	1 000	3 941	3.94	2020.8
9	Research on the bioaugmentation of food functional components	829	971	1.17	2020.6
10	Cell factory technology for sustainable production of lactic acid from lignocellulose	68	1 817	26.72	2019.0

Table 2.1.2 Annual number of core patents published for the Top 10 engineering development fronts in environmental and light textile engineering

No.	Engineering development front	2017	2018	2019	2020	2021	2022
1	Low-carbon source wastewater denitrification technology	96	116	151	164	175	239
2	River and lake eutrophication ecological management technology and equipment	64	83	75	67	76	98
3	Cross media collaborative prevention and control technology for emerging and traditional pollutants	136	147	165	157	197	198
4	Integrated soil pollution reduction and carbon emission control technologies for chemical industrial park	86	119	112	115	171	339
5	Laser detection technology of bio-optical profile in upper ocean water	55	66	63	81	92	74
6	Development of a regional earth system model with convective resolution scale	0	1	0	2	2	4
7	Construction technology of large-scale aquaculture platform in deep sea	3	7	4	17	22	19
8	Antimicrobial textile derived from cellulose	52	64	60	71	394	359
9	Research on the bioaugmentation of food functional components	59	76	87	83	154	370
10	Cell factory technology for sustainable production of lactic acid from lignocellulose	16	16	15	6	6	9

it is imperative that research focuses on the biological and physiological characteristics of bacterial strains. Additionally, efforts should be directed towards the domestication, cultivation, and preservation of these strains. Secondly, the accumulation of nitrite plays a pivotal role in achieving low-carbon nitrogen removal. Consequently, optimizing design parameters, such as pH, dissolved oxygen, and influent conditions, to enhance shortcut nitrification reactions represents a crucial avenue for process improvement.

(2) River and lake eutrophication ecological management technology and equipment

Eutrophication of river and lake refers to the phenomenon of water pollution caused by excessive content of nitrogen, phosphorus and other nutrients in water. The essence is that the destroyed balance of nutrient salt migration and transformation in river and lake water bodies results in community composition disorder, species distribution imbalance and nutrient structure instability in river and lake water ecosystems, which hinders the flow of matter and energy in the system and makes the whole water ecosystem tend to collapse. The sources of nutrients such as nitrogen and phosphorus in rivers and lakes are complex, including both endogenous and exogenous sources, both point and non-point sources, causing great difficulties in the treatment of eutrophication in rivers and lakes. Regardless of the source of nutrients, the formation of water eutrophication is affected by many factors, including both natural factors and man-made factors. Effective control of exogenous pollution is the basis of controlling river and lake eutrophication. By regulating the structure of aquatic ecosystem, a complete nutrient level of ecosystem is built; natural, healthy and stable functions of aquatic ecosystem are restored; resistance to external interference is enhanced; and aquatic ecosystem is kept in an environmentally benign and sustainable cycle. Therefore, ecological management technology, that is, improving the biological purification function of water body through internal regulation, is an important research direction to solve the eutrophication of rivers and lakes.

(3) Cross media collaborative prevention and control technology for emerging and traditional pollutants

The composite superposition effect of multiple pollutants in industrial, agricultural, and urban areas is prominent, and the mutual transformation and transmission of multi medium pollutants such as atmosphere, soil, surface water, and groundwater are significant. Further improvement of ecological environment quality cannot be achieved solely through pollution control through a single medium and single element. The disciplinary differentiation of “water pollution control”, “air pollution control”, and “soil pollution control” has led to boundary solidification, often resulting in taking stopgap measures, causing pollutants not to be removed from the environment, but to be transmitted between air, liquid, and solid media, increasing the difficulty of improving environmental quality. Due to the lack of a unified joint pollution control mechanism for cross medium pollution, disconnection in pollution control is quite serious. Based on the results of research on cross media transmission mechanisms and processes, a cross media transmission model for emerging and traditional pollutants is established by using numerical simulation and other methods to simulate the migration process of emerging and traditional pollutants in media such as atmosphere, soil, surface water, and groundwater. The mechanism of regulation and governance of pollutants across media among solid waste, water, air, soil is studied; a cross media collaborative governance technology system for emerging and traditional pollutants is constructed; an efficient, economical, and safe pollution multi medium combination technology optimization and collaborative remediation mechanism is established. These moves aim to break through the cross medium collaborative monitoring technology system for emerging and traditional pollutants, to monitor the distribution and changes of emerging and traditional pollutants in different media, to evaluate prevention and control effects and environmental risks, thus providing theoretical and technological support for achieving cross medium collaborative prevention and control of emerging and traditional pollutants.

(4) Integrated soil pollution reduction and carbon emission control technologies for chemical industrial park

Currently, there are over 22 000 industrial parks in China, more than 600 chemical industrial parks and over 200 provincial-level chemical parks, including petrochemical, fine chemical, pesticide chemical. Some chemical park sites cause severe soil and groundwater pollution, characterized by multiple sources of pollution, multiple generations of cumulative pollution, and multi medium composite pollution. Potential risk management is difficult, and sudden site soil pollution incidents occur from time to time. In addition, the total energy consumption and carbon emissions of the chemical industry account for 12% and 13% of the national total, respectively. Pollution and carbon are highly homologous, and the source sink mechanism is complex, seriously affecting the surrounding environment. Therefore, it is urgent to develop collaborative governance technologies for soil pollution reduction and carbon reduction in chemical park sites, and implement pollution reduction and carbon reduction and pollution prevention in chemical industry parks to realize synchronized production, control and restoration; and conduct precise identification and pollution tracing for retired chemical parks to achieve risk control, green restoration, and safe utilization. Existing technologies only focus on single approach to pollution reduction or carbon reduction, lacking an integrated solution of source control, process control, end treatment, and safe utilization for the overall system. Therefore, it is necessary to establish a refined and intelligent management platform for chemical parks based on material flow and energy flow, develop collaborative disposal technologies and equipment for soil and groundwater pollution in chemical parks with multi medium processes, and use collaborative physicochemical and bioremediation technologies to treat soil pollution in chemical parks. Chemical park site classification and grading management and remediation should be carried out, and management system for pollution tracing, remediation and green development need to be constructed, and a new collaborative governance model for pollution reduction and carbon reduction in chemical industrial parks should be established.

(5) Laser detection technology of bio-optical profile in upper ocean water

The acquisition of three-dimensional data of marine water bodies is a fundamental demand problem that need to be solved urgently in the research of multi-sphere coupling of the Earth system and marine science. The existing marine remote sensing technology is generally two-dimensional plane remote sensing, which has a huge gap with the three-dimensional detection requirements of water profile structure or material and energy migration and spatial and temporal distribution required by marine business and scientific applications. Laser radar can obtain the profile information of bio-optical parameters of upper ocean water by emitting laser to seawater and measuring the spectrum, waveform, intensity and frequency shift of time resolution echo signal. It is a necessary way to realize remote sensing from sea surface to water profile structure. It is an important development direction of satellite ocean remote sensing and an international frontier in the field of ocean optics and water color remote sensing.

The space-borne ocean profile detection technology has not yet broken through, so it can only rely on expensive and sparse field observation methods, which seriously restricts the range and accuracy of satellite ocean remote sensing observation. It is urgent to develop space-borne laser ocean high-precision profile detection technology to realize large-scale remote sensing detection of key parameters of global upper ocean profile and realize the leap from two-dimensional to three-dimensional ocean remote sensing. At present, the main research directions and development trends include: First, the development of new laser detection technologies such as blue-green multi-wavelength, high spectral resolution, and single-photon detection of ocean profiles; second, develop a three-dimensional laser radar radiation transmission simulation technology coupled with complex marine environment and remote sensors; third, develop high-precision lidar ocean optical and biological parameter profile inversion, active and passive fusion and authenticity verification technology; fourth, carry out the application technology of marine laser in frontier science, ecological environment and carbon cycle, and form engineering and large-scale application.

(6) Development of a regional earth system model with convective resolution scale

Regional earth system model and convective resolution scale simulations are two important development directions for regional climate model. Based on the regional climate model, the regional earth system model further considers the biogeochemical cycles such as carbon and nitrogen cycles in the climate system. Its core remains the multi-layer coupled physical climate system of atmosphere-ocean-land-ice. The convective resolution model ($\leq$ 4 km model) no longer requires parameterization of deep convective processes and can provide more realistic terrain, land cover, and explicit description of convective processes, resulting in a more reliable and process-based medium and small-scale climate. Therefore, it is considered an important way to reduce the uncertainty and errors. With the widespread demand for refined regional climate information and the rapid development of high-performance computing resources in recent years, developing convection-resolved scale regional earth system models is needed to accurately describe and predict the impact of climate change and human activities on land surface physical, biological, and geochemical processes, and to improve the understanding of complex interactions between the various layers. It can also provide strong scientific support for weather/climate prediction, climate change adaptation and mitigation, disaster prevention and mitigation and so on.

(7) Construction technology of large-scale aquaculture platform in deep sea

The large-scale aquaculture platform in deep sea is a fishery production comprehensive platform based on marine engineering equipment, industrial aquaculture, marine biological resources development and processing application technology, integrating marine large-scale aquaculture, large-scale breeding of famous and excellent seedlings, fish harvesting and material replenishment, and aquatic product classification and storage. The development and application of the platform have important strategic significance for driving china's marine aquaculture industry from the offshore to the deep sea, creating a "blue granary" and contributing to build china into a strong maritime country.

In recent years, the construction technology of large-scale aquaculture platform in china has been innovating and developing in the direction of information, intelligence and integration. The research and development of specialized deep-sea large-scale aquaculture cage facilities, offshore stability and hydrodynamic control technology of aquaculture platform, intelligent equipment and systems such as automatic precision feeding, water quality monitoring, red tide protection, automatic control technology. In the future, it is necessary to constantly promote the development and application of equipment and facilities for the whole process of "breeding-fishing-processing", further study the hydrological law of deep sea and the construction of aquaculture environment, build a collaborative control and big data management system for deep sea large-scale aquaculture platforms, establish a multi-energy supply and energy security management system and build the whole process industrialization control system and the operation management mode of land-sea linkage.

(8) Antimicrobial textile derived from cellulose

In the aftermath of the epidemic, there has been a growing emphasis on individuals' consciousness towards personal safety. There is much concern among scientific experts on the optimal methods for efficiently inhibiting the proliferation of pathogenic germs and achieving their total eradication. Textiles serve as the primary protective barrier for the human body, with a loose and porous structure along with a substantial specific surface area. These characteristics facilitate the absorption of oil and sweat produced during human metabolism, thus creating a favorable environment for the colonization, proliferation, and propagation of microorganisms. Harmful bacteria exhibit rapid proliferation on textile surfaces, resulting in the emission of unpleasant smells and facilitating the transmission of illnesses via indirect mechanisms within certain public settings. Consequently, this phenomenon presents a significant risk to human well-being. Hence, the prioritization of developing functional textiles, particularly those that are low-carbon and ecologically sustainable, has emerged as a critical objective.

Cellulose-based materials include functional materials derived from cellulose as the primary constituent, following specific chemical or biological processes, hence exhibiting a multitude of properties. Cellulosic materials have ecological and environmental benefits, including their biodegradability and renewability. Cellulose-based antibacterial materials often include many types of fibers, such as bamboo fiber, chitosan fiber, hemp fiber, and kapok fiber. Antimicrobial textile materials represent significant potential for diverse applications within the textile industry. Notably, they may be used in the production of medical supplies, including surgical garments and medical dressings, as well as home products like towels and beds. Due to the growing environmental consciousness among individuals, there has been a notable preference for cellulose-based antibacterial textile materials by several brands and organizations. The advancement of technology will contribute to the enhanced performance and refinement of cellulose-based antibacterial textile materials, hence expanding their potential applications within the textile industry.

(9) Research on the bioaugmentation of food functional components

In recent years, nutrition and health problems have become increasingly prominent, and the health risks caused by poor diet and nutritional imbalance have ranked first among the global disease risks, seriously affecting human life and health, and restricting the orderly development of society and economy. Using bioaugmentation technology to increase the content of important functional components in food is an important way to reduce and prevent malnutrition and micronutrient deficiencies prevalent in developing countries. Improving the micronutrient content in crops that can be absorbed and utilized by the human body through breeding techniques is an important means of bioaugmentation. Major crops such as rice, wheat, maize and sweet potato, which is enriched with micronutrients such as iron, zinc and vitamin A, have been successfully cultivated and will transit from farmland to dining tables, greatly improving the nutritional deficiencies of the poor. In addition, selenium is an essential trace element for human body, and 29% of China's areas are severely selenium deficient. The bioaugmentation of selenium-rich crops relies on the inheritance and genetic engineering technology based on modern molecular biotechnology, and the more effective way is to improve the added value of agricultural products and promote the high-quality development of selenium-rich industry through agronomic management technology based on soil selenium fertilizer and foliar selenium application. Compared with crop bioaugmentation, food bioaugmentation can solve micronutrient deficiency in the short term and can accurately target nutrient deficient populations. Unsaturated fatty acids such as DHA and EPA are crucial for fetal brain development, but the body's own synthesis is very limited. The content of DHA in ruminant milk and the nutritional value of dairy products were improved by oral intake of algae or fucoxanthin as feed additives. Systematically sorting out the invention patents in the field of bioaugmentation of food functional components will be conducive to evaluating the degree of technological development of this industry, indicating the future development direction of this field, and providing a practical reference for the implementation of precision nutrition strategies and the improvement of national health.

(10) Cell factory technology for sustainable production of lactic acid from lignocellulose

Lactic acid is a biocompatible organic carboxylic acid with a wide range of applications in the fields of pharmaceutical, food and cosmetic, etc. The production methods of lactic acid mainly include chemical synthesis and biosynthesis. Due to the advantages of environmental friendliness and low production cost, the biosynthesis method is gradually replacing the conventional chemical synthesis method. However, biosynthesis usually employs fermentation production of cassava starch and other food crops to obtain lactic acid, which has led to social controversy over food and fuel issues. Therefore, bulk lactic acid chemicals still suffer from oversupply. Lignocellulose, a second-generation biomass substrate, is a non-edible renewable resource. In this case, lignocellulose as a raw material for the biosynthesis of lactic acid can effectively solve the above social issues. However, the structure and components of lignocellulose are relatively complex, and most of them are carried out by batch fermentation in the production of lactic acid. This inevitably causes long fermentation time, low yield, and easy generation of impurities. Cell factory technology can be used to produce target products through biosynthetic pathways by engineering reconfiguration of complex living organisms. In terms of both industrial application and economics, the use of cell plant technology is an effective way to achieve sustainable production of lactic acid bulk chemicals from lignocellulose. In the future, there is still a need for further research and development of raw material pretreatment and biodetoxification processes accompanying the cell factory technology for sustainable lactic acid production from lignocellulose, as well as further improvement of the production efficiency of the biosynthesis stage, so as to realize the continuity of the whole process of lactic acid production.

2.2 Interpretations for three key engineering development fronts

2.2.1 Low-carbon source wastewater denitrification technology

In the face of the increasing global production of reactive nitrogen, establishing a "low-nitrogen society" has become an essential measure to control environmental pollution and maintain the health of ecosystems. Continuously raising standards for nitrogen discharge in wastewater is an enduring theme in the global water treatment industry. However, urban wastewater treatment plants often face a shortage of carbon sources, making it challenging for traditional denitrification processes to achieve the desired treatment results. Against the backdrop of the world's move towards dual carbon goals (the goal of reaching peak carbon emissions before 2030 and achieving carbon neutrality before 2060), the development of low-carbon source wastewater denitrification technologies is a crucial pathway to achieving green water treatment processes.

To meet the demand for low-carbon source wastewater denitrification, researchers have developed several innovative denitrification processes, each with distinct characteristics.

1) Sulfur-based autotrophic denitrification: This technology utilizes sulfur and other inorganic compounds as electron donors. It eliminates the need for adding organic carbon sources, making it compatible with existing treatment processes. It has already found application in some wastewater treatment plants.

2) Shortcut nitrification-denitrification: In this process, nitrification is controlled to primarily occur at the nitrite phase. This reduces the requirement for carbon sources, lowers energy consumption during the reaction, reduces the reactor's footprint, and ultimately lowers treatment costs.

3) Simultaneous nitrification-denitrification: This process achieves both nitrification and denitrification simultaneously under conditions of low dissolved oxygen. This approach offers advantages such as shortened reaction times, reduced reactor volume, and decreased consumption of organic carbon sources.

4) Anaerobic ammonia oxidation (anammox): Anammox processes use ammonia as an electron donor to reduce nitrite under anaerobic or anoxic conditions. This results in the production of nitrogen gas without the need for carbon sources, making it an economically and technically feasible option. These innovative denitrification processes provide various solutions for addressing nitrate pollution while minimizing the carbon footprint and treatment costs.

By combining multiple processes, it's possible to optimize denitrification under low-carbon source conditions. For instance, the combination of shortcut nitrification and anammox theoretically allows for denitrification in wastewater without the need for carbon sources. This technology has been widely applied in high-concentration ammonia wastewater with limited carbon sources, such as leachate, dyeing wastewater, and anaerobic digestion supernatant. However, applying the shortcut nitrification-Anammox process to municipal mainstream sewage still faces significant challenges, and there are no stable, long-term practical applications yet.

In an international context, China leads in the number of core patent related to "low-carbon source wastewater denitrification technology", accounting for 98.51% of the total (Table 2.2.1). China has absolute advantages in quantity over other countries. While France and the USA have fewer patent publications than China, their patents tend to receive more citations on average. This suggests that China's research and innovation in low-carbon source wastewater denitrification technology are on the rise in terms of quantity but require further enhancement in terms of influence and originality.

Among the institutions contributing to core patents in "low-carbon source wastewater denitrification technology", the Top 10 are all based in China (Table 2.2.2). Beijing University of Technology ranks first with 92 core patents, and the citations per patent is relatively high at 6.37. While commercial companies like China Petroleum & Chemical Corporation and Beijing Enterprises Water Group (China) Investment Company Limited have also contributed to core patent output, there is room for further enhancing their influence. It's worth noting that there is currently no collaboration among these organizations in the field of low-carbon source wastewater denitrification technology. In the future, it is essential to move beyond a purely quantitative approach, emphasizing assessments that measure the quality and impact of research output. This approach can encourage research institutions to focus on the quality and influence of their work, promote collaboration between universities and businesses, and foster the sustainable growth of this field.

Looking ahead to the future trends in wastewater denitrification technology, it should be grounded in the fundamental principles of autotrophic biological denitrification and technological development. Researchers should explore the coupling of Anammox with other denitrification processes. Additionally, efforts should be focused on the development of new aeration systems and intelligent precise control technologies. This will help address challenges in controlling shortcut nitrification and Anammox under low-temperature and low-ammonia-nitrogen conditions, reduce greenhouse gas emissions during the process, and further achieve efficient total nitrogen removal in urban sewage (Figure 2.2.1).

Table 2.2.1 Countries with the greatest output of core patents on “low-carbon source wastewater denitrification technology”

No.	Country	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	China	927	98.51	2 543	86.70	2.74
2	France	4	0.43	226	7.71	56.50
3	Republic of Korea	4	0.43	8	0.27	2.00
4	USA	2	0.21	102	3.48	51.00
5	Austria	2	0.21	0	0.00	0.00
6	Japan	1	0.11	32	1.09	32.00
7	Netherlands	1	0.11	22	0.75	22.00

Table 2.2.2 Institutions with the greatest output of core patents on “low-carbon source wastewater denitrification technology”

No.	Institution	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	Beijing University of Technology	92	9.78	586	19.98	6.37
2	Harbin Institute of Technology	15	1.59	47	1.60	3.13
3	China Petroleum & Chemical Corporation	15	1.59	15	0.51	1.00
4	Tongji University	14	1.49	42	1.43	3.00
5	Beijing Enterprises Water Group (China) Investment Company Limited	13	1.38	54	1.84	4.15
6	Anhui Jianzhu University	13	1.38	33	1.13	2.54
7	Hohai University	12	1.28	18	0.61	1.50
8	Institute of Hydrobiology Chinese Academy of Sciences	11	1.17	75	2.56	6.82
9	Chongqing University	11	1.17	8	0.27	0.73
10	Nanjing University	10	1.06	96	3.27	9.60

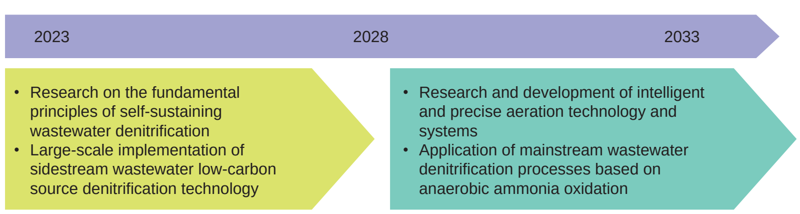

Figure 2.2.1 Roadmap of the engineering development front of “low-carbon source wastewater denitrification technology”

2.2.2 Laser detection technology of bio-optical profile in upper ocean water

The laser detection technology of marine water profile is an emerging technology that emits one or more beams of laser from the laser to the seawater, and the detection system receives the echo signal emitted by the marine water target after being excited by the laser, and then collects and analyzes the signal data through the computer system to obtain the bio-optical profile of the upper water body of the ocean. It is the only remote sensing technology that could obtain the information of the layered marine biogeochemical profile. The existing marine remote sensing technology is generally two-dimensional plane remote sensing, which has a huge gap with the detection requirements of water profile structure required by marine business and scientific applications. Marine lidar can promote the detection ability of existing marine remote sensing from two-dimensional to three-dimensional. Its application scope involves bio-optics, ecology, marine dynamics, target detection, etc., and has great potential in marine observation. Ocean laser remote sensing is a new generation of "probe" for ocean remote sensing. It provides a new three-dimensional observation method for national space security, resource development and dual-carbon strategy. It is an international frontier in the field of ocean remote sensing and an important part of the three-dimensional ocean monitoring system. It is of urgent national demand and important scientific significance to carry out research on laser detection technology of bio-optical profile of upper ocean water.

In recent years, both domestically and internationally, the development of systems and technologies related to the fluorescence and profile parameters of substances in seawater has mainly focused on the detection needs of marine biogeochemical profiles. Most of these systems and technologies are mainly ship borne, and research on the principles and mechanisms of large-scale three-dimensional detection in airborne and even spaceborne environments is still being carried out, which is in the stage of key technological breakthroughs. In terms of detection principles, the focus is on meter scattering or fluorescence detection, and there is relatively little research on hyperspectral resolution lidars with higher detection accuracy. In terms of inversion algorithms and applications, there is relatively little research on the challenges of multiple scattering by LiDAR and active passive optical closure, and scientific applications are still in the early stages. The technology of satellite-based ocean profile detection has not yet broken through, and there is currently no specialized LiDAR satellite for ocean profile detection internationally.

At present, the main research directions and development trends include: ① developing new system lidar systems such as blue-green multi wavelength, hyperspectral resolution, and single photon in ocean profiles, breaking through key technologies such as seawater hyperspectral resolution detection, narrow linewidth high-power blue light sources, and instantaneous large dynamic range and high sensitivity detection; ② developing a new multimodal three-dimensional radiation transfer simulation technology for lidar coupled with complex marine environments and remote sensors, forming an industry recognized and widely available commercial lidar multiple scattering simulation software tool; ③ developing high-precision lidar ocean optical and biological parameter profile inversion, active passive fusion, and authenticity verification technologies, breaking through key challenges such as multiple scattering correction, active passive optical parameter closure, active passive spatial fusion, and spectral fusion; ④ developing the application technology of ocean laser in cutting-edge science, ecological environment, and carbon cycle fields, promoting the process of China's ocean profile detection LiDAR satellite from scientific experiments to commercialization.

Among the main countries with the greatest output of core patents on "laser detection technology of bio-optical profile in upper ocean water" (Table 2.2.3), China ranks first in terms of published patents and second in terms of citations; the USA ranks second in terms of published patents and first in terms of citations. The total number of published patents in China and the USA accounts for approximately 67.52%. According to Figure 2.2.2, there is a lack of cooperation among other countries except for the USA and Germany. In terms of the main output institutions (Table 2.2.4), the top ten institutions with published patents are mainly concentrated in China and the USA. There is a lack of cooperation among various institutions. In a word, although China and the USA are in a dominant position in this field, the cooperation between countries is still relatively lacking. It is necessary to strengthen the cooperation between China and other countries and strengthen the international influence and greater voice of research in this field. Figure 2.2.3 shows the roadmap of the engineering development front of "laser detection technology of bio-optical profile in upper ocean water".

Table 2.2.3 Countries with the greatest output of core papers on “laser detection technology of bio-optical profile in upper ocean water”

No.	Country	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	China	193	44.78	364	26.13	1.89
2	USA	98	22.74	454	32.59	4.63
3	Japan	44	10.21	63	4.52	1.43
4	Germany	38	8.82	86	6.17	2.26
5	Republic of Korea	12	2.78	11	0.79	0.92
6	Russia	6	1.39	1	0.07	0.17
7	Canada	5	1.16	24	1.72	4.80
8	India	4	0.93	4	0.29	1.00
9	Italy	4	0.93	4	0.29	1.00
10	Switzerland	4	0.93	2	0.14	0.50

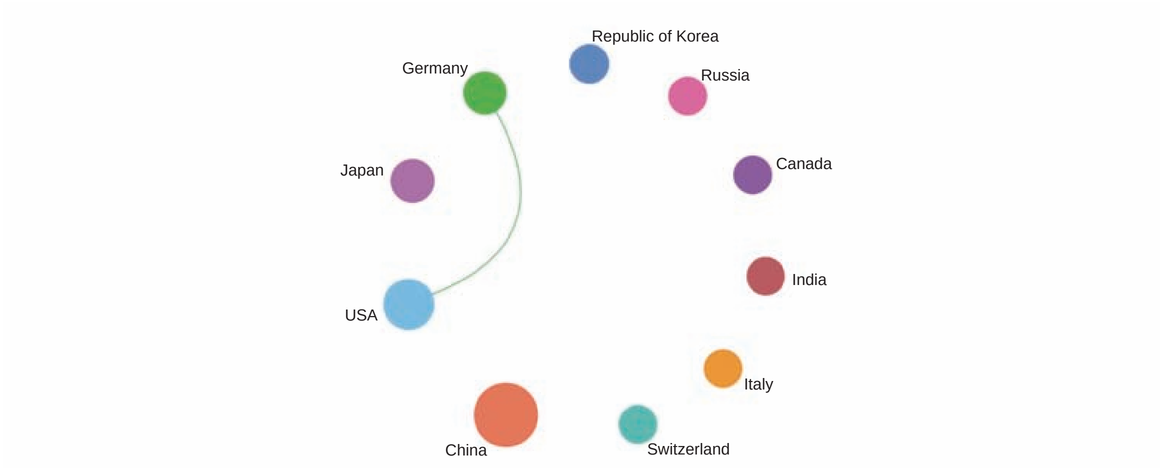

Figure 2.2.2 Collaboration network among major countries in the engineering development front of “laser detection technology of bio-optical profile in upper ocean water”

Table 2.2.4 Institutions with the greatest output of core patents on “laser detection technology of bio-optical profile in upper ocean water”

No.	Institution	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	AMADA Holdings Company Limited	12	2.78	24	1.72	2.00
2	Jilin University	11	2.55	34	2.44	3.09
3	University of Rochester	6	1.39	44	3.16	7.33
4	Beijing University of Technology	6	1.39	18	1.29	3.00
5	Beijing Institute of Technology	6	1.39	14	1.01	2.33
6	Daimler AG	6	1.39	11	0.79	1.83
7	Xi’an Jiaotong University	5	1.16	10	0.72	2.00
8	Fudan University	4	0.93	18	1.29	4.50
9	IPG Photonics Corporation	4	0.93	17	1.22	4.25
10	University of California	4	0.93	12	0.86	3.00

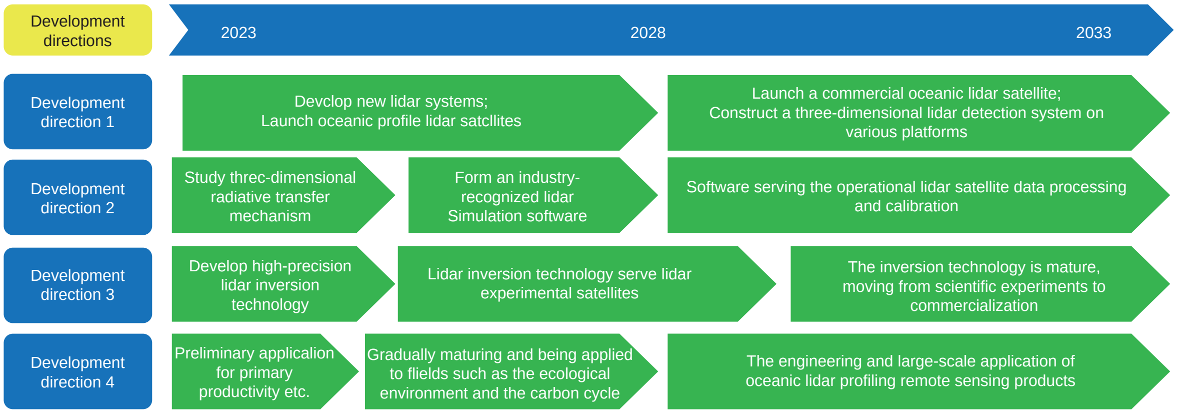

Figure 2.2.3 Roadmap of the engineering development front of “laser detection technology of bio-optical profile in upper ocean water”

2.2.3 Antimicrobial textile derived from cellulose

As individuals experience an increase in their level of living and a heightened knowledge of health and hygiene, they place more emphasis on the preservation of personal safety and well-being. Antibacterial textile materials have the capacity to inhibit the growth of bacteria and fungi, hence safeguarding the materials against contamination and fiber deterioration. Furthermore, these materials play a crucial role in impeding the transmission of illnesses. Hence, the development of antibacterial functional materials, the production of antibacterial functional products, and the investigation of high-performance sterilizing and virus-killing medical and protective materials, with a specific focus on environmentally sustainable and renewable cellulose-based antibacterial textile materials, assume significant importance. This necessitates the implementation of innovative strategies and the advancement of developmental initiatives. In recent years, China has consistently emerged as a leading global investor in research and development pertaining to cellulose-based antibacterial textile materials. Moreover, China’s ongoing efforts in advancing the technology associated with cellulose-based antibacterial textile materials have shown a continuous drive for innovation.

According to the data shown in Table 2.2.5, China has disclosed a total of 722 core patents in recent years, representing 72.20% of the overall number of publicly declared patents. The USA and Germany followed with 69 and 44 published patents respectively. The quantity of technological patents pertaining to cellulose-based antibacterial textile materials in China surpasses that of industrialized nations such as the USA, Germany, and Japan. Nevertheless, according to the data shown in Table 2.2.5, China’s patents just exhibit a citations per patent of 1.39, which is much lower than that of industrialized nations such as the USA, Germany, and Japan. Cellulose-based antibacterial textile materials are still less original in technology, lacking in innovation and influence. As indicated by the data presented in Table 2.2.6, among the main institutions in terms of patent production, Jiangnan University in China holds the highest position. However, its patents exhibit relatively low citation frequency and average citations. Figures 2.2.4 and 2.2.5 depict the collaborative network among major countries and institutions within this particular domain. The level of collaboration and research partnership among institutions or firms in this developmental front is notably deficient. The only entities that have established cooperative contacts are University of North Carolina at Chapel Hill and Entregrion Incoporated Corporation. It is worth noting that the degree of industrialization in this context is rather low. The potential for collaboration between production, education, and research in the development of cellulose-based antibacterial textile materials technology remains significant. It is imperative to intensify international exchanges and collaborations with foreign countries and institutions. Additionally, it is crucial to augment China’s innovation capacity in this domain. Moreover, there is a need to amplify the assessment of the impact of scientific research output to incentivize research institutions to prioritize the quality and influence of their research. Furthermore, it is essential to foster the integration of academic institutions and enterprises and facilitate the expeditious advancement of specific disciplines.

Table 2.2.5 Countries with the greatest output of core patents on "antimicrobial textile derived from cellulose"

No.	Country	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	China	722	72.20	1 002	25.43	1.39
2	USA	69	6.90	1 917	48.64	27.78
3	Germany	44	4.40	177	4.49	4.02
4	Japan	26	2.60	58	1.47	2.23
5	Republic of Korea	22	2.20	2	0.05	0.09
6	Israel	20	2.00	131	3.32	6.55
7	Sweden	11	1.10	109	2.77	9.91
8	Canada	11	1.10	71	1.80	6.45
9	Austria	10	1.00	35	0.89	3.50
10	India	10	1.00	1	0.03	0.10

Table 2.2.6 Institutions with the greatest output of core patents on "antimicrobial textile derived from cellulose"

No.	Institution	Published patents	Percentage of published patents/%	Citations	Percentage of citations/%	Citations per patent
1	Jiangnan University	20	2.00	25	0.63	1.25
2	Argaman Technologies Company Limited	17	1.70	152	3.86	8.94
3	Entegrion Incoporated	13	1.30	1 160	29.43	89.23
4	University of North Carolina at Chapel Hill	13	1.30	1 160	29.43	89.23
5	Luolai Life Science and Technology Company Limited	11	1.10	20	0.51	1.82
6	OrganoClick AB	10	1.00	105	2.66	10.50
7	Lenzing AG	10	1.00	35	0.89	3.50
8	Qingdao Niximi Biotechnology Company Limited	10	1.00	11	0.28	1.10
9	Badische Anilin-und-Soda-Fabrik (BASF)	9	0.90	146	3.70	16.22
10	Nippon Paper Industries Company Limited	9	0.90	17	0.43	1.89

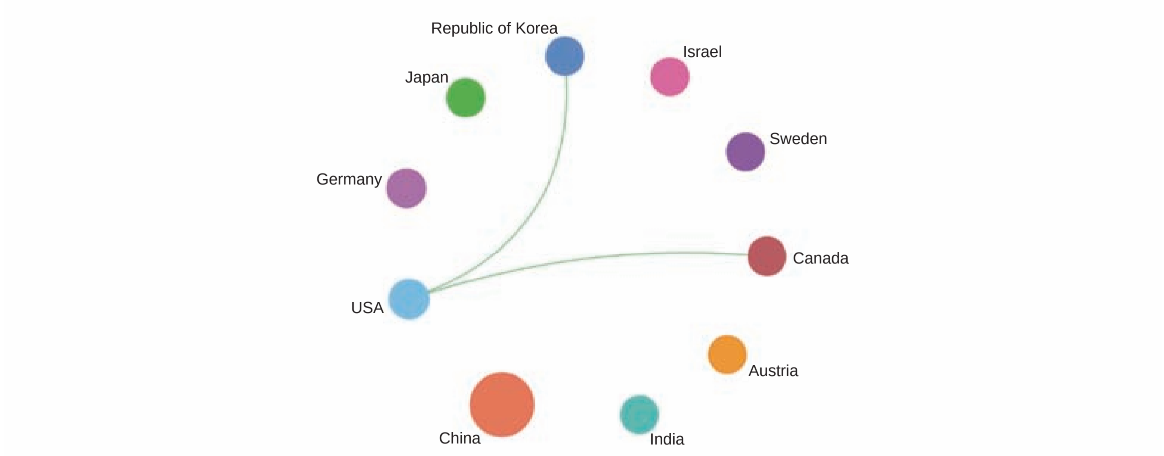

Figure 2.2.4 Collaboration network among major countries in the engineering development front of "antimicrobial textile derived from cellulose"

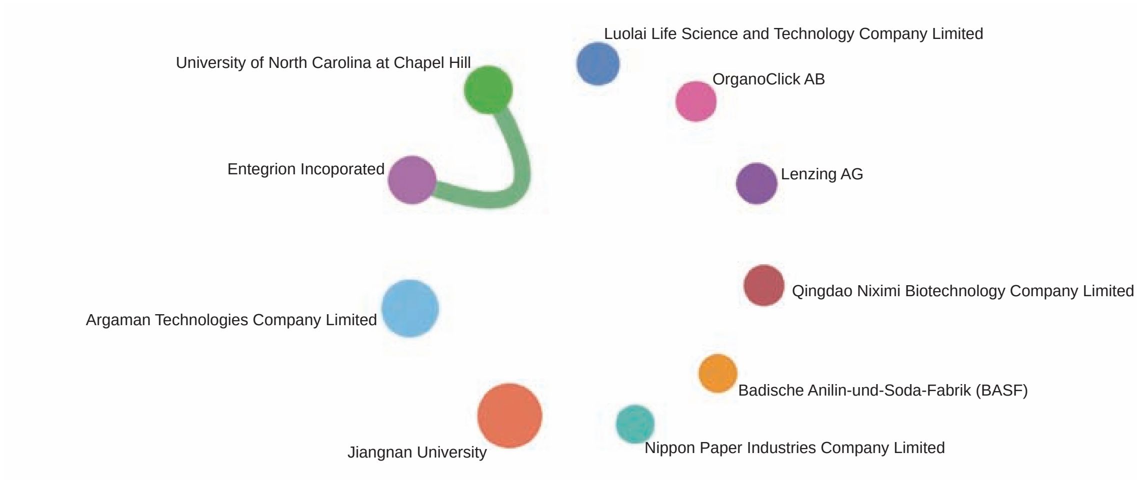

Figure 2.2.5 Collaboration network among major institutions in the engineering development front of “antimicrobial textile derived from cellulose”

In recent years, the emergence of microbial pollution and various bacterial maladies has had a significant impact on human health and safety, resulting in a greater concern for health and higher requirements for antimicrobial materials. High-molecular-weight cellulose is the most prevalent biodegradable material and renewable energy source in nature. It is primarily comprised of glucose linked by β-(1,4)-glycosidic bonds. It features a large specific surface area, effective water absorption, stable chemical properties, biodegradability, and outstanding biocompatibility. The creation of cellulose materials with superior antibacterial properties has become a prominent area of study.

Currently, cellulose-based antimicrobial materials consist of two components: matrix cellulose or derivatives of cellulose and antimicrobial agents. There are plant cellulose matrix, bacterial cellulose matrix, and ascidian cellulose matrix present in the cellulose matrix. Inorganic antimicrobial agents, organic synthetic antimicrobial agents, and natural antimicrobial agents are examples of antimicrobial agents. Methods for preparing cellulose-based antibacterial materials mainly include: ① directly preparing antimicrobial textiles from natural antibacterial cellulose fibers, which have general durability in terms of antibacterial performance; ② preparing antimicrobial fibers by spinning the antimicrobial agent into fibers and then processing the fibers into products. The co-blending method has certain limitations in selecting the antimicrobial agent, which requires thermal stability and good compatibility with polymer resins; the composite spinning method uses less antimicrobial agent than the co-blending method, combined with the special structure of the prepared fibers, the product’s resistance to water washing is better, but its manufacturing process is more complex and its production cost is relatively higher; and ③ the antibacterial material is obtained by finishing the matrix cellulose with antibacterial agent. Currently, this technique is the industry standard for producing antimicrobial textiles. There are various preparation techniques, such as immersion, surface coating, resin finishing, surface grafting modification, and microencapsulation, based on the method of preparation. These approaches are simple to process and have effective antibacterial properties.

The primary research directions for antimicrobial materials based on cellulose include:

1) Modification of cellulose fibers: enhancing their antibacterial efficacy by modifying the fibers’ surface structure, polarity, and hydrophobicity.

2) Synthesis and addition of antimicrobial agents: synthesis of novel antimicrobial agents or addition of existing antimicrobial agents to cellulose fibers in order to accomplish antibacterial functionality.

3) Composite of cellulose fibers with other materials: producing composite materials with improved antibacterial efficacy by combining cellulose fibers with other antibacterial-functional materials.

4) Processing and production of cellulose-based antimicrobial textiles: researching the production processes and techniques of cellulose-based antimicrobial textiles in order to enhance production efficiency and product quality.

Trends in the development of antimicrobial materials based on cellulose include:

1) High-performance: the development of cellulose-based antimicrobial textile materials with enhanced antibacterial performance to increase market competitiveness;

2) Diversification: the development of a variety of types and functions of cellulose-based antimicrobial textile materials to satisfy the requirements of various sectors;

3) Environmental protection: using environmentally benign and sustainable raw materials and production procedures to create antimicrobial textile materials based on cellulose with environmental properties;

4) Individuation: developing personalized and fashionable antimicrobial textile materials based on cellulose to increase product value.

Figure 2.2.6 shows the roadmap of the engineering development front of "antimicrobial textile derived from cellulose" during a timeframe of five to ten years. It showcases the progression of cellulose-based antimicrobial textiles from the initial laboratory phase, through the engineering phase, and ultimately towards the industrialization phase.

As people continue to pursue health and quality of life, the market demand for antimicrobial textiles derived from cellulose will increase. In the future, environmental protection, health, functionality, and intelligence will play a larger role in the development of antimicrobial textiles derived from cellulose. Simultaneously, the efficacy and added value of cellulose-based antimicrobial textiles will be continuously enhanced through the continued application and development of new technologies. In the future, it is anticipated that cellulose-based antimicrobial textiles will be applied and developed in additional fields.

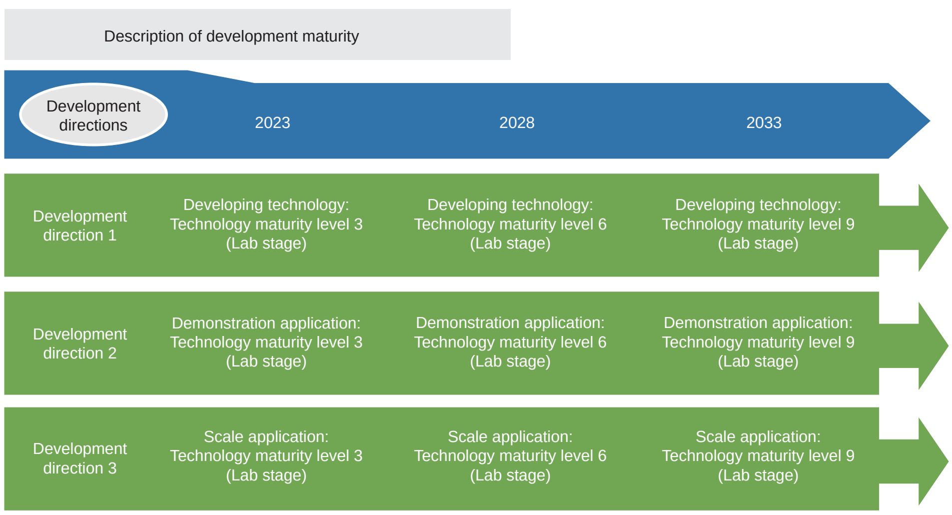

Figure 2.2.6 Roadmap of the engineering development front of "antimicrobial textile derived from cellulose"

Participants of the Field Group

Leaders

HAO Jiming, QU Jiuhui

Experts Group

HE Kebin, WEI Fusheng, ZHANG Quanxing, YANG Zhifeng, ZHANG Yuanhang, WU Fengchang, ZHU Lizhong, PAN Delu, DING Yihui, XU Xiangde, HOU Baorong, ZHANG Si, JIANG Xingwei, REN Zhengfa, PANG Guofang, SUN Jinliang, YU Jianyong, CHEN Kefu, SHI Bi, QU Jinping, CHEN Jian

Working Group

HUANG Xia, LU Xi, HU Chengzhi, LI Yan, XU Renji, CHEN Baoliang, PAN Bingcai, XI Beidou, XU Ying, SONG Yafang, BAI Yan, MA Xiumin, LI Jie, GUO Huiyuan, LIU Yuanfa, LIU Donghong, FAN Pei, QIN Xiaohong, HUANG Xin

Office Staff

WANG Xiaowen, ZHU Jianjun, ZHANG Xiangyi, ZHANG Jiao, ZHENG Jing, GAO Yue

Report Writers

HUANG Xia, LU Xi, HU Chengzhi, LI Yan, PAN Bingcai, SHAN Chao, XI Beidou, BAI Junhong, LU Keding, JIANG Yonghai, JIA Yongfeng, SHANG Changjian, GU Zhenao, SHENG Yaqi, XIE Tian, CHEN Guozhu, YU Jianzhao, ZHENG Fei, XU Renji, XU Ying, SHI Ying, WANG Zhihong, BAI Yan, LI Jie, MA Xiumin, LV Lina, CHEN Peng, MA Zheng, GUO Huiyuan, FANG Bin, QIN Xiaohong, ZHANG Hongnan, HUANG Xin, XIAO Hanzhong, LIANG Jie