Research on Development of Fluoride Pollution Control Technology in China Based on Patent Document Analysis

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Abstract. In order to clarify the technical layout and development trend of fluorine pollution control technology in China, this paper analyzes the patent applications related to domestic fluorine pollution control from 1985 based on the SooPAT patent search database. It also reveals the overall development trend of patent technology in this field. This paper concretely analyzes the annual changes trend of the patent, the legal status of the patent, the focus of technology research and layout, patent-related subjects. Finally, this paper summarizes the fluorine pollution control technology on the base of patent data analysis.

1. Introduction
At present, the use of patent literature analysis to predict industry trends has been widely used in various fields of industry and agriculture[1,2]. The patent literature can objectively and quantitatively reflect the development trend of a certain field. Through the analysis of the patent literature, it can analyze the research progress in this field, predict the development trend, and provide information support for the development of the country, region and industry[3,4]. Fluoride is an important trace element in the human body, but excessive fluoride intake can cause diseases such as human bones and internal organs, and has been ranked as the third largest human pollutant by the World Health Organization[5]. In order to ensure the ecological environment and sustainable development of human beings, it is urgent to study and propose economic, effective and feasible fluorine pollution control technologies.

This study intends to interpret and analyze the patents related to China's fluorine pollution control technology from the perspective of patent analysis, in order to provide reference for relevant researchers to carry out the next research work.

2. Data sources and statistical methods
This paper selects the SooPAT patent search engine database and the China Patent Database of the State Intellectual Property Office website as the data source, and retrieves all Chinese patent applications in the field of fluorine pollution control since 1985, and analyzes the macro situation of patents, the layout of patents based on IPC classification, and patent related subjects.

3. Results and analysis

3.1. Annual change trend analysis of patent applications
From the trend of patent application volume related to fluorine pollution control technology (Fig. 1), it can be found that in 1985, patent applications for fluorine pollution control appeared in China, and the application volume from 1985 to 2008 generally showed a slow upward trend. In 2009-2014, there
was a rapid growth trend. By 2014, the total number of patent applications in this field had reached 311, nearly three times that of 2009. In 2015 and 2016, the number of patent applications in this field showed a slight downward trend, but it was still much higher than that in 2013, indicating that China's research in this field has been showing a relatively active trend.

3.2. Patent legal status analysis
The results of the legal state analysis of the fluorine pollution control technology patent are shown in Fig. 2. It can be seen from Fig. 2 that among the 2202 patents for fluorine pollution control, 902 have been authorized, accounting for 41% of the total; 476 are in the actual review stage, accounting for 22% of the total; 135 are in the disclosure, accounting for 6.1%; 689 are invalid patents, accounting for 31%. Taking into account the specific examination procedure for invention patents, 22% of patents in the actual review stage should be invention patents, plus some publicly-held patents, the proportion of invention patent applications in total patent applications has exceeded 63%, indicating that China’s development and utilization of patents in fluorine pollution control field is in a good state of positive development trend. However, the 31% invalid ratio also indicates that the patent application process in this field is easily negated by the existing technology, and it also reflects that the domestic protection of patent applications is insufficient.

3.3. Classification analysis according to department
The research in this field is based on the IPC classification number, and the results are shown in Fig.3. It can be seen from Fig. 3 that the research direction of fluorine pollution control is relatively uniform, mainly concentrated in the C department (chemistry; metallurgy), the number of patent applications is 1689, accounting for 57.29%; the second is B (operation; transportation), and the number of patent applications is 878, accounting for 29.78%; C and B applications account for 87.07% of the total number of applications. The rest are scattered in H (Electrical), G (Physical), Part A (required for human life), F (mechanical engineering; lighting; heating; weapons; blasting), D (textile; paper) and E (Fixed buildings), the number of patent applications is 113, 95, 81, 42, 32 and 18, respectively, accounting for 3.83%, 3.22%, 2.75%, 1.42%, 1.09% and 0.61% of the total number of applications. It can be found from Fig. 3 that the total number of patent applications for C, B, H, G, A, F, D, and E is greater than the total number of patents retrieved, which is caused by the cross-cooperation of research directions. As shown in the statistics in Table 1, there are certain intersections in different research directions in this field. The technology layout is extensive, the inventions created by the cross-cooperation of research directions, the high level of innovation technology, and the value and practicality of the patent market are often higher.
Table 1. Research direction cross-cooperation statistics.

| Section | Code | IPC | A | B | C | D | E | F | G | H |
|---------|------|-----|---|---|---|---|---|---|---|---|
|         | Mean | C   | 16 | 570 | 1689 | 5 | 1 | 14 | 25 | 38 |
|         |      | B   | 16 | 878 | 570 | 24 | 6 | 8 | 27 | 31 |
|         |      | H   | 31 | 38 | 1 | 3 | 113 |
|         |      | G   | 27 | 25 | 95 | 3 |
|         |      | A   | 81 | 16 | 16 | 2 | 2 |

3.4. Trend analysis of research direction development

The development trend of fluorine pollution control research direction is shown in Fig. 4. It can be seen from Fig. 4 that the research hotspots of fluorine pollution control technology patents are quite significant. From 1985 to 2003, the research was mainly concentrated in the field of “chemistry; metallurgy” of Part C, Part B “Operation; Transportation” and Part A “Necessity of Human Life” also had certain involvement, but a bit less compared with the “Chemistry; Metallurgy” field of Part C. From 1985 to 2003, the research hotspots were concentrated, but the total number of patent applications was low. The research after 2003 is involved in C, B, H, G, and A, but the growth of C and B is faster, H, G, and A are relatively slow, indicating that the research hotspots began to disperse after 2003, but the hotspots still focuses on C and B, and the growth rate of C and B is also the fastest. This is consistent with the analysis of the “A. Annual Change in the Number of Patent Applications”.

3.5. Major classification distribution analysis of fluorine pollution control technology by IPC classification

Table 2. Major classification distribution of fluorine pollution control technology by IPC.

| IPC | Code meaning                                      | Number of patents | Percentage |
|-----|---------------------------------------------------|-------------------|------------|
| C02F| Treatment of water, wastewater, sewage or sludge | 973               | 28.02%     |
| B01J| Chemical or physical methods, such as catalysis, colloid chemistry; Related equipment | 586 | 16.88% |
| B01D| Separation                                        | 256               | 7.37%      |
| C01B| Non-metallic elements; other compounds            | 175               | 5.04%      |
| C22B| Metal production or refining                      | 89                | 2.56%      |

The top 10 research areas of the fluorine classification control technology IPC classification are shown in Table 2. As can be seen from Table 2, the patents involved are mainly distributed in the "treatment of water, wastewater, sewage or sludge", "chemical or physical methods, such as catalysis, colloid chemistry; related equipment" and "separation". The IPC categories are “C02F”, “B01J” and “B01D”
respectively. The number of patent applications is 973, 586 and 256, respectively, accounting for 28.02%, 16.88% and 7.37% of the total number of patent applications.

3.6. Group distribution analysis of IPC classification fluorine pollution control technology

Table 3. Group distribution of IPC classification fluorine pollution control technology.

| IPC        | Code meaning                              | Number of patents | Percentage |
|------------|-------------------------------------------|-------------------|------------|
| C02F1/28   | Adsorption                                | 459               | 6.83%      |
| B01J20/30  | Method of preparation, regeneration or reactivation | 403               | 6.00%      |
| C02F101/14 | Fluorine or fluorochemical                | 350               | 5.21%      |
| C02F1/58   | Removal of specific dissolved compounds   | 318               | 4.73%      |
| C02F9/04   | At least one chemical processing step      | 215               | 3.20%      |

The top ten group distribution of the IPC classification fluorine pollution control technology is shown in Table 3. It can be seen from Table III that the top three group classification numbers of the existing patents for fluorine pollution control technology are mainly concentrated in C02F1/28 (459 pieces), B01J20/30 (403 pieces) and C02F101/14 (350 pieces), respectively, accounting for 6.83%, 6.00% and 5.21% of the total application volume. Other groups have relatively low filings.

3.7. Patent related subject analysis

The applicants for the top 20 patent applications for fluorine pollution control technology in China are shown in Table 4. As can be seen from Table 4, there are 14 universities, 3 research institutes and 3 enterprises. This shows that in the field of fluorine pollution control, universities are the main force in the field of invention and creation, and the main body of technological innovation in the field of fluorine pollution control. Among the top 20 applicants, 3 universities, 2 research institutes and 1 enterprise are located in Beijing, three universities and one enterprise are located in Jiangsu Province, indicating that these two regions have strong patent layout awareness in the field of fluorine pollution control and certain degree of technological innovation ability. On the other hand, research in other regions is not concentrated enough, and the awareness of layout needs to be improved.

Table 4. Applicants for the top 20 patent applications.

| Applicants                                                                 | Numbers | Percentages |
|---------------------------------------------------------------------------|---------|-------------|
| Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences | 38      | 1.56%       |
| Jiangsu Yongguan Water Supply and Drainage Equipment Co., Ltd.              | 36      | 1.48%       |
| Jiangsu University                                                        | 35      | 1.44%       |
| Hohai University                                                          | 26      | 1.07%       |
| Central South University                                                  | 26      | 1.07%       |
| South China University of Technology                                      | 24      | 0.98%       |
| Zhejiang University                                                       | 20      | 0.82%       |
| Southwest University of Science and Technology                            | 19      | 0.78%       |
| Qingdao Boruilin New Material Co., Ltd.                                   | 17      | 0.7%        |
| China University of Mining and Technology                                 | 16      | 0.66%       |
| China Petroleum & Chemical                                               | 15      | 0.62%       |
| Dalian Institution of Chemical Physics, Chinese Academy of Sciences       | 14      | 0.57%       |
| Northwest A&F University                                                  | 14      | 0.57%       |
| Shaanxi University of Science & Technology                                | 14      | 0.57%       |
| Beijing University of Chemical Technology                                | 13      | 0.53%       |
| Tsinghua University                                                      | 13      | 0.53%       |
| Kunming University of Science and Technology                              | 13      | 0.53%       |
| Institute of Geographic Sciences and Natural Resources Research           | 13      | 0.53%       |
| Wuhan University of Technology                                           | 13      | 0.53%       |
| Tongji University                                                        | 12      | 0.49%       |

4. Conclusions

The macro-situ analysis of patent applications shows that China's research in this field is active, and the overall application is on the rise. The development and utilization of patents in the field of fluorine pollution control in China has shown a positive trend, but there are also problems of insufficient patent
protection. The research direction of fluorine pollution control in China is relatively uniform, and the research hotspots are more significant. The research directions involved show a cross trend and the technology layout is extensive. Colleges and universities are the main force in the invention and creation of fluorine pollution control in China. The research of major domestic applicants in this field has continued to rise.

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