Research on the Trend of Landfill Ecological Restoration Technology Based on Patent Analysis

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Abstract. Ecological restoration, as one of the important technologies for landfill treatment, has attracted much attention from governments and the academy of science and technology. In this paper, the focus is the analysis of the trends of ecological restoration technology of landfill, we make a comparative analysis of domestic and foreign patents from the perspective of application trends, major technical fields, main patentees, competition and risks by comprehensively using the platforms and tools such as the Chinese Patent Database, Derwent World Patent Index Database, and the European Patent Office Patent Literature Database. Our work is of referential significance for the development of China in this field.

1. Introduction
Ecological restoration is a popular treatment today. The theme of this paper is to study the restoration technology of source pollution in landfill, this paper focuses on the analysis of the development trend of landfill ecological restoration technology, from the aspects of application trend, main technical fields, main patentees, competition and risk, the comparative analysis database of domestic and foreign patents, Chinese Patent Database, Derwent World Patent Index Database, and the European Patent Office Patent Literature Database are carried out [1-4]. It is worth mentioning that to some extent there is a lag on the date of the patent publication and database update. Therefore, some patent applications filed in 2018-2019 have not been included by major database, which leads incompleteness of patent applications statistics. To some extent, it may have influence on the analysis results [5-9].

2. Material retrieval and methods
In this paper, all patent documents about comprehensive treatment technology of point source pollution in landfill before July 15, 2019 are searched. The retrieval of this study consists of preliminary search, full search and supplementary search. Preliminary search—search relevant documents by keywords and classification numbers, carry out statistical analysis of the keywords and classification numbers, do sampling of documents by manually reading to find out the keywords. Preliminary search needs to do search strategy adjustment, feedback, and summary the position of each retrieval element in search strategy, then devise full search strategy.
Full search—select, expand and make keywords precise, expand the classification numbers as the main elements of search, adopt search strategy properly and make full use of operator and truncation operator and take advantages of different database like foreign database and Chinese database to search precisely and thoroughly.
Supplementary search—on the base of full search, count up applicants who are professional and focused by enterprises, gain the search box to search applicants for integrity of this retrieval.

3. Analysis of retrieval results

3.1. Analysis of landfill ecological restoration patent competitive environment in foreign countries

3.1.1. Analysis of patent time series

![Figure 1. Trends of patent application for ecological restoration in foreign landfill](image)

The landfills which have constructed final closure are processed by ecological restoration, namely using plants domestically and overseas. Some developed countries are early in using this technique. As shown in figure 1, the number of applications was no more than 5 from 1977 to 2010. The application number increased rapidly from 2010 to 2014. The peak of annual applications had reached 13, which maybe related to increasing attention of protecting environment abroad. Then, it went an apparently decline in this field [5-7]. It is possibly related to the characteristics of this field. That is the limit of the depth and width in research because there is little physics and chemistry knowledge. It is difficult to transfer research and development results to a patent.

3.1.2. Analysis of main competitors

As is shown in figure 2, from the perspective of original research countries in ecological restoration techniques, the top three are America (39%), Korea (28%), Japan (9%). The total quantity of these three countries is as high as 76%. As the largest exporter of ecological restoration techniques, America
had been in leading position and kept stable output before 2012, but became 0 after 2015. Korea began later and had sustained output from 2001 to 2017. Japan had intensive output from 1998 to 2010 [10-12].

Figure 2. Distribution of original research countries for ecological restoration patents in foreign landfill

With the development of environmental technology, landfill cannot be content with only pollutant treatment. It is an objective to abate the pollution and protect the environment based on ecological recovery in sustainable utilization, and regenerate local ecology and economic value. From the perspective of patent data, the techniques distribute dispersively abroad. The elimination of solid waste which is highest rate takes up only 22%, followed by soil restoration, environmentally benign chemistry, microbial remediation, solid wastes recycling and sewage treatment. On the one hand, it reflects diversity of eco-treatment technology. On the other hand, it embodies eco-treatment technology as comprehensive technology, which need to use various ways at the same time.

The advent of ecological restoration technology is later than landfill leachate technology and landfill gas treatment technology. The initial phrase is dominated by sewage treatment, soil restoration, solid waste elimination and eco-treatment technology. In regard to ecological remediation, there is certain continuity in sewage treatment application in time, as well as strong continuity in solid waste elimination in time regarding to ecological restoration technology [8-9].

Among the foreign patent applicants in landfill ecological restoration, research and development institutions account for the highest proportion (45.2%), followed by individual (35.7%) and enterprises (19.1%). Due to the feature of slow effect and heavy investment, it is a problem to transform into enterprization for ecological technology. Enterprise applicants are less and the majority of technology is in charge of institution and individuals.

Table 1. Collaborative innovation of foreign patents for landfill ecological restoration technology

| Joint Application Type                      | Application volume |
|--------------------------------------------|--------------------|
| Company & Company                          | 23                 |
| Company-Research Unit                      | 5                  |
| Research Unit&Individual                   | 6                  |
| Scientific Research Unit & Scientific Research Unit | 3               |
| Individual Individual                      | 5                  |
| Company&Individual                         | 1                  |

It is clear in table 1, applications where there are more than two people are 23. 3 patent applications are submitted by company cooperation, 5 patent applications are submitted by cooperation of companies and R&D institutions. There are 3 patent applications submitted by cooperation of R&D
institutions. From specific applicants, it mainly makes up by companies which rely on university, like University of Georgia Research Foundation, University of Yuva Foundation.

3.1.3. Risk and opportunity of patent
In Figure 3, there are 36 authorized patents (37%) on landfill ecological restoration and 51 invalid patents (53%).

EWHA UNIVERSITY-INDUSTRY COLLABORATION FOUNDATION has 3 related patents. Respectively they are WO2012111875A1 (Date of Publication 2012-08-23), KR2019012099A (Date of Publication 2019-02-08), KR2019033890A (Date of Publication 2019-04-01); WATERSHED GEOSYNTHETICS LLC owns 3 patents including US20140030023A1 (Date of Publication 2014-01-30), US20140251473A1 (Date of Publication 2014-09-11), US20190143384A1 (Date of Publication 2019-05-16).
TERRANALYSIS CORP owns 2 invalid patents including US5348422A (Date of Publication 1994-09-20), US5435176A (Date of Publication 1995-07-25); MIYOSHI YUSHI KK owns 2 invalid patents including JP2005238050A (Date of Publication 2005-09-08), JP2007061704A (Date of Publication 2007-03-15); ECOLAND CO LTD owns 2 invalid patents including KR2007111103A (Date of Publication 2007-11-21), KR2007111104A (Date of Publication 2007-11-21); FRAUNHOFER GES FOERDERUNG ANGEWANDTEN owns 1 invalid patents, that is DE19510917C1 (Date of Publication 1996-02-22).

3.2. Analysis of landfill ecological restoration patent competitive environment in China

3.2.1. Analysis of patent time series
Landfill ecological restoration technology have a late start in China. We can see in figure 4, there are three periods. The applications are annually no more than 10 before 2010; could hit 10 from 2011; and increase sharply in 2015 to the peak in 2018. The annual application number is 45.
3.2.2. Analysis of main competitors

Among the domestic patent applicants in landfill ecological restoration, figure 5 shows the detail, enterprises applicants account for the highest proportion (45.8%), followed by universities and colleges (24.6%), and individual (17.5%).
As shown in figure 6, Zhejiang University is the first to submit related applications in 2006, but no more after 2012. Nanjing Yikebang Ecological Environment Technology Co., Ltd submitted 12 applications only in 2018. There are few applications submitted by other applicants. From the perspective of Chinese distributions in landfill ecological restoration patent applications, soil restoration is research focus. We can get more brief information in figure 7 and figure 8, solid waste elimination is focus too with share 12%. There are certain proportion in eco-treatment technology by microbial remediation, protozoan remediation and foundation structure restoration.

From the perspective of patent applications time series, soil restoration which has the highest proportion mainly started developing in 2011 and reach 15 in 2016. The numbers of patent application are high in recent years. Due to land scarcity, it is clear that soil restoration has been valued. Solid waste elimination develops quickly as well, microbial remediation and other technology is a new research direction as the emerging technology.

Chinese enterprises pay more attention to coapplications with universities and R&D institutions and other enterprises.

Figure 7. Technical distribution of landfill ecological treatment technology in China

Figure 8. Timing distribution of landfill ecological treatment technology in China
In figure 9, Chinese distributions in landfill ecological restoration patent applications are mostly in the East, West, South, Southwest and Centre of China which are developed area in China. That applications from Jiangsu Province and Beijing ahead of other areas reflects the strength of these two areas is stronger than others. Shandong, Zhejiang, Guangzhou and Shanghai focus on research and development with above 15 annual applications. There are also applications from Hubei, Sichuan, Hunan and Liaoning, which maybe closely related by great attention of refuse treatment in these areas. With reference to assignment and license trend of Chinese landfill ecological restoration, related technical transfers started in 2007, and kept about 1 in next few years. In 2019, the number is 3, which can show the low states of technology operation.

![Figure 9. Distribution of landfill ecological treatment technology in China](image)

3.2.3. Risk and opportunity of patents

From the perspective of landfill ecological restoration patent risk, currently, we can see in figure 10, there are 69 authorized patents (30%) and 75 patents in examination status (33%).

- **NANJING YIKEBANG ECOLOGICAL ENVIRONMENT TECHNOLOGY CO., LTD** owns 12 patents in examination status including CN108941192A, CN108941193A, CN108927406A, CN108838205A, CN108822861A, CN108641990A, CN108480378A, CN108480392A, CN108384552A, CN108273844A, CN108262345A, CN108262352A; Wu Hongsheng owns 8 patents in examination status including CN108822860A, CN108517212A, CN108410473A, CN107969182A,
CN107597834A, CN107497847A, CN107497849A, CN107470351A. QINGDAO UNIVERSITY OF TECHNOLOGY owns 10 patents including 2 authorized patents and 8 invalid patents. Authorized patents are CN103978024B, CN103978025B. Invalid patents include CN106040733A, CN105964674A, CN105964675A, CN105945057A, CN105945058A, CN105945059A, CN105935686A, CN105935690A.

4. Conclusion
We have made a comparative analysis of domestic and foreign patents from the perspective of application trends, major technical fields, main patentees, competition and risks by using the platforms and tools. In view of the current situation, both China and foreign countries have a long way to go. Our work makes a huge influence on the development of this field.

5. References
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Acknowledgements
This work was financially supported by Xiamen High-Value Patent Portfolio Project "High-Value Patent Portfolio for Point Source Pollution Comprehensive Remediation Technology" (Project Approval Document Number: Xiazhi [2019] No. 2), Research project of young and middle-aged teachers of Fujian Provinicial Department of Education "Research on the Production Process of Biofuel Ethanol from Plant Residues using Heat-Resistant Yeast (JT180452).