



## A bibliometric analysis on incineration ash during 2000 to 2020

A. Mostafa Hatami<sup>1</sup>, M. R. Sabour<sup>1\*</sup>, M. Nikravan<sup>2,3</sup>

<sup>1</sup>Department of Civil Engineering, K.N. Toosi University of Technology, Tehran, Iran

<sup>2</sup>Faculty of Civil Engineering, Amirkabir University of Technology, Tehran, Iran

<sup>3</sup>Building Materials and Construction Chemistry, Technische Universität Berlin, Berlin, Germany

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**ABSTRACT:** Even though incineration has been extensively studied by many researchers, a few bibliometric analyzes have been presented in this area. This bibliometric paper aims to value the research trend and identify the most used topics in the field of “incinerator ash” during the years 2000 to 2020 by social network analysis comprehensively. This research includes examining document type, distribution of journals, the activity of institutes and countries, language, and keywords. The results show that among the 6,179 publications surveyed related to incinerators, more than 57% of them belong to the field of environment and the number of publications in 2020 was almost four times larger than the ones in 2000. “China” has played a key role in publishing among the countries, followed by Japan and the United States. “Waste Management” was the leading scientific journal in the field with a total of 579 articles related to incinerators, and the “Journal of Cleaner Production” had the most growth. The keywords “fly ash”, “heavy metals” and “bottom ash” have been the most frequently used keywords in 21 years. In recent years, words related to stabilization and solidification have been among the most widely used words, which shows the growth of this category of research. The significant growth of the words in the newfound fields of “life cycle assessment” and “sustainable development” as well as laboratory incineration-related research containing “XRD” and “SEM” can also be seen. The paper results provide a better comprehension of recent research and can also affect forthcoming research in this field.

### 1- Introduction

The main advantages of incineration are energy production, reducing waste volume, decreasing land use, and reducing pollution resulting from landfills [1]. However, in the waste incineration process, by-products such as bottom ash and fly ash are produced, which consist 20-30% of the initial volume of the waste [2] progress is promoting a shift in perspective from environmental impacts to resource recovery. Municipal solid waste incineration (MSWI). Incineration ashes, especially fly ash, contain significant amounts of toxic materials and leachable heavy metals [3]. The concentration of heavy metals in these ashes depends on how volatile the metals are; improper disposal of ash will lead to environmental pollution [4] ion exchange, acid solubility as well as the influence of reducing and oxidizing agents, were investigated using reagents which are typically applied in sequential extractions. Potential error sources and the suitability and selectivity of individual steps and extracting agents were also evaluated. Additionally, the amounts of total dissolved solids were determined for each extraction step, and the results were validated by comparison

with the analysis data of the elemental composition. All the investigated incineration residues exhibited a very similar solubility behavior. Only the alkali metals in the bottom ash were considerably less water-soluble than those in the fly ash. The solubility behavior among the rare earth elements was alike. The pH of the fly ash suspensions in water increased over several hours from neutral to alkaline. Concentration changes of water-soluble elements were investigated during the pH increase and to what extent precipitated elements can be re-dissolved by a subsequent neutralization. Meanwhile, it was shown that chloride ions in commonly used sequential extraction agents (e.g.,  $MgCl_2$  and  $NH_2OH \cdot HCl$ ). This has made the proper disposal of incinerators a critical issue in the world [5]. With the development of technologies related to waste incineration, research in this field has grown significantly [6]. Bibliometric is a valuable method, which could be used to quantitatively analyze the development and growth of each specific field of research [7, 8] a bibliometric analysis of the research output was carried out to depict existing research activities on alternative energy and future directions. The article was the main type of publications

\*Corresponding author's email: sabour@kntu.ac.ir



**Table 1. Ten leading countries in the number of incinerators**

#	Country	Number of incinerators	Number of publications
1	China	552	1559
2	Japan	551	535
3	France	248	199
4	America	210	476
5	Germany	192	293
6	Italy	97	309
7	South Korea	72	163
8	Sweden	67	187
9	Denmark	64	149
10	Taiwan	62	338

with the English as the dominate language to explain their results. With the publications increasing rapidly since 2008, the researches mostly focused on the fields of Energy & Fuels and Environmental Sciences. Energy Policy was the journal that published the largest number of research articles on the alternative energy. The bioenergy and solar energy were popular items in the commonly used 20 journals. Among the countries, the USA was leading on alternative energy related research, publishing the largest number of articles (TP=2368). The present study examines the latest developments in “incineration ash” research through bibliometric analysis of the publications produced from 2000 to 2020, using the Scopus database for the first time. It shows the general trend of research in the form of various criteria.

## 2- Methodology

The bibliometric study presented in this article included data selecting (publications) from a comprehensive database (Scopus), data converting to use in bibliometric software (VOSviewer), and evaluating them using statistical analysis (network visualization maps). Social network analysis (SNA) is used to accurately examine the relationship between nodes in different structure clusters [6]. In the present study, the existing nodes represent keywords, and the links indicate their relationship.

The Scopus database is the leading database of abstracts and citations (including scientific journals, books, and conference papers) [9]. The input of the present bibliometric method was all the literature related to incineration ash from 2000 to 2020 so that the publications that contained the words “Incineration” and “Ash” in “Title,” “Abstract,” or “Keywords” have been evaluated.

## 3- Results and Discussion

Of the 6,179 publications related to incineration ash from 2000 to 2020, 90.8% (5612) of these were in English. Chinese, Japanese and German were next with 6.2% (381), 0.1% (62) and 0.7% (42). In total, more than 82% (5070) of the publications were in the form of scientific articles in journals, followed by conference papers, book series, books, and trade journals with 12.1% (752), 3.5% (216), 1.5% (87), and 0.9% (54), respectively. The number of publications and articles has increased from 115 and 98 in 2000 to 553 (4.8 times) and 496 (5.1 times) in 2020, respectively. Also, the most subject areas of publications were environmental sciences (57.2%), engineering (25.8%), energy (16.9%), and chemistry (16.7%).

Among the journals with the most articles in this field, “Waste Management,” with the total of 579 articles related to incineration ash over 21 years, has been ranked first since 2010. The number of articles in “Journal Of Hazardous Materials,” “Chemosphere,” “Environmental Science And Technology,” and “Waste Management And Research” were 328, 220, 157, and 132, respectively. “Journal Of Cleaner Production” also grew the most in recent years, with 35 articles in 2020 compared to 3 in 2014.

China tops the list of countries with the highest number of published articles in the field of incineration ash with 1,559 publications (more than a quarter of all articles in the field), followed by Japan, the United States, Taiwan, and Italy with 535, 476, 338, and 309, respectively. 78% of Chinese publications, 85% of Taiwanese publications, 85% of Indian publications, and 84% of Russian publications were independent (Mono-national), while more than half of the publications of the United Kingdom, the Netherlands, and Belgium have been in collaboration with other countries (Multinational). Table 1 compares the number of incinerators used in the leading countries in the industry and the number of publications from these countries. According to statistics collected in 2017 [10], among the top 14 countries in terms of publishing articles related to incineration ash, ten countries belong to the most advanced countries in the field of waste incinerator usage.

Based on the illustration map of Figure 1, 500 commonly used keywords were classified into 4 clusters. According to the links between the keywords, the first cluster (red) has 220, the second cluster (green) 107, the third cluster (blue) 95, and the fourth cluster (yellow) 78 keywords. As could be seen, the most significant nodes are “Fly Ash,” “Heavy Metals,” “Incineration,” “Bottom Ash,” and “Heavy Metal,” which show the most repetition during the interval. The keyword “fly ash” is more than twice the use of the keyword “bottom ash,” showing the importance and sensitivity of the field related to fly ash to the bottom ash.



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