Bibliometric Analysis of the IronRefs Database: Status and Trends in Published Research on Remediation Applications of Zero-Valent Metals

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http://cgr.ebs.ogi.edu/ironrefs

1. Abstract

The IronRefs database (http://cgr.ebs.ogi.edu/ironrefs/) was recently updated and upgraded. The bibliographic database on remediation using zero-valent metals now contains over 1000 records, including greatly improved coverage of patents, thesis, and government documents. Most records now include abstracts, which makes keyword search results much reliable. The database continues to be freely available online, without fee or registration.

Now that the IronRefs database has reached sufficient size to begin more robust statistical bibliometric analysis, we have begun to pursue this with the hope of providing useful insights into the current state and emerging trends in the published body of knowledge on this topic.

Types of bibliometric analysis we've used include simple and more complex multivariate data visualization. In principle, multivariate analyses have the potential to identify "interaction effects" such as whether a particular type of zero-valent metal is emerging as preferred for treatment of a particular type of contaminant. Such interpretations are very sensitive to how the database records are indexed, however, and indexing of the current database is still in progress.

2. IronRefs 1998–2007

The "IronRefs" database evolved from a simple list of references, first posted on the web in early 1996, to a flexible search engine in 1998. Since then, the search engine has been serving a database that has been updated every few months. We include any published contribution that fits IronRefs' scope, is "substantive", and is retrievable.

From 1998 until last summer, the IronRefs search interface was (shown below) allowed searching only (Boolean strings composed of) 7 fields (author, year, etc.).

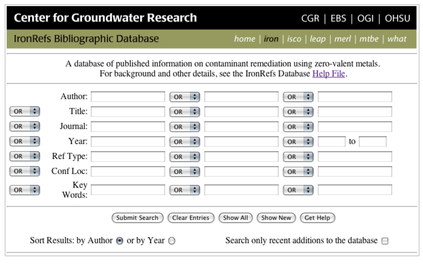


Figure 1. Screen capture of original IronRefs search interface. This is still accessible at http://cgr.ebs.ogi.edu/ironrefs/advanced.htm.

3. First Bibliometrics, 2002

When the IronRefs database first reached 500 records, in 2002, we reported a limited bibliometric analysis of the data at that time (Tratnyek, 2002). We noted, for example, that the remediation application of zero-valent iron was increasingly being used in the justification of research papers in journals quite far a field from the literature for groundwater, environmental engineering, or even environmental chemistry.

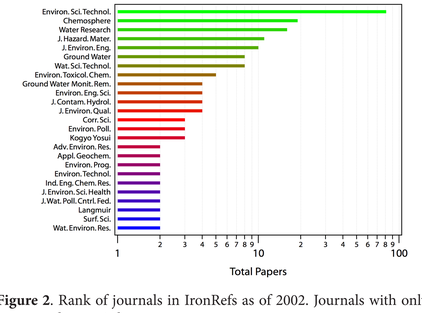


Figure 2. Rank of journals in IronRefs as of 2002. Journals with only one record are not shown.

4. IronRefs 2007 Upgrade

In the Summer of 2007, the IronRefs database was updated and upgraded. A new, simpler default search interface was created (shown below). The new interface searches text strings exactly as entered, which makes more targeted searches possible.

The database now contains over 1500 records, including greatly improved coverage of patents, thesis, and government documents. Most records now include abstracts, which makes keyword search results much reliable.

It takes a bit longer to return results, though, because the database is much larger and the amount of data per record is increased greatly (due to the abstracts).

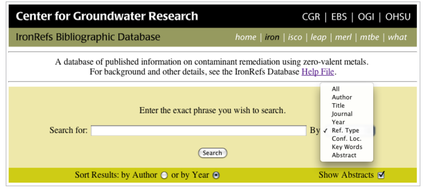
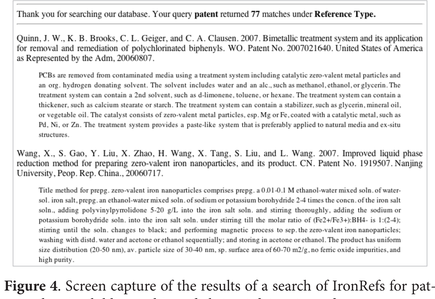


Figure 3. Screen capture of the new IronRefs search interface. This is now the default screen at http://cgr.ebs.ogi.edu/ironrefs/.

5. Upgraded Results Interface

An option is now provided to have IronRefs return abstracts with the bibliographic information that results from a search. The example below shows abstracts for a search that was restricted to theses. That database now has very good coverage of theses, patents, and government reports (which had not been the case previously).

The keyword field is the only data that can be searched by IronRefs but not viewed by users of the web interface.


Thank you for searching our database. Your query **patent** returned **77** matches under **Reference Type.**

Quinn, J. W., K. B. Brooks, C. L. Geiger, and C. A. Clausen. 2007. Bimetallic treatment system and its application for removal and remediation of polychlorinated biphenyls. WO. Patent No. 2007021640. United States of America as Represented by the Adm, 20060807.

PCBs are removed from contaminated media using a treatment system including catalytic zero-valent metal particles and an org. hydrogen donating solvent. The solvent includes water and an alc., such as methanol, ethanol, or glycerin. The treatment system can contain a 2nd solvent, such as d-limonene, toluene, or hexane. The treatment system can contain a thickener, such as calcium stearate or starch. The treatment system can contain a stabilizer, such as glycerin, mineral oil, or vegetable oil. The catalyst consists of zero-valent metal particles, esp. Mg or Fe, coated with a catalytic metal, such as Pd, Ni, or Zn. The treatment system provides a paste-like system that is preferably applied to natural media and ex-situ structures.

Wang, X., S. Gao, Y. Liu, X. Zhao, H. Wang, X. Tang, S. Liu, and L. Wang. 2007. Improved liquid phase reduction method for preparing zero-valent iron nanoparticles, and its product. CN. Patent No. 1919507. Nanjing University, Peop. Rep. China., 20060717.

Title method for prepg. zero-valent iron nanoparticles comprises prepg. a 0.01-0.1 M ethanol-water mixed soln. of water-sol. iron salt, prepg. an ethanol-water mixed soln. of sodium or potassium borohydride 2-4 times the concn. of the iron salt soln., adding polyvinylpyrrolidone 5-20 g/L into the iron salt soln. and stirring thoroughly, adding the sodium or potassium borohydride soln. into the iron salt soln. under stirring till the molar ratio of (Fe2+/Fe3+):BH4- is 1:(2-4); stirring until the soln. changes to black; and performing magnetic process to sep. the zero-valent iron nanoparticles; washing with distd. water and acetone or ethanol sequentially; and storing in acetone or ethanol. The product has uniform size distribution (20-50 nm), av. particle size of 30-40 nm, sp. surface area of 60-70 m2/g, no ferric oxide impurities, and high purity.

Figure 4. Screen capture of the results of a search of IronRefs for patents, showing bibliographic and abstract data returned.

6. Current Bibliometrics—Totals

The literature covered by the IronRefs database continues to grow, at roughly a constant rate. Modest variations in the annual totals of new records (right plot) are negligible relative to the grand totals of records (left plot).

The initial sharp increase in the rate of accumulation of publications in this field occurs in 1995, corresponding to the (first) Symposium on Contaminant Remediation with Zero-Valent Metals took place at the ACS National Meeting in Anaheim, CA (2-7 April 1995).

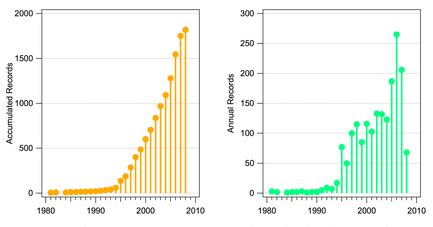


Figure 5. Left: Accumulated total records in the database. **Right:** Total records added annually. Note that the last point in each plot is for 2008, and therefore only reflects records that have been recorded so far this year. These plots , and the rest below, reflect the IronRefs database content as of May 2008.

7. Current Bibliometrics—Core Trends

Now that there has been almost 15 years of intensive research in this field, progress in the field should have produced trends in broad, cross-cutting issues. For example, one might hypothesize a shift from laboratory to field studies that emphasize interaction effects rather than individual factors insolation, etc.

We have not yet found a way to systematically probe the database for such trends, but we can make ad hoc tests for hypothesized trends in core issues. For example, we anticipated that there might be a trend away from further work on dechlorination in favor of other degradation pathways, and this can be seen in Fig. 3.

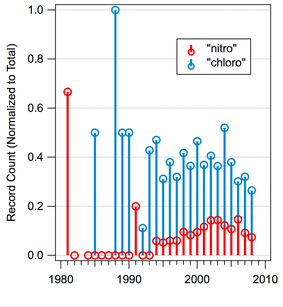


Figure 6. Records for nitro- and chloro-contaminants normalized to the total annual new records..

8. More Bibliometrics—New Trends

In addition to shifts in core research themes, we can also use the data to compare the impacts of various new directions the field has taken (nano-sized Fe^0, other material enhancements, application to emerging contaminants such as arsenic, etc.)

The development that has received the most attention in the last few years is nano-sized Fe^0, and yet the data (Fig. 7) show that this literature still makes up only a modest portion of overall work in the field. The rate at which new work on contaminant remediation with nano-Fe^0 is growing, however, which is in contrast to bimetallic enhancements, for which the amount of new research is only steady.

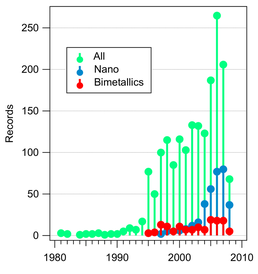


Figure 7. Annual records for nano- and bimetallic- enhancements, with the total number of records for comparison.

9. Multivariate Bibliometrics

Using appropriate software (in this case, RefViz), we can perform multivariate analysis for higher-order patterns in the data. In the example below, it can be seen that applications of Fe^0 to catalyze oxidation (i.e., activating H_2O_2) have been described mostly in terms of application to water treatment, not in situ groundwater remediation,

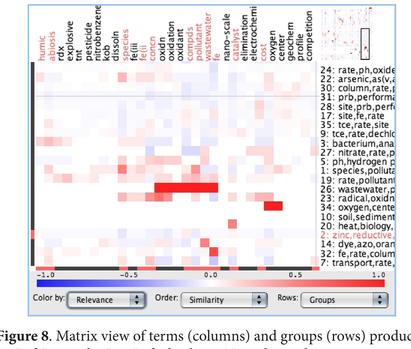


Figure 8. Matrix view of terms (columns) and groups (rows) produced by RefViz on the IronRefs database. Note that red represents positive associations and blue negative. Color intensity reflects relevance of the terms to defining the groups.

10. Multivariate Bibliometrics

A typical application of multivariate bibliometric analysis is to produce maps of related records. In principle, this can reveal the "structure" of the field, but the first step is to train the software to create meaningful groups.

Fig. 9 shows an example of such a result, showing about a dozen well defined grouping of records. The records represented in isolation tend to be unique studies that—in some cases—can be among the most interesting.

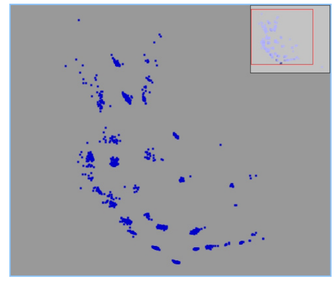


Figure 9. "Galaxy" view of the IronRefs data set generated by RefViz. Each blue point represents a record. The groupings are based on a multivariate pattern recognition analysis performed by the software.

11. Multivariate Bibliometrics

Some groups that results from this analysis have subtle definitions: e.g., several groups seems to be distinguished by their degree of emphasis on lab vs. field methods (not shown).

Other groups are straight-forward to interpret: e.g., the groups highlighted in yellow below represent to work emphasizing remediation of explosives (TNT, RDX, etc.) and arsenic.

The distances between groups can be meaningful (reflecting similarity), but the classification algorithm will need more calibration for this to be reliable for these data.

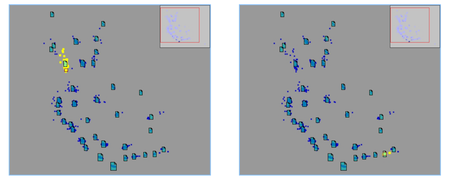


Figure 10. Left: Galaxy view of the whole IronRefs data set with the group corresponding to explosives highlighted. **Right:** Records concerning arsenic highlighted.

12. References

Tratnyek, P. G. (2002) "Keeping up with all that literature The IronRefs database turns 500", Groundwater Monitoring & Remediation, 22(3): 92-94.

13. Acknowledgements

The recent upgrade in the IronRefs database was done by several summer students (Rachel Schneider and Jason Lou) who were funded by a grant from EnviroMetal Technologies, Inc. (an Adventus company). Special thanks to John Vogan for this.