Research Roadmap Of Bioremediation: Review Of In Situ Method On Land Bioremediation

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Abstract. The existence of a study that can map various existing research topics with the intention of providing information to researchers about the research gap in order to determine the position of research is needed. This study was conducted by analyzing the theme of 250 bioremediation scopus indexed international journals from 1980s until 2015 to obtain the distribution of research, trending topic, hot topic, and potential topics in the future. The distribution of research is grouped based on bioremediation objectives, type of pollutants, type of research, aspects of study and bioremediation techniques used. The results showed that 84.5% of the bioremediation researchs were land bioremediation and 34% were heavy metal bioremediation. Those studies are still dominated by laboratory research (75.9%), mainly microbial aspects (59%) and 82.9% using bioreactor as bioremediation techniques in the laboratory. In situ research still had a small portion (12.9%). The trending topic of the last ten years was the land bioremediation with hydrocarbons contamination and the hot topic was the land bioremediation with heavy metal contamination. Bioremediation of polluted groundwater by in situ various pollutants will become a potential topic in the future.

1. Introduction

Bioremediation is an effort to control pollution by utilizing biological processes and parts of environmental biotechnology (Hardiani et al., 2011). Some of the bioremediation method’s advantages compared to conventional methods were relatively low cost, high efficiency, relatively less usages chemical, less sludge, less biosorben regeneration, and possibly metals recovery (Kratchovil&Volesky 1998).

Naturally, the provision of contaminants from the environment was done by indigenous bacteria which is often called natural bioremediation (natural attenuation). Bioremediation by spatial planning for environmental resource management was called technical bioremediation or often "simply" called bioremediation. Bioremediation in the site will be depend on the metabolic capacity of indigenous microorganisms and environmental conditions (Rodrigues, 2015). Indigenous bacteria in many cases,
could not effectively exclude pollutant compounds, so the alternative that can be done was to add bacteria that have the ability to set aside contaminants on contaminated land. This approach was called bioaugmentation (Pimmata et al., 2013) (Gupta and Ali, 2004). Bioremediation studies in the world that have been conducted in the last four decades, including based on bioremediation purposes research; type of pollutant; aspects of microorganisms as bioremediation agents; bioremediation strategies and various techniques in bioremediation methods. Those studies consist of laboratory and field research. Several studies were conducted by combining laboratory and field research.

The high interest of researchers in the field of bioremediation shown that the use of bioremediation methods in pollution control increasingly in demand. The vast scope of the research, making bioremediation research became "puzzles" with incomplete pieces of research. Recent research or research plan is expected to fill it. There is always room for researchers to get the position, by looking at a research roadmap in the world. The existence of a study that can map existing bioremediation studies with the intention of providing information to researchers or prospective researchers interested in the field of bioremediation in determining the necessary position of his research. The analysis of 250 internationalized bioremediation indexed journals theme from 1980s to 2015 will provide information on the distribution of research, trending topics, hot topics, and potential topics studied in the future.

2. Distribution Of Research

| Theme                      | Sub-theme                  | Frequency |
|---------------------------|----------------------------|-----------|
| Purpose of Bioremediation | Ground Water Bioremediation| 0.97%     |
|                           | Land Bioremediation        | 84.5%     |
|                           | Surface Water /Waste       | 15.5%     |
| Pollutant types           | Hydrocarbon                | 30%       |
|                           | Metal                      | 17%       |
|                           | Heavy Metal                | 34%       |
|                           | Radioactive                | 5.5%      |
|                           | Halogenated Organic (pesticides, herbicides, etc.) | 3.9% |
|                           | Organic                    | 3.9%      |
|                           | Other types                | 5.5%      |
| Type of research          | Laboratory                 | 75.9%     |
|                           | In situ (field study)      | 12.9%     |
|                           | Ex situ (field study)      | 5.2%      |
|                           | Laboratory-in situ         | 4.3%      |
|                           | Laboratory-ex situ         | 1.7%      |
| Aspect of research        | General                    | 9.4%      |
|                           | Microbial                  | 59%       |
|                           | Bioremediation strategy    | 31.5%     |
| Bioremediation methods    | Bioreactor                 | 82.9%     |
|                           | Bio-pile                   | 4.8%      |
|                           | Composting                 | 5.7%      |
|                           | Land farming               | 6.6%      |

Bioremediation research is basically done to exclude a pollutant from ground water, surface water and soil/land. Groundwater bioremediation studies still had very small portions until now, one example was Farhadian et al (2008), which examined the performance of bioremediation (in situ) in removing polluted hydrocarbon from groundwater. Ground water bioremediation is a strategic study because
groundwater is potentially polluted with pollutants and mobile, so the area of spreading pollutants becomes very large. Bioremediation of surface water is a research of waste water bioremediation, either existing in natural reactors such as water bodies or artificial reactors. Research conducted by Dobler (2003); Zahoor and Rechman (2009) examined bacterial capabilities in bioremediation of contaminated water mercury and chrom are examples of waste water bioremediation using artificial reactors (bioreactors). The term “soil” used by researchers in laboratory and land research is used in field research.

Bioremediation with land recovery was highly identical due to the large number of bioremediation studies of land compared to other types of bioremediation research. Especially for water pollution, from existing literatures it turns out that in those research tend not to use the word bioremediation as a keyword or research title although basically such research was included into bioremediation research.

Initially, bioremediation research was aimed to clear the land from heavy metals produced by industrial and mining activities. Until 2000s, the amount of research on bioremediation of heavy metals was always higher than other types of pollutants. Several studies of bioremediation of heavy metals in this period of time were done by Jeyasingh and Philip (2005), Umrania (2006), Jaysankar et al (2008), Chowdhary (2009) in India, Chai et al (2009) in China and Adeyemi (2009) in English.

In the next period, in 2010s, the number of bioremediation studies of heavy metals was less than hydrocarbon bioremediation research. An increasing number of hydrocarbons bioremediation studies occur due to the utilization of bioremediation methods in the recovery of polluted land of hydrocarbons by petroleum companies in many countries. Bioremediation methods are the primary choice and for many cases the only alternative to land restoration caused by hydrocarbon pollution has encouraged many researchers to develop bioremediation research. Nevertheless, the amount of heavy metal bioremediation research has also increased but not as big as hydrocarbon bioremediation research.

Bioremediation research was still dominated by laboratory research and still very little portion of field research, either done in situ or ex situ. The main reason is that many aspects of bioremediation require extensive laboratory, in-depth and meticulous research including the microbial aspect. Another reason was the uncertainty of larger field research, has prompted researchers to conduct laboratory research before implementing in the site, as Santi and Goenadi (2009), Suja et al (2014) did.
In 1980s and 1990s all bioremediation research was conducted entirely in the laboratory. From 2000s there were only a few field research (22%), consisting in situ, ex situ, lab-in situ and lab-ex situ. However, due to land recovery demands that bioremediation research should be applicable in the site, there was a increasing tendency on the percentage of field research in the last 10 years, especially in situ research, which rose significantly compared to the previous period in some Asian Countries. Research conducted by Suja et al (2014), Mizwar and Trihadiningrum (2014) were examples of in situ hydrocarbon bioremediation research at Asia.

Both laboratory and in situ research studies had experienced an upward trend in the last ten years. It means that the increased interest of researchers on in situ or field research in general did not reduce the interest of other researchers to keep doing laboratory research. Compared to in situ bioremediation studies, ex-situ research had relatively lower growth, since ex-situ research was mainly directed to contaminated spills of hydrocarbon compounds alone, in relatively small locations, and at relatively high cost in the implementation, especially contaminated soil transport pollutant. In situ research advantages compared with ex situ in terms of opening opportunities implementation cost for community-based in situ bioremediation applications in the recovery of contaminated land for agricultural land.

Most of the bioremediation research, especially laboratory research, examines the microbial aspect, such as done by Appanna and Hamel (1996), Jeyasingh and Philip (2005), Umrania (2006), Jaysankar et al (2008), Bai et al (2008) Chowdhary and Sar, P. (2009), Chai et al (2009), Adeyemi (2009), Keramati et al (2011), Hardiani et al (2011), Sriram et al (2011), Alexandrino et al (2011), Gaonkar and Bosle (2013), Singh et al (2013), Wang et al (2013), Xu et al (2014) and Ge et al (2015) and others. The microbial aspect had a very wide scope of studies and microorganisms as bioremediation agents played a decisive role in the success of bioremediation. The scope of the study, varying from the study of potential bacterial isolates, the identification of microorganisms that playing a role, the mechanism of pollutant removal, bacterial growth kinetics and the removal of pollutants, and the physiology of microorganisms including the involved genes.

In addition to the microbial aspects, in the last two decades, there were other sub-topics of research widely used which was bioremediation strategies. The demands of bioremediation applications in the site were the researcher reason to conduct bioremediation research. Many researchers conduct
bioremediation strategy research as a hub between laboratory research and its application in the site. The increasing number of these studies in the last twenty years suggests an association between the increasing numbers of field studies including in situ with increasing research on bioremediation strategies. Because a lot of number of the bioremediation research done in the site by in situ. Singh and Cameotra (2004), Jeyasingh et al (2005), Vaxevanidow et al (2008), Park et al (2008), Polti et al (2011), Sprocati et al (2012), Fang et al, (2012), do it in the laboratory. Kathiravan et al (2011) did it ex situ with chromium metal pollutants. Pelaez et al (2013) in Spain, Suja et al (2014) in Malaysia, Mizwar and Trihadiningrum (2014) in Indonesia did the research by in situ with the type of hydrocarbon pollutants.

The high interest on laboratory research of bioremediation until now affect the application of bioremediation techniques. Most laboratory studies used bioreactors as bioremediation techniques. As for field research, there was a tendency for in situ bioremediation research using land farming technology, as conducted by Suja et al (2014) in Asia and most ex situ method used bio-pile technology, as Lin, et al (2010) in Asia, Beskoski et al 2011) in Europe, Chemlal et al (2012) in Africa, Gomez and Sartaj (2013) did in America.

Research with land farming technique was not only done by in situ research but also conducted by some researchers that conducting ex situ research, especially research that done in the period of 2000s, such as done by Hamdi et al (2007), so that the percentage of land farming research larger than in situ research over the same period.

In the period of 2010s, along with the development of in situ research, the technique used was not limited only to land farming, but researchers then tried to use other approaches such as composting. Although originally composting has been widely used in ex situ research, Mizwar and Trihadiningrum (2014) have conducted in situ bioremediation research of contaminated hydrocarbon land using indigenous bacteria derived from compost; Setyo et al (2011) has also conducted in situ bioremediation of contaminated pesticides by utilizing existing microbes in compost. This led to a larger percentage of in situ research (73%) of bioremediation research using land farming (57%).

3. Challenges In The Future
Future bioremediation research in the world should lead to more in-situ field research so that bioremediation methods developed in the laboratory could add value directly to pollution control. In situ bioremediation research can be done with community participation so that many cases of pollution in Indonesia can be resolved.

4. Conclusion
There was a large gap between laboratory research and field research in land bioremediation research in the world. Bioremediation studies of polluted land of various pollutants, especially heavy metals and hydrocarbon, are mostly carried out in the laboratory to see their microbial potential and examine bioremediation strategies for the best bioremediation performance. But in the last 10 years, they already started doing field research, especially with in situ method.
The bioremediation strategy on hydrocarbons contaminated land, in the last decade had been trending topic at bioremediation research in Asia, Europe, and America. Although microbial aspects of research were still widely practiced, there had been a decrease in line with an increasing bioremediation laboratory research, field research or combination of both methods.

Bioremediation research on heavy metals contaminated soil in various periods of the year had become a hot topic because the nature of the pollutants, while the potential bioremediation research topic developed in the future is polluted ground water bioremediation research by in situ method.

For each topic and sub topic of bioremediation research, there was an upward trend over the last year period, suggesting that the researcher's interest in developing bioremediation methods, either in the laboratory or in the site such as in situ was increasing. Bioremediation methods were increasingly believed to solve various contamination cases today. Yet, there is no researcher has done any field research and then conducted laboratory testing in order to support and provide information about the phenomenon that occurred in the site during research.

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