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Analysis of Patents Pertaining to Arsenic Removal from Contaminated Water Bodies

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The paper discusses patent activity in the field of arsenic removal from contaminated water bodies. It emphasises the importance of patent information in monitoring research and development trends worldwide. The paper analyses the major areas of patenting, and technological trends. The patenting activity was found to be maximum in Japan followed by China, United States, Europe and Australia. The number of patents shows an increasing trend, which symbolises the increasing research activities in the field globally.

Arsenic contamination of drinking water has been reported from many parts of the world. Arsenic is distributed throughout the earth's crust. Elevated arsenic concentrations are found in some natural waters due to oxidative weathering and dissolution of arsenic containing minerals. Arsenic is also a common pollutant in groundwater and wastewater. Combustion of fossil fuel is another source of arsenic in the environment[1]. Studies on long-term human exposure show that arsenic in drinking water is associated with liver, lung, kidney and bladder cancers as well as skin cancer. To minimise these risks the US Environment Protection Agency has reduced the maximum contaminant level from 50 μg/l to 10 μg/l [2]. Inorganic arsenic occurs in the environment in several forms. It is mostly found as trivalent arsenite As (III) or pentavalent arsenate As (V) in natural waters and drinking water. There are many countries in the world where arsenic in drinking water has been detected at concentration greater than the Guideline Value-0.01 mg/L or the prevailing national standard. These include Argentina, Australia, Bangladesh, Chile, China, Hungary, India, Mexico, Peru, Thailand and United States of America. Countries where adverse health effects have been documented include Bangladesh, China, India (West Bengal), and USA.

A lot of research and development and technological advancement has taken place due to the global problem faced because of arsenic contamination in water. The present study aims to provide an insight to the technological

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advancement by studying the patent information on arsenic in water. This information also gives an overview of the technological trends and R&D activities going on in this field.

Effects of Arsenic

Arsenic is very hazardous to health as chronic arsenic poisoning occurs after prolonged exposure to contaminated drinking water and may prove fatal. Though there is no way of differentiating between the cancer caused by arsenic intake and that induced by other factors, the possibility of arsenic intake being carcinogenic cannot be ignored. Signs and symptoms caused by arsenic intake vary between individuals, populations, groups, and geographic areas. Skin changes such as pigmentation and thickening and skin-lesions have also been observed due to arsenic intake. A severe disease of blood vessels leading to gangrene in China known as 'black foot disease' is also the result of exposure to arsenic through drinking water.

Technological Status

There are many complexities involved in the removal of arsenic from water. Most of the methods involved in arsenic removal have some drawbacks. Some are effective but not economically feasible, some are economically feasible but not effective. Some methods are not user-friendly and technologically sound. They are energy dependant and require post-treatment by skilled manpower. The quality of treated water does not meet the standards required.

The 'Best Available Technology'[3] should fulfil the following criteria:

—High removal efficiency

—Affordability (using large system basis)

—General geographic applicability

—Compatibility with other water treatment processes

—Process reliability

Despite the drawbacks a variety of technologies have been developed for the removal of arsenic. Some of the technologies available for arsenic removal are listed in Table 1.

The above-mentioned technologies are the most commonly used ones. The most recently developed method is Phytoremediation**.** This is a relatively new idea and its viability is unknown. In this process, an arsenic hyper accumulating fern, commonly known as Chinese brake fern (*Pteris vittata* L), was grown hydroponically to examine its effectiveness for arsenic removal from groundwater. It has been found that Chinese brake fern is effective in reducing arsenic from 46 ppb to 10 ppb in three days. Young ferns are considered to be more effective in removing arsenic than older fern plants. Previous studies have shown that almost all arsenic in Chinese brake is found to be in inorganic forms, with much greater amounts of arsenite in the fronds (47-80%) than in the roots (8.3%). Similar results have recently been reported in another fern (*Pityrogramma calomelanos*), which is also an arsenic-hyperaccumulator [6].

Table 1—Technologies on arsenic removal from water [4,5]

S. No.	Technologies	Advantages	Disadvantages
1	Oxidation/Precipitation		
	—Air Oxidation	—Relatively simple, low cost but slow process	—The processes remove only a part of arsenic
	—Chemical Oxidation	—Relatively simple and rapid process	
		—Oxidises other impurities and kills microbes	
2	Coagulation Coprecipitation		
	—Alum Coagulation	—Relatively low capital cost and simple operation	—Produces toxic sludges
			—Low removal of As(III)
	—Iron Coagulation	—Common chemicals available	—Pre-oxidation may be required.
3	Sorption Techniques		
	—Activated alumina	—Relatively well-known and commercially available	—Produces toxic solid waste
	—Iron coated sand	—Well defined technique	—Replacement/regeneration
	—Ion exchange resin	—Plenty possibilities and scope of development	required
	—Other sorbents		—High-tech operation and maintenance
			—Relatively high cost
4	Membrane Techniques		
	—Nanofiltration	—Well defined and high removal efficiency	—Very high capital and running cost
	—Reverse Osmosis	—No toxic solid wastes produced	
			—High-tech operation and maintenance
	—Electrodialysis	—Capable of removal of other contaminants	—Toxic wastewater produced

Patent Analysis

Patent information is priceless. Patents comprise a vast information resource, being filed across the world in every area of technology. Patent information enhances the business intelligence of an individual by ensuring that time, effort and resources are not wasted in duplicating already available research. This information also helps in keeping a close watch on competitors. It gives an indication of new developments and also provides an insight into the R&D trends worldwide. Patent information also helps to detect any infringements of one's own patents. Apart from this, patent information is in itself a unique source of information full of practical descriptions providing a broader view of the market and a state-of-the-art review. It helps in obtaining a grasp of the latest technology trends, gathering technology information and avoiding disputes.

In this paper, the patent information on 'arsenic in water' serves as a tool for collection of data on the trends of the

latest technologies in this field, state-of-art reviews on the technologies and R&D trends worldwide in the field of arsenic removal from water. This information has been very vital for the study and has helped to analyse the collected data in a global perspective.

Data and Methodology

Data for analysis was obtained from INPADOC/EPIDOS patent database maintained by the National Informatics Centre, New Delhi. This database consists of patents filed and granted in sixty-five countries in a wide variety of fields. Patent search was made in the database for the years 1991 to 2002. A search on the title was made for the patents by giving the keywords of 'arsenic' and 'water'. Similar searches were made in the US patent database provided by the US Patent and Trademark Office, the Singapore database provided by the Singapore Patent Office and the METADEX database. This resulted in a total of 81 patents after eliminating those that did not relate to 'arsenic' and 'water'.

Trends in Patenting

Growth of Patents

Since the year-wise output of patents during 1991-2002 was very small, the output was divided into two blocks, i.e. 1991-1996 and 1997-2002. The distribution of output in the two blocks has been given in Table 2. Analysis of the data (Table 2) indicates that in the second block the output of patents grew by 26% of the first block, which indicates the importance of the subject.

Country-wise Analysis of Output

The analysis of the data for the patents indicated that the maximum patenting activity relating to 'arsenic removal from water' was carried out in Japan followed by China, United States, Europe and Australia (Table 2). Japan has the maximum number of patents filed though it is not one of the countries facing problems due to arsenic contamination. Japan being an economically developed country can afford research in a wide variety of areas, thereby providing solutions to problems worldwide. Another reason could be that Japan being the world leader where technologies are concerned, it would be in the interest of various countries to file patents there as this could result in collaborations that would benefit both the countries. On the other hand, it can be seen that out of the countries most severely affected by arsenic contamination, only US, China and Australia show a significant amount of research in this field .The research activities going on in India and Bangladesh (two of the worst affected countries) are poorly reflected in the patenting activity. One cause contributing

Table 2—Patenting trends in arsenic research

Country	1991-96	1997-2002	Total
Japan	9	14	23
China	5	5	10
USA	2	8	10
Australia	0	5	5
Europe	2	3	5
Denmark	1	3	4
Canada	1	3	4
WIPO/PCT	1	3	4
Others	9	7	16
Total	30 (37%)	51 (63)	81

to this could be that both being developing countries, they lack resources to carry out sufficient research in this field of importance. It is also observed that in the second block, i.e. 1997-2002, the activity has gone up in all countries except China, where there is no change in output.

Technological Trends

Table 3 gives the state-of-the-art evaluation of the various areas in which research is being carried out in the field of arsenic removal of contaminated water. It is seen that the maximum concentration of patents is in the area of arsenic removal from drinking water (49.38%), followed by 'removal of arsenic from wastewater' (37.04%). Patenting in other areas such as 'estimation of arsenic' (3.7%), 'use of arsenic reagents in iodine determination in water' (2.47%) and 'production of fine–dispersed arsenic by electrolysis' (1.23%) is very less. This proves that the problem of arsenic contamination in water is global and efforts are being made worldwide to tackle this problem. Research in this area is not confined only to those countries, which are affected by arsenic contamination. The intensity of the problem can be seen from the fact that the majority of research in the field of arsenic is related to removal of arsenic from water. It may be mentioned here that market factors, environmental factors, social factors and political factors also affect the technological trends.

A year-wise analysis (Table 4) of the research areas shows that the patents filed

Table 3—No of patents in arsenic research

S. No	Research areas related to arsenic	No of patents	Percentage
1	Method of arsenic removal from waste water	30	37.04
2	Method of arsenic removal from drinking water	40	49.38
3	Estimation of arsenic	3	3.7
4	Determination of iodine in water using arsenic reagents	2	2.47
5	Production of fine-dispersed arsenic by electrolysis of water-alkali solution	1	1.23
6	Others	5	6.17
7	Total	81	

Table 4—Block-wise distribution of patents in various research areas

Research areas	1991-96	1997-2002	Total
Method of arsenic removal from waste water	8	22	30
Method of arsenic removal from drinking water	14	26	40
Estimation of arsenic	3	—	3
Determination of iodine in water using arsenic reagents	2	—	2
Production of fine-dispersed arsenic by electrolysis of water-alkali solution	1	—	1
Others	5	—	5
Total	33	48	81

in the area of 'method of arsenic removal from wastewater' increased from 8 in 1991-96 to 22 during 1997-2002. Similarly, the number of patents in arsenic removal of drinking water also increased from 26 in 1991-96 to 40 in 1997-2002. The number has increased from 3 in 1997 to 8 in 2002. This proves that great stress is being laid on the removal of arsenic from drinking water all over the world, which was not there earlier. Scientists have become aware of this acute problem and are trying hard to reduce this problem globally. Very few patents have been filed in other areas in the last ten years. Majority of the research related to arsenic is being concentrated on its removal either from wastewater or drinking water.

Conclusion

A lot remains to be done despite the significant amount of research being carried out globally to tackle the problem of arsenic contamination. Most of the developed countries are carrying out research in this field irrespective of whether they are affected by arsenic contamination and are therefore contributing in reducing the problems faced by the affected countries. On the other hand, some of the developing countries severely affected by arsenic contamination are not carrying out sufficient amount of research to tackle the problem. This could be due to lack of resources or lack of awareness of the intensity of the problem. It is therefore important that research efforts should be properly channelled and prioritised keeping in view the intensity of the problem and emerging competition. Scientists and R&D organizations of developing countries should identify research priorities based on patent analysis so that they can meet the challenges within themselves and also of the growing global competition.

References

1 Arsenic in drinking water, *WHO Fact Sheet No 210*, May 2001, 1-8

2 Meng X, Bang S, and Korfiatis G K, Effects of silicate, sulphate and carbonate on arsenic removal by ferric chloride, *Water Research*, **34**(4) 2000, 1255-1261

3 Saha J C, Ph D Thesis, Removal of Arsenic from Water Environment by New Adsorbent, 1999

4 Ahmed F, Jalil M A, Hossain M D, and Badruzzaman A B M, An overview of arsenic removal technologies in BUET, In *Bangladesh Environment-2000* (Bangladesh Poribesh Andolon) 2000, 177-188.

5 *http://www.unu.edu/env/Arsenic/Han.pdf*

6 Cong T M, Lena Q, Zhang W, Cai Y, and Harris W G, Arsenic species and leachability in the fronds of the hyper accumulator Chinese brake (Pteris Vittata L), *Environmental Pollution*, **124**(2) 2003, 223-230