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UNIVERSITY OF TECHNOLOGY

Department of Chemical Technology

Identification of Research Portfolio for the Development of Filtration Equipment

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ABSTRACT

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This piece of work which is Identification of Research Portfolio for Development of Filtration Equipment aims at presenting a novel approach to identify promising research topics in the field of design and development of filtration equipment and processes. The projected approach consists of identifying technological problems often encountered in filtration processes. The sources of information for the problem retrieval were patent documents and scientific papers that discussed filtration equipments and processes. The problem identification method adopted in this work focussed on the semantic nature of a sentence in order to generate series of subject-action-object structures. This was achieved with software called Knowledgist.

List of problems often encountered in filtration processes that have been mentioned in patent documents and scientific papers were generated. These problems were carefully studied and categorized. Suggestions were made on the various classes of these problems that need further investigation in order to propose a research portfolio.

The uses and importance of other methods of information retrieval were also highlighted in this work.

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1. INTRODUCTION

Decision makers in industries are often confronted with challenges of channelling the company's resources and funds to those areas that seem beneficial to the company while addressing the societal needs. A lot of questions about the future developments need to be dealt with. Appropriate approaches to these questions help the company to take proper decisions and hence adopt technological strategies that would help satisfy present and future needs of the society. A company incurs tremendous loss if in any case the resources are allocated and distributed to unsuccessful and unprofitable projects.

The major question that comes into our mind is how to identify these projects that are promising and need utmost attentions. There exist many decision-making methods which helps decision makers to assess different alternatives in order to achieve their objectives. Semantic method of problem identification and technological forecasting has been adopted to help build collections of projects for the R&D departments. This would help the management of a company to take the appropriate decisions on which projects need execution at a given time.

1.1 Objective of the work

The objective of this work is to identify and propose promising research areas of interest in the field of design and development of filtration equipment.

It is also required to suggest a novel approach of identifying these research areas of interest.

1.2 R&D portfolios

In a firm, many potential fields of technology advancement are identified but due to limited funds, few are chosen at a time. Among these few selected, senior management have to decide how the funds are to be distributed to achieve the best investment. In order to aid decision making process, the concept of portfolio has been adopted. Portfolios are used in the R&D sections to make strategic decisions. The advantage of portfolios is that

they envisage difficult problems and try to solve them using the best decision making criteria

Therefore, decision takers need a systematic method of technology approach and forecast in order to identify those technological fields that are of most interest and hence channel the company's resources in the right and profitable direction.

Suggesting a R&D portfolio in filtration equipments is the subject of this work.

2 TEXT MINING

Documents (e.g. patents, articles) are made up of a collection of large volumes of structured text and numbers with unstructured textual information. These documents are often extensive and made up of technical expression that they become difficult to analyze manually. If carefully analyzed, they can show technological details and relations, reveal business trends, inspire novel industrial solutions, or help make investment policy [1]. For better understanding of the information contained in the documents, text mining becomes important. Text mining facilitates the retrieval and understanding of the information encoded in the text.

2.1 Definition of text mining

Text mining is a method of obtaining high quality information from a collection of unstructured textual information. In this context, high quality information does not only involve information that is related to the topic in view but also that which the user can understand.

According to Yair Even-Zohar, text mining is “a non trivial extraction of implicit, previously unknown and potential useful information from (large amount of) textual data [2]. Another useful definition of text mining is “an exploration and analysis of textual (natural language) data by automatic and semi automatic means to discover new knowledge [2].

The process of text mining usually involves collection of documents, formatting or structuring the input text, generating trends or patterns within the formatted data (text) and subsequent evaluation and interpretation of the results (output). 'High quality’ in text mining usually refers to some combinations of relevance, novelty, and interestingness [3].

To ease the process of text mining, the textual information is first transformed into numerical data. This transformation aims at structuring the unstructured data and hence the text mining methods will become similar to data mining after the text is transformed to standard numerical forms. A question arises “is there difference between text mining and data mining”? The first distinction between text and data mining is that data mining

methods like to use the data in spreadsheet format while text mining methods like to see a document format, and the standard presentation for learning is a variant of the format called XML (Extensible Markup Language) used in the document world [4]. Data mining methods uses a high degree of structured format for data while text mining methods looks at a collection of documents. Another difference which distinguishes data mining from text mining is the source of information. In text mining, patterns are often retrieved from natural textual language while data mining focuses on structured database of facts.

2.2 Applications of text mining

Presently, the topic of text mining has become useful in many applications. Areas of interest that have adopted this method include security, commercials, marketing, banking, job seeking field etc. For the purpose of this work, we lay more emphasis on the industrial and academic applications.

2.2.1 Industrial application

Text mining could be a management tool in identifying the web pages of some companies that are competing in a given field. Text mining could also be used to find out the competing products and their respective prices. For example, one can extract all the names of people and companies that occur in news text surrounding the topic of wireless technology to try to infer who the players are in that field [5]. There are a number of companies that are investigating this kind of applications.

2.2.2 Academic Applications

In genomics, proteins behaviour has been under investigation to know the proteins that interact with each other. There has been notable success in looking at which words co-occur in articles that discuss the proteins in order to predict such interactions [5]. This method involves identifying the articles that mentioned some names of individual protein and to note other words highlighted in these articles, and subsequently find other articles that mentioned the same set of words.

Text mining becomes a very useful tool for publishers who work with large databases of information which could be retrieved by indexing. This is very evident in scientific fields

where important and specific information are contained within the text. Initiation of text mining has also started in academic institutions

2.3 Methods of text mining

2.3.1 Information retrieval

The first thing to do in text mining is to collect the set of relevant documents that contain the required information. In most cases, these documents may already be available or it may be required to carry out initial search of these relevant documents before proceeding with the mining. For example, a web page retrieval application for an intranet explicitly specifies the relevant documents to be the web pages on the intranet [4]. In this case, since the document has already been identified, it is important to ensure that the samples are of high quality by cleansing the collection of data. In some cases where the set of data are in large volumes, data sampling techniques are employed to select a set of relevant documents that can easily be handled.

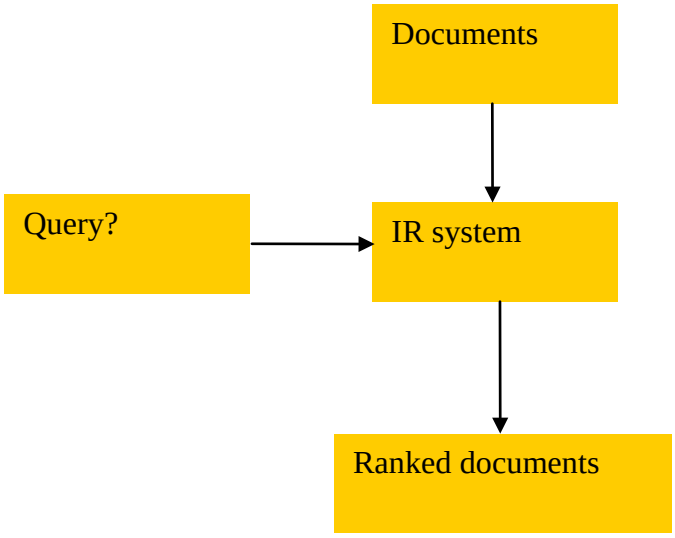

Figure 1: Information retrieval scheme [2].

The above figure illustrates the process of information retrieval. There is usually a source of the documents, a user query which results in a set of ranked documents that are related to the query.

2.3.2 Information extraction

In order to extract some information from a source of textual documents, a well defined and precise query has to be used. A query could be a word, group of words or phrase which characterizes the information the user wants to find. In this situation, it is required to identify the sentences that contain the relevant information needed, extract the important information and subsequently associate the related information and output in a predetermined form. The query has to be specific in order to leave out unimportant information as to ease handling of the documents. Figure 2 represents the process of information extraction.

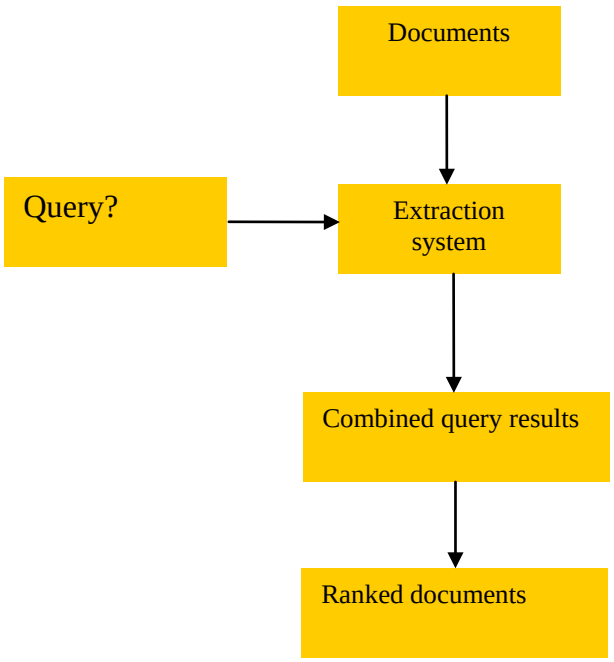

Figure 2: Information extraction scheme [2].

2.3.3 Web mining

Technological advancement has introduced a faster means of circulation of information. The World Wide Web (the Web) has recently becomes the easiest means and platform to spread different kinds of information to various people irrespective of the location. The web stores a lot of textual information in different forms. This information could be in the form of books, CDs, videos, etc. The information contained in the web is large, varied and disseminate over the whole web with little or no structure and thus makes web

mining a difficult task to accomplish. Web mining has found useful applications in the area of investigating customers' behaviours, appraisal and distinction of several websites and evaluation of the achievements of market campaigns. One characteristic of web pages is that they are always under reformation, some parts being removed and more information being generated and improved. It is more difficult to use the normal data mining methods, which work perfectly for traditional structured data to mine the web pages. There is a lot of unwanted information in the form of noise contained in the web pages (advertisement, copyright statement, etc) and these noises affect the use of normal data mining methods to mine the web. There are key information implanted in web pages and these have been found useful when the web is to be mined. Key information refers to particular information found in web pages and this information helps to distinguish web pages that are related to each other. Therefore, key information helps in the classification of web pages as well as identification of a particular web page in a website. For example, a distinctive menu item in each web page indicates the category of the main content in this page; a hierarchical navigation indicator shows the main topic of the page[6]. Such menu items and navigation indicators are considered as key information as they can effectively categorize web pages into different classes [7].

An intelligent web search uses a combination of the information retrieval tools and the quality of the information being retrieved depends on the meaning of the words, orders of the words, user dependency for data, and authority of the source.

Web mining uses three forms of mining approaches to identify the pattern in data in the web. They are:

- Content mining which is mainly used to study information obtained by search engines and web spiders
- Structure mining studies information associated with the construction of a particular website
- Usage mining is used to study information that concerns a particular user's web browser and also information obtained by forms the user may have submitted during web transaction.

The information gathered through Web mining is evaluated by using traditional data mining parameters such as clustering and classification, association, and examination of sequential patterns [8]

2.3.4 Clustering

Clustering is the process of organizing objects into different groups, or simply, grouping of data (text) into subgroups called clusters, in such a pattern that there are common features among these subgroups. Clustering is an important tool used in text mining to recognise interesting data distribution and patterns that exist in the data. Using this technique, interesting structures or clusters can be found directly from the data without relying upon any background knowledge [6]. Data clustering is useful in the fields of machine learning, data mining, pattern recognitions, image analysis and bioinformatics.

Other fields of application of clustering include:

- Marketing*:* finding groups of customers with similar behaviour given a large database of customer data containing their properties and past buying records.
- Biology*:* classification of plants and animals given their features.
- Libraries*:* book ordering.
- Insurance*:* identifying groups of motor insurance policy holders with a high average claim cost; identifying frauds.
- City-planning*:* identifying groups of houses according to their house type, value and geographical location.
- Earthquake studies*:* clustering observed earthquake epicentres to identify dangerous zones.
- *WWW*: document classification; clustering web log data to discover groups of similar access patterns [9].

Clustering techniques are very important tools in identifying emerging research trends. These trends could be identified by extracting clusters of co-cited scientific publications in each year. When a cluster of a given year is compared with those of previous years, it is easy to identify the addition of new members to the most current cluster. New members

could be research fields, authors and works, articles, key words, phrases, etc. introduction of new members gives an idea of the latest development in a given field of interest.

Current clustering techniques can be broadly classified into the following categories

- Exclusive Clustering
- Overlapping Clustering
- Hierarchical Clustering
- Probabilistic Clustering

In exclusive clustering, the data are grouped in a restricted manner which prevents a point already in a given cluster to be included in another cluster. A point can only belong to one cluster as illustrated in figure 3.

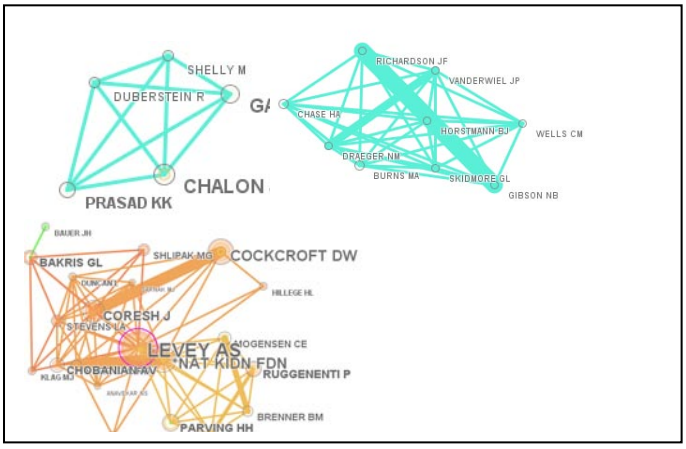

Figure 3: Exclusive clustering

Figure 3 consists of three clusters which are independent of each other. There is no point that belongs to more than one cluster.

On the other hand, overlapping clustering uses fuzzy sets to cluster data in such a manner that any given point may belong to more than one clusters, with varying degree of membership. In this case, data will be associated to an appropriate membership value [9].

Hierarchical clustering algorithms are ideal tools for their interactive visualization and browsing as they provide data-views that are consistent, predictable, and with different

granularity levels [6]. This algorithm depends on the merger between two clusters that are nearest to each other. The basis for using hierarchical clustering algorithm is realized by setting every datum as a cluster. After a few iterations it reaches the final clusters wanted.

The aim of data clustering is to achieve clusters of high quality with high intra-class similarity and low inter-class similarity.

2.4 Text characteristics

Knowing the characteristics of a given text to be mined helps the user to choose the appropriate methods and tools during text the mining process. Below are listed some of the characteristics of text documents.

- They may be obtained in form of large volume of database. This determines the efficiency of text mining.
- High dimensionality (sparse input). Each word or phrase is considered as a dimension.
- Several input modes e.g. web mining: information about user is generated by semantics, browse pattern and outside knowledgebase.
- Dependency: relevant information is a complex conjunction of words/phrases e.g. document categorization, Pronoun disambiguation.
- Ambiguity: word ambiguity (pronouns…he, she, etc), semantic ambiguity (one phrase having so many meanings).
- Noisy data: spelling mistakes
- Not well structured text: chat rooms (e.g. r u there?), incorrect speech.

2.5 Text mining process

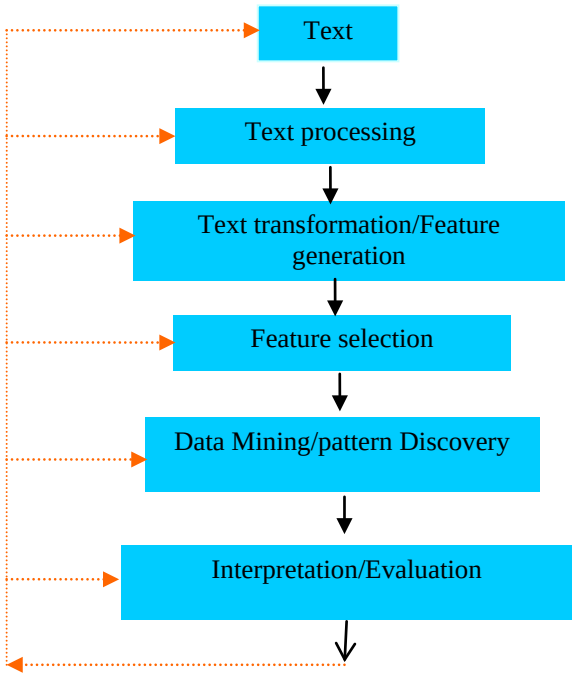

Figure 4: Process of text mining.

The above scheme gives an overview of text mining process. Details of the process are not covered in this work.

2.6 Using text for predictions

Predictions and forecasting involve taking significant decisions about the future and sometimes may be full of inaccuracies. Generally, prediction is a straightforward problem that always has a solution but the solution might be sometimes defective. The idea about using text to make future prediction stems on using the past trend of events obtained in the text as a guide to know what the future looks like. The notion is that an accurate prediction could be made if there are similarities between the future and the past. Figure 5 gives a general idea of how the past and the future could be integrated to make forecast.

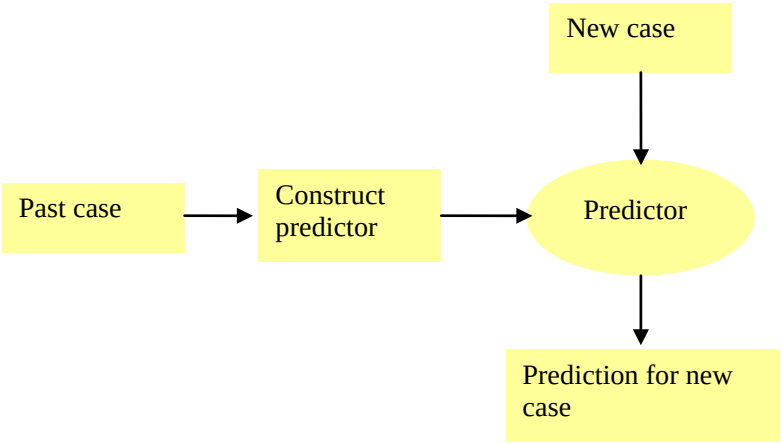

Figure 5: Predicting the future based on the past [4]

Just knowing the past experience is not enough to make accurate predictions of the future. For good prediction of the future, there must be a pattern or trend followed by the past experiences. In such situation where the future project deviates from the pattern of the old projects, it then becomes difficult to use the past to forecast the future.

3 SCIENCE AND TECHNOLOGY INDICATORS

Science and Technology have recently attracted a general attention because of its role in the enhancement of economic and technological development. There are many science and technology indicators listed in various text but the most significant ones are patents and publications. Publications and patents provide the primary 'raw material' for building and developing an R&D indicator system [10].

The number of scientific publications provides a measure of scientific productivity, while the number of patents produced by a particular organisation, country or region provides a first order indicator of its technological vitality [10].

For the purpose of this work, we lay more emphasis on patents and publications as indicators of science and technology advancement. The next sections will explain further how patents and publication determine science and technological activities.

3.1 Analysis of science and technology indicators

Science and technology requires the initiation, adoption, processing, dissemination and exploitation of scientific knowledge. Therefore, knowledge generated by one person is often useful to many people that depend on it to advance their studies. The strength of these indicators could be identified by:

- Citations analysis
- Citation frequency
- Words frequency
- Problem identification in scientific papers and in patents.

3.1.1 Citations analysis

Citation analysis is the assessment of the regularity and trend of citation in scientific publications and books. It is important to make a citation analysis in order to make a study on the field that has the greatest impact on science and technology innovations. One person's writing most times affect the writing of other people. It is a good method of identifying a rapidly developing field. Therefore, citation analysis helps to determine how

much written works depend on each other by identifying sets of articles, authors or journals in a given field of study.

Reasons why some researchers carry out citation analysis include:

- Investigation on the effects of a given written work to the other and to estimate how relevant the information contained in a paper is to future study.
- Citation analysis reveals more information and knowledge about a given field of study by grouping some works that are inter-related.
- It also identifies and singles out the efforts of authors by indicating how many times his or her work has been used by other people.

Citation analysis requires the determination of the frequency and pattern of citations in articles and books. The easiest way to achieve this is by counting which indicates the number of times a given article has been cited over a given period of time. It is always difficult to get the exact number of counts. Recently, two techniques for identifying papers that have something in common have been developed. These methods are bibliographic coupling and co-citing analyses.

Two documents are related bibliographically if they have cited one or more same documents in their reference lists. This relationship is represented pictorially as shown in figure 6.

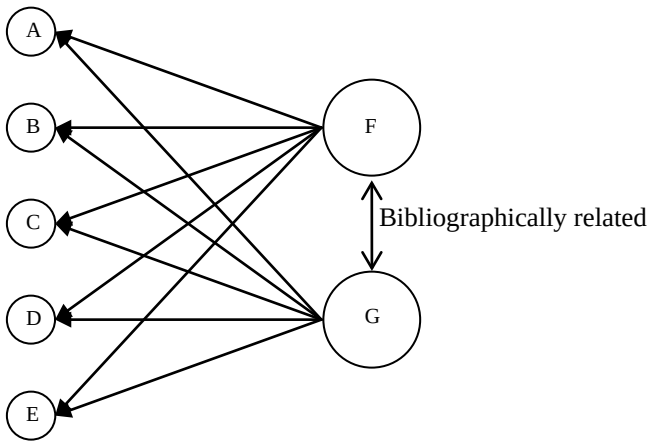

Figure 6: Bibliographic coupling.

In figure 6, the circles lettered A to G represent different documents. Documents F and G are the citing documents while documents A, B, C, D, and E are the cited documents. In this kind of relationship represented by the figure 6, documents F and G are related by bibliographic coupling because they cited documents A, B, C, D and E in common. Bibliographic coupling has a major draw back in that two papers that cited some papers in common might not discuss the same information from those papers. It is more difficult to quantify the impact of bibliographic coupling on information retrieval. Bibliographic coupling is backward-looking and obsolete and hence has been recently displaced by co-citation clustering.

Co-citation coupling operates on a similar principle as bibliographic coupling, but in a way it is the mirror image of bibliographic coupling as could be seen in the figure 7. Co-citation analysis has been in use to detect the relationship that exists between authors, journals and articles. This analysis requires the identification of papers that are highly cited in a given field of study.

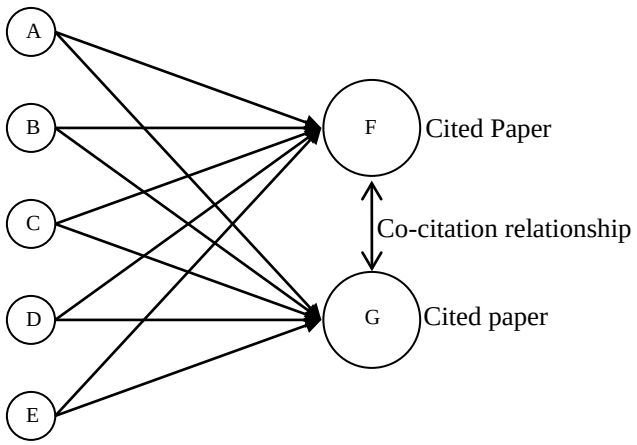

Figure 7: Co-citation coupling.

Figure 7 shows the relationship which exists between 7 documents (papers). Documents A, B, C, D and E have each cited documents F and G. Therefore, F and F are related by co-citation. This proves to be a means of tracking the emergence of new topics. Through co-citation, clusters of research begin to emerge when the same pairs of papers are co-cited with other papers by many authors.

Co-citation analysis has found tremendous application in the field of information science and knowledge analysis. During co-citation analysis, counts are made to determine the number of co-citations and hence a matrix of the cited documents is built. This matrix is statically built to scale which gives a distinct idea of the developing and changing trend of knowledge structure in a given filed at a given time. This technique helps information scientist carry out their studies and identify the structure of a research field. Contrary to bibliographic coupling, co-citation is effectively a forward-looking viewpoint of mapping information.

3.1.2 Citation frequency

Citation frequency often serves as a measure of research activity and performance of communication about research activities. This factor is a measure of how strong a patent or paper is in the field of interest. A patent document or article which receives many citations by subsequent documents has a very strong influence on the emerging technologies.

3.1.3 Word frequency

In word frequency analysis, the aim is to look for articles that mention specific words, keep note of other words which occur in these articles and then look out for other articles that contain the same group of words. This method does not give any direct meaning of text but it could yield good results. The frequency of certain words mentioned in articles could give an idea of the hottest topics in a research field and hence would attract more investigation on those words.

3.1.4 Problem identification

This is a useful technique that has been widely adopted to investigate the trend of research activities. Simply, the method focuses on identifying those problems which have been mentioned in written document (patent documents and scientific papers) and uses the information obtained to project future research activities. Details of this method forms the basis of this work and will be presented in subsequent sections of this work.

3.2 Patents

The analysis of patent information is considered to be one of the most established, directly available and historically reliable methods of quantifying the output of a technology system [11].

A patent is a document issued by an authorised governmental agency, granting the right to exclude anyone else from the production or use of a specific device, apparatus or process for a stated number of years [11].

For a patent to be granted, certain condition must prevail. These include:

- Novelty
- Inventive step
- Commercial application

3.2.1 Importance of patent information as a technology indicator.

The competitive structures in many industries have been found to depend on technological changes. A study of the US hard drive industry showed that companies which had led the markets were driven out because they did not recognise the potential of new disruptive technologies [12]. An industry that allocates a substantial resource to R&D usually has a competitive advantage. As a result, industrial research and development has attracted special attention in most industries.

Technology management which involves the management of creation, storage and use of technological knowledge aims at maximizing the impacts of R&D to a firm's strategic and commercial objectives. It has been shown that patents can support technology management.

3.2.2 Functions of patents

1. A patent acts as a protection of an invention for a specified period of time. Within this period, no body is allowed to imitate this invention.
2. There is lots of information contained in patents. This information is very important for technology management.

When compared with other sources of information for technology management, patents are considered the best and most reliable source for timely recognition of technology changes [12].

3. Patent study is an indication of the progress in R&D since technological activities which lead to market changes are identified.
4. Technologists other than inventors can use information obtained from patent as a guide to know the progress of technological knowledge.
5. The publicity of the information contained in patents enhances the diffusion of technological innovations. This system fulfils an important role in the information diffusion in the sense that it avoids needless duplication of R&D efforts.

3.2.3 Applications of patent information

a. Patent information allows access to competitor's R&D strategies

Results obtained from patent analysis give access to important strategies which other firms have adopted in their R&D departments. These results help to identify those technologies that are promising in the future and hence indicate in what areas direct the company's resources. Some important issues of technology management addressed in this context include:

- Determination and evaluation of technology changes and advancement in the industries of competitors.
- Evaluation of firm's position when compared with the competitor's technological field.
- Identification of changes in competitor's technology strategies.
- Allocation of R&D budgets to most promising technologies and projects.

b. External generation of technological knowledge

Information from patents is vital to identify and gain access to different alternative measures for external generation of knowledge for technological development. Issues of paramount interest often addressed in this context are:

- Identifying those external technology competences which are relevant to the firm.

- Evaluation of technological positions of potential acquisition and R&D alliance patterns.
- Determination of the technological fit between the acquisition target or the R&D alliance partner and one's own firm.

c. Storage of information

Knowledge management requires the storage of relevant information which is utilized by the R&D departments. The issues of high importance in this context are:

- Availability of relevant knowledge to the organisation.
- Identification of leading inventors in a specific field.
- Maintenance of strategic competitive positions by leading investors in a given industry.

3.3 Scientific publications

A scientific publication can be defined as any kind of written material, either in a physical format, or as its electronic equivalent in a computerized database, containing information with respect to scientific research activities [10]. Examples of publications are research reports, books, conference proceedings and articles in scientific journals.

A well written scientific paper has two major characteristics.

First, procedures that were adopted and results that were obtained must clearly and completely be stated.

Second, results obtained must be compared with those obtained with previous similar experiments, and their importance to real life explained. The results must be fully interpreted for future revision. For the clarity of a scientific publication, it must summarize the state of knowledge on the general topic, relate the work to previous study on same topic, state clearly the significant theory on which the work was based on, obtain and interpret results relating them to the aforementioned theory and to the general state of

knowledge and finally, discover lapses in the work and where future development of the topic should be focused.

The number of scientific publications is used to evaluate scientific production which measures the degree to which contributions to research activities create scientific results.

According to Arnold, quality of a scientific paper describes how well the research has been done, whether it is free from obvious error, how aesthetically appealing the mathematical formulations are, how original the conclusions are and so on [10].

The importance of publication is determined by the extent it affect research activities i.e. whether it helps to enhance scientific activities. The research problems encountered exclusively in the papers are subject of actual great scientific interest but probably do not have any important practical meaning [13].

4 TECHNOLOGY FORECAST AND INFORMATION ANALYSIS

Before a project is undertaken in a company, the decision makers have to make a feasibility study. A feasibility study aims at analysing a given idea while considering its future prospects. The results obtained from this study help the law makers to take appropriate decisions whether to proceed with the project or not. Therefore, some tools are required to help in taking the appropriate decisions on where and when to carry out a given project by predicting its future viability. The main aim of technology forecasting is to predict future technological viabilities, attributes, and parameters. According to Jack R. Meredith, we define technological forecasting as the process of predicting the future characteristics and timing of technology [14]. When possible, the prediction will be quantified, made through a specific logic, and will estimate the timing and degree of change in technological parameters, attributes, and capabilities [14].

4.1 Methods of technological forecasting and information analysis

Technology forecasting methods are generally grouped into two broad headings. They are numeric data-based techniques and judgement based techniques.

4.1.1 Numeric data-based technological forecasting techniques

Trend extrapolation: Extrapolation means to predict the future based on the past experience. Trend extrapolation in technology forecasting uses the ideas generated from the previous trends in a particular technology to predict what the future looks like. The assumption behind this method is that the past and present trend in a given technology will continue into the future. Some drawbacks are often encountered with this method of technology forecasting. In some cases, it is a misleading notion that the trend in the past will continue into the future. Information retrieved by this method is based only on one variable condition. External factors could be of influence to this variable in the future and hence the trend will change.

Growth curves: In this concept, it is assumed that the growth trend of technology (invention phase, introduction and innovation phase, diffusion and growth phase, and maturity phase) is similar to that of biological life (S shaped). Technology forecasting

helps to estimate accurately the timing of these different stages of growth of technology. This growth curve forecasting method is particularly useful in determining the upper limit of performance for a specific technology [14]. Technology forecasting by this method is achieved by series of mathematical models developed to fit the best curves for given data.

Envelope Curves: Fundamentally, envelope curves are a combination of growth curve and trend analysis methods

Modeling: This method uses analytical techniques to model and predict the future performance of complex systems. Modelling of complex systems requires the use of equations to show the relationship between variables and how changes in one variable affect the other in the future.

4.1.2 Judgment-Based Technological Forecasting Techniques

Monitoring: This approach to technology forecasting assumes that the forecaster knows his target and therefore engages in state-to-stage development of a new technology with strict monitoring or supervision of the various stages before it is made open to the public. The major draw back of monitoring is that it does not give enough warning of the time constraint for any future development.

Scenarios: The scenario is a narrative forecast that describes a potential course of events [15]. This method identifies and predicts the relationship between system components and the impacts they have on each other and the entire system. The scenario is a hypothetical view of the future based on past experience and conjecture, usually containing little rigorous analysis [14]. Scenarios consider events such as new technology, population shifts, and changing consumer preferences [15].

Morphological Analysis: This analysis examines what people may desire to have in the future and therefore looks for different means of satisfying these needs. Of all the techniques available for forecasting new products or processes, morphology is one of the most systematic.

Decision trees: A decision tree is a graphical decision support tool that demonstrates the possibilities of achieving a goal using alternative choices. With a decision tree, it is possible to identify a particular strategy or choice of action that is most likely to achieve the desired target. A decision tree also explains the risks and benefits associated with each of the identified strategies of action. A forecaster should be able to differentiate between sets of possible technologies and make a good future prediction of them with the help of decision trees. The relevance tree method essentially involves the drawing of one or more tree diagrams which structure the sequence of technological problems that must be solved in order to reach the objectives

Delphi Method: The Delphi technique is a method for obtaining forecasts from a panel of independent experts over two or more rounds [16]. The experts write down their predictions in the first round after which each copy is circulated among all the experts for comments. Subsequently, the participants are asked to modify, defend or explain their opinions based on what the other participants have commented. This process continues until a consensus is reached and the points are documented.

Cross-impact matrix method: The cross-impact matrix method recognizes that the occurrence of an event can, in turn, affect the likelihoods of other events [15]. This method takes into account the common influence of events. The purpose of cross-impact analysis is to study the mutual influence of events clearly and analytically, and to include those influences when forecasting. Each event is considered to occur independent and dependent of other events and each event's impact is measures against each related event with the help of a cross-impact matrix. This forecast can be done manually or by computer programmes which have been developed specially for this task. The advantage of this technique is that it forces forecasters and policy-makers to look at the relationships between system components, rather than viewing any variable as working independently of the others [15].

4.2 Knowledge retrieval methods

Knowledge or information retrieval (IR) involves searching for information in documents and may also require the search of documents themselves. It is very difficult to find the required information quickly because of the large compilation of documents in different sources. It is usually required that the information being retrieved from the search is related to a given input query. Input queries are used to search for the information items pertinent to the information need. They are often viewed as virtual items which aims at finding factual information that are related to the queries. Few of the knowledge retrieval methods are discussed below.

4.2.1 Keyword search

The simplest form and widely adopted search method is the keyword search using the simplest forms of Boolean operators. The Boolean algebra model comprises of union, intersection, and negation operators. The problem of this model is this ``all-or-nothing" response. This results to too many documents being retrieved or no document is found.

4.2.2 Statistical based search methods

A solution to the problems encountered in keyword search method is resolved by the use of statistically based search methods. These methods include:

- Bayesian
- Probabilistic model
- Scoring
- Pattern recognition
- Proximity searching
- Word frequency
- Claude Shannon’s principles
- Data visualization
- Data mining

Despite the ability of this method to assess large volume of text, it also has some intrinsic drawbacks. A statistical method makes a very “mechanical” document analysis using, for example, word-by-word comparison, word distance calculations, or word frequency

counting [17]. This method does not allow the detection of association between documents that are not represented through the use of common vocabularies.

In contrast to deep knowledge acquisition, this method does not support the active creation of knowledge about a domain but rather uses superficial textual analysis to create the links [18].

The purpose of this work is to identify promising research topics in the field of design and development of filtration equipments. Therefore, a knowledge retrieval method which should be adopted is one that is capable of understanding text and determines the relationships between the words.

4.2.3 Natural language processing

All our documents come in the natural language which can be understood by the reader. Due to large collection of text material, it is not possible to retrieve much information by just reading. Therefore, a Natural Language Processing tool has been invented which tries to extract meanings from text. This tool is capable of handling large volume of text materials. The natural language processing is based on the subject-object-action analysis.

4.2.3.1 Subject-object-action analysis:

The structure subject-action-object is a universal template of all sentences of any natural language [13]. In this analysis, the action-object pair is taken as the problem while the subject is considered as the solution. It is possible to obtain this problem-solution relationship with the use of a specialized knowledge base. The procedure works in such a way that the textual documents are analysed and grouped into subject-action-object pair (SAO) after which the problem-solution pairs are identified.

Generally, every sentence is made up of three major parts in order to convey a full meaning to the reader. These parts are subject, action and object.

- The Subject: What is performing the action
- The Action: What is happening in the sentence
- The Object: What is receiving the action being performed?

4.3 Process of text analysis

The linguistic/textual analysis is achieved through the following steps.

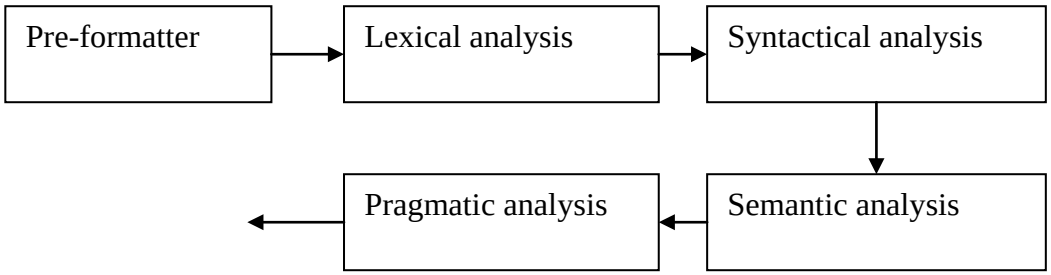

Figure 8: Process of analysis of a textual document [17]

For the analysis to be performed, a data base where the software retrieves information is required. This database could be the web, patents, articles, local files etc. An overview of the process of text analysis is discussed below.

Pre-formatter: At this step, the text is pre-formatted and all the documents which may come in different format (txt, .doc, .rtf, .pdf, .htm, or .html) into simple, correct and understandable format. All non-text objects including images are ignored after which the text is split into sentences.

Lexical Analysis: Lexical analysis makes use of the dictionary database to identify the parts of speech of the input sentences. This is a context independent analysis that relies on the fact that each word found in the analyzed sentence can be found in the dictionary used [17]. Each word found in the dictionary is classified into its part of speech. In most cases, one word may have different meaning and therefore it may appear in different classes of speech.

Syntactic Analysis: In this process, the grouping of the words into the various classes of speech is completed making sure that one word has only one class of speech. This is performed by taking into account the context of the sentence [17].

Semantic Analysis: Semantic analysis tries to determine the actual meaning of each sentence by analysing the structure of each sentence. In some cases, a sentence might not have any reasonable meaning based on the subject-action-object analysis. Sentences that have direct meaning are analysed as shown below:

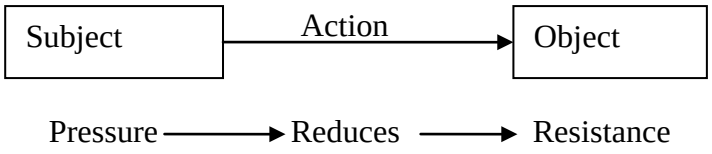

Figure 9: Analysis of a sentence

Pragmatic Analysis: This is the last stage of the text analysis. Here, the extracted semantic information is arranged in a manner that it's meaning becomes useful. It could arrange the extracted semantic information into problem-solution format where the action-object pair is the problem and the subject is the solution.

4.4 Methodology adopted

The method adopted in this work tries to identify the problems encountered in filtration equipments and processes that are mentioned in patents documents and scientific publications. The problems retrieved from scientific papers are compared with those identified from patent documents and an observation is made on how these problems overlap in each case. The adopted methodology could be summarized as follows.

1. Identify the group of problems cited in patents and note them as PP.
2. Identify the group of problems cited in publications and note them as P_1P
3. Group the problems identified into
    - Set PP problems: problems in patents only
    - Set P_1P problems: problems in publications only
    - Set P_2P problems: common problems in sets PP and P_1P
4. Observe the frequency of occurrence of the problems in the above sets.
5. Bases on the frequency of occurrence of the problems retrieved, promising projects are identified.

The idea of the above concept is represented in the figure 10.

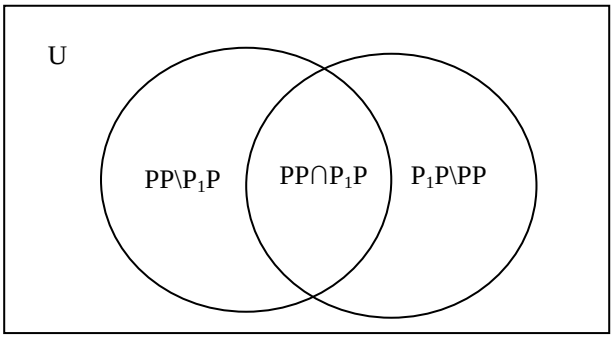

Figure 10: Sets of problems identified

In figure 10, U is a universal set of all the problems often encountered in filtration processes which are cited in both papers and patents. $PP\backslash P_1P$ represent set PP problems, $P_1P\backslash PP$ represents set P1P problems and set P2P problems are represented by $PP\cap P_1P$.

The set of problems PP which have already been solved and their solutions patented needs no further investigations unless there are few new improvements to be made on the existing technologies. The Set P_2P which denotes those problems common to both patents and publications more or less needs little attention. More emphasis should be laid to those problems in set P_1P. These problems have been identified in scientific papers and their solutions have not yet been patented. It would benefit any firm that directs its project to solving these problems listed in set P_1P.

In order to identify these problems, we adopt the natural language processing method which requires identifying problems cited in textual documents. In quest to develop a faster means of analysing a textual documents using natural language processing method, Invention Machine Corporation has invented software called “Knowledgist”. This software was used throughout this work in analysing documents. A brief overview of the software and hoe it works is found in the next section.

4.5 Knowledgist

Knowledgist is a personal research, innovation, and organisation application that dramatically reduce the amount of time people spend looking for relevant information on

the web, an intranet, patent databases, network drives, personal email, or their own computer [17]. Knowledgist can access documents in .txt, .doc, .rtf, .pdf, .htm, or .html formats. This software is a useful tool when carrying out market research, and helps to quickly extract, analyze and categorize information into a useful knowledge database.

The analysis is based on the semantic nature of every sentence which identifies all the parts of speech in the sentence. Each sentence in the entire document is examined by this software and the subject, object and action selected.

Each knowledge base is built in the form of semantic index, which captures both topic and concept from natural language.
Knowledgist works best if certain conditions suffice. The sentences must

- Be correct grammatically and syntactically
- Not be questions
- Not contain characters such as “ ‘({ [ ) } / \ ~^ @ ~¨ > | < * etc.

The main interface of Knowledgist is shown in figure (11).

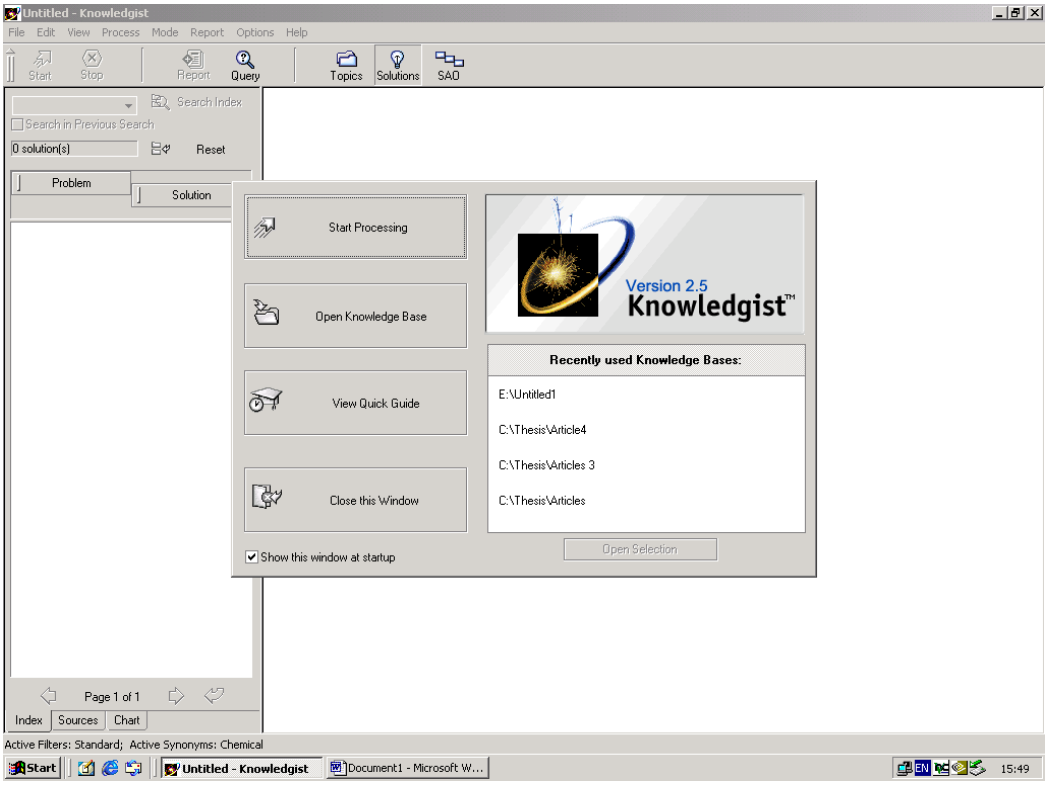

Figure 11: Main Knowledgist interface

5 RESULTS

5.1 Problems formulation

This work aims at identifying a research portfolio for R&D project in the field of filtration. The proposed method of achieving the said objective is to compare industrial problems which are mentioned in scientific papers with those mentioned in patent documents.

5.2 Identification of problems mentioned in patents

This involves searching patent databases with the software. During the course of this project, some patent databases had restrictions and could not be accessed. Therefore, the only database that was accessed was the US patent office database. The key words for the search was “filtration equipment and processes” while the focus words were “improving filtration”. After several searches, the software generated a list of subject-action-object results which are displayed on the screen as shown in figure 12.

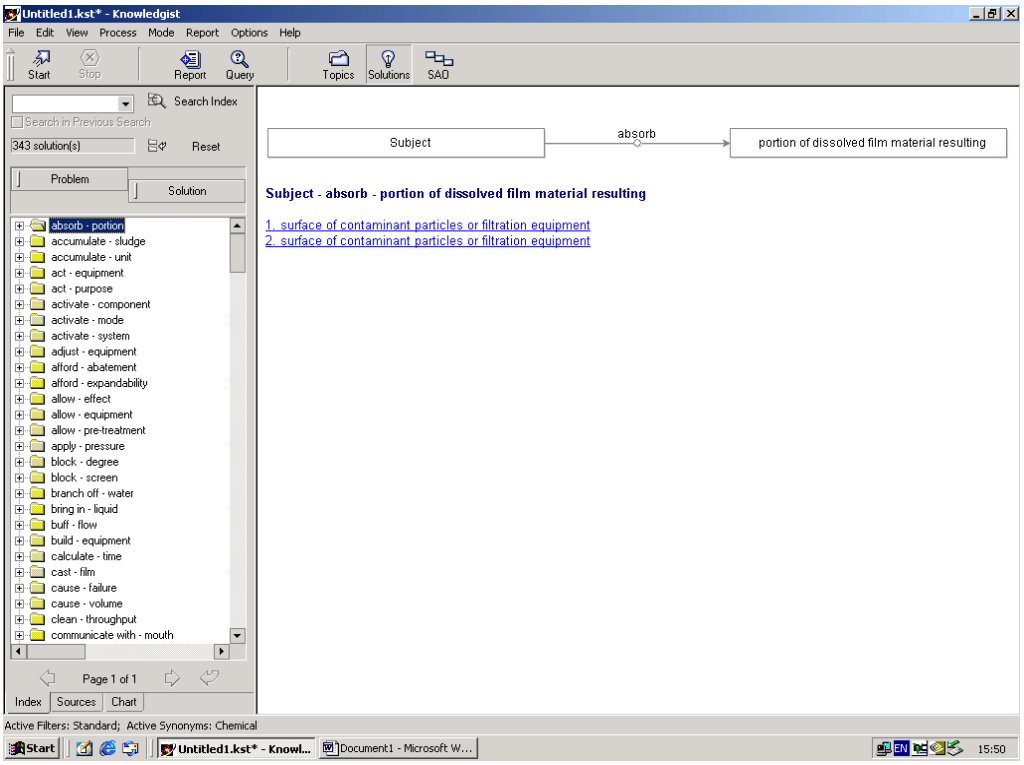

Figure 12: The SAO screen of Knowledgist: On the left are list of problems dealing with filtration equipment and on the right an example of the problem presentation.

As mentioned in the earlier chapters, the action-object pair is taken as the problem in this context while the subject is considered to be the solution to the given problem.

There was large volume of documents in the patent databases and Knowledgist uses only the semantic structure of a sentence to analyse documents. Therefore, many of these subject-action-object pairs which were generated are irrelevant to the subject matter. The software has a setting which uses filters to exclude unwanted words or phrases. After several iterations, a list of problems which relates to those encountered in filtration processes was generated. The problems were grouped into three broad heading:

- Problems related to filtration of a named products
- Filtration operational problems
- Improvement of filtration equipments and processes

The problems generated from the patent search are listed in appendix I.

5.3 Identification of problems mentioned in scientific papers

A similar search was made among scientific papers that discussed about filtration equipments and processes. These papers were retrieved from the ELSEVIER database. The search word was “filtration equipment and processes”. In order reduce the volume of documents, the search focussed only on those papers which were published between 1990 and 2007.

Knowledgist could not analyse documents directly from the ELSEVIER database but is capable of analysing local files saved on the hard disk. Therefore, these scientific papers were converted to word documents after which it was sent to the software for analysis. With the same settings as were in the case of patents, the software analysed these word documents and a list of subject-action-object pairs were also generated. The list of problems generated from this search is presented in appendix II.

5.4 Identification of the various sets of problems

The problems mentioned in patents and papers were studied carefully, one after the other. Three classes/sets of problems were generated as highlighted in the previous chapter. These sets are.

- Set PP problems: Problems mentioned only in patents
- Set P_1P problems: Problems mentioned only in publications
- Set P_2P problems: Problems common to Set PP and Set P_1P

Set PP and P_2P are listed in appendix III. The set that is of paramount importance that should attract the interest of R&D department for further investigations and subsequent improvement and development of filtration equipments and processes is set P_1P problems. Problems in this set have been identified and highlighted in scientific paper through series of experiments and mathematical computations. Set P_1P problems are listed in table 1.

Table 1: Set P_1P problems

S/No	Problems
1.	Allow for rapid filtration of large volumes of polyol dispersion
2.	Determination of red cell filterability in leukocyte-free suspensions of washed erythrocytes
3.	Effective separation of toxin from large culture volume of corynebacterium diphtheriae vaccine strain
4.	Molten metal filtration
5.	Cake filtration of cellulose fibers
6.	Fast filtration of diluted honey samples
7.	Refining and concentrating the agricultural antibiotic in aqueous solutions
8.	Detect white spot syndrome virus
9.	Improving filtration performance of a slurry containing crystallized wax, de-waxed oil and de-waxing solvent
10.	Improving gypsum slurry filtration
11.	Facilitate easier detachment of cake
12.	Facilitate operation of solid processing

13.	Filter fabrics
14.	Improving method for performing prosthesis conduit for use with living tissues
15.	Improve clarification, filtration and scale control of red-mud containing liquors
16.	Alter filtration mechanisms for pulps containing magnetic particles
17.	Performing gel filtration chromatography of proteins
18.	Increase rate of water removal
19.	Efficient utilization of protein
20.	Evaluate uranium removal efficiency from drinking water.
21.	Integrate biological degradation of wastewater pollutants
22.	Selective separation and total recovery of hydroxytyrosol, water and organic substances
23.	Provide facile means to improve phosphate removal capacity of biomass based stormed water
24.	Re-circulate purified water
25.	Recover peak of protein and associated aggregates, hydrophobic proteins or hydrophobic peptides
26.	Remove interfering bicarbonate anions by means of single filtration step
27.	Employ natural filtration process of surface water
28.	Cooling and simultaneous filtration of gas-aerosol fire extinguishing mixture
29.	Method for purifying aquaculture water
30.	Dead-end filtration of wastewater
31.	Improve solid and COD effluent quality
32.	Remove insoluble matter from crude ester product
33.	Neglect actual pore structure and pores
34.	Broad range of adhesion affinity
35.	Surfactant loss
36.	Allow intermittent membrane filtration
37.	Allow only water
38.	Compaction of membrane
39.	Cause membrane resistance

40.	Induce strong shear stress
41.	Determine thickness of filtration cake
42.	Increase in turbulence
43.	Forming multi-walled filtration plate
44.	Detect fault condition
45.	Consist of a collector, storage and filtering assembly
46.	Consists of membrane filtration processes and distillation process
47.	Control various zones throughout filtration cycle
48.	Find potential applications of membrane systems
49.	Facilitate creation of loading maps, monitoring, addition and replacement of fluid filtration devices
50.	Facilitate operation of solid filtration processes
51.	Comprising filtration medium (filtering water) and grid (preventing channelling) within the filter
52.	Have many permeable hollow membranes
53.	Have simple structure
54.	Contain natural fibers and flocculants
55.	Development of dot-immunogold filtration assay protocol
56.	Adopt integrated filtration process
57.	Generate bio destruction
58.	Yield drier filter cakes
59.	Produce concentrated fractions
60.	Prolong carbon-filter media's lifetime
61.	Cause harmful downstream particle emission
62.	Provide negative airflow
63.	Provide necessary filtration constants
64.	Provide better modelling of large scale vacuum drum
65.	Suit for use in a process-scale cross-flow filtration system
66.	Supply high voltage DC potential
67.	Test new hybrid process

68.	Deliver very short back pulses to the membrane during filtration
69.	Employ wide range of membrane processes
70.	Use air-moisture separator
71.	Increase reactivity of UV light
72.	Predict filtration
73.	Treat reuse of final effluent
74.	Treat final effluent
75.	Attachment of bacteria to spherical surfaces of granular porous medium

5.5 Classes of problems mentioned in patents documents and scientific papers

In order to build a research portfolio for R&D project in the field of filtration processes, the problems identified in patents and scientific papers were group into different classes. It was observed that many of the problems identified were related to each other. Therefore, different classes of these problems were built to clearly distinguish them from each other. The different classes are given in the table below.

Let the alphabets A-Q represent the various classes of problems. Their definitions are given as follows.

A Filtration and purification of liquids

B Quality

C Hazards and toxicity

D Filtration and purification of solids

E Filtration and purification of gases

F Rate of filtration

G Operating conditions

H Multi-purpose equipment

I Deterioration

J Economy

K Mode of operation

L Application

M Operability

N Measurement

Table 2: Classes of problems

Classes	Problems	Cited in patents documents	Cited in scientific Papers
A	Filtration and purification of liquid	1. Pre-treatment of water, 2. Incorporate raw water pre-filter device, 3. Improve filtration of beer 4. Improve filtration of paints 5. purification of aqueous cyclodextrin 6. Disperse untreated water 7. Achieve good filtration of cane juice sugar 8. Remove high polymer from water 9. Draw liquid through membrane	1. Allow for rapid filtration of large volumes of polyol dispersion 2. Molten metal filtration 3. Fast filtration of diluted honey samples 4. Get required clarity of beer, ciders, wines and bottled water 5. Improve clarification, filtration and scale control of red-mud containing liquor 6. Increase rate of water removal 7. Purify unfiltered raw water 8. Method for purifying aquaculture water 9. Improve wine filtration
B	Quality	1. Presence of degreased liquid or chemical liquid 2. Produce minute amount of fullerene in squalane after filtration 3. Contain oil and mist 4. Reduce odour in air 5. Introduce a method of depyrogenation/ sterilization in stainless steel filtration equipment 6. Treat noxious fumes 7. Remove residual solid	1. Effective removal of organic and inorganic contaminants and biological materials from municipal/industrial waste waters 2. Removal of iron hydroxide completely from water 3. Evaluate uranium removal from water 4. Provide facile means to improve phosphate removal capacity of biomass based storm water 5. Remove gaseous contaminants from air

		impurities 8. Recover lithium contained in mother liquor bleed stream 9. Recover ferrate salts from solutions 10. Produce technical grade lithium carbonate 11. Produce technical grade lithium carbonate 12. Reduce alkalinity 13. Prepare a wet cake of pigments 14. Improvement of filtration properties 15. Improve filtration efficiency 16. Improve filtration disk cleaning efficiency 17. Improve effectiveness of filtration 18. Provide more efficient disc filtration service 19. Remove residual solid impurities 20. Remove sub-micron sized particles	6. Remove airborne contaminant 7. Determination of red cell filterability in leucocyte-free suspension of washed erythrocytes 8. Effective separation of toxin from large culture volume of corynebacterium diphtheriae 9. Selective separation and total recovery of hydroxytyrosol, waater and organic substances 10. Recover peak of proteins and associated aggregates 11. Remove insoluble matter from crude ester product 12. Allow only water 13. Refining and concentration of agricultural antibiotic in aqueous solutions 14. Improve solid and COD effluent quality 15. Yield drier filter cakes 16. Produce concentrated fractions 17. Improve filtration performance 18. Calculate level of reduction achieved by filtration 19. Ensure effective filtration 20. Enhance effectiveness of filtration 21. Enhance fractional efficiency 22. Reduce infiltration of dust 23. Achieve good filtration with single filtration step 24. Provide better and smoother aperture size 25. Collect micron-sized particles

C	Hazards and toxicity	1. Cause massive hydrogen gas volume 2. Minimize accumulation of ozone 3. Reduce alkalinity 4. Decompose hardly decomposable harmful substance by means of filtration equipment 5. Results in evolution of CO_2 6. Reduce engine noise 7. Ensure safe environment 8. controlling the operation of sanitation system of spa 9. Have part of exhaust silencing system to reduce noise 10. Meet sanitary requirements 11. Disposable filtration unit 12. Perform detoxification 13. Treat noxious fumes 14. Remove hazardous germs 15. Include bacteriological filters 16. Comprise of inlet collector and built-in disinfection and filtration system 17. Have layer of over-layed element of elastically deformable material 18. Include bacteriological filters	1. Covert airborne radicals and ozone to harmless by-products 2. Effective removal of organic and inorganic contaminants and biological materials from municipal/industrial waste waters 3. Integrate biological degradation of waste water pollutants 4. Improve solid and COD effluent quality 5. Generate bio-destruction 6. Cause harmful particle downstream emission 7. Treat reuse of final effluent 8. Attachment of bacteria to spherical surfaces of granular porous medium 9. Ensure sterility 10. Eliminate large fractions of pathogens 11. Removal of pathogens

D	Filtration and purification of solids	1. Improve colour of crystallized sugar product 2. Separation of plasma and plasma components 3. Separate aromatic dicarboxylic acid crystals	1. Cake filtration of cellulose fibers 2. Improve gypsum slurry filtration 3. Filter fabrics 4. Facilitate operation of solid filtration processes
E	Filtration and purification of gases	1. Improve air quality 2. Filter air 3. Suitable for separation and purification of gas 4. Reduce odour in air	1. Allow gas for purification 2. For pre-separation of gas and filtrates 3. Remove particulate nitrate in air by filtration 4. Remove gaseous contaminants from air 5. Achieve high flow air filtration system
F	Rate of filtration	1. Emcompass the use of active enzymes 2. Improve filtration throughput 3. Enlarge contact area 4. Provide wide filtration areas	1. Increase rate of filtration 2. Calculate total interfacial area 3. Estimate flow rate across membrane 4. Cause significant loss of filtration capacity
G	Operating conditions	1. Control of air filtration system 2. Control electric field carried by fly ash 3. Sustaining minimum pressure 4. Increase flux 5. Improve flushing performance 6. Reduction of back flush waste volume 7. Improve small pores and high porosity	1. Neglect actual pore structure and pores 2. Induce strong shear stress 3. Filtration flux 4. Pressure dependency of filtration resistance and porosity 5. Increase pressure drop of filters 6. Increase in turbulence 7. Keep filtration pans horizontal 8. Maintain temperature of fluids 9. Provide negative airflow 10. Deliver very short back pulses

		8. Control regulated high voltage 9. Guide airflow 10. Enable effect of push and pull 11. Have positive pressure 12. Control airflow and heat delivery rate 13. Keep stable 14. Generate pulling effects	to membrane during filtration
H	Multiple-purpose equipment	1. Move patients blood 2. Decompose hardly decomposable harmful substance by means of filtration equipment 3. Dislodge debris 4. Provide heating, ventilation and/or air conditioning of air supply 5. Provide mobile power generation system 6. Provide a unit of HVAC 7. Comprise oxygen-supply-capable cooling water equipment 8. Perform primary and secondary clarification 9. Comprise of disinfection and filtration	1. Detect white spot syndrome virus 2. Auto sampling, pipetting, filtration and dilution of samples and final injection 3. Detect fault conditions 4. Consists of a collector, storage and filtering assembly 5. Comprising filtration medium and grid(preventing channelling) within the filter 6. Supply high voltage DC potential
I	Deterioration	1. Prevent scaling and fouling of equipment 2. Blockage of screens 3. Afford abatement of wear and tear 4. Cast films 5. Results from pad wear,	1. Improve clarification, filtration and scale control of red-mud containing liquor 2. Permeability of membrane 3. Neglect actual pore structure and pores 4. Cause reversibility of fouling

		substrates polishing by products or external contaminants 6. Prevent passage of particles 7. Reduce wear and tear 8. Refurbish screens 9. Prevent plugging of injection wells 10. Generate fines 11. Include scale inhibitors 12. Include honeycombed or lattice porous material 13. Inhibiting the formation of bio-films deposits in membrane separation systems 14. Failure of equipment 15. Generate fines 16. Results in catalyst loss	5. Break up of filaments and colonies 6. Compaction of membrane 7. Cause membrane resistance 8. Determine specific filter cake resistance 9. Include fouling control 10. Avoid blinding of clothes 11. Comprising filtration medium and grid(preventing channelling) 12. Protect membrane filtration system 13. Provide better and smoother aperture size 14. Require large filtration surface 15. Suppress damage of metal filter mesh 16. Attachment of bacteria to spherical surfaces of granular porous medium 17. Surfactant loss Broad range of adhesion affinity
J	Economy	1. Result in reduced maintenance cost, less downtime and longer equipment life 2. Eliminate costly and difficult onsite equipment alterations necessary 3. Require periodic chemical/mechanical cleaning of membrane filtration equipment 4. Require high degree of operator's attendance 5. Require routine	1. Cope with variable hydraulic loads, occupies small footprints and has low maintenance requirements 2. Prolong carbon-filter media's lifetime 3. Economic filtration process 4. Require large amount of technician time 5. Require large filtration surface 6. Reduce filtration cost 7. Improve replacement time of filter clothes 8. Process for cleaning filtration membrane

		maintenance 6. Require relatively large space 7. Use of expensive filtration treatment equipment	
K	Mode of operation	1. Initiate backwashing mode of operation 2. Not utilize vibration 3. Shelter design flexibility, programmability and expandability 4. Include nano-filtration 5. Use ultra filtration film 6. Include bacteriological filters 7. Facilitate solubility of oxygen 8. Solubilize precipitate 9. Dissolve biological and chemically prompting oxidation of substance 10. Include belt filters 11. Process batch of product 12. Include microprocessor 13. Self cleaning drums	1. Improving methods for performing prosthesis conduit for use with living tissues 2. Alter filtration mechanism for pulps containing magnetic particles 3. Performing gel filtration chromatography of proteins 4. Integrate biological degradation of waste water pollutants 5. Re-circulate purified water 6. Employ natural filtration process of surface water 7. Cooling and simultaneous filtration of gas-aerosol fire extinguisher 8. Dead-end filtration of wastewater 9. Allow intermittent membrane filtration 10. Forming multi-walled filtration plate 11. Allow flexible capacity expansion 12. Enable recirculation of water 13. injection 14. Consists of membrane filtration processes and distillation process 15. Have more permeable hollow membranes 16. Development of dot-immunogold filtration assay protocol

			17. Test new hybrid system processes 18. Use novel combination of filtration and selective solubilization 19. Use air-moisture separator 20. Improve ultrafiltration processes 21. Increase reactivity of UV light during filtration 22. Include microprocessors 23. Achieve automated system 24. Adopt self cleaning filters 25. Provide necessary filtration constants 26. Provide better modelling of large scale vacuum drum filter 27. Auto sampling, pipetting, filtration and dilution of samples and final 28. Detect fault conditions 29. Control various zones throughout filtration cycle
L	Applications		1. Employ wide range of membrane filtration 2. Find potential applications of membrane systems 3. Suit for use in a process-scale cross-flow filtration system
M	Operability	1. Disposable filter 2. Ease of interchangeable of disposable filter 3. Reduce required cleaning efficiency 4. Reduce cleaning frequency	1. Facilitate easier detachment of cake 2. Have simple structure 3. Easily disposable filter 4. Facilitate creation of loading maps, monitoring, addition and replacement of fluid filtration device

N	Measurements	1. Compute replacement time 2. Require filter passing times 3. Receive information from customers	1. Comprise measuring device 2. Include multicoloured LED bar graph to indicate voltage potential applied to filtration system 3. Have flow meters and fluid conductivity meters 4. Estimate flow rate across membrane 5. Predict filtration 6. Detect fault conditions 7. Calculate total interfacial area 8. Determine thickness of filtration cake 9. Estimate flow rate across membrane 10. Detect white spot syndrome virus

A summary of the number of problems that appear in each class is given in table 3.

Table 3: Number of problems in each class

Classes	No. in patents	No. in Papers
A	9	9
B	20	25
C	18	11
D	3	4
E	4	5
F	4	4
G	14	10
H	9	6
I	16	17
J	7	8
K	13	29
L	0	3
M	4	4
N	3	10

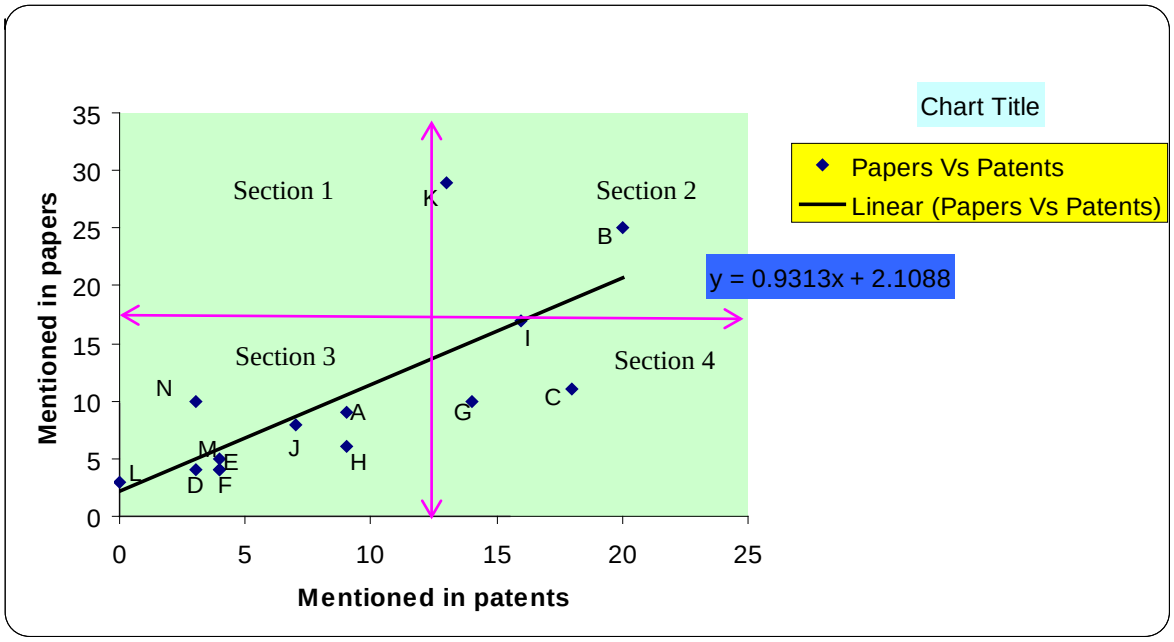

Figure 13: Plot of Number of problems mentioned in papers Vs Number of problems mentioned in patents.

Fig 13 is a plot of the various classed of problems mentioned in scientific papers and patent documents. The chart area is divided into four sections to aid its interpretation. Section 1 comprises of classes of problems that have received high number of citations in scientific literatures and few numbers of citations in patent documents. Classes of problems in section 2 have received high number of citations in both scientific literatures and patent documents. Section 3 consists of classes of problems that have received few number of citations in scientific literatures and high number of citation in patent documents. Classes of problems in section 4 have received low number of citations in scientific literatures and high number of citations in patent documents.

6 VISUALIZATION OF NETWORKS IN SCIENTIFIC PUBLICATIONS

The purpose of this chapter is to introduce a general method to identify and to envisage promising patterns in scientific publications in the field of filtration. This could be done by having a view on how scientific papers are related to each other. This is referred to as citation; a method by which a publication references to another publication. The number of times a particular paper is being cited by other papers indicates the level of development of that field.

Scientific literatures are often characterized by a term called half life. Citation half-life is a term used to denote the number of years from date of publication; it takes a paper to obtain half of its citation [19]. Some papers receive unceasingly high citations [classic articles] while some just receive high citation within a given period of time which is usually short [transient articles].

Promising developments and sudden variation in the scientific literatures could be as a result of internal and external factors. New discoveries and scientific advancement constitute internal causes. External causes are related to events that could compel researchers to investigate on a subject from an entirely new viewpoint.

Another useful term often encountered in citation is research front. A research front comprises of those group of articles that are often cited by researchers in a given discipline. They receive citations unceasingly from present authors working in a given field. In other words, research front could mean the line or direction of research. Study on the trend of citation reveals that the most recently published papers receive the highest number of citations.

Two types of citations were defined in chapter 3. They are bibliographic coupling and co-citation. In review, two documents are related bibliographically if they have cited one or more similar documents in their reference lists. We talk about co-citation when two items, such as authors, documents, or journals, are cited by a publication.

6.1 Network analysis

A network consists of a graph which normally links main object with vertices and lines. The objects in the networks are represented by the node while the vertices and lines link the objects together. Therefore network analysis simply means the analysis of networks.

6.1.1 Social network analysis

Social network analysis (SNA) is a term which identifies the social relationships that exist between objects in a network. Objects in a network may be human beings, groups, organisations, citations, countries or websites. These objects in a network are related in one way or the other which could be in the form of values, vision, social lives, ideas, financial exchange, friendship, sexual relationship, academics etc.

The main goal of a social network analysis is detecting and interpreting patterns of social ties among actors [20]. It would be interesting to note that social network also exist among scientists who work in different fields. Analysis of social networks could involve studying of the entire networks, all the links that specify a given relationship between objects or by studying personal networks, the links that exist between specified people only.

To understand networks and their participants, we evaluate the location of objects in the network. This gives an insight into the various roles individuals play in a network. Some participants in a given network are identified to be:

- Connectors: These are participants that have the highest number of links in a network. They therefore act to link other participants together.
- Mavens: they are participants that are experts in the given field, without them there would be appreciable progress in the network,
- Leader: They are participant that are in the helm of affairs in the network. They take most decisions in the network.
- Bridgers: They act to fill in the gap between different networks and therefore link different networks together.,

The usefulness and importance of a social network to its members depends on the structure of the network. We introduce the concept of strong ties and weak ties

Strong ties exist in small networks and between few participants that have similar information, share similar interest, are in the same profession or occupy the same geographical region. As a result, the network becomes less useful to the participants after a given time because they don't have much more to gain from each other.

Weak ties exist in larger networks. Participants in this kind of network are weakly and socially connected. Therefore, such participants do not have much in common and the information each member acquires is different from the others. As a result, the network provides opportunities for transmission of new ideas between the members and even between networks. Weak ties have generally been identified to disseminate information rapidly. Therefore, it would be more profitable for an individual to be linked with as many networks as possible.

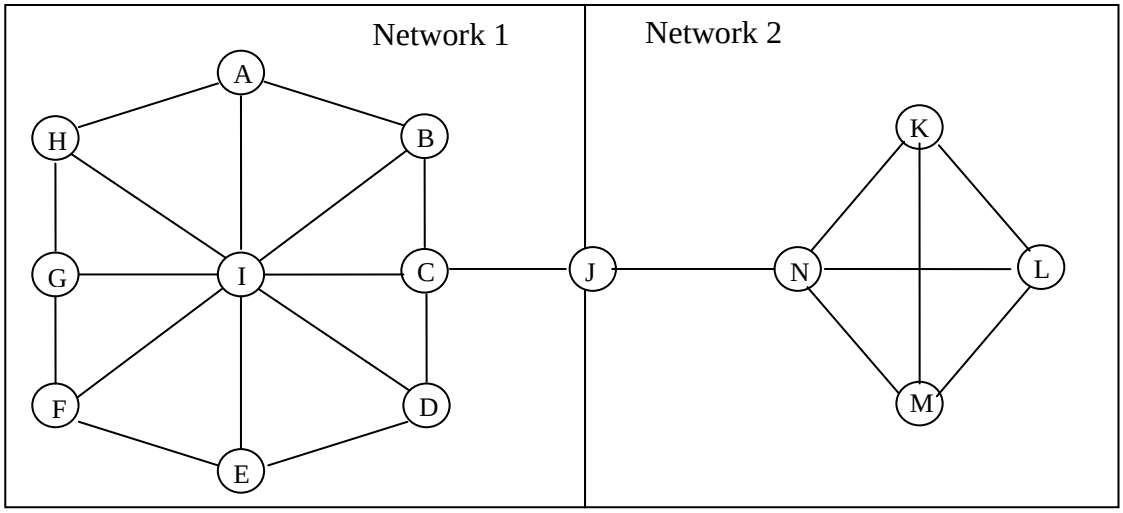

Figure 14: Example of a network

Figure 14 represents two networks 1 and 2 which are linked together. Let nodes A to J represent individuals in the networks. We have to define some terms based on the network in figure 14.

Structural hole: In the network above, individual J belongs to the two networks and therefore acts as a link between them. If individual J does not belong to the two networks, there would not be any relationship between them. In such a situation, a structural hole is said to exist between the networks. Therefore, J is said to be filling the structural hole.

Degree of centrality: Network analyzers often use this term to describe the individual that receives the highest number of direct links from other members of the group. Node "I" in figure 14 has more direct connection than the other members making it the most active in the network. It is a 'connector' or 'hub' in this network.
Analysis of a network does not always depend on how many links an individual has, in most cases, the idea is to find the role of the individuals in the networks. In figure 14, node "I" is only connected to other members in its immediate group. It connects only those who are already connected to each other.

Betweenness centrality: It could be observed from the network above that object J has fewer connections than every member in the network but yet its roles are outstanding in the network. It acts to fill the gap (hole) between the two networks. Without it, there would not be exchange of information between the two networks. Therefore, J is said to have a high betweeness centrality. A node with high betweenness control what flows out and flows in the network.

Closeness centrality: Object C has fewer connections than Object I but it occupies an easily accessible node in the network which allows it to monitor information flow in the networks. Its location allows it to have the shorted direct or indirect link to other members of the network. It is closer to every other member of the two networks.

Network centralization: This is a term used to describe how much the power of a network rests on few individuals. A centralized network has more of its links distributed around few objects in the network while a decentralized network has little variation between the numbers of links each node receives.

The disadvantage of a centralized network is that the success or failure of the network depends only on few members. A highly central node can become a point of target for the failure of the group. A less centralized network is more resistant to failures in event of an attack because the power of the network is distributed evenly amongst the members.

Network accessibility: The links to all the members in a network are not equal. It has been proved by researchers that the shorter the path between members in a network, the more successful the network is. If the network path becomes so long, it would results to ineffective flow of information because the effect of some of the members will not be felt. It is always important in a network for members to know each other. The so-called rule of 150, asserts that the size of a genuine social network is limited to about 150 members (sometimes called Dunbar's number) [21].

Boundary spanners: Nodes that link their members to different networks occupy very important positions in the networks. In the figure 14, nodes C and N are boundary spanners to their networks because their positions are more central in the entire network than other members who are connected locally in their immediate cluster. As a result, boundary spanners receive more information than other members.

Peripheral members: It is often the case that larger networks neglect the information that comes from small networks. Object, K, L, M and N play a very important role in the entire network despite their low centrality scores in the entire network. Their network could be a very vital source of information to the entire network because they could be linked to other networks.

6.1.2 Applications of social network

Researchers working in various academic fields have shown that social networks operate on many levels, from families up to the level of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

Social network has been applied in various disciplines but this study lays more emphasis on the industrial, academic and innovative aspects of its applications.

Social networks have been used to identify the relationship that exists between different units. These units could be institutions, journals, individuals, objects, technologies etc. Social networks offer means of monitoring information flow between various units.

Social networks have been found very vital in the diffusion of innovations. When different networks are linked together, there is efficient and effective flow of new ideas, practices and information between them.

Social networks could be used to identify professionals and key players in a given field. Such networks are helpful to trace the professionals when their ideas and services are needed. They could also be used to find influential leaders in an organisation.

Social networks instigate activeness in project team members due to competition which exist between networks.

Finally, social networks could be a source of information retrieval, investigation of the trends and tracking hot topic in scientific publications. This involves finding the relationship which exists between authors of different scientific articles. Such a relationship is referred to as citation.

6.2 Building and visualizing networks

Many free online computer softwares have been developed to help in the building and visualization of social networks. For the purpose of this work, we will briefly introduce and explain two of such applications.

6.2.1 Pajek

This is free on-line software that was developed by Wouter de Nooy, Andrej Mrvar and Vladimir Batagelj in November 1996. The software is able to analyse and visualize networks that have large number of vertices. These vertices could run into thousands or even millions. With this software, it is possible to locate clusters (groups) in a network, identify and classify vertices that are in the same cluster and represent them

independently, and also demonstrate the relationship between different clusters. The main Pajek interface is shown in figure 15.

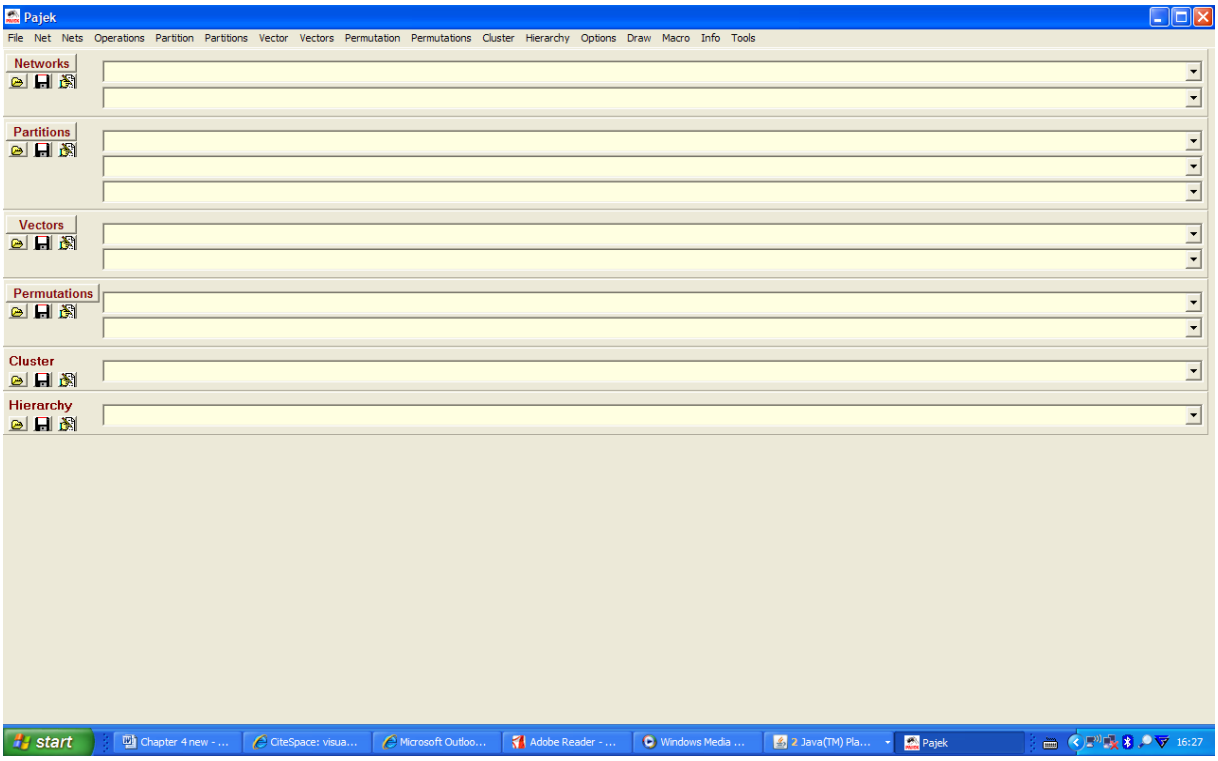

Figure 15: Main Pajek interface.

6.2.1.1 Building network with Pajek

The first thing to do before building a network is to gather the data and information needed to build it. This could be done manually or with the help of software. In this work, the data collection was carried out manually. This involved identifying those groups of scientific papers that either cited each other or that made reference to a particular paper in the field of filtration. These articles were retrieved from Elsevier database. The keyword for the search is “filtration equipment and processes”. More than 2000 articles were retrieved from this search. Due to time constraint, the inter-relationship between all the retrieved articles was not sought for. Emphasis was laid on about 121 articles which inter-relation could easily be identified. The numbers and corresponding titles of these 121 articles are given in appendix IV.

The network was built with the software by applying the necessary commands in Pajek menu bar. Figure 16 represents the network built with the 121 articles.

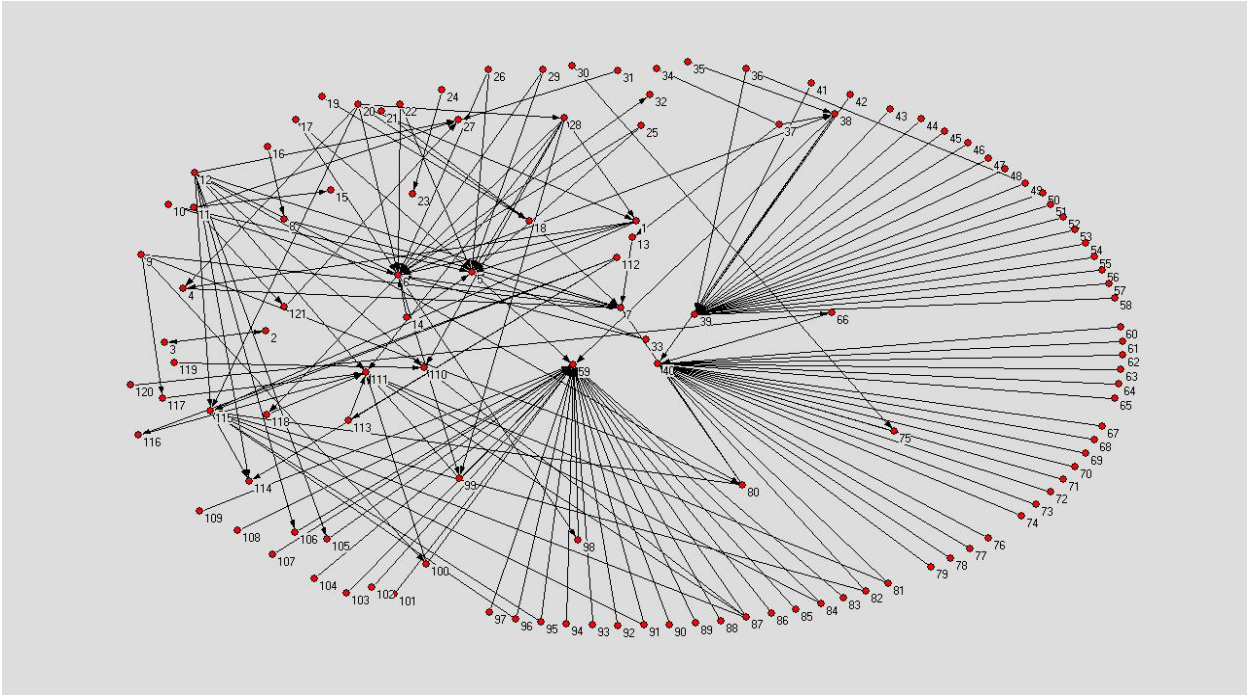

Figure 16: Network of articles built with Pajek.

For detailed information about Pajek and its application, refer to [22]

6.2.2 Citespace

Citespace is another free online Java application for analyzing and visualizing co-citation networks [19]. It was developed by Chaomei Chen in 2004. Its primary goal is to facilitate the analysis of emerging trends in a knowledge domain.

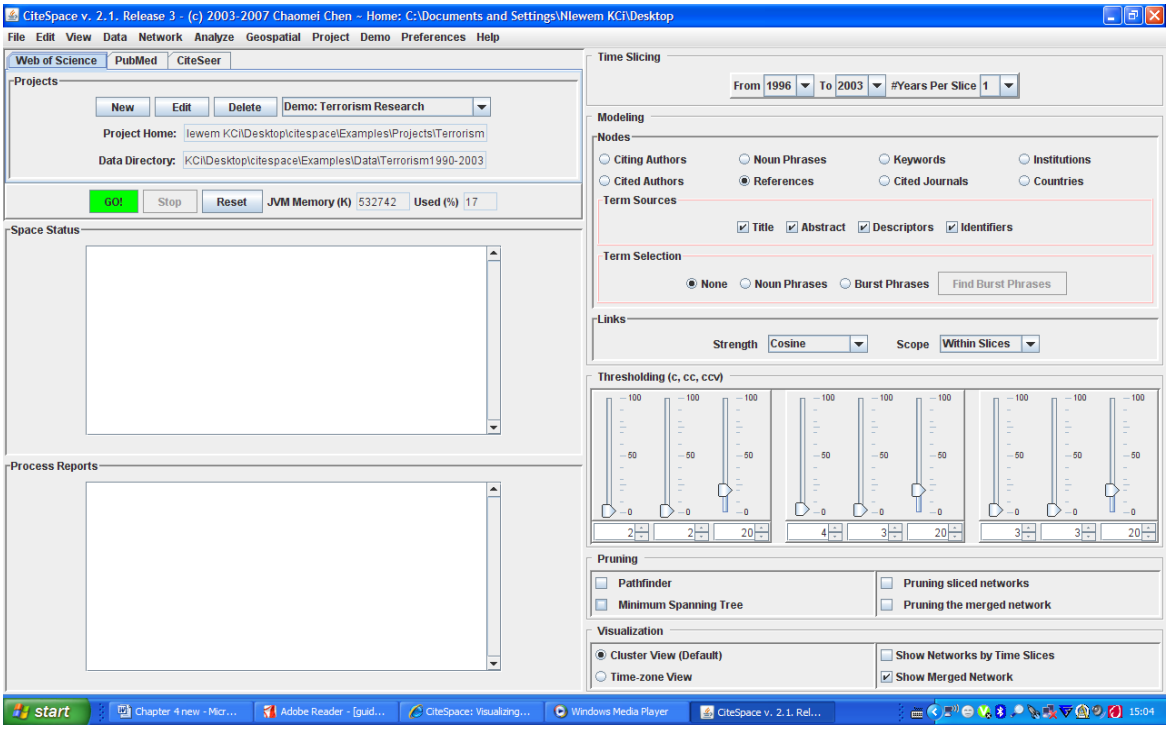

Figure 17: Main Citespace interface.

6.2.2.1 Building network with Citespace

Before Citespace is used for analysis, an input data has to be built. Such data is retrieved from the ISI Web of Science database.

Information used by Citespace in building the network includes authors, title, descriptors, identifiers, abstract, cited references, number of times cited and year of publication.

This information is all found in the bibliographic records of an article.

Citespace is capable of building author co-citation network, document co-citation networks, journal co-citation network, co-author's countries network, co-authorship network, co-occurring keywords and identifiers and noun phrase network

For the purpose of this work, networks of interest are

- Author co-citation network: shows authors that are cited by a publication.
- Document co-citation network: Relates publications that are cited by another publication.

- Co-authorship network: Link authors who appear in the author field of the same bibliographic record.
- Co-occurring keywords and identifiers: Network of most frequent words in publications.

For detailed information on the use of Citespace, refer to [19].

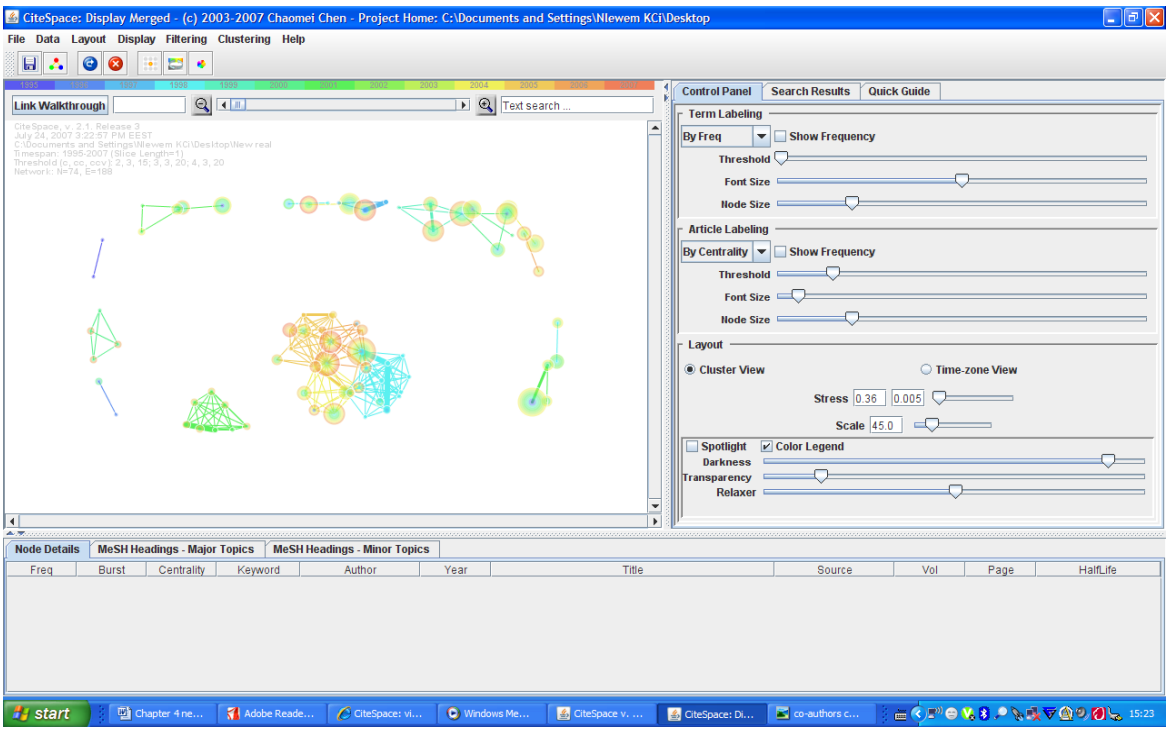

Figure 18: Citespace visualization window.

The networks in appendix V (1) were created at default settings of Citespace. Citespace allows the variation of threshold frequency and time interval. The threshold frequency specifies the number of times articles would be co-cited before they could belong to a given cluster. The time interval specifies the period of time of which the cluster of co-citation is needed.

By gradual lowering the threshold frequency of co-citation the intellectual base grew larger as more articles with lower co-citations were added to the co-citation clusters [19]. Networks of lower threshold frequencies built from the same data are shown in appendix V (2).

7 DISCUSSION

The subject of this work is to build a portfolio of R&D projects in relation to filtration processes. Various ways to obtain information in order to achieve the goal have been discussed. The main sources of ideas and information which this work was based on is patent documents and scientific publications.

The first method which was considered to be a novel approach in achieving the aforementioned objective is the subject-action-object analysis. As discussed in the previous chapters, this method focussed on identifying those problems which were mentioned in patents documents and scientific publications. It is easier to find solutions to specific problems when they are already identified. This approach would save enormous time which would have been spent if trial and error method was adopted in building research portfolios.

Other methods of identifying such problems were also highlighted. Network analysis as a source of getting information was considered in this work. Pajek and Citespace were computer applications used in this work to highlight how information could be obtained from networks of scientific publications.

Pajek is able to build a network of authors and their publication. This social network which exists between authors is important in tracking the line of research in a given field but it only shows the major players in the field of filtration. Of course, such information is important during the development of new technology but it does not actually suggest the problem to be solved. It only becomes more important after the problem has been identified. Advantages of such networks are that they depict major sources of information. As could be seen from figure 15, articles 5, 6, 7, 39, 40, 59 receive the most citations from other articles. This information is very important during information retrieval. A person working on related topics exactly knows which articles to find vital information instead of searching from one article to another thus saving a lot of time.

Citespace on the other hand is also a useful application in detecting and visualizing emerging trends and transient patterns in scientific literatures. Citespace is capable of building many networks but the most interesting is network of keywords. Network of keywords helps to identify a set of hot topics which forms the focus of scientific researchers. Keyword analysis (text mining) may help to identify the most frequently used words or phrases over a given period of time as shown in appendix V(1b).

There are several drawbacks associated with using keyword analysis as a means of detecting research specialities.
Firstly, there is wide range of dissimilar words which may not have coherent meanings. As a result, users of such methods are faced with the task of interpreting the relationships between the words. On the other hand, clusters formed from combinations of such diverse words give varied meanings. It is often important to most users to know the commonly used terms and also terms that would result to new trends in innovation. In most cases, terms that could pave way to the introduction of a new trend could be silenced by a more familiar term. In such networks, there are no explanations how the articles that are connected differ from each other or what they share in common.

Bases on the objective of this work, it would be more promising to address it with the subject-action-object analysis. This analysis would present series of problems which are related to the field in question. These problems would be analysed by experts and hence a conclusion is drawn on which problems that need utmost attention.

7.1 Analysis of results

Table 3 represents classes of problems which were identified in patents documents and scientific publications. A plot of these classes was shown in figure 13. The chart area is divided into 4 sections to ease interpretation of the results.

A critical study of the chat would show the sections that need more investigations. Problems located in sections 2 and 4 have been cited several times in patent documents and therefore numerous efforts have been made to address these problems. Referring to figure 13, problems in classes B, I K, C and G require little or no attention. These

problems have been addressed so many times in patent documents and scientific papers As a result, further investigations on these problems and possibly new solutions would not really make tremendous waves in the industry unless the new solutions are better than the existing ones in terms of economy, precision and operability.

The section that would be most interesting to investigate on is section 3. This is because problems in this section have been cited few times in both scientific literatures and patent documents. There are more possibilities of introducing better solutions to these problems.

Therefore, the classes of problems that could be of interest for R&D projects are listed in table 4 in their order of preference.

Table 4: Preferred classes of problems.

Class	Problem
L	Applications
D	Filtration and purification of solids
F	Rate of filtration
E	Filtration and purification of gases
M	Operability
H	Multi-purpose equipment
J	Economy
A	Filtration and purification of liquids
N	Measurements

The inventors of any technology that would be able to address any of the problems represented in these sections would win the market before other could get into it.

Specific problems that need direct investigations are listed in table 1.These problems have been identified through series of laboratory experiments and mathematical computation but their applications may not have been actualized in real life.

8 CONCLUSION

The purpose of this study is to identify a research portfolio for the development of filtration equipment and processes. It is also required to propose a novel approach of identifying those problems that would form a research portfolio for R&D projects in the field of filtration.

Recent studies have shown that patents and scientific publications hold numerous and vital information that could lead to innovations and inventions in any field. The relationship between patent information and scientific publication helps in knowledge and information diffusion as well as technological inventions.

Based on the content of this work and the results obtained, it could be suggested that one of the promising methods of building research portfolios is the problem identification method in patent documents and scientific papers. This method tries to extract and specifies those problem often encountered in a process which need to be investigated on.

9 RECCOMMENDATIONS

A lot of difficulties were encountered during the course of this work. More comprehensive results would have been obtained if certain conditions have sufficed. Firstly, patent search in filtration processes was supposed to be carried out in all the patent databases. There was restriction in gaining access to other patent databases except the US patent database. It would have been a more comprehensive and reliable results if there were access to other databases.

Secondly, for complete results, more time is needed for this work. The articles were so many and the software could not analyze them directly. Much time was spent organising the articles before the software was able to extract information from them. The software bases its action on the semantics of a sentence (subject-object-action). Therefore, not all the problems generated have real life applications in the industries. Much time is also needed to analyse these problems and find out those that are realistic.

There was restricted access to the full-text version of articles in various sources. Getting the most relevant information from these articles was not possible. Some articles in pdf formats were protected by their authors. As a result, the software could not extract information from them.

There are several possible directions to improve on this topic.
Institutions and research centres should expand their network accessibilities to as many databases as possible. This would help to obtain as much information as the user needs. The more the information extracted, the more there is possibilities of having more solutions to given problems.
There is vast information obtainable from patents and scientific publications. For complete analysis of this information, more time should be allocated to this project

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APPENDICES

Appendix I: Problems mentioned in patents

Table 1: Improvement of filtration of named products

S/N	Problems	Description	Inventors
1.	Pre-treatment of water	An installation may be placed after coagulation, settlement and filtration equipment enabling pre-treatment of water	Gaid Abdelkader; Uyttewaal Mickael; Tazi-pain Annie, "*US Patent 20,060,000,771*: *Water treatment method using an inorganic powder reagent with high specific surface area including a step of recycling said reagent*", Oct 3 2004
2.	Presence of degreased liquid or chemical liquid	Contamination by a degreased liquid or chemical liquid brought in by automobile body or volatilization of a solvent during filtration	Sawada Hidenori; Iijima Hideki; Nishiguchi Shigeo; Kamikado Koji, "*US Patent 20,030,171,473: Cationic electro-deposition coating composition*", Nov 2 1999
3.	Facilitate solubility of oxygen	Enhance oxygen solubility during filtration	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply.capable cooling water equipment and filtration-function-equipped cooling water equipment incorporated with these equipment*" Feb 10 2005
4.	Incorporate raw water pre-filter devices	Including a membrane which prevents flow of contaminants	Haney Harold Ernest; Mogourian Viktor, "*US Patent 20,020,162,803: Apparatus and method for treatment of water*", Nov 7 2002
5.	Recover lithium contained in mother liquor bleed stream	S special means of recovering lithium	Boryta Daniel Alfred; Kullberg Teresita Frianeza; Thurston Anthony Micheal, "*US Patent 20,040,005,267: Production of lithium compounds directly from lithium containing brine*", Jan 8, 2004

6.	Improve filtration of beer	Introduction of a filter aid that help in filtration of beer	Brocheton Sophie; Rahier Georges; Janssens Philippe, "*US Patent 20,050,189,285: Filter aid used in alleviation*", Jan 17 2006
7.	Cause massive hydrogen gas volume	In the event of flow stoppage during filtration, a flow switch failure could cause a massive hydrogen gas volume to accumulate in the filtration equipment and therefore becomes hazardous	Bremauer Ben, "*US patent 20,060,249,400: Electrolysis sanitiser generator*", Nov 9, 2006
8.	Drip untreated water onto a cooling oxidant unit	Using a dripping membrane	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply.capable cooling water equipment and filtration-function-equipped cooling water equipment incorporated with these equipment*" ,Feb 10 2005
9.	Improve colour of crystallized sugar product	Method to improve the colour of crystallized sugar product using lime during the filtration of cane juice	Reisig Richard C; Donovan Michael, "*US Patent 20,020,011,246: Process for production of purified cane juice for sugar manufacture*" ,Jan 31 2002
10.	Improve air quality	Improving the air quality using an air filtration equipment	Anderson James; Stoll Alexander; Loch; Thomas, "*US Patent 20,060,045,641: Machining system with integrated chip hopper*" March 2, 2006
11.	Separate plasma and plasma components	Separation of plasma components	Nip Raymond Lee, "*US Patent 20,050,187,508: Optimized hollow fiber membranes*" Aug 14 2003
12.	Improve filtration of paint	Enhance filtration of paints	Yamane Tsuyoshi, "*US Patent 20,020,000,191: Recycling system of aqueous paint*" Jan 3, 2002
13.	Separate aromatic dicarboxylic acid crystals	Method of separating aromatic dicarboxylic acid crystals from mother liquor at temperature below the boiling point of the solvent	Lin Robert; O'Meadhra Ruairi Seosamh; Kingsport Ronald Buford, "*US Patent 20,020,193,630: Process for the production of purified*

			terephthalic acid", Dec 19 2002
14.	Purification of aqueous cyclodextrin	Invention comprises a process of forming a purified cyclodextrin solution by contacting cyclodextrin with an activated carbon absorbent, an ion exchange resin or membrane filtration equipment	Wood Willard E; Beaverson neil J; Lawonn Phillip A; Huang Xiaoyan, "*US Patent 20,030,232,208: Reducing concentration of organic materials with substituted cyclodextrin compound in polyester packaging materials*", Dec 18 2003
15.	Controlling the operation of sanitation system of spa	A method of controlling the operation of filtration system of a spa or other body of fluid including filtration components, activation and deactivating the filtration system components on a cyclic basis and controlling the timing of said activating and deactivating	Collins Jeffrey W, "*US patent 20,020,108,913: Timing of spa water treatment*", Nov 23 2006
16.	Disperse untreated water	A method of using dripping water membrane to drip untreated water in order to disperse the untreated water is introduced©	Miyamoto Hisashi; Nakano Akira. "*US Patent 20,050,029,176: Oxygen-supply-capable cooling water equipment and filtration-function equipped cooling Presence of degreased liquid or chemical liquid water equipment incorporated with these equipment*" Feb 10 2005
17.	Solubilize precipitate	The invention introduces a method of solubilizing precipitates formed in a filtration equipment by bringing it into contact with a suitable solution without physical manipulation©	Ristol Debart Pere; Rabaneda Gimenez Francisco; Lopez Hernandez Ma Teresa, "*US Patent 20,020,151,688: Process for the production of virus-inactivated human gammaglobulin*" Oct 2, 1999
18.	Encompasses the use of active enzymes	Use of active enzymes in porous support in filtration equipments©	Ackerman Eric; Liu Jun, "*US Patent 20,040,106,178: Proteins in a porous support*", June 3 2004
19.	Filter air	Introduces an air filtration system	Baten Robert Allen; Austin Kenneth Robert, "*US Patent 20,030,057,704: Mobile power generation unit*" ,March 27, 2003

20.	Produce minute amount of fullerene in squalane after filtration	Introduces a method of reducing the amount of fullerene conatained in squalane (improves health)	Hirata Yoshihiro; Ueda Yoshio; Takase Hiroaki, "*US Patent 20,030,113,315: Squalane containing ultra fine particles of burning residue of carbon and method for producing the same*" June 9, 2003
21.	Contain oil mist and chip	Contain oil mist and chip without the need for coolant filtration equipment and air filtration	Anderson James; Stoll Alexander; Loch; Thomas, "*US Patent 20,060,045,641: Machining system with integrated chip hopper*", March 2, 2006
22.	Control of air filtration system	Improve air control during filtration of air	Anderson James; Stoll Alexander; Loch; Thomas, "*US patent 20,060,045,641: Machining system with integrated chip hopper*", March 2, 2006
23.	Move patient's blood	A filtration system that generates actuating pressure that helps circulate patient's blood	Weaver Karla; Culhane Jim, "*US Patent 20,040,267,185: Pressure actuated valve with improve biasing member*", "*US patent 20,050,027,261: Pressure actuated valve with improved slit configuration*", Feb 3, 2005
24.	Control electric field carried by fly ash	To enhance the operation of electrostatic precipitators or filtration equipment	Jone Rogers H JR, "*US Patent 20,030,106,467: Cement, reduced-carbon ash and controlled mineral formation using sub-and supercritical high velocity free-jet expansion into fuel-fired combustor fireball*", June 12, 2003
25.	Achieve good filtration of cane juice for sugar	Introduction of large amount of lime helps to achieve good filtration of cane juice	Reisig Richard C; Donovan Michael, "*US Patent 20,020,011,246: Process for production of purified cane juice for sugar manufacture*" ,Jan 31, 2002
26.	Recover ferrate	Recovering of ferrate from liquid	Minevski Zoran; Maxey Jason;

	salts from solutions	by magnetic means	Nelson Carl; et al, "*US Patent 20,040,166,040: Electrochemical method and apparatus for producing and separating ferrate(VI) compounds*" Aug 26, 2004
27.	Minimize accumulation of ozone	Introduces a method to reduce ozone accumulation during air filtration	Helt Robert W; Vendt Stephen J; Boydstum Roger L; Hagan J. Mark, "*US Patent 20,070,039,462: Air filtration system control*" , Feb 22, 2007
28.	Remove high polymer	Method of using ultra filtration film to remove high polymer materials in water	Mukogawa Yasukazu; Hama Masaharu, "*US Patent 20,020,134,722: Ultra water producing apparatus*", Sept 26, 2002
29.	Suitable for separation and purification of gas	Obtaining a compact, functional gas separation system	Bikson Benjamin; Bartholomew Scott Andrew; Giglia Salvatore, "*US Patent 20,020,162,455: Hollow fiber membrane gas separation cartridge and gas purification assembly*", Nov 7, 2007
30.	Reduce Odour in air	Cleaning of air during filtration	Lin Chin-Liang, "*US Patent 20,030,232,592: Air curtain apparatus for ophthalmological inspection instrument*" Dec 18, 2003
31.	Produce technical grade lithium carbonate	Introduces a method of producing a high quality of lithium carbonate from lithium containing brine	Boryta Daniel Alfred; Kullberg Teresita Frianeza; Thurston Anthony Micheal, "*US patent 20,040,005,267:Production of lithium compounds directly from lithium containing brine*", Jan 8, 2004
32	Reduce Alkalinity		US Patent 20,050,011,832 "*Water desalination process using ion selective membranes*"

Table 2: Filtration operational problems

1.	Sustaining minimum pressure	Maintaining the normal pressure required during filtration	Tucker Jeffrey C.; Andersen Brian L.; Mittelstadt Robert, "*US Patent 20,020,117,214: Fluid flow control system, fluid delivery and control system for a fluid delivery line, and method for controlling pressure oscillations within fluid of a fluid delivery line*", May 2,2002
2.	Improvement of filtration properties of porous multilayered hollow fibers	Porous multilayered hollow fibers are composed of porous tubes such as polytetrafluoroethylene which are used in filtration equipment for solid-liquid separation treatement in food, pharmacy and environmental preservation.	Morita Tooru; Ida Kiyoshi; Funatsu Hajime, "*US patent 20,040,118,772: porous multilayered hollow fiber and filtration module, and method of manufacturing porous multilayered hollow fiber*", June 3, 2004
3.	Afford abatement of wear and tear,	Reduction of back flush and cleaning frequency helps to reduce the wear and tear on the equipment	Harris James Jeffrey; Harris James William, "*US Patent 20,040,000,515: Filter Back-flushing reaction chamber apparatus*", Jan 1 2003
4.	Improve filtration disk cleaning efficiency	Method to improve cleaning efficiency to avoid wear and tear of the equipments	Harris James Jeffrey, "*US Patent 20,060,144,768: Filtrate immersed activation assembly for disk filters", "US Patent 20,040,000,515: Filter back flushing reaction chamber apparatus*", July 6 2006
5.	Increase flux	Increase the filtration flux	Sengupta Arup K.; Li Ping; Murray Brendan J., "*US Patent 20,070,039,895: Process for treating concentrated salt solutions containing doc*", Feb 22,2007
6.	Improve flushing performance	Enhance the flushing performance of the filters during cleaning	Harris James Jeffrey, "*US Patent 20,060,144,768: Filtrate immersed activation assembly for disk filters*", July 6, 2006
7.	Reduction of back	Helps to reduce wear and tear	Harris James Jeffrey; Harris James

	flush waste volume		William, "*US patent 20,060,144,768: Filtrate immersed activation assembly for disk filters*", July 6, 2006
6.	Prevent catalyst attrition	Catalyst attrition breaks the catalyst into fines and blocks the filtration scrrens	Balan Prakash, "*US Patent 20,040,179,983: Multiphase reactor design incorporating filtration system for a fixed-bed catalyst*", Sept 16, 2004
7.	Reduce required cleaning efficiency	A method that does not need frequent cleaning of the equipment	Harris James Jeffrey, "*US Patent 20,060,144,768: Filtrate immersed activated assembly for disk filters*", July 6, 2006
8.	Improve filtration efficiency	Enhance filtration performance	Takahashi Osamu; Ogasawara Kunio, "*US Patent 20,040,191,674: Chemical amplification resist composition*", June 30, 2005
9.	Improve filtration properties	Enhance filtration properties of the products	Takahashi Osamu; Ogasawara Kunio, "*US Patent 20,040,191,674: Chemical amplification resist composition*", June 30 2005
10.	Improve filtration throughput	Increase in the quantity of filtrate per unit time	Harris James Jeffrey; Harris James William, "*US patent 20,060,144,768: Filtrate immersed activation assembly for disk filters*", June 6, 2006
11.	Blockage of screens	A method that helps to keep the screen open all the time	Ferro Larry S.; O'Brien Stephen C.; Camin Henry J.; Wright BruceM, "*US Patent 20,020,096,473: Potato wastewater treatment method*" June 4 , 2004
12.	Prevent scaling and fouling of equipments	Avoid deposition of particles on the walls of the equipment	Kepner Bryan; Mintz Eric, "*US Patent 20,060,219,641: Anti-microbial compositions and methods of making and using same*", Oct 5 2006
13.	Improve small	Achieve tiny pores on the filter	Morita Tooru; Ida Kiyoshi; Funatsu

	pores and high porosity	media and hence high porosity	Hajime, "*US Patent 20,040,118,772: Porous multilayered hollow fiber and filtration module, and method of manufacturing porous multilayered hollow fiber*" June 3, 2004
14.	Cast films	Reduced tendency towards gelation by a copolymer during film casting and other solution applications	Wille Roice Andrus; Burchill Michael T. "*US Patent 20,030,11,614: Copolymers of vinylidene fluoride and hexafluoropropylene having reduced extractable content and improved solution clarity*", April 6, 2000
15.	Result from pad wear, substrate polishing by-products or external contaminants	Particles that result from wear and tear may reduce filtration efficiency	James David B; Budinger William D.; Robert John; Et al, "*US Patent 20,020,020,495: Apparatus and method for chemical-mechanical polishing of semiconductor wafers*", Feb 21, 2002
16.	Cause Failure of equipment	Irregular replacement of filters reduces the effectiveness of filtration equipment and may cause failure of the equipment	Seibert Roy E, "*US Patent 20,020,062,221: Distribution and notification system and method for filter replacement cartridges*", May 23, 2002
17.	Control regulated high voltage power supply, voltage and current monitoring circuit, input signal filtering circuit.	Invention provides a control system which includes a microprocessor for controlling a regulated high voltage power supply, voltage and current monitoring circuits, input signal filtering circuits connected to the microprocessor and to signal circuit connected to a thermostat for a unit of HVAC equipment	Helt Robert W; Vendt Stephen J; Boydstum Roger L; Hagan J. Mark, "*US Patent 20,050,284,622: Dynamic fluid delivery system with compensation*", Feb 22, 2007
19.	Decompose hardly decomposable harmful substances by	A membrane system has been developed to decompose hardly decomposable harmful substances from wastewater.	Suzuki Motoshi; Kawabata Takahiro; Miyamoto hideo et al, "*US patent 20,060,226,083: Method of treating wastewater containing*

	means of filtration equipment		*hardly decomposable harmful substances*" Jan 2, 2001
20.	Guide airflow	Guide airflow in a slit-lamp microscope to remove the hazardous germs and odour contained in the air exhaled by a patient.	Lin Chin-Liang, "*US Patent 20,060,045,641: Machining system with integrated chip hopper*" , Dec 18, 2003
21.	Dislodge debris	Invention consists of combination of scrapping and milling operations carried out at the same time which helps to remove any debris from the walls of a filtration equipment	Howlett Paul David; Telfer George, "*US Patent 20,040,011,528: Combined milling and scraping tool*", July 28,2002
22.	Result in evolution of carbon dioxide gas	Evolution of CO_2 during filtration of some substances lead to unwanted foam generation which dry on the walls of the filtration equipment and cause blockage	Williams Neal, "*US Patent 20,050,256,252: Aqueous dispersions of polyurethane-addition polymer hybrid particles especially for use in coating compositions*" ,Nov 17, 2005
23.	Results in catalyst loss	Attrition of catalyst during filtration produces fines which cause blockage and hence catalyst loss	Balan Prakash, "*US Patent 20,040,179,983: Multiphase reactor design incorporating filtration system for fixed-bed catalyst*", Sept 16, 2004
24.	Prevent passage of particles	Introduced method to prevent passage of specific sized particles in a filtration equipment	Cort Steven L. "*US Patent 20,030,082,084: Methods for removing heavy metals from water using chemical precipitation and filed separation methods*", May 1, 2003
25.	Enable effect of push and pull	Introduces a method to effectively remove the air exhaled from the ophthamological patient	Lin Chin-Liang, "*US Patent 20,030,232,592: Air curtain apparatus for ophthalmological inspection instrument*" Dec 18, 2003
26.	Result in reduced maintenance cost, and less downtime	A method to reduce the cost of maintenance, downtime, and longer equipment life is introduced in filtration equipments.	Hamza Hassan H. "*US Patent 20,060,260,034: Electromechanical safety valve system for swimming pool and spa pumps*" ,Nov 23, 2006

27.	Improve effectiveness of filtration	Introduces methods of improving performance of membranes	Seibert Roy E., "*US Patent 20,020,062,221: Distribution and notification system and method for filter replacement cartridges*", "*US Patent 20,070,039,895: Process for treating concentrated salt solution containing doc*", May 23, 2002
28.	Reduce engine output noise	Introduces an exhaust silencer to reduce the noise generated during filtration	Baten Robert Allen; Austin Kenneth Robert, "*US Patent 20,030,057,704: Mobile power generation*", March 27, 2003
29.	Reduce wear and tear	Suggest methods of reducing wear and tear of filtration equipments reduction in cleaning frequency	Harris James Jeffrey, "*US Patent 20,060,144,786: Filtrate immersed activation assembly for disk filters*", July 6, 2006
30.	Have positive pressure	Ensure a positive pressure above the membrane	MacMillan David S, "*US Patent 20,010,035,379: Method for treating coating formulations*" ,Nov 1 2001
31.	Control of airflow and heat delivery rate	Control of air flow during filtration of air	Bias Larry Stephen; Field Jay Ernest; Salvage Scott Anthony; et al, "*US Patent 20,070,039,472: Air filtration system*", Feb 22, 2007
32.	Refurbish screens	Introduces a method of repairing and refurbishing worn-out screens	Cook Gordon James; Hughes Andrew; Bailey Arthur Robert; et al, "*US Patent 20,020,096,470: Filtering screen and support frame thereof*" ,July 25, 2002
33.	Prevent plugging of injection wells	Avoid blockage of injection wells	Balan Prakash, "*US patent, 20,040,179,983: Multiphase reactor design incorporating filtration system for fixed-bed catalyst*", Sept 16, 2004
34.	Remove sub-micron sized particles	Introduces a method for removal of sub-micron sized particles using microfiltration	Cort Stephen L. "*US Patent 20,050,258,103: Methods for removing heavy metals from water using chemical precipitation and field separation methods*" Nov 24,

			2005

Table 3: Improvement of filtration equipments

S/N	Problem	Description	Inventorss
1.	Initiate Backwashing mode of operation	Introduce a back washing mode operation in filtration equipments.	Hamann Knud; Hamann Holger, "*US Patent 20,040,159,599: Installation for the removal and deactivation of organisms in the ballast water*", Aug 19, 2004
2.	Not utilize vibration	A filtration system that does not utilize vibration but may utilize pressure or other means of filtration	Tueshaus Ruediger; McGrenera Patrick, "*US Patent 20,050,014,429: Wire mesh panel and method", "US Patent 20,050,072,744: Filtering screen support construction and methods*", Jan 20 2005
3.	Shelter design flexibility, programmability and expandability	Introduction of a controller in a system helps affords shelter design flexibility, programmability for easy incorporation of shelter operation changes, and expansibility for easy incorporation of new sensors, advanced user interfaces, power sources and air filtration equipment	Garcia-Ortiz Asdrubal, "*US Patent 20,050,09,753: Apparatus for monitoring and controlling an isolation shelter and providing diagnostic and prognostic information*", March 3, 2005
4.	Compute replacement time	Using information received from customers to compute a replacement time for the filter and contact the customer in one or more different ways at the right time	Seibert Roy E, "*US patent 20,020,062,221: Distribution and notification system and method for filter replacement cartridges*", May 23, 2002
5.	Dissolve biologically and chemically prompting oxidation of substances	The invention introduces a method of handling systems that are prone to biological and chemical oxidation of substances that are dissolved by dissolving oxygen efficiently into circulating water	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply-capable cooling water equipment and filtration-function-equipped cooling water equipment incorporated with these*

			equipment", Feb 10, 2005
6.	Ensure safe environment	This invention introduces a modular air filtration unit with a disposable filter which can be changed easily without leakage	Tilley Greg A, "*US patent 20,060,230,730: Modular air purification unit*", Oct 10, 2000
7.	Exert effect of suction	This introduces air suction and cleaning device connected to an air suction device.	Lin Chin-Liang, "*US Patent 20,030,232,592: Air curtain apparatus for ophthlmological inspection instrument*" ,Dec 18, 2003
8.	Enlarge contact area	Method introduces a system of enlarged contact area between water and air	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply.capable cooling water equipment and filtration-function-equipped cooling water equipment incorporated with these equipment*", Feb 10 2005
9.	Generate fines	Prevention of catalyst attrition which may cause them to break up into fines and hence block the filtration screens.(C)	Balan Prakash, "*US patent 20,050,165,216: Process and systems for recovery of Peptides*" ,Sept 16, 2004
10.	Have layer of over-layed element of elastically deformable material	A method for the removal and deactivation of organisms in the ballast water is introduced	Hamann Knud; Hamann Holger, "*US patent 20,040,159,599: Installation for the removal and the deactivation of organisms in the ballast water*" ,Aug 19, 2004
11.	Have part of exhaust silencing system to reduce noise	Reduces the noise output of a mobile power generating system	Baten Robert Allen; Austin Kenneth Robert; "*US Patent 20,030,057,704: Mobile power generation unit*", March 27, 2003
12.	Include belt filters	Incorporation of belt filters in a filtration system	Micco Daniel J; Hinchey Richard J, "*US Patent 20,030,050,219: Zeolites and zeolite mixture having enhanced cation exchange properties*", March 13, 2003
13.	Include scale	Include anti-microbial	Kepner Bryan; Mintz Eric, "*US*

	inhibitors	compositions and scale inhibitors	*Patent 20,060,219,641: Anti-microbial compositions and methods of making and using the same*", Oct 5, 2006
14.	Comprise honeycombed or lattice porous material	For enlargement of contact areas between air and water	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply.capable cooling water equipment and filtration-function-equipped cooling water equipment incorporated with these equipment*" Feb 10, 2005
15.	Include microprocessor	microprocessor for controlling a regulated high voltage power supply	Helt Robert W.; Vendt Stephen J.; Boydstum Roger L.; et al , "*US patent 20,070,039,462: Air filtration system control*", Feb 22 2007
16	Include Nanofiltration	Incorporating a filtration system with nanofiltration	Wood Willard E.; Beaverson Neil J.; Lawonn Phillip A.; et al, "*US Patent 20,030,232,208: Reducing concentration of organic materials with substituted cyclodextrin compound in polyester packaging material*", Dec 18, 2003
17.	Keep stable	Keeping the operating conditions of a filtration equipment stable	Iijima Hideki; Kamikado Koji; Shimoda Masaharu; et al, "*US Patent 20,060,009,593: Polyaddition compound and cationic electrodeposition paint which contains polyaddition compound*", Jan 12, 2006
18.	Meet sanitation requirement	Filtration systems that meets the required sanitation conditions	Collins Jeffrey W, "*US Patent 20,060,049,112: Coolant fluid cleaning method, system and apparatus*", Aug 15, 2002
19.	Disposable filtration unit	Introduction of an easily disposable filtration unit	Straeffer Gregory; Yavorsky David P.; DeCoste Leonard D. JR; et al , "*US Patent 20,050,279,695: Disposable integral filter unit*", Dec

			22, 2005
20.	Perform Depyrogenation/sterilization of stainless steel filtration equipment	Introduces a method of Depyrogenation/sterilization of stainless steel filtration equipment	Niklas Thorsten; Wechs Friedbert; Nothdurft Annekatrin, "*US Patent 20,010,006,160: Shaped objects for pyrogen retension and processes for their manufacture*", July, 2001
21.	Perform detoxification	Introduced a method of using active enzymes to perform detoxification	Ackerman Eric; Liu Jun, "*US Patent 20,040,106,178: Proteins in a porous support*", June 3, 2004
22.	Process batch of product	Introduces a batch filtration disposable system	Kossik John Micheal; Delys Jeff F., "*US patent 20,020,008,061: Disposable rotary drum filter*", Jan 24, 2002
23.	Treat noxious fumes	Introduces a process that treat noxious fumes that are generated during filtration	Santelli Thomas Robert, "*US patent 20,040,071,902: Biocide containing laminate as tape or packaging material", "US Patent 20,040,197,504: Laminate sheeting for pouches*", April 15 2004
24.	Prepare a wet cake of pigment	Introduces a method of obtaining a wet cake of pigments by washing crystals with tetrahydrofuran during filtration	Toda Naohiro; Niimi Tatsuya; "*US Patent 20,060,105,255: Electrophotographic image forming apparatus"*, May 18, 2006
25.	Generate pulling effects	A system that generates a pulling effect during filtration especially in the filtration of air exhaled to the atmosphere by a patient	Lin Chin-Liang, "*US Patent 20,030,232,592: Air curtain apparatus for ophthalmogical inspection instrument*", Dec 18, 2003
26.	Provide wide filtration area	Using filtration equipment that provides high filtration area for low temperature and high viscous fluids	Ishikawa Kenichi; Yokoi Keizou; Takeuchi Kosuke; et al , "*US Patent 20,060,073,088: High purity phosphoric acid and method for production thereof*", April 6, 2006
27.	Provide heating, ventilation and/or air conditioning	An air filtration system that conditions, heats the air and filtration of airborne toxic agents	Laiti Peter J., "*US Patent 20,040,058,637: Environmental control unit, and air handling*

	of air supply	and all in a single unit	*systems and methods using same*", March 25, 2004
28.	Provide mobile power generation system	A mobile power generation system comprising of air filtration system	Baten Robert Allen; Austin Kenneth Robert, "*US Patent 20,030,057,704: Mobile power generation system*", March 27, 2003
29.	Provide a unit of HVAC	Includes a unique intense field dielectric air filtration system	Bias Larry Stephen; Field Jay Ernest; Salvage Scott Anthony; et al, "*US Patent 20,070,039,472: Air filtration system*", Feb 22 2007
30.	Draw liquid through membrane	Positive pressure helps to draw liquids through membrane	MacMillan David S., "*US Patent 20,010,035,379: Methods for treating coating formation*", Nov 1, 2001
31.	Remove hazardous germ	Introduces methods of removing hazardous germs in an air filtration system	Lin Chin-Liang, "*US Patent 20,030,232,592: Air curtain apparatus for ophthalmological inspection instrument*", Dec 18 2003
32.	Remove residual solid impurities	Removal of residual solid impurities from the oligomeric products of first stage of hydrolysis	Sirek Milan; Jirousek jaroslav, "*US Patent 20,030,032,840: Method of chemical recycling of polyethylene terephthalate waste*" ,Feb 13, 2003
33.	Eliminates costly and difficult onsite equipment alterations necessary	Introduces a method to eliminate the costly and difficult onsite equipment alterations necessary for facilitating filtration changes	Harris James Jeffrey; Harris James William, "*US patent 20,040,000,515: Filter back-flushing reaction chamber apparatus*", Jan 1 200
34.	Require large amount of solvents and large filtration equipment	Some filtration methods require large amount of solvent and large filtration equipment	Schottek Joerg; Paczkowski Nicola Stefanie; Winter Andreas; et al, "*US Patent 20,050,239,979: Metallocene ligands, metallocene compounds and metallocene catalyst, their synthesis and their use for the polymerization of olefins*", Oct 27, 2005
35.	Require periodic chemical/mechanical cleaning of	Periodic cleaning of filtration plants lead to shutting down of the plants	Pitts M. Micheal JR; Romo Rodrigo F.V, "*US Patent 20,040,173,451: Capacitive electrostatic process for*

	membrane filtration equipment		*inhibiting the formation of biofilm deposits in membrane separation system*", Sept 9, 2004
38.	Require High degree of operator attendance	Some filtration systems require high degree of attension by the operators	Kossik John Micheal; Delys Jeff F., "*US patent 20,020,008,061:, Disposable rotary drum filter*", Jan 24, 2002
39.	Require routine maintenance	Filtration systems require routine maintenance	Seibert Roy E, "*US Patent 20,020,062,221: Distribution and notification system and method for filter replacement cartridges*", May 23, 2002
40.	Require relatively large space	Some filtration units require large space	Beretta David III, "*US Patent 20,050,133,456: System and method for in-well aeration*" ,June 23, 2005
41.	Require filter passing times	Introduces a method to measure the time for a liquid to pass through a filter	Adachi Kouichi; Koyata Minoru; Kubota Atsushi, "*US Patent 20,040,174,405: Ink evaluation method,ink and ink jet unit*", Sept 9, 2004.
42.	Use ultra filtration film	Using an ultrafiltration film in a pressure filtration equipment for affecting filtration according to the size of the molecules, its capable of removing polymers	Mukogawa Yasukazu; Hama Masaharu, "*US Patent 20,020,13,722: Ultrapure water producing apparatus*", Sept 26, 2002
43.	Use of expensive filtration treatment equipment	Some filtration processes require the use of expensive equipments	Umezawa Hiroyuki; Iseki Masahiro; Tsuihiji motoyuki, "*US Patent 20,060,231,472: Waste water treatment equipment*", Oct 19, 2006
44.	Receive information from customers	Receive information from customers related to a filter of filter system and use this information to compute a replacement time for the filter	Seibert Roy E, "*US patent 20,020,062,221: Distribution and notification system and method for filter replacement cartridges*" ,May 23, 2002
45.	Comprise oxygen-supply-capable cooling	Filtration equipment with an oxygen supply	Miyamoto Hisashi; Nakano Akira, "*US Patent 20,050,029,176: Oxygen-supply-capable cooling*

	water equipment		*water equipment and filtration-function-equipped cooling water equipment incorporated with these equipment*", Feb 10, 2005
46.	Ease of interchange of disposable filter in an air filtration unit	Easily interchangeable and disposable filters	Anderson James; Stoll Alexander; Loch; Thomas, "*US patent 20,060,045,641: Machining system with integrated chip hopper*" ,March 2, 2006
47.	Include bacteriological filters	Incorporates bacteria filters in filtration equipments	Heyer Toni; Swan Dale G; Chudzik Stephen J., "*US Patent 20,050,281,857: Methods and reagents for preparing biomolecule-containing coating*", Dec 22, 2005
49	Perform primary and secondary clarification	Achieving several stages of filtration in one equipment	Straeffer Gregory; Yavorsky David P.; DeCoste Leonard D. JR; et al , "*US Patent 20,050,279,695: Disposable integral filter unit*", Dec 22, 2005
50.	Disposable filter	Introduce a filter which is easily disposable	Kossik John Micheal; Delys Jeff F. "*US patent 20,020,008,061: Disposable rotary drum filter*", Jan 24
51.	Provide more efficient disc filtration service	Introduce a disk filter that gives better filtration	Harris James Jeffrey; Harris James William, "*US Patent 20,030,178,350: Integral Valve filter*", Sept 25 2003
52.	Provide a unit of HVAC(high voltage alternating current)		Helt Robert W; Vendt Stephen J; Boydstum Roger L; Hagan J. Mark, "*US Patent 20,050,284,622: Dynamic fluid delivery system with compensation*", Feb 22, 2007
53.	Inhibiting the formation of biofilm deposits in membrane separation	Biofilms deposited on the membrane reduces its effectiveness	Pitts M. Micheal JR; Romo Rodrigo F.V., "*US Patent 20,040,173,451: Capacitive electrostatic process for inhibiting the formation of biofilm deposits in membrane separation*

	systems		*system*", Sept 9 2004
54.	Self cleaning drum filter	Introduces a filter that could clean itself	Kossik John Micheal; Delys Jeff F. "*US patent 20,020,008,061: Disposable rotary drum filter*", Jan 24

Appendix II: Problems mentioned in scientific papers

Table 1: Problems related to filtration of named products

S/N	Problem	Authors
1.	Allow gas for purification	Li Yang, James E. Braun and Eckhard A. Groll "The impact of evaporator fouling and filtration on the performance of packaged air conditioners", International Journal of Refrigeration, Volume 30, Issue 3, May 2007, Pages 506-514
2.	Allow for rapid filtration of large volumes of polyol dispersion	S.P.J. van Leeuwen and J. de Boer, "Extraction and clean-up strategies for the analysis of poly- and perfluoroalkyl substances in environmental and human matrices" Journal of Chromatography A, Volume 1153, Issues 1-2, 15 June 2007, Pages 172-185
3.	Determination of red cell filterability in leucocyte-free suspensions of washed erythrocytes	S. Baar, "A convenient and reproducible filtration technique for the determination of erythrocyte deformability", Burns, Volume 16, Issue 5, October 1990, Pages 385-389
4.	Effective separation of toxin from large culture volume of corynebacterium diphtheriae vaccine strain	Bheeman Sundaran, Chitrambalam Palaniappan, Yarlagadda Udaya Bhaskara Rao Et al, "Tangential flow filtration technology applicable to large scale recovery of diphtheria toxin", Journal of Bioscience and Bioengineering, Volume 94, Issue 2, 2002, Pages 93-98
5.	Molten metal filtration	Z. Taslicukur, C. Balaban and N. Kuskonmaz "Production of ceramic foam filters for molten metal filtration using expanded polystyrene", Journal of the European Ceramic Society, Volume 27, Issues 2-3, 2007, Pages 637-640
6.	Cake filtration of cellulose fibers	Nadine Oschmann, Long D. Nghiem and Andrea I. Schäfer "Fouling mechanisms of submerged ultrafiltration membranes in grey water recycling", Desalination, Volume 179, Issues 1-3, 10 July 2005, Pages 215-223
7.	Fast filtration of diluted honey samples	Pascale M. Lutier and Bernard E. Vaissière "An improved method for pollen analysis of honey", Review of Palaeobotany and Palynology, Volume 78, Issues 1-2, 1 July 1993, Pages 129-144 27
8.	Refining and concentrating the agricultural antibiotic in aqueous solutions	Cai Bang-Xiao, Lang Kong-Min, Liu Yu-Rong and Chen Yi-Ming "The refinement and concentration of agricultural antibiotic A in aqueous solution using membrane processes",

		Desalination, Volume 62, 1987, Pages 341-351
9.	Convert airborne radicals and ozones to harmless by-products	Takayuki Kameda, Koji Inazu, Yoshiharu Hisamatsu, Norimichi Takenaka and Hiroshi Bandow "Isomer distribution of nitrotriphenylenes in airborne particles, diesel exhaust particles, and the products of gas-phase radical-initiated nitration of triphenylene", Atmospheric Environment, Volume 40, Issue 40, December 2006, Pages 7742-7751
10.	Detect white spot syndrome virus	Xiaojie Wang, Wenbin Zhan and Jing Xing "Development of dot-immunogold filtration assay to detect white spot syndrome virus of shrimp", Journal of Virological Methods, Volume 132, Issues 1-2, March 2006, Pages 212-215
11.	Give required clarity to beer, ciders, wines, and bottled waters	Ken Sutherland "Opinion: Optimizing product quality", Filtration & Separation, Volume 43, Issue 5, June 2006, Pages 31-33
12.	Improving filtration performance of a slurry containing crystallized wax, de-waxed oil and de-waxing solvent	Ken Southerland, "Bulk chemical filtration in the bulk chemical industry", Filtration & Separation, Volume 44, Issue 4, May 2007, Pages 15-17
13.	Improving gypsum slurry filtration	Dr MP Sukumaran, Tilting pan filters – the industrial work-horses of filtration, Filtration & Separation, Volume 43, Issue 10, December 2006, Pages 28-30
14.	Facilitate easier detachment of cake	Richard J. Wakeman "Separation technology for sludge dewatering", Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619
15.	Filter fabrics	Richard J. Wakeman "Separation technology for sludge dewatering", Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619
16.	Improving method for performing prosthesis conduit for use with living tissues	S. Ramtani "Steady diffusion of an ideal fluid through a pre-stressed and reinforced hollow conduit subjected to combined finite deformations", International Journal of Solids and Structures, Volume 44, Issues 14-15, July 2007, Pages 4819-4829
17.	Improve clarification, filtration and scale control of red-mud	A. Agrawal , K. K. Sahu and B. D. Pandey "Solid waste management in non-ferrous industries in India", Resources,

	containing liquors	Conservation and Recycling, Volume 42, Issue 2, September 2004, Pages 99-120
18.	Alter filtration mechanisms for pulps containing magnetic particles	J. L. Watson and P. L. Gardner "Multi-force dewatering for magnetic waste materials", Minerals Engineering, Volume 8, Issues 1-2, January-February 1995, Pages 191-200
19.	Performing gel filtration chromatography of proteins	Florence Dalle Ore , El Hassan Ajandouz, Thierry Giardina and Antoine Puigserver "The membrane-bound basic carboxypeptidase from hog intestinal mucosa", Biochimica et Biophysica Acta (BBA) - Biomembranes, Volume 1421, Issue 2, 15 October 1999, Pages 234-248
20.	Increase rate of water removal	Nicholas Beier, David Sego, Rob Donahue and Kevin Biggar "Laboratory investigation on freeze separation of saline mine waste water", Cold Regions Science and Technology, Volume 48, Issue 3, June 2007, Pages 239-247
21.	Efficient utilization of protein	Yu Cao, Qi Zhang, Chao Wang, Yuanyuan Zhu and Gang Bai "Preparation of novel immunomagnetic cellulose microspheres via cellulose binding domain-protein A linkage and its use for the isolation of interferon α-2b", Journal of Chromatography A, Volume 1149, Issue 2, 18 May 2007, Pages 228-235
22.	Effective removal of organic and inorganic contaminants and biological materials from municipal/industrial waste waters	Won-Young Ahn, Moon-Sun Kang, Seong-Keun Yim and Kwang-Ho Choi, "Advanced landfill leachate treatment using an integrated membrane process", Desalination, Volume 149, Issues 1-3, 10 September 2002, Pages 109-114
23.	Removal of iron hydroxide completely from water	Birgit Daus, Wolf von Tümpling, Rainer Wennrich and Holger Weiss "Removal of hexafluoroarsenate from waters", Chemosphere, Volume 68, Issue 2, June 2007, Pages 253-258
24.	For pre-separation of gas and filtrates	Richard J. Wakeman "Separation technologies for sludge dewatering", Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619
25.	Evaluate uranium removal efficiency from drinking water.	Oliver Raff and Rolf-Dieter Wilken, "Removal of dissolved uranium by nanofiltration", Desalination, Volume 122, Issues 2-3, 7 July 1999, Pages 147-150
26.	Integrate biological degradation of wastewater pollutants	A. Pollice, C. Giordano, G. Laera, D. Saturno and G. Mininni "Physical characteristics of the sludge in a complete retention membrane bioreactor", Water Research, Volume 41, Issue

		8, April 2007, Pages 1832-1840
27.	Selective separation and total recovery of hydroxytyrosol, water and organic substances	Claudio Russo "A new membrane process for the selective fractionation and total recovery of polyphenols, water and organic substances from vegetation waters (VW)" , Journal of Membrane Science, Volume 288, Issues 1-2, 1 February 2007, Pages 239-246
28.	Purify unfiltered raw water	Jaeshin Kim, Wei Shi, Yeping Yuan and Mark M. Benjamin "A serial filtration investigation of membrane fouling by natural organic matter", Journal of Membrane Science, Volume 294, Issues 1-2, 15 May 2007, Pages 115-126
29.	Provide facile means to improve phosphate removal capacity of biomass based stormed water	Thomas L. Eberhardt, Soo-Hong Min and James S. Han, "Phosphate removal by refined aspen wood fiber treated with carboxymethyl cellulose and ferrous chloride", Bioresource Technology, Volume 97, Issue 18, December 2006, Pages 2371-2376
30.	Re-circulate purified water	F.C. Motta, M.M Siqueira, A.K. Lugon, S.M. Straliotto, S.B. Fernandes and M.M. Krawczuk "The reappearance of Victoria lineage influenza B virus in Brazil, antigenic and molecular analysis", Journal of Clinical Virology, Volume 36, Issue 3, July 2006, Pages 208-214
31.	Recover peak of protein and associated aggregates, hydrophobic proteins or hydrophobic peptides	E. Marti, L. Mara, J.I. Marti, T. Muiño-Blanco and J.A. Cebrián-Pérez "Seasonal variation in antioxidant enzyme activity in ram seminal plasma", Theriogenology, Volume 67, Issue 9, June 2007, Pages 1446-1454
32.	Reduce infiltration of dust	Emad A. Khorshid and Aly M. Nawwar "Review of the effect of sand dust and filtration on automobile engine wear", Wear, Volume 141, Issue 2, January 1991, Pages 349-371
33.	Remove interfering bicarbonate anions by means of single filtration step	Sanjay P. Kamble, Sneha Jagtap, Nitin K. Labhsetwar, Dilip Thakare, Samuel Godfrey, Sukumar Devotta and Sadhana S. Rayalu "Defluoridation of drinking water using chitin, chitosan and lanthanum-modified chitosan", Chemical Engineering Journal, Volume 129, Issues 1-3, 1 May 2007, Pages 173-180
34.	Employ natural filtration process of surface water	Bernhard Wett, Hannes Jarosch and Kurt Ingerle "Flood induced infiltration affecting a bank filtrate well at the river", Journal of Hydrology, Volume 266, Issues 3-4, 15 September

		2002, Pages 222-234
35.	Cooling and simultaneous filtration of gas-aerosol fire extinguishing mixture	M. A. de las Heras, A. Valcarcel, C. Furnus, L. Pérez, D. Moses and H. Baldassarre "Changes in sperm-bound amidase activity suggest subtle damage to ram sperm acrosomes by freezing/thawing, not detected by light microscopy", Animal Reproduction Science, Volume 45, Issues 1-2, 2 December 1996, Pages 81-89
36.	Method for purifying aquaculture water	Santosh Kumar Sarkar, Mahua Saha, Hideshige Takada, Asokkumar Bhattacharya, Pravakar Mishra and Badal Bhattacharya "Water quality management in the lower stretch of the river Ganges, east coast of India: an approach through environmental education", Journal of Cleaner production, Volume 15, Issue 16, November 2007, Pages 1559-1567
37.	Dead-end filtration of wastewate	I. le Roux, H.M. Krieg, C.A. Yeates and J.C. Breytenbach "Use of chitosan as an anti-fouling agent in a membrane bioreactor", Journal of Membrane Science, Volume 248, Issues 1-2, 15 February 2005, Pages 127-136
38.	Improve solid and COD effluent quality	Anthony Bennet, "Wastewater treatment: green technologies rise to the bait", Filtration & Separation, Volume 43, Issue 7, September 2006, Pages 12-17
39.	Remove gaseous contaminants from air	Lars D. Hylander, Hans Sollenberg and Håkan Westas "A three-stage system to remove mercury and dioxins in flue gases", The Science of The Total Environment, Volume 304, Issues 1-3, 20 March 2003, Pages 137-144
40	Remove insoluble matter from crude ester product	T.Y. Wu, A.W. Mohammad, J. Md. Jahim and N. Anuar "Palm oil mill effluent (POME) treatment and bioresources recovery using ultrafiltration membrane: Effect of pressure on membrane fouling", Biochemical Engineering Journal, Volume 35, Issue 3, 1 August 2007, Pages 309-317
41	Remove particulate nitrate in air by filtration	Martyn V. Twigg "Role of catalytic oxidation in control of vehicle exhaust emissions", Catalysis Today, Volume 117, Issue 4, 15 October 2006, Pages 407-418
42.	Improve wine filtration	S. Gergely, E. Bekassy-Molnar and Gy. Vatai "Use of multiobjective optimization to improve wine filtration", Journal of Food Engineering, Volume 58, Issue 4, August 2003, Pages 311-316

Table 2: Operational problems

S/N	Problem	Authors
1.	Permeability of membrane	E. Lanzarone, P. Liani, G. Baselli and M.L. Costantino "Model of arterial tree and peripheral control for the study of physiological and assisted circulation" *Medical Engineering & Physics, Volume 29, Issue 5, June 2007, Pages 542-555*
2.	Neglect actual pore structure and pores	Scott A. Bradford, Saeed Torkzaban and Sharon L. Walker "Coupling of physical and chemical mechanisms of colloid straining in saturated porous media" *Water Research, Volume 41, Issue 13, July 2007, Pages 3012-3024*
3.	Broad range of adhesion affinity	Nathalie Tufenkji "Modelling microbial transport in porous media: Traditional approaches and recent developments", Modeling microbial transport in porous media: Traditional approaches and recent developments *Advances in Water Resources, Volume 30, Issues 6-7, June-July 2007, Pages 1455-1469*
4.	Surfactant loss	Monica A. James-Smith, Kile Alford and Dinesh O. Shah "A novel method to quantify the amount of surfactant at the oil/water interface and to determine total interfacial area of emulsion" *Journal of Colloid and Interface Science, Volume 310, Issue 2, 15 June 2007, Pages 590-598*
5.	Allow intermittent membrane filtration	Xia Huang, Yaobin Meng, Peng Liang and Yi Qian "operation conditions of membrane filtration reactor coupled with photocatalytic oxidation" *Separation and Purification Technology, Volume 55, Issue 2, 15 June 2007, Pages 165-172*
6.	Allow only water	M. Rzechowicz and R.M. Pashley "The effect of degassing on the efficiency of reverse osmosis filtration", *Journal of Membrane Science, Volume 295, Issues 1-2, 31 May 2007, Pages 102-107*
7.	Cause reversibility of fouling	Z. Geng, E.R. Hall and P.R. Bérubé "Membrane fouling mechanisms of membrane enhanced biological phosphorus removal process", *Journal of Membrane Science, Volume*

		296, Issues 1-2, 15 June 2007, Pages 93-101
8.	Break up of filaments and colonies	Allegra A. Cangelosi, Nicole L. Mays, Mary D. Balcer, Euan D. Reavie et al,"The response of zooplankton and phytoplankton from North American great lakes to filtration", *Harmful Algae, Volume 6, Issue 4, August 2007, Pages 547-566*
9.	Calculate total interfacial area	Monica A. James-Smith, Kile Alford and Dinesh O. Shah "A novel method to quantify the amount of surfactant at the oil/water interface and to determine total interfacial area of emulsion" *Journal of Colloid and Interface Science, Volume 310, Issue 2, 15 June 2007, Pages 590-598*
10.	Calculate level of reduction achieved by filtration	Michael R. Templeton, Robert C. Andrews and Ron Hofmann "Removal of particle-associated bacteriophages by dual-media filtration at different filter cycle stages and impact on subsequent UV disinfection", *Water Research, Volume 41, Issue 11, June 2007, Pages 2393-2406*
11.	Estimate flow rate across the membrane	Mohd Hafez Mohd Isa, Diego Esteban Coraglia, Richard A. Frazier and Paula Jauregi "Recovery and purification of surfactin from fermentation broth by two-step untrafiltration process", *Journal of Membrane Science, Volume 296, Issues 1-2, 15 June 2007, Pages 51-57*
12.	Compaction of membrane	M. Kallioinen, M. Pekkarinen, M. Mänttäri, J. Nuortila-Jokinen and M. Nyström "comparism of the performance of two different regenerated cellulose untrafiltration membranes at high filtration pressure", *Journal of Membrane Science, Volume 294, Issues 1-2, 15 May 2007, Pages 93-102*
13.	Cause significant loss of filtration capacity	M. Kallioinen, M. Pekkarinen, M. Mänttäri, J. Nuortila-Jokinen and M. Nyström "comparism of the performance of two different regenerated cellulose untrafiltration membranes at high filtration pressure", *Journal of Membrane Science, Volume 294, Issues 1-2, 15 May 2007, Pages 93-102*
14.	Cause membrane resistance	Z. Geng, E.R. Hall and P.R. Bérubé "Membrane fouling mechanisms of membrane enhanced biological phosphorus removal process", *Journal of Membrane Science, Volume*

		296, Issues 1-2, 15 June 2007, Pages 93-101
15.	Induce strong shear stress	Z. Geng, E.R. Hall and P.R. Bérubé "Membrane fouling mechanisms of membrane enhanced biological phosphorus removal process", *Journal of Membrane Science, Volume 296, Issues 1-2, 15 June 2007, Pages 93-101*
16.	Filtration flux	Sze Sze Chin, Tuti Mariana Lim, Ken Chiang and Anthony Gordon Fane "Factors affecting the performance of low pressure submerged membrane photo catalytic reactor" *Chemical Engineering Journal, Volume 130, Issue 1, 15 May 2007, Pages 53-63*
17.	Pressure dependency of filtration resistance and porosity	M.J. Venter, N.J.M. Kuipers and A.B. de Haan "Modelling and experimental evaluation of high pressure expression of cocoa nibs", *Journal of Food Engineering, Volume 80, Issue 4, June 2007, Pages 1157-1170*
18.	Determine specific filter cake resistance	Soo-Khean Teoh, Reginald B.H. Tan and Chi Tien "A new procedure for determining specific filter cake resistance from filtration data" *Chemical Engineering Science, Volume 61, Issue 15, August 2006, Pages 4957-4965*
19.	Determine thickness of filtration cake	Y.M.J. Chew, W.R. Paterson and D.I. Wilson "Fluid dynamic gauging: a new tool to study deposition on porous surfaces", *Journal of Membrane Science, Volume 296, Issues 1-2, 15 June 2007, Pages 29-41*
20.	Ensure effective filtration	Guoren Wang, Xiangmin Zhou, Bin Wang, Baiyou Qiao and Donghong Han "A hyperplane based indexing technique for high dimensional data", *Information Sciences, Volume 177, Issue 11, 1 June 2007, Pages 2255-2268*
21.	Include fouling control	Sze Sze Chin, Tuti Mariana Lim, Ken Chiang and Anthony Gordon Fane "Factors affecting the performance of low-pressure submerged membrane photocatalytic reactor" *Chemical Engineering Journal, Volume 130, Issue 1, 15 May 2007, Pages 53-63*
22.	Increase pressure drop of filters	R.S. Barhate and Seeram Ramakrishna "Nanofibrous filtering media: Filtration problems and solutions from tiny material" , *Journal of Membrane Science, Volume 296, Issues 1-2, 15 June 2007, Pages 1-8*

23.	Enhance effectiveness of filtration	Allegra A. Cangelosi, Nicole L. Mays, Mary D. Balcer, Euan D. Reavie et al "The response of zooplankton and phytoplankton from North American great lakes to filtration", *Harmful Algae, Volume 6, Issue 4, August 2007, Pages 547-566*
24.	Enhance fractional efficiency	R.S. Barhate and Seeram Ramakrishna "Nanofibrous filtering media: Filtration problems and solutions from tiny material", *Journal of Membrane Science, Volume 296, Issues 1-2, 15 June 2007, Pages 1-8*
25.	Increase in turbulence	Tung-Wen Cheng and Li-Nan Li "Separation and purification technology: Gas-sparging cross flow ultrafiltration in flat-plate membrane module", *Separation and Purification Technology, Volume 55, Issue 1, 15 May 2007, Pages 50-55*
26.	Avoid blinding of clothes	Richard J. Wakeman "Separation technology for sludge dewatering", *Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619*

Table 5: Filtration operational problems

Table 3: Improvement of filtration equipment

S/N	Problems	Authors
1.	Forming multi-walled filtration plate	Tsukasa Akasaka, Fumio Watari, Yoshinori Sato and Kazuyuki Tohji "Apatite formation on carbon nanotubes", *Materials Science and Engineering: C, Volume 26, Issue 4, May 2006, Pages 675-678*
2.	Allow flexible capacity expansion	T.C. Michael Law and Ian D "Numerical modelling of tight fitting flexible liner in damaged sewer under earth loads", *Tunnelling and Underground Space Technology, Available online 27 February 2007*
3.	Enable recirculation of water	Carlos E. Mariano-Romero, Víctor H. Alcocer-Yamanaka and Eduardo F. Morales "Multi-objective optimization of water-using systems", *European Journal of Operational Research, Volume 181, Issue 3, 16 September 2007, Pages 1691-1707*
4.	Detect fault condition	Takumi Inoue, Atsuo Sueoka, Hiroyuki Kanemoto, Satoru Odahara and Yukitaka Murakami "Detection of minute signs of a small fault in a periodic or a quasi-periodic signal by the

		harmonic wavelet transform" , *Mechanical Systems and Signal Processing, Volume 21, Issue 5, July 2007, Pages 2041-2055*
5.	Auto-sampling, pipetting, filtration and dilution of samples and final injection	V. Diamantis, P. Melidis and A. Aivasidis "Continous determination of volatile products in anaerobic fermenters by online capillary gas chromatography", *Analytica Chimica Acta, Volumes 573-574, 28 July 2006, Pages 189-194*
6.	Consist of a collector, storage and filtering assembly	E. Lanzarone, P. Liani, G. Baselli and M.L. Costantino "Model of arterial tree and peripheral control for the study of physiological and assisted circulation", *Medical Engineering & Physics, Volume 29, Issue 5, June 2007, Pages 542-555*
7.	Consists of membrane filtration processes and distillation process	K. Azrague, P. Aimar, F. Benoit-Marquié and M.T. Maurette "A new combination of a membrane and a photocatalytic reactor for the depollution of turbid water", *Applied Catalysis B: Environmental, Volume 72, Issues 3-4, 30 March 2007, Pages 197-204*
8.	Control various zones throughout filtration cycle	Brent L. Lewis and William M. Landing "The investigation of dissolved and suspended-particulate trace metal fractionation in the Black Sea", *Marine Chemistry, Volume 40, Issues 1-2, November 1992, Pages 105-141*
9.	Find potential applications of membrane systems	Attila Rektor and Gyula Vatai "Membrane filtration of mozzarella whey", *Desalination, Volume 162, 10 March 2004, Pages 279-286*
10.	Facilitate creation of loading maps, monitoring, addition and replacement of fluid filtration devices	Claude Portier, Liliane Dondon and Marianne Grunberg-Manago "Translational autocontrol of the *Escherichia coli* ribosomal protein S15", *Journal of Molecular Biology, Volume 211, Issue 2, 20 January 1990, Pages 407-414*
11.	Facilitate operation of solid filtration processes	Q. Gan, S. J. Allen and G. Taylor "Design and operation of an integrated membrane reactor for enzymatic cellulose hydrolysis", *Biochemical Engineering Journal, Volume 12, Issue 3, December 2002, Pages 223-229*
12.	Rehabilitation of granular media filter boxes	Gil F. Crozes, Dan Hugaboom, Tom Seacord, Vincent Roquebert and Jean Michel Espenan "New options for achieving regulatory compliance with low-pressure membranes" *Desalination, Volume 144, Issues 1-3, 10 September 2002, Pages 151-156*

13.	Comprising filtration medium (filtering water) and grid (preventing channelling) within the filter	Z. Yang, X.F. Peng, Ming-Yuan Chen, Duu-Jong Lee and J.Y. Lai "Intra-layer flow in fouling layer on membranes", *Journal of Membrane Science, Volume 287, Issue 2, 15 January 2007, Pages 280-286*
14.	Have more permeable hollow membranes	K. Kneifel, S. Nowak, W. Albrecht, R. Hilke, R. Just and K.-V. Peinemann "Hollow fiber membrane contactor for air humidity control: Modules and membranes", *Journal of Membrane Science, Volume 276, Issues 1-2, 1 May 2006, Pages 241-251*
15.	Have simple structure	Yuichi Hashimoto and Olaf Karthaus "Preparation of an ordered array of cyanine complex microdomes by a simple dewetting method", *Journal of Colloid and Interface Science, Volume 311, Issue 1, 1 July 2007, Pages 289-295*
16.	Comprise measuring devices	J. Barker ,"In-situ measurement of the thickness changes associated with cycling of prismatic lithium ion batteries based on $LiMn_2O_4$ and $LiCoO_2$", *Electrochimica Acta, Volume 45, Issues 1-2, 30 September 1999, Pages 235-242*
17.	Include multicoloured LED bar-graph display to indicate voltage potential applied to filtration system	Yoshinobu Tanaka "Mass transport and energy consumption in ion-exchange membrane electrodialysis of seawater", *Journal of Membrane Science, Volume 215, Issues 1-2, 15 April 2003, Pages 265-279*
18.	Contain natural fibers and flocculants	Riccardo A. A. Muzzarelli "Chitin and its derivatives:New trend os applied research", *Carbohydrate Polymers, Volume 3, Issue 1, 1983, Pages 53-75*
19.	Achieve high flow air filtration system	Bob Mcilvaine "Opinion: Air pollution – the next generation" *Filtration & Separation, Volume 43, Issue 8, October 2006, Pages 18-20*
20.	Include microprocessors	A. S. Merlin "Latest developments and future prospects of power system operation and control", *International Journal of Electrical Power & Energy Systems, Volume 16, Issue 3, June 1994, Pages 137-139*
21.	Development of dot-immunogold filtration assay protocol	Xiaojie Wang, Wenbin Zhan and Jing Xing "Development of dot-immunogold filtration assay to detect white spot syndrome virus of shrimp", *Journal of Virological Methods, Volume 132, Issues 1-2, March 2006, Pages 212-215*

22.	Adopt integrated filtration process	Seong-Keun Yim, Won-Young Ahn, Geon-Tae Kim, Gi-Won Koh, Jaeweon Cho and Seung-Hyun Kim "Pilot-scale evaluation of an integrated membrane system for domestic wastewater reuse on islands", *Desalination, Volume 208, Issues 1-3, 5 April 2007, Pages 113-124*
23.	Keep filtration pans horizontal	MP Sukumaran Nair "Tilting pan filters-the industrial work-horse of filtration", *Filtration & Separation, Volume 43, Issue 10, December 2006, Pages 28-30*
24.	Improve replacement time of filter cloth	M. I. Picollo, E. Seccacini, C. Vassena and E. Zerba "Feeding and mating deterrence by sulfhydryl reagents in Triatoma infestans", *Acta Tropica, Volume 52, Issue 4, January 1993, Pages 297-307*
25.	Achieve automated system	Douglas A. Spicer, Lisa R. Booth, Karin A. Hughes, Robert J. Kaiser and Amy L. Springer "A Fully Automated Process Using a Magnetic Particle Based Kit for Removal of Dye Terminators from Sequencing Reactions", *Journal of the Association for Laboratory Automation, Volume 6, Issue 2, 1 May 2001, Pages 63-66*
26.	Cope with variable hydraulic loads, occupies a small footprint and has low maintenance requirements	Anthony Bennett "Waste water treatment:green technologies rise to the bait", *Filtration & Separation, Volume 43, Issue 7, September 2006, Pages 12-17*
27.	Adopt self-cleaning fibers	"Self cleaning filter for process fluids and water systems", *Filtration & Separation, Volume 34, Issue 2, March 1997, Page 114*
28.	Generate bio destruction	N. I. Vykhodtseva, K. Hynynen and C. Damianou "Pulse duration and peak intensity during focused ultrasound surgery: Theoretical and experimental effects in rabbit brain in vivo", *Ultrasound in Medicine & Biology, Volume 20, Issue 9, 1994, Pages 987-1000*
29.	Yield drier filter cakes	MP Sukumaran Nair "Tilting pan filters-the industrial work-horse of filtration", *Filtration & Separation, Volume 43, Issue 10, December 2006, Pages 28-30*
30.	Produce concentrated fractions	Kenji Morimoto, Chang-Su Park, Motofumi Ozaki, Kei Takeshita, Tsuyoshi Shimonishi, Tom Birger Granström, Goro Takata, Masaaki Tokuda and Ken Izumori "Large scale production of D-allose from D-psicose using continuous

		bioreactor and separation system", *Enzyme and Microbial Technology, Volume 38, Issue 6, 1 April 2006, Pages 855-859*
31.	Protect membrane filtration systems	Anthony Bennett "Wastewater treatment: Green technologies rise to the bait", *Filtration & Separation, Volume 43, Issue 7, September 2006, Pages 12-17*
32.	Prolong carbon-filter media's lifetime	Richard J. Wakeman "Separation technologies for sludge dewatering", *Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619*
33.	Easily disposable filter	"Small scale continuous cake filtration using the disposable rotary drum filter", *Filtration & Separation, Volume 40, Issue 9, November 2003, Pages 26-27*
34.	Maintain temperature of fluid	Nicolas Alvarez, Geneviève Gésan-Guiziou and Georges Daufin "the role of surface tension of re-used caustic soda on the cleaning efficiency in dairy plants", *International Dairy Journal, Volume 17, Issue 4, April 2007, Pages 403-411*
35.	Cause harmful downstream particle emission	Xavier Simon, Sandrine Chazelet, Dominique Thomas, Denis Bémer and Roland Régnier "Experimental study of pulse jet cleaning of bag filters supported by rigid rings", *Powder Technology, Volume 172, Issue 2, 20 March 2007, Pages 67-81*
36.	Provide negative airflow	Andrew H. Liu "something old, something new: indoor endotoxin, allergens and asthma", *Paediatric Respiratory Reviews, Volume 5, Supplement 1, January 2004, Pages S65-S71*
37.	Provide necessary filtration constants	R. G. Holdich "Solid-liquid separation equipment selection and modelling", *Minerals Engineering, Volume 16, Issue 2, February 2003, Pages 75-83*
38.	Provide better modelling of large scale vacuum drum	Small scale continuous cake filtration using the disposable rotary drum filter", *Filtration & Separation, Volume 40, Issue 9, November 2003, Pages 26-27*
39.	Provide smother and finer aperture size	Richard J. Wakeman "Separation technologies for sludge dewatering", *Journal of Hazardous Materials, Volume 144, Issue 3, 18 June 2007, Pages 614-619*
40.	Collect Micron-sized particles	A.M. Squires "Granular-bed filtration assisted by filter cake formation: Advanced design for panel-bed filtration and gas treating", *Powder Technology, Volume 155, Issue 1, 13 July 2005, Pages 74-84*

41.	Remove airborne contaminants	Zoe Grainge "Food and beverage production", *Filtration & Separation, Volume 44, Issue 2, March 2007, Pages 16-19*
42.	Economic filtration process	M. Gómez, F. Plaza, G. Garralón, J. Pérez and M..A. Gómez "A comparative study of tertiary wastewater treatment by physico-chemical-UV process and macrofiltration–ultrafiltration technologies", *Desalination, Volume 202, Issues 1-3, 5 January 2007, Pages 369-376*
43.	Have flow meters and fluid conductivity meters	A. S. Merlin "Latest developments and future prospects of power system operation and control", *International Journal of Electrical Power & Energy Systems, Volume 16, Issue 3, June 1994, Pages 137-139*
44.	Process for cleaning a filtration membrane	G. Gésan-Guiziou, N. Alvarez, D. Jacob and G. Daufin "Cleaning-in-place coupled with membrane regeneration for re-using caustic soda solutions" , *Separation and Purification Technology, Volume 54, Issue 3, 1 May 2007, Pages 329-339*
45.	Require large amount of technician time	Douglas A. Spicer, Lisa R. Booth, Karin A. Hughes, Robert J. Kaiser and Amy L. Springer "A Fully Automated Process Using a Magnetic Particle Based Kit for Removal of Dye Terminators from Sequencing Reactions", *Journal of the Association for Laboratory Automation, Volume 6, Issue 2, 1 May 2001, Pages 63-66*
46.	Require large filtration surfaces	MP Sukumaran Nair "Tilting pan filters-the industrial work-horse of filtration", *Filtration & Separation, Volume 43, Issue 10, December 2006, Pages 28-30*
47.	Suit for use in a process-scale cross-flow filtration system	M.S. El-Bourawi, Z. Ding, R. Ma and M. Khayet "A framework for better understanding membrane distillation separation process", *Journal of Membrane Science, Volume 285, Issues 1-2, 15 November 2006, Pages 4-29*
48.	Supply high voltage DC potential	Rupesh M. Bande, B. Prasad, I.M. Mishra and Kailas L. Wasewar "Oil field effluent water treatment for safe disposal by electroflotation", *Chemical Engineering Journal, Available online 8 May 2007,*
49.	Suppress damage of metal filter mesh	John P. A. Neeft, Michiel Makkee and Jacob A. Moulijn "Diesel particulate emission control", *Fuel Processing Technology, Volume 47, Issue 1, April 1996, Pages 1-69*
50.	Test efficacy of filtration machine	M.C. Cammarota and D.M.G. Freire "A review on hydrolytic enzymes in the treatment of waste water with high oil and

		grease content", *Bioresource Technology, Volume 97, Issue 17, November 2006, Pages 2195-2210*
51.	Test new hybrid process	V. Mavrov, S. Stamenov, E. Todorova, H. Chmiel and T. Erwe "New hybrid electrocoagulation membrane process for removing selenium from industrial wastewater", *Desalination, Volume 201, Issues 1-3, 30 November 2006, Pages 290-296*
52.	Deliver very short back pulses to the membrane during filtration	Rishi Sondhi and Ramesh Bhave "Role of backpulsing in fouling minimization in crossflow filtration with ceramic membranes", *Journal of Membrane Science, Volume 186, Issue 1, 15 May 2001, Pages 41-52*
53.	Use novel combination of filtration and selective solubilization	Orla M. J. Flynn, Ian S. Blair and David A. McDowell "A novel rapid procedure for the isolation of outer membrane proteins from Campylobacter jejuni", *Journal of Microbiological Methods, Volume 21, Issue 1, January 1995, Pages 61-66*
54.	Employ wide range of membrane processes	Ken Southerland "Bulk chemical filtration in the bulk chemical industry", *Filtration & Separation, Volume 44, Issue 4, May 2007, Pages 15-17*
55.	Use air-moisture separator	Jack Mahoney "Methods for removing moisture and oil from compressed-air lines in paint facilities" , *Metal Finishing, Volume 98, Issue 6, 2000, Pages 402-404*
56.	Improving ultra filtration processes	Madan L. Arora and Kenneth M. Trompeter "Fouling of RO membranes in wastewater applications", *Desalination, Volume 48, Issue 3, 1983, Pages 299-319*
57.	Increase reactivity of UV light	Mst. Shamsun Nahar, Kiyoshi Hasegawa, Shigehiro Kagaya and Shigeyasu Kuroda *Science and Technology of Advanced Materials, Volume 8, Issue 4, May 2007, Pages 286-291*
58.	Predict filtration	Sirkka Liisa Jämsä-Jounela and Marja Oja "modelling module of intelligent control system for the variable volume pressure filter", *Filtration & Separation, Volume 37, Issue 2, March 2000, Pages 39-49*
59	Treat reuse of final effluent	Filtration industry analyst, Feb 2006
60.	Occupy small footprints	Anthony Bennet, "Wastewater treatment: green technologies rise to the bait", Filtration & Separation, Volume 43, Issue 7, September 2006, Pages 12-17
61.	Treat final effluent	Suck-Ki Kang and Kwang-Ho Choo "Use of MF and UF

		membranes for reclaimation of glass industry wastewater containing colloidal clay and glass particles", *Journal of Membrane Science, Volume 223, Issues 1-2, 15 September 2003, Pages 89-103*
62.	Attachment of bacteria to spherical surfaces of granular porous medium	K.E. Nelson, A. Massoudieh and T.R. Ginn "E.coli fate and transport in the Happel sphere-in-cell model". *Advances in Water Resources, Volume 30, Issues 6-7, June-July 2007, Pages 1492-1504*
63.	Ensure sterility	Millipore Corp's Biopharmaceutical division "Valves ensure process sterility", Filtration & Separation, Volume 40, Issue 7, September 2003, Page 15
64.	Facilitate operation of solid processing	A.F Blandin , D. Mangin, A. Rivoire, J. P. Klein and J. M. Bossoutrot "Agglomeration in suspension of salicylic acid fine particles", Powder Technology, Volume 130, Issues 1-3, 19 February 2003, Pages 316-323
65.	Eliminate large fractions of pathogens	Sunny Aiyuk, Ilse Forrez, De Kempeneer Lieven, Adrianus van Haandel and Willy Verstraete "Anaerobic and complementary treatment of domestic sewage in regions with hot climate", Bioresource Technology, Volume 97, Issue 17, November 2006, Pages 2225-2241
66.	Reduce filtration cost	Filtration industry analyst, Feb 2006
67.	Removal of pathogens	Michael R. Templeton, Robert C. Andrews and Ron Hofmann "Removal of particle-associated bacteriophages by dual-media filtration at different filter cycle stages and impact on subsequent UV disinfection", *Water Research, Volume 41, Issue 11, June 2007, Pages 2393-2406*

Table 6: Improvement of filtration equipment and processes

Appendix III: Sets of problems identified

Table 1: Set PP problems

1.	Presence of degreased liquid or chemical liquid
2.	Facilitate solubility of oxygen
3.	Recover lithium contained in mother liquor bleed stream
4.	Cause massive hydrogen gas volume
5.	Drip untreated water onto a cooling oxidant unit
6.	Improve colour of crystallized sugar product
7.	Separate plasma and plasma components
8.	Improve filtration of paint
9.	Separate aromatic dicarboxylic acid crystals
10.	Purification of aqueous cyclodextrin
11.	Controlling the operation of sanitation system of spa
12.	Disperse untreated water
13.	Encompasses the use of active enzymes
14.	Produce minute amount of fullerene in squalane after filtration
15.	Contain oil mist and chip
16.	Control of air filtration system
17.	Move patient's blood
18.	Control electric field carried by fly ash
19.	Achieve good filtration of cane juice for sugar
20.	Recover ferrate salts from solutions
21.	Reduce Odour in air
22.	Produce technical grade lithium carbonate
23.	Improvement of filtration properties of porous multilayered hollow fibers
24.	Improve filtration disk cleaning efficiency
25.	Improve flushing performance
26.	Reduction of back flush waste volume
27.	Prevent catalyst attrition
28.	Cast films
29.	Result from pad wear, substrate polishing by-products or external contaminants
30.	Control regulated high voltage power supply, voltage and current monitoring circuit, input signal filtering circuit.
31.	Decompose hardly decomposable harmful substances by means of filtration equipment
32.	Guide airflow

33.	Dislodge debris
34.	Result in evolution of carbon dioxide gas
35.	Results in catalyst loss
36.	Enable effect of push and pull
37.	Reduce engine output noise
38.	Control of airflow and heat delivery rate
39.	Prevent plugging of injection wells
40.	Initiate Backwashing mode of operation
41.	Not utilize vibration
42.	Dissolve biologically and chemically prompting oxidation of substances
43.	Exert effect of suction
44.	Have layer of over-layed element of elastically deformable material
45.	Have part of exhaust silencing system to reduce noise
46.	Include belt filters
47.	Comprise honeycombed or lattice porous material
48.	Meet sanitation requirement
49.	Process batch of product
50.	Prepare a wet cake of pigment
51.	Generate pulling effects
52.	Provide heating, ventilation and/or air conditioning of air supply
53.	Provide mobile power generation system
54.	Provide a unit of HVAC
55.	Eliminates costly and difficult onsite equipment alterations necessary
56.	Require large amount of solvents and large filtration equipment
57.	Receive information from customers
58.	Comprise oxygen-supply-capable cooling water equipment
59.	Ease of interchange of disposable filter in an air filtration unit
60.	Include bacteriological filters
61.	Perform primary and secondary clarification
62.	Provide more efficient disc filtration service
63.	Inhibiting the formation of biofilm deposits in membrane separation systems
64.	Comprise of inlet connector and built-in disinfection and filtration equipment
65.	Remove high polymer
66.	Perform Depyrogenation/sterilization of stainless steel filtration equipment

Table 2: Set P_2P problems

S/No	Patents documents	Scientific papers
1.	Suitable for separation and purification of gas	Allow gas for purification
2.	Pre-treatment of water	Removal of iron hydroxide completely from water
3.	Incorporate raw water pre-filter devices	Effective removal of organic and inorganic contaminants and biological materials from municipal/industrial waste waters, Purify unfiltered raw water
4.	Improve filtration of beer	Give required clarity to beer, ciders, wines, and bottled waters, Improve wine filtration
5.	Improve air quality	Achieve high flow air filtration system
6.	Filter air	For pre-separation of gas and filtrates, Remove particulate nitrate in air by filtration
7.	Minimize accumulation of ozone	Convert airborne radicals and ozones to harmless by-products
8.	Sustaining minimum pressure	Increase pressure drop of filters
9.	Afford abatement of wear and tear,	Suppress damage of metal filter mesh
10.	Increase flux	Filtration flux
11.	Reduce required cleaning efficiency	Test efficacy of filtration machine
12.	Improve filtration efficiency	Enhance fractional efficiency
13.	Improve filtration properties	Maintain temperature of fluid
14.	Blockage of screens	Avoid blinding of clothes
15.	Prevent scaling and fouling of equipments	Cause reversibility of fouling, Include fouling control
16.	Improve small pores and high porosity	Pressure dependency of filtration resistance and porosity, Provide smother and finer aperture size
17.	Cause Failure of equipment	cause significant loss of filtration capacity
18.	Prevent passage of particles	Collect Micron-sized particles
19.	Improve effectiveness of filtration	Ensure effective filtration,

		Enhance effectiveness of filtration
20.	Reduce wear and tear	Protect membrane filtration systems
21.	Have positive pressure	Pressure dependency of filtration resistance and porosity
22.	Remove sub-micron sized particles	Collect Micron-sized particles
23.	Compute replacement time	Improve replacement time of filter cloth
24.	Enlarge contact area	Require large filtration surfaces
25.	Include scale inhibitors	Include fouling control
26.	Include microprocessor	Comprise measuring devices, Include microprocessors, Have flow meters and fluid conductivity meters
27.	Disposable filtration unit	Easily disposable filter
28.	Perform detoxification	Ensure sterility
29.	Provide wide filtration area	calculate total interfacial area
30.	Remove hazardous germ	Ensure sterility Removal of pathogens
31.	Remove residual solid impurities	Reduce infiltration of dust
32.	Require periodic chemical/mechanical cleaning of membrane filtration equipment	Process for cleaning a filtration membrane
33.	Require High degree of operator attendance	Require large amount of technician time
34.	Require routine maintenance	Cope with variable hydraulic loads, occupies a small footprint and has low maintenance requirements
35.	Require relatively large space	Cope with variable hydraulic loads, occupies a small footprint and has low maintenance requirements
36.	Use ultra filtration film	Improving ultra filtration processes
37.	Use of expensive filtration treatment equipment	Reduce filtration cost, Economic filtration process
38.	Disposable filter	Easily disposable filter
39.	Treat noxious fumes	Remove gaseous contaminants from air, Remove airborne contaminants

40.	Draw liquid through membrane	Permeability of membrane
41.	Generate fines	Break up of filaments and colonies
42.	Shelter design flexibility, programmability and expandability	Allow flexible capacity expansion
43.	Refurbish screens	Rehabilitation of granular media filter boxes
44.	Keep stable	Keep filtration pans horizontal
45.	Auto-sampling, pipetting, filtration and dilution of samples and final injection	Achieve automated system
46.	Self cleaning drum filter	Adopt self-cleaning fibers
47.	Solubilize precipitate	Use novel combination of filtration and selective solubilization

Appendix IV: Article citation Network

S/No	Title of paper
1	Nadine Oschmann, Long D. Nghiem and Andrea I. Schäfer "Fouling mechanisms of submerged ultrafiltration membranes in grey water recycling", *Desalination, Volume 179, Issues 1-3, 10 July 2005, Pages 215-223*
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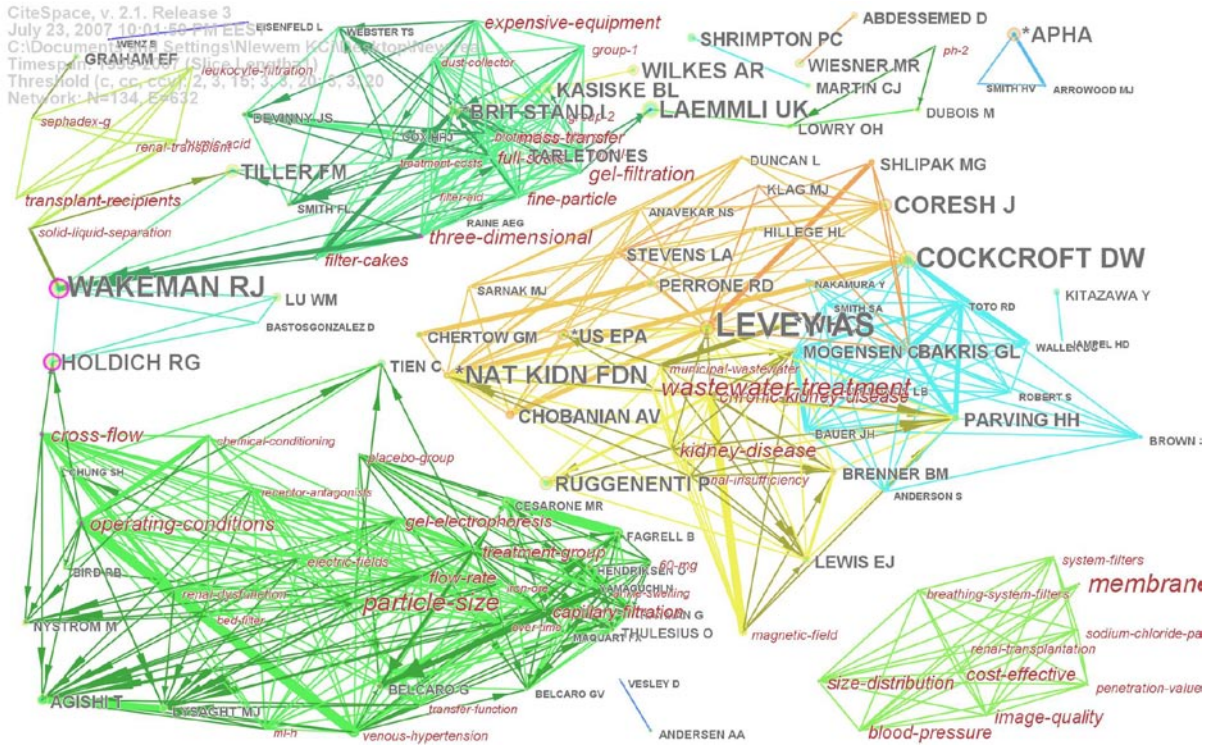
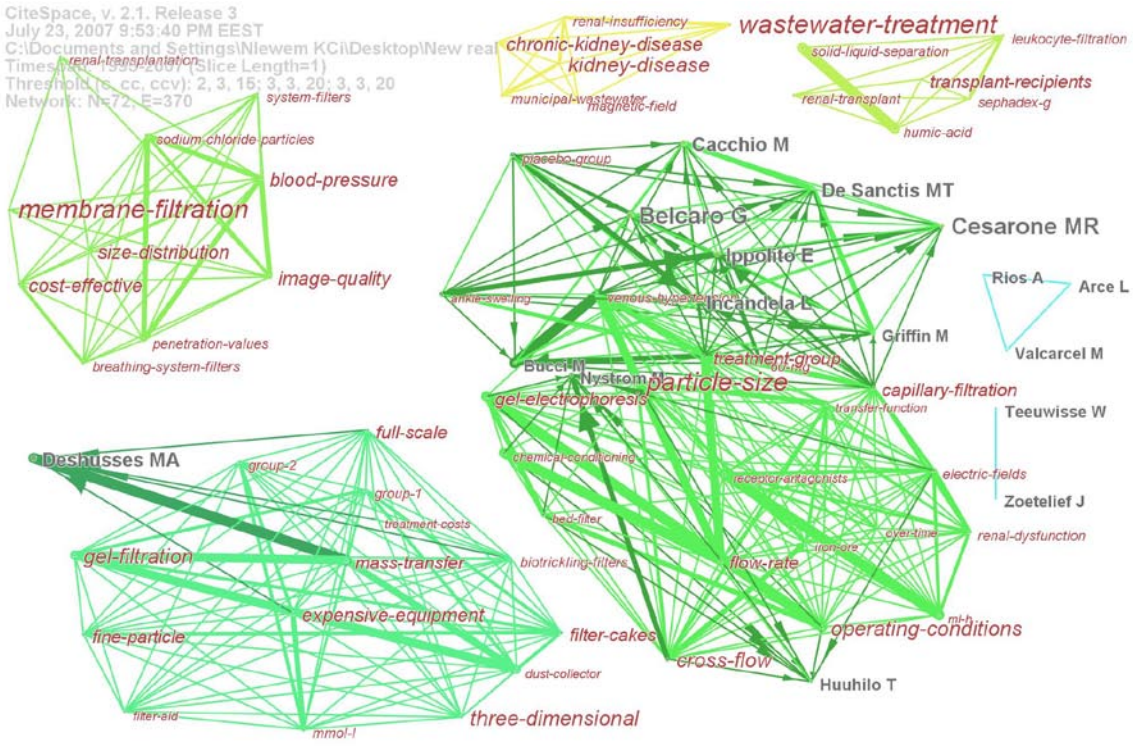
Appendix V: Network visualization with Citespcae

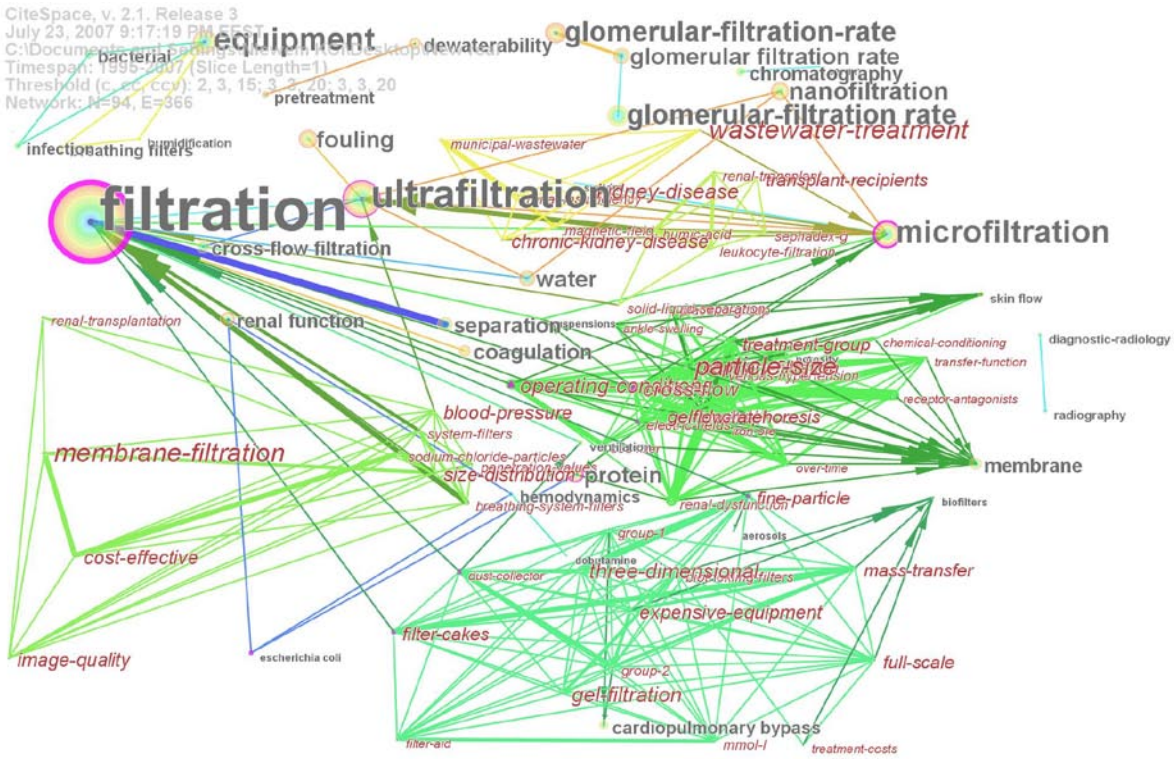
1: Network visualization at default settings



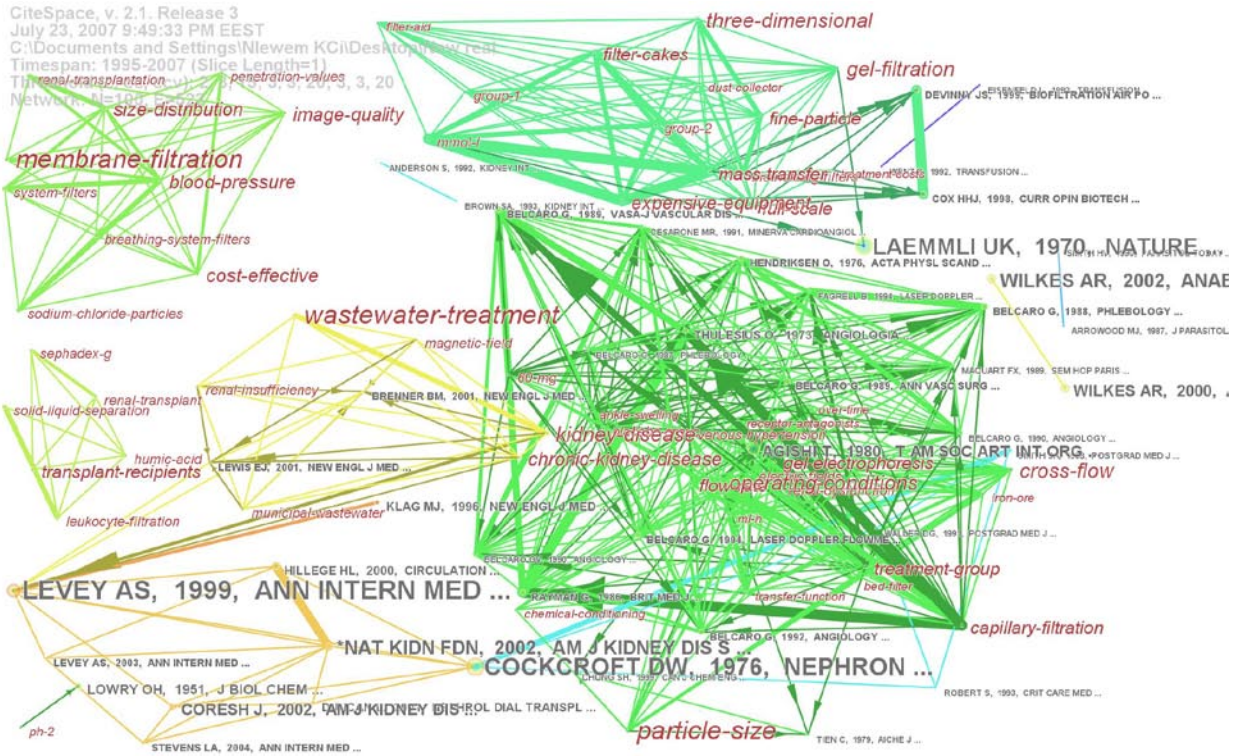
1a: Author co-citation network.



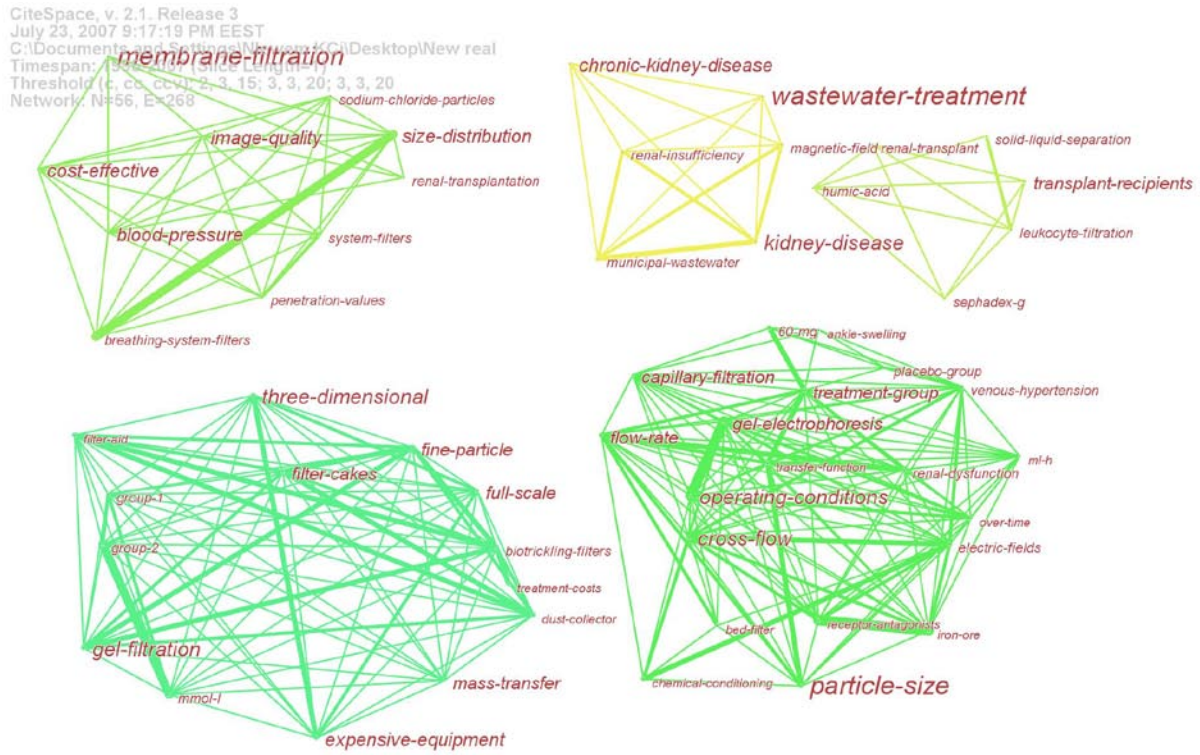
1b: Co-authorship network.



1c: Network of co-occurring keywords and identifiers.

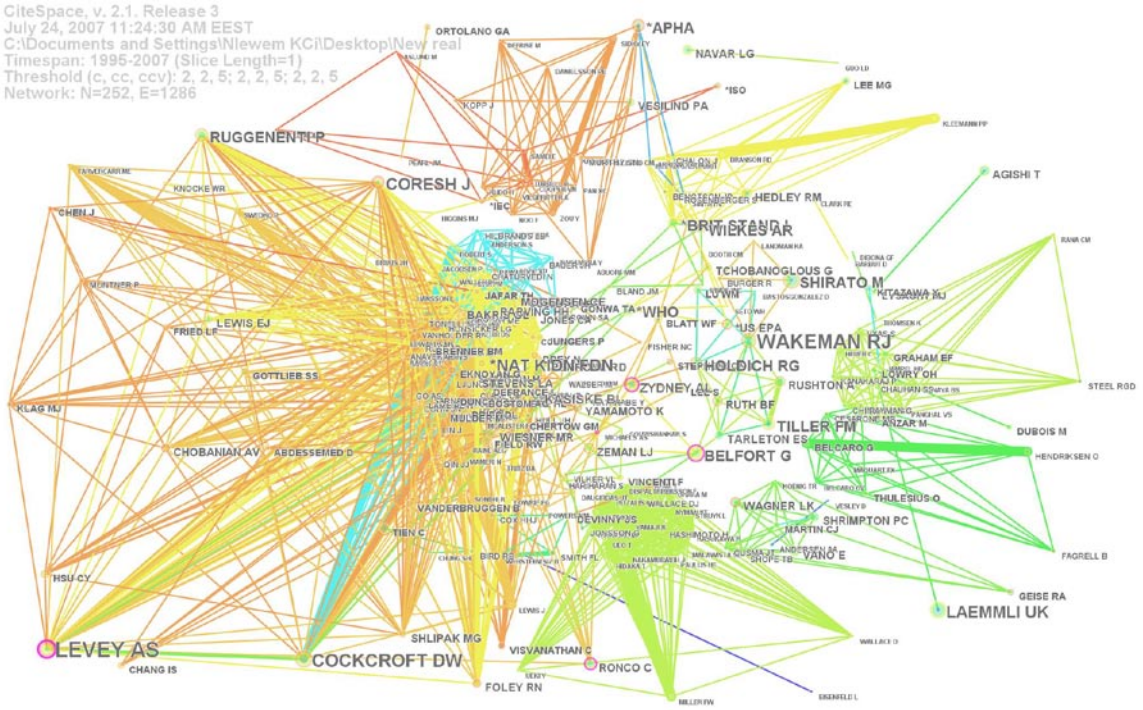


1d: Document co-citation network.

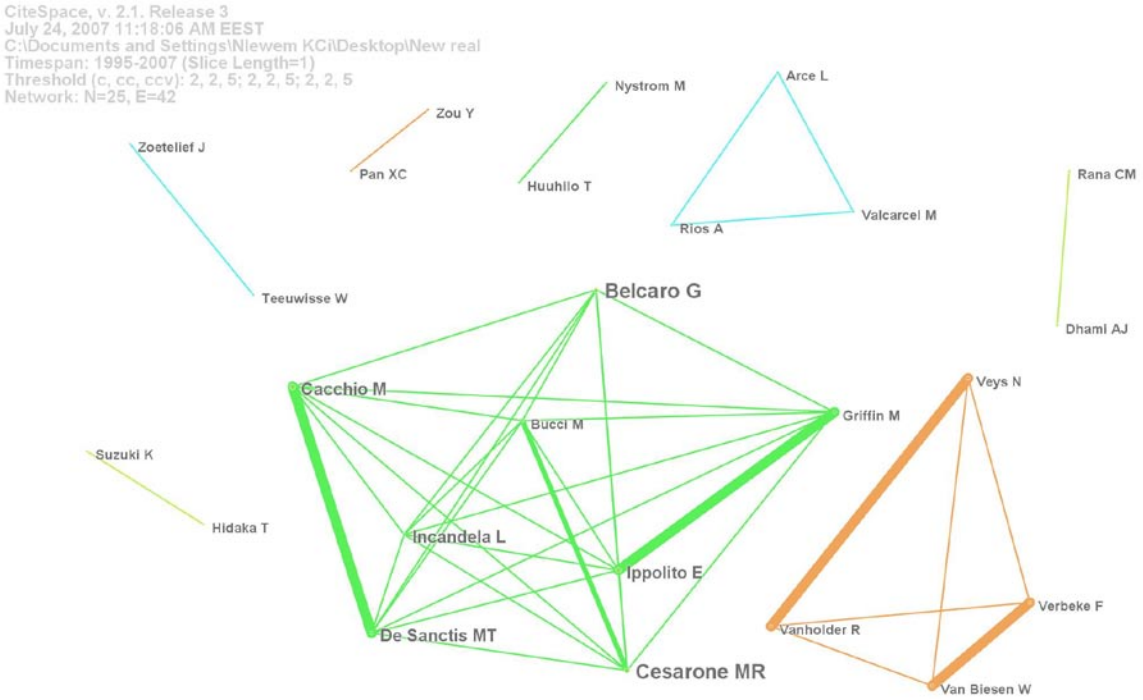


1e: Network of co-occurring phrases.

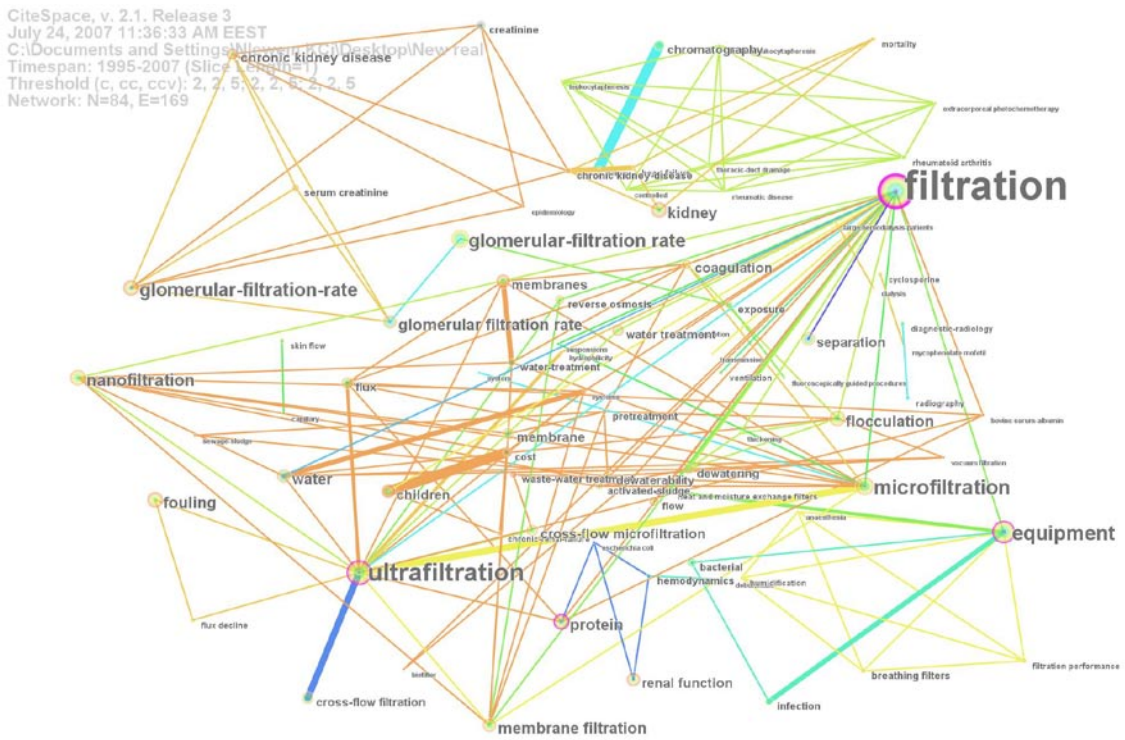
2: Network visualization at lower threshold frequencies



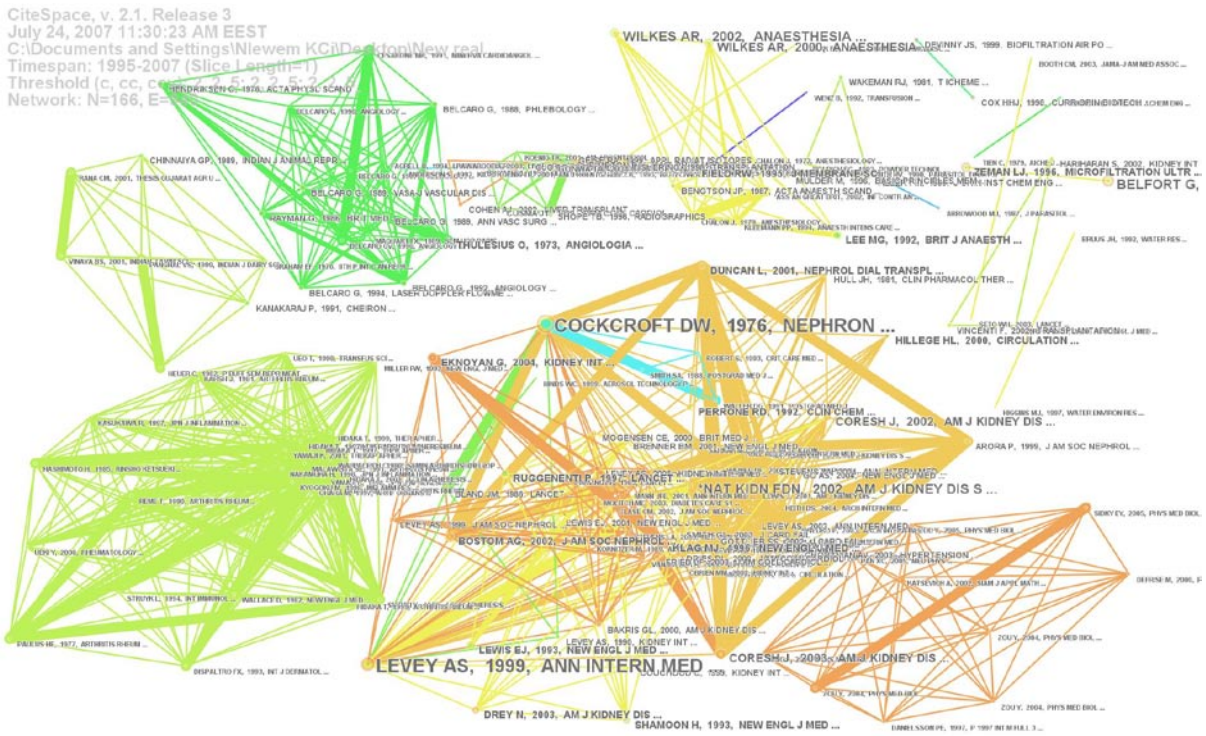
2a Author co-citation network.



2b:Co-authorship network.



2c: Network of co-occurring keywords and identifiers.



2d: Document co-citation network.