An Introduction into Patents

with Nereda example

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Colophon

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The source can be found on Github.

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Chapter 1

Introduction

1.1 To the audience

This reader presents an introduction on the use of know-how and intellectual properties (IP) and its benefits for students in science, engineering, medical and business courses. The basic concepts and definitions of IP will be treated and also their use and purpose will be described.

The different topics of IP are explained with an example relevant to your background.

Those interested will find additional information in the appendix appendix B by following the links.

1.2 Every day IP

Chances are that you are using products or services appropriated by a variety of intellectual property rights (IPR) on a daily basis, eg. brands, designs, patents, copyrights.

Many of the products that you will buy or use daily are from a certain brand. Such a brand makes you recognize the product and the manufacturer. For example the brand Coca-Cola for cola. On the other hand manufacturers and organisations use their brands to market their products and services.

Next to brands, organisations have their tradenames registered at the Chamber of Commerce.

The book you are reading or the music you are listening to are works made by an author or musician. These makers would like to be rewarded for the efforts put into the making of their work. You are therefore not allowed to copy this work without their permission since it is copyrighted.

In the development and production of bicycles and cars there are many proprietary technologies. Manufacturers of these product would like to earn back their investments in research and development by using patents.

When you are already developing products yourself now or in the future and when involved as entrepreneur or manager you will have to work with different kinds of IP. As a student it is therefore useful to acquire sufficient knowledge of IP for your future career. Even during studies you it can be worthwhile to use them for many reasons, for example for design assignments.

1.3 Why do IP rights exist?

Several hundred years ago the use of intellectual property rights was hardly known. At the beginning of the book printing technology it became possible to copy and disseminate works of literature far more easily. From that moment authors and publishers started to feel the need to appropriate the rights for the production and distribution of these works. With new technologies during the Industrial Revolution mass production in large quantities became feasible for products and devices. This gave rise to a growing interest by manufacturing companies to appropriate trademarks, logos and patents for their products and inventions.

> **The modern patent in Venice**
>
> During the fifteenth century, Venice was a rich and flourishing city. One of the reasons for this prosperity was the stained glass produced on the island of Murano.
>
> This was a rare and expensive product that became an important economical asset for the city.
>
> However, the formula for making coloured glass was known only to a few people: the glassmakers of Murano.
>
> The Senate of Venice began to worry about the possibility that the glassmakers might die or flee to other countries, thus losing this precious secret.
>
> To avoid such hypothesis, Venice offered the glassmakers to train some apprentices sent by the city. However, the glassmakers refused because accepting the offer would have meant that they loose their monopoly and create potential competitors.
>
> Understanding Murano's concern, Venice offered, in exchange for the secret, an exclusive right for a limited time to guarantee

the glassmakers monopoly. The document granting this right was called a "patent", from the Latin verb "patere", meaning to make known.

Thanks to this, the craftsmen accepted the offer and Venice managed to keep the secret, so that we can still enjoy the beautiful coloured glass of Murano today.

In 1474, Venice published the first patent statue in history, to regulate the matter. See figure 1.1.

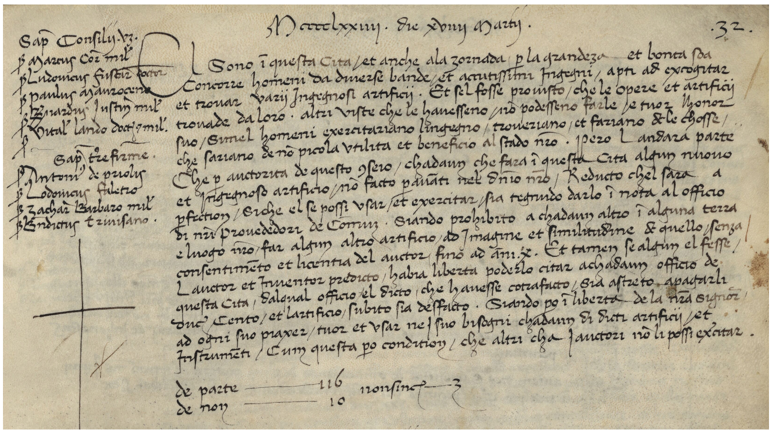

Figure 1.1: The Venetian Patent Statute, enacted by the Senate of Venice in 1474, is widely accepted to be the basis for the earliest patent system in the world.

The general concept behind the use of intellectual property rights is that the creator or manufacturer can apply for a temporary exclusive right hence appropriating their (often intangible) assets and stopping competitors. By doing so the IP owner acquires the possibility to exploit the production of these assets which are otherwise easily copied or manufactured by competitors. So, on the one hand intellectual property rights incentivize persons and innovators who invested both time and money to develop a new product. While on the other hand competitors cannot copy the product and sell it at a cheaper prices without making such investments.

Consumers of those products which have been appropriated with intellectual property rights may have to pay a higher price. Without these intellectual property rights competitors would have been able to sell the products at a lower price. For society at large the introduction of IPR is not only to have all products available at the lowest prices, but to have access to new products and innovations. While using IPR innovative companies are temporarily in a position to charge higher prices thus enabling a return on (earlier made) investments. This is shown in figure 1.2.

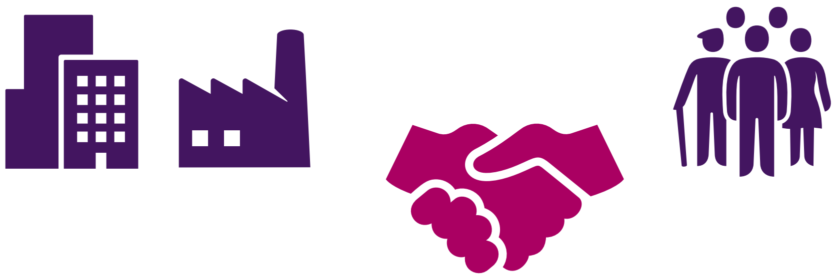

Figure 1.2: Use for business and society

1.4 Well known IP

Companies, entrepreneurs, authors, engineers, developers, scientists and inventors can use a variety of IPRs like copyrights, trademarks, patents, trade names, logos, designs, databases, plant breeders, integrated circuit layout and trade secrets.

Some of the well known IP rights are:

Copyright Will give the creator (author) at the end of the creation automatically global protection for original works like text, music and images. Copyrights limit free distribution of the work.

Trademarks After registration, the trademark owner receives the exclusive right to use the trademark for certain goods and services. A trademark right can be used to take action against competitors who want to exploit the same or similar trademark in the same market.

Patents After the application, registration and examination of a patent, others can be excluded from the commercial exploitation of the patented invention.

Tradenames Trade and company names are used to make a company known to customers in the market and ensure a reputation and thus customer loyalty. Another company may not cause confusion with its trade name by using a trade name that is too similar to a previously registered trade name.

Designs After registration, the design holder receives the exclusive right to use the design. A design right can be used to take legal action against competitors who wish to exploit a similar design.

1.5 Frequently used IP for innovations

This document will not describe the legal aspects of IP. See the links to several articles of different laws in appendix D. We will describe how to use IP, and more specifically for innovations. An overview of the importance of the different IP rights for innovations can be seen in the following table.

Table 1.1: Effectiveness of appropriability mechanisms for product innovations; % product innovations for which deemed effective.

Sector	n	Secrecy	Patents	Other IPRs	Lead time	Complementary sales services	Complementary manufacturing
Food	89	59	18	21	53	40	51
Petroleum	15	62	33	6	49	40	36
Basic chemicals	35	48	39	12	38	46	45
Drugs	49	54	50	21	50	33	49
Machinery tools	10	62	36	9	61	43	35
Computers	25	44	41	27	61	40	38
Electrical equipment	22	39	35	15	33	32	32
Semiconductors	18	60	27	23	53	42	48
Medical equipment	67	51	55	29	58	52	49
Autoparts	30	51	44	16	64	45	53
All	1118	51	35	21	53	43	46

From: Scotchmer [Sco04] Table 9.1, page 260.

Source: Cohen, Nelson, and Walsh [CNW00], table 1. Note: Each number is a mean response, representing the percentage of product innovations in the row category for which the type of protection in the column is deemed "effective". The response categories are <10%, 10%–40%, 41%–60%, 61%–90%, >90%.

In general we can see that secrecy (including what we call know-how) is one of the most frequently used appropriability mechanisms. At the same time patents are important in the sectors drugs and medical equipment.

Other IPRs (for example trademarks or designs) are less frequently used for innovations, but are of course very important for sales and marketing.

1.6 An example using patents and IP rights for technology transfer

In this section we introduce the example which will be elaborated in next chapters, which elaborates the commercial use of an academic patent in one of the Dutch topsectors of industry. Research took place at the University of Technology at Delft in the Netherlands by professor Mark van Loosdrecht and dr. Merle de Kreuk in the mid nineties.

Based upon their research a novel methodolology for sewage water treatment using more efficient sludge granules was developed. This methodology has been patented by the university. These granules show a better performance in waste water treatment plants due to improved settling properties while at the same time removing nitrogen and phosphorous. Therefore this technology enables a fast, simple and compact treatment with less energy consumption. In the end the water quality of the effluent is better leading to less pollution problems for the environment.

The subsequent steps of developing and piloting this technology on site has been executed by engineering company Royal Haskoning DHV together with the university. Funding for this work in research and development and scaling has been provided by several organisations eg. the Netherlands Entreprise Agency (RVO). After piloting at the waste water treatment plants Veluwe, Rijn and Ijssel and Rijnland, the technology has been implemented by contractors in other plants worldwide. In 2020 the Nereda technology has been a nominated as a breakthrough technology in this sector. As such the case of Nereda shows an excellent example of research commercialisation enabled in a public private partnership.

See for more information about the Nereda technology section E.5.

The priority patent for this technology entitled ‘Method of the treatment of waste water’ can be found in NL1021466C2. During the priority year the application has been continued as WO2004/024638A1 and subsequently as EP1542932B1. The first patent is owned by the University of Technology Delft and in 2005 the patent has been assigned to engineering company DHV (later Royal Haskoning DHV, or RHDHV). Meanwhile the title has changed into ‘Method of the treatment of waste water with sludge granules’. These patent application procedures will be elaborated and used as example in this case on academic patents (see section 4.6).

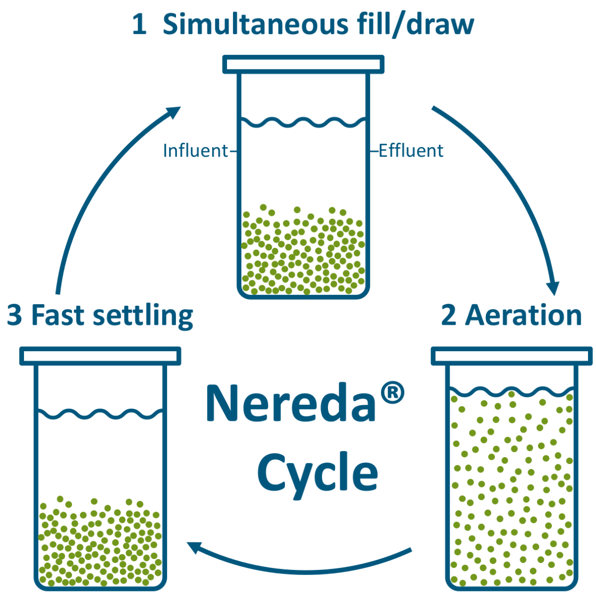

Figure 1.3: Nereda process cycle

This patent application is used as the example for the explanation of patents. The application can be seen in section E.1

Chapter 2

Know-how and trade secrets

2.1 Introduction

Know-how and trade secrets are important assets for companies and public research institutes.

Many entrepreneurs consider know-how as one of the most valuable assets of their company. Hence and although know-how is not a IP right as such we will go into know-how in this chapter.

2.2 What is know-how?

> Know-how is defined by certain knowledge and skill set obtained by a limited number of specific persons involved in manufacturing, marketing and sales processes of an organisation. By its very nature know-how is not accessible freely or without certain limitations to third parties and persons.

General knowledge in textbooks available to everybody is not considered know-how. See for an example of this definition of know-how Nieuwenhoven Helbach, Huydecoper, and Nispen [NHN02] chapter 5 (in Dutch).

In this context, third parties can be defined as organisations or persons who do not have access to certain know-how. In general very few persons within an organisation have access to specific know-how. Third parties and outsiders will always have to invest considerable time and resources to build up comparable know-how. As such, we conclude that know-how in an organisation is kept secret from third parties.

It is evident that persons must possess certain kills and knowledge in order to fulfill certain processes and tasks, for example the design and assembly of a product, the draft of an algorithm, the acquisition and analysis of data. Therefore know-how consists of the combination of technical skills, the processing of information thereby using technical knowledge. Besides, non-technical knowledge like market data, marketing techniques, information about rules and regulations within a political context, data about relations and networks are also part of the know-how of organisations.

Investments in research and development contribute to the formation of valuable know-how, as well as working experience of and technical courses for personnel. In this case the acquisition and storage of information like technical data, equations, standards, specifications, processes, methods, recipes, drawings and their use by professional personnel.

2.3 Using know-how

Many corporations, public research institutes and multinationals have a division with IP specialists or in house council. They make sure that procedures, certain rules and codes of conduct concerning IP and know-how are in place and will be followed upon. Such procedures and conduct are often mentioned explicitly in labor contracts. An example of this is a non-disclosure clause.

But also at small and medium sized enterprises or startup companies without in house IP specialists or council it is important to implement internal procedures and codes of conduct to deal with IP and know-how. For those companies which supply parts, products or processes in a supply chain these procedures and codes of conduct are even more important. Without them such companies may run the risk that employees share too much essential know-how with customers or clients.

2.3.1 Using know-how by the company itself

The use of IP rights enable companies to have a positive return on investment in their research, development, marketing and manufacturing with a healthy commercial margin. On top of this, it is important to realise that the combined use of know-how and patents contribute to the successful introduction of technical innovations in the marketplace. In this process know-how of specialists is essential to deliver products and services to customers and clients. In the economic domain the concepts and use of know-how and patents show a striking number of resemblance. Both are a source of (technical) knowledge enabling the owner and user to use technical capacities and developments and thereby a head start or lead advantage which is not available to competitors. The owner of the know-how can exploit this technological advantage in the marketplace, for example in certain manufacturing processes.

2.3.2 Using know-how by third parties

Many companies do not have manufacturing plants in all countries over the globe. In those countries where there is an outlet for their products or services but where they are not operational themselves in terms of manufacturing, marketing and sales it may be profitable to act as a licensor and work with license agreements. These license agreements are often struck for both patents as well as for know-how. The temporary, exclusive nature of patents provide either the patentee or the patent licensee protection against infringement by competitors. On the other hand, license agreements between the licensor and licensee determine the scope and field of use, geographical area, region or country, time frame in years and royalties or milestones to be paid.

2.4 Rules and regulations

Rules and regulations for know-how can be found in the EU directive 2016/943 and in the Dutch Act of Trade secret protection.

> This act rules the protection against unlawful public use of know-how and business information. This combination of know-how and business information is often defined as trade secrets.

According to the act and the directive a company or organisation must comply to certain conditions with regard to the information which:

a. is kept secret because it is not common knowledge or accessible by third parties,
b. has value in relationship with the trade or transactions of the company or organisation, and
c. is kept secret by the company or organisation by means of certain measures (for example a registration system and limited accessible for persons only on a need to know basis).

All in all it must be clear that know-how is a personalized asset. At the end of a labor contract the know-how does not automatically disappear (see figure 2.1). This situation raises the question if know-how can be claimed by the employer at all?

Figure 2.1: Know-how: There it is and there it goes.

Chapter 3

Patents

3.1 Introduction

> With a patent you become the owner of your invention.

Thus a patent is property which you can use:

a. preventing others to use your invention, or
b. giving permission to others to use your invention.

The concept of property is defined under (inter) national law and regulations. This is also true for patents since patents are part of industrial property rights. Using a patent in a specific country will always depend on the framework of laws and legislation in that country.

Since the use of an invention is often not limited to a particular country only, it can be profitable to use it in other countries as well.

> The world of inventions is therefore multinational or worldwide.

Since patents are used on a globally there are several international treaties for patents next to national patent laws. An introduction into the most important international treaties can be found in section 3.2.

Most relevant features of patents are elaborated in following sections.

From section 3.6, the contents of a patent will be described using the main example (see section 1.6).

3.2 Patent laws and treaties

Every country has its own patent law. In addition, there are often regional or international cooperations through treaties. An example of such a regional cooperation is the European Patent Convention. This European cooperation has ensured that the patent laws in the 38 member states are harmonised. There is also a global treaty for a central worldwide patent application through the World Intellectual Property Organization (WIPO) (193 member states).

- The Dutch Patent Act is determined in the Rijksoctrooiwet 1995 (ROW). The Netherlands Patent Office (Octrooicentrum Nederland) grants Dutch patents.
- The patent law for European patents is determined in the European Patent Convention (EPC). A European patent is granted by the European Patent Office (EPO). Next they are registered by the applicant in the countries of interest.
- The route a worldwide patent application is determined in the Patent Cooperation Treaty (PCT). However, no patent will be granted in this procedure. After this central application, the patent application is continued in the countries or regions of interest.

3.3 Patent rights

Patent law excludes others from commercially:

- making,
- using,
- selling, or
- stocking

the invention.

Such exclusivity lasts for a maximum period of 20 years after the filing date of the patent application.

The restrictions that a patent exerts are determined by the legislation of a country in question. These restrictions can therefore differ greatly from country to country. It should be noted that the Treaty of Paris (1883) guarantees a minimum harmonisation.

In Europe, a patent generally restricts the commercial making, use, sale and stocking of the invention, but it does allow to use the invention for one's own non-commercial use.

> So you can build a Ferrari for yourself, but don't sell it to your neighbour, because that would be a commercial act.

Under certain conditions, it is also permitted to use the invention for scientific and research purposes, without being able to be prosecuted for infringement.

For a precise description of the legal consequences of a patent in the Netherlands, see article 53 ROW (in Dutch).

The patent right can no longer be used if the patent holder, or someone else with the consent of the patent holder, has sold the patented product. You can then do whatever you want with the patented product. This is called exhaustion. This is described in article 53 paragraph 5 ROW.

3.4 Inventions

Most people have a general idea about inventions and inventors. For example, it is:

- a new development,
- often with a technical background and
- an improvement over existing technologies.

More formally, an invention is often described as a technical solution to a problem.

> However, an invention is not defined in patent law!

In patent law, the definition of an invention has been avoided by defining accurately what is not considered an invention. For example, theories and mathematical methods are not regarded as inventions hence they cannot be patented.

Furthermore, an invention must be industrially applicable. This requirement of industrial applicability separates patent law from the other intellectual property rights.

The requirements for novelty and inventive step ensure that certain technical developments and inventions are only considered to be patentable inventions, if their subject-matter is not already known by (or disclosed to) the public and is also not obvious.

For a more accurate description of the exceptions on patentability and the basic requirements, see article 52 EPC or article 33(1) PCT.

3.5 Requirements for a patent

There are many requirements that a patent must meet. In addition to formal requirements, there are substantive requirements. Formal requirements are necessary for the proper processing of the application. For example, it is necessary that the patent office can contact the applicant and that the application is written in the correct language.

To obtain a granted patent, the most important substantive requirements are that the invention is:

- new,
- inventive,
- must be sufficiently clear disclosed.

The invention must be new and inventive, otherwise the patent would not contribute to the general knowledge and improvement of technology. It must therefore also be described clearly enough.

3.5.1 Novelty

Novelty means that the invention has not been disclosed. All information that is publicly accessible to the person skilled in the art can be used to determine this. It is an objective criterion, whereby the person skilled in the art is supposed to know all state of the art.

For the assessment of novelty (and inventive step) all information before the filing date of the application is taken into consideration. This is the date of the first filing: 'first to file'.

Until recently, the United States had a different system: 'first to invent'. The moment when the inventor conceived the invention was the moment for the assessment of the requirements. Although fundamentally correct, this brings with it all sorts of problems of proof when conflicts arise. That is why in 2011 the United States also switched to the 'first to file' principle.

Documents with a later publication date than the filing date can not be detrimental to novelty, nor can they take away inventiveness.

So if not all features of the invention are already known, the invention is new:

> An invention shall be considered to be new if it does not form part of the state of the art (see also article 54 (1) EPC or article 33(2) PCT).

3.5.2 State of the art

The state of the art is accurately defined in the patent law:

> The state of the art shall be held to comprise everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the patent application (see also article 54 (2) EPC or Rule 64 PCT).

This definition stipulates that all information that is publicly accessible in the world is regarded as state of the art. This also includes the documents in a small library in a Chinese mountain village. An important limitation is that the information must be *publicly* accessible. Documentation, such as technical drawings used in a company, is normally not publicly accessible (due to confidentiality). These documents can therefore not be used to assess novelty.

The filing date is an important date. Anything that has become available public after this date will not affect the patent application. If the same invention is applied for on different dates, the person who applied first has the right to the invention.

Each patent application is published 18 months after the first filing. Thereby it also becomes part of the state of the art.

3.5.3 Inventive step

Inventive step means that it is not obvious for the person skilled in the art to carry out the improvement or modification, for which protection is requested, in the particular solution:

> An invention shall be considered as involving an inventive step if, having regard to the state of the art, it is not obvious to a person skilled in the art (see also article 56 EPC or article 33(3) PCT).

In the practice of patent examination, this means that all claimed properties are known from a combination of two embodiments, described in one or two documents. The person skilled in the art is thereby also hinted to combine the features of the two embodiments.

or

If the only difference with a known embodiment is an alternative that is obvious to the person skilled in the art, which he knows on the basis of his general knowledge, then the invention is considered to lack an inventive step. For example: To attach something on a wall, a screw is a well-known alternative to a nail.

3.5.4 Clear and sufficiently disclosed

In a patent, the invention must be made public. This must be done in such a way that it can be performed by the person skilled in the art. It is therefore not possible to obtain a patent and keep your invention secret. See also article 83 and 84 EPC and article 5 PCT.

> A perpetuum mobile is therefore by definition not patentable.[1]

Features that are well known by the person skilled in the art do not need to be described. For example: It is not necessary to describe how something should be fastened, if it is clear to the person skilled in the art that it can be either welded or glued.

The person skilled in the art is defined in patent law as skilled in the field of the invention with broad professional knowledge. The skilled person only knows obvious solutions to problems, but cannot become inventive himself.

3.6 Contents patent application

A patent application consists of the following parts:

Description The description consists of an introduction and a section containing at least one complete embodiment of the invention. The introduction briefly describes what is known in the state of the art, what problem still exists in this known state of the art and a short description of the solution (the invention) to this problem.

Claims The claims define the scope of the patent protection. These claims are normally written as a set of claims. Usually there is a main claim and several dependent claims. The main claim therefore offers the broadest scope of protection. The dependent claims add further features and therefore have a smaller scope of protection than the main claim.

Figures The figures are there to clarify the invention.

The claims determine the scope and type of protection. The legal scope of protection of the patent is therefore determined by the claims. The claims are therefore written in a legal style.

[1] Why is a perpetuum mobile not sufficiently disclosed? Click for explanation.

For maximum protection, the invention is described as broadly as is possible in the claims. But if the invention is described too broadly, then the possibility increases, that it is deemed not new or not inventive.

3.7 Publication patent application

The patent application is published 18 months after the date of the first filing. Figure 3.1 shows the front page of the publication of the application for the Nereda technology. Next to the publication of the front page following pages describe the application as filed. The entire publication can be found in section E.1.

This is the A publication (see the A1 code in the publication number WO 2004/024638 A1) of the patent application. The next publication is the B publication describing the contents of the granted patent.

Bibliographic data are published on the first page of a patent document. Following data are most interesting:

Title gives a very quick indication of the subject of the patent.

Abstract gives a short summary of the contents.

Figure next to the abstract is normally a figure from the list of figures which is representing the invention.

Other data on the front page of the publication can be of interest to follow for the legal aspects of the patent application and status of the patent:

Applicant is the company or organisation who has filed the application and the usually also the one who will appropriated have the patent rights and is known as the owner or patentee.

Inventor is one person or are more persons who have made a significant intellectual contribution to the invention. Under US patent law the inventor is the one who has the rights to own the patent. In most other countries it is the applicant who has these rights.

Priority data is the date of the first patent application filed globally and for which a priority is claimed. The patent rights start from this date. In this case there is a Dutch priority (NL 1021466).

Filing date is the date this patent application was filed.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 March 2004 (25.03.2004)

PCT

(10) International Publication Number
WO 2004/024638 A1

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(25) Filing Language: Dutch

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 2004/024638 A1

(54) Title: METHOD FOR THE TREATMENT OF WASTE WATER WITH SLUDGE GRANULES

(57) **Abstract:** The invention relates to a method for the treatment of waste water comprising an organic nutrient. According to the invention, the waste water is in a first step fed to sludge granules, after the supply of the waste water to be treated the sludge granules are fluidised in the presence of an oxygen-comprising gas, and in a third step, the sludge granules are allowed to settle in a settling step. This makes it possible to effectively remove not only organic nutrients but optionally also nitrogen compounds and phosphate.

Figure 3.1: Front page of WO 2004/024638 A1

Designated states are all the countries where the applicant wishes patent protection at the filing date of this application under the PCT. The PCT procedure is commonly used to start a world wide patent application.

Publication date is the date that the contents of this patent was published and thereby openly accessible to the public. Before this date the patent application was secret and the contents of the patent application are not known by the public.

The publication also describes some administrative data making the identification and retrieval of the document more easy:

Publication number is a unique number to identify a patent document. It also gives information on the type of document. The first letters are the country code. In this case WO where WO stands for a patent in the PCT world wide application. Other country codes are for example EP for the European procedure at the European Patent Office (EPO), NL for the Netherlands, US for the United States, DE for Germany, etc. Next there is also a kind code. In this case A1, which stands for application published with search report. When a patent application is granted then often the B code is used.

Application number is the number the application receives when it patent application is filed.

In the publication there are also patent classification codes on the document. These classification codes are used for searching.

3.8 Claims

The claims determine the scope of protection of the patent. Usually there is a main claim with several dependent claims. The dependent claims define further features of the invention.

The function of the dependent claims is to have more specific claims in case the main claim does not hold up in the examination procedure or in court.

3.8.1 Claim in the Nereda patent

The main claim in the patent application of the Nereda technology in WO 2004/ 024638 A1 and continued as in EP 154 2932 A1 reads as follows:

> A method for the treatment of waste water comprising an organic nutrient, wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge and the discharge of organic nutrient-depleted waste water characterised in that: - in a first step the waste water is fed to sludge granules; - after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step, with the granules being in a fluidised condition; and - in a third step, a settling step, the sludge granules are allowed to settle.

The language used in the claim is a lot more complicated than the language one might normally use to describe the invention. The invention can also be described as:

> A method to treat waste water using sludge which is enriched with certain microorganisms to reduce the organic nutrients in the effluent.

One reason for this complicated language in claims is that patents are also legal documents hence the text has a legal character. In order to grant exclusive rights the claims in the patent must be accurately and clearly described in both legal as well as technical terms. In this example the text and used formulations in the claim do not provide any description of the technical features of the invention. We know that the invention is about treating waste water with a certain kind of sludge, but how much sludge, the technical features of the sludge, how much oxygen needs to be supplied to the sludge during the treatment process remains unclear and undefined. This may seem irrelevant but will give serious issues determining the requirements for novelty for this patent application throughout the granting procedure.

Another reason for the use of this kind of language in a patent application is that the patent holder wants the largest possible scope of protection. The patent holder would also like to include a number of embodiments of the invention that differ in features that are not important for the invention. In this example the details of the embodiments are not described in the main claim.

3.8.2 Test for novelty

As mentioned before the claims in a patent application disclosing the invention must be new and not yet earlier described prior to the date of the

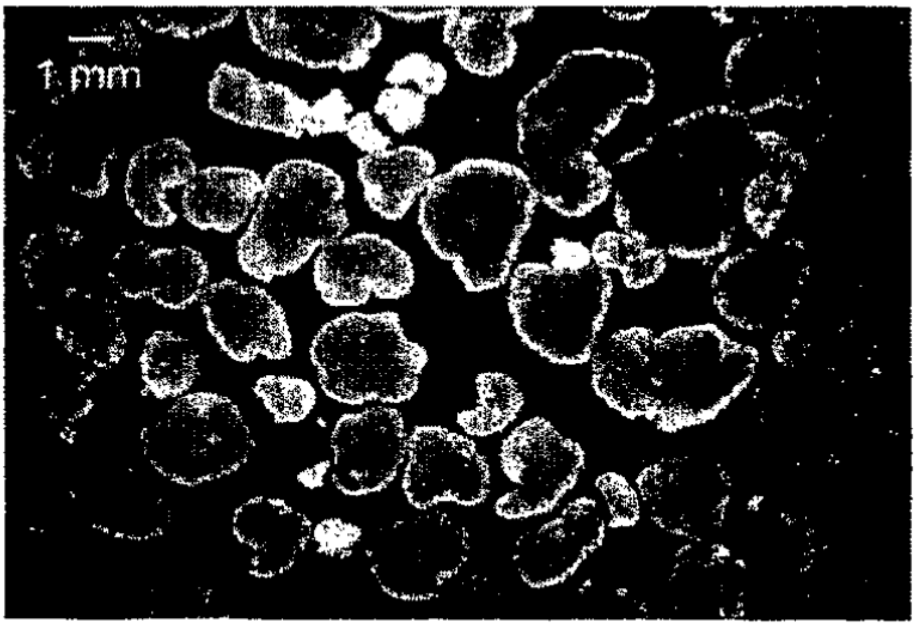

Figure 3.2: Nereda figure 2 b in WO 2004/ 024638 A1

patent application or else they cannot be granted throughout the procedures. In the search report in the publication of the patent application in section E.4 it can be seen that several documents are cited as state of the art. The search report is used by the examiner to asses the novelty and inventive step of the patent application. In this search report six of these documents are considered to take away the novelty or inventive step of the Nereda technology as claimed in the original patent application.

The following demonstrates how novelty can be assessed. It starts with breaking down the claim into separate features. It is then determined whether these features are collectively known in a prior art document. For this exercise the first document of the search report is used. This document with title Aerobic Granulation in a Sequencing Batch Airlift Reactor (2002) - can be found in Beun, van Loosdrecht, and Heijnen [BvH02].

First try to find the answer to the question yourself before you will look into the answer.

Features of claim 1 of the patent application	**Where to be found in the paper?**

A method for the treatment of waste water comprising an organic nutrient; wherein the waste water is brought into contact with microorganisms-comprising sludge particles	Click for answer.
an oxygen-comprising gas is fed to the sludge particles	Click for answer.
and the method further comprises the settling of the sludge and the discharge of organic nutrient-depleted waste water	Click for answer.
in a first step the waste water is fed to sludge granules	Click for answer.
after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step	Click for answer.
in a third step; a settling step; the sludge granules are allowed to settle	Click for answer.

In the search report the examiner also refers to three other scientific documents describing all remaining claimed features in the total of 10 claims of the patent application. Hence, it is shown that the Nereda invention as claimed in this patent application is known in the prior art. Therefore the original patent application with these 10 claims cannot be granted due to lack of novelty. In the following section describing the patent procedures can be seen that the main claim has been adapted several times by the applicant's patent attorney. Next to that action, other claims have also been adapted.

3.9 Patent application procedures

Patents can be applied for in different countries, but also regionally. In Europe, a European patent can be applied for at the European Patent Office (EPO). A worldwide patent application can be applied for via the PCT procedure at the WIPO.

These different patent application procedures have great similarities, but they are not the same. Therefore, the different procedures are briefly described below. Finally, the procedures chosen in the example are described.

3.9.1 EP patent application

The patent application procedure for a European patent (EP) will be discussed first. This procedure is similar to the patent application procedures used in many countries. Figure 3.3 shows an overview of the EP procedure.

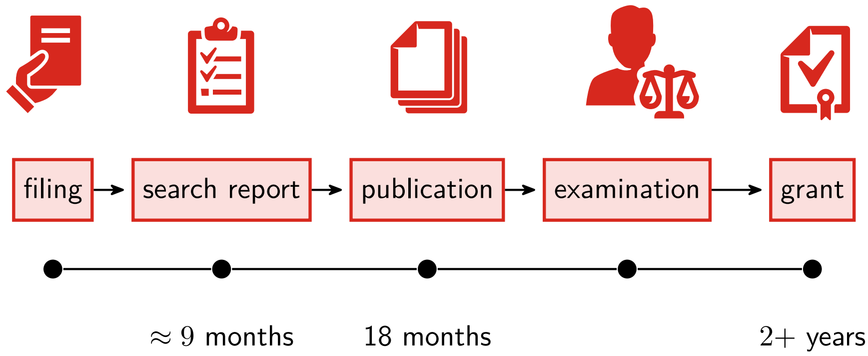

Figure 3.3: EP procedure

The application starts with the filing of the application at the patent office. The first substantive response to the request is a search report. The most relevant state of the art is mentioned in the search report. The state of the art mentioned in the search report is used in the assessment of the requirements for a patent. This assessment of the requirements takes place during the examination. In addition to the search report, a written opinion is delivered with the search report. Possible objections to the grant of the patent are noted in the written opinion. Not being new or not having an inventive step are the most well-known objections.

The application will be published 18 months after the first filing date. Up to the publication date, the application is secret. From the moment of publication, the invention is known all over the world.

Before the patent is granted, first an assessment is made whether the application meets all the requirements. If not all requirements are met, a communication will be written by the examiner and sent to the applicant. This communication states the objections against the grant and that the application can thus not be granted. The applicant has the possibility of overcoming these objections, for example, by amending the claims. This round of objections and amendments can take place several times. At the end of the procedure an oral hearing may also be held to come to a decision.

If there are no objections, the application will be granted. There is also the possibility that the application will be refused if the objections are not overcome.

After the grant, the patent must be validated at the national patent offices in the desired countries in Europe. The European patent then becomes a bundle of national patents.

3.9.2 NL patent application

The Dutch procedure for a patent is simpler than, for example, the European procedure. The Dutch procedure is shown in figure 3.4. A similar procedure is also used in other countries, such as Belgium.

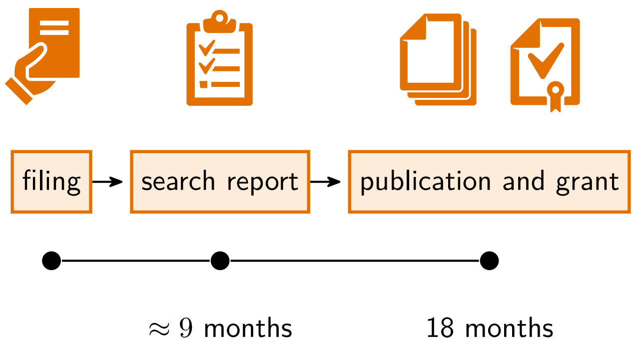

Figure 3.4: NL procedure

The big difference with, for example, the EP procedure is that there is no examination. The patents are granted automatically together with the publication. Also patents that do not meet the requirements are automatically granted. The information from the search report and the accompanying written opinion must then be used to estimate the extent to which the patent holder can exercise his patent rights. A possible lawsuit will clarify these patent rights.

3.9.3 PCT patent application

The PCT (Patent Cooperation Treaty) procedure, for the worldwide application of a patent, is shown schematically in Figure 3.5. The single central application for the most relevant countries in the world is the advantage of the PCT procedure over national or regional procedures.

However, there are 2 characteristics that form an important difference to the other procedures:

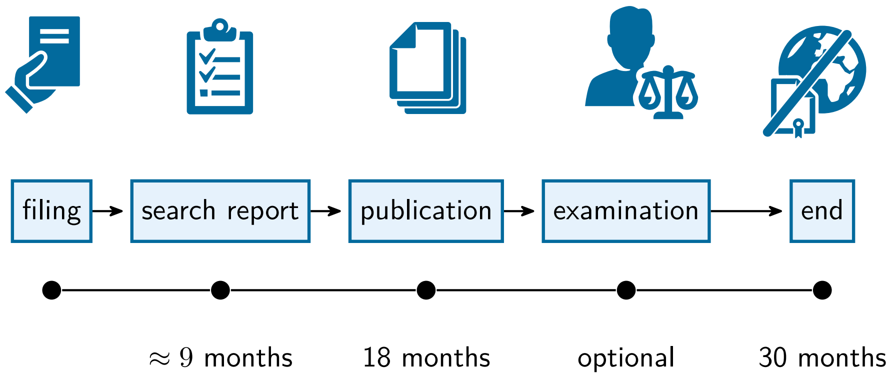

Figure 3.5: PCT procedure

1. The PCT procedure ends after 30 months. At that moment no patent has been granted.
2. The examination is optional.

The procedure to obtain a patent must be continued in regional or national proceedings. So the PCT procedure is only the beginning of the patent procedure. The optional examination is therefore not a decision to grant or refuse the patent, but an opinion on patentability.

The postponement of the choice of the desired countries and therefore also a postponement of costs is a reason why often the PCT procedure is chosen. Furthermore, the costs of a search report happen only once, because the search report from the PCT phase is used in the later national or regional examination. Otherwise, if parallel applications were made in different countries, these costs would have to be incurred in all the selected countries.

The PCT procedure is therefore of interest if patent rights are expected to be desired in several countries in different regions.

3.9.4 Priority year

It is usually only possible to assess whether continuing the application is useful after receipt of the search report. That is why most countries have the rule that the priority of a previous application from another (or the same) country can be used for 1 year. The applicant then has one year to determine in which countries a patent is also wanted. The later application will then receive the priority date of the earlier application. It is then as if the later application was filed on the date of the earlier application (see also article 87 – 89 EPC or article 8 PCT).

This priority right can also be used for regional procedures such as the EP procedure or for the PCT procedure. It is therefore possible to start with the patent application in one country and then go to the worldwide PCT procedure within 1 year. You then have the opportunity to estimate the usefulness of the patent application before larger costs have to be incurred.

3.9.5 Patent procedure of the Nereda technology

Figure 3.6 shows an overview of the procedure for the patent application of the Nereda technology up to grant of the patent.

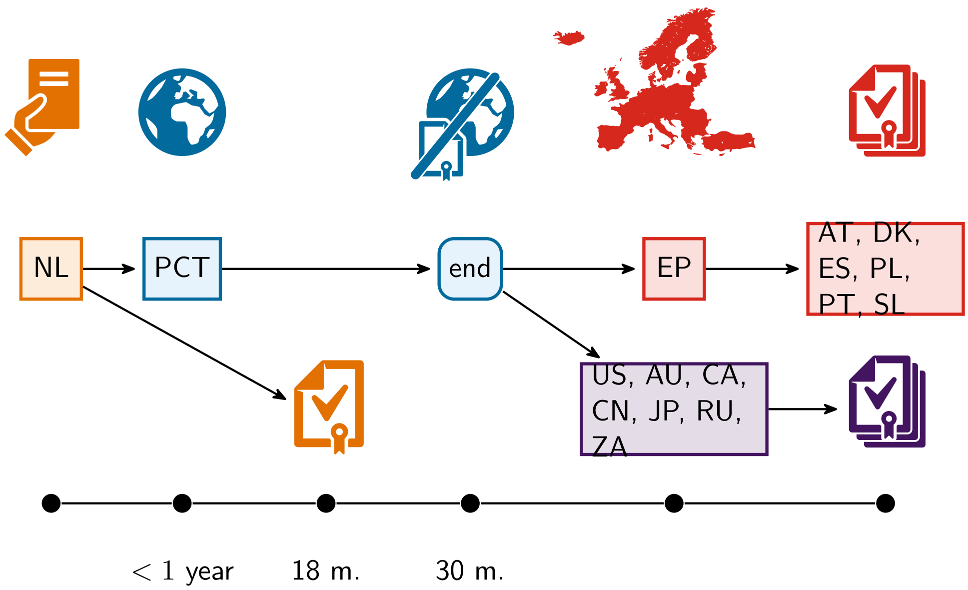

Figure 3.6: Procedure of the Nereda patent

The first patent application NL 1021466 A for this technology was filed in the Netherlands. This application document was published and the patent granted 18 months after the filing date. Due to certain rules in the Dutch patent act there is no examination in the granting procedure in the Netherlands and the patent was granted automatically.

Before the end of the first year of the filing of the Dutch patent appliciation a second patent application was filed as a PCT application WO 2004/024638A. The second filing claimed the priority of the first filing. The PCT procedure ends after 30 months.

They decided to continue during the PCT phase in various international procedures amongst others through a European application EP 1 542 932 A. Via the PCT procedures national procedures have started and patents have been granted in the Canada (CA), China (CN), Japan (JP), Russia (RU), the United States of America (US) and South Africa (ZA). Via the EP application procedure patents have been granted in Denmark (DK), Spain (ES), the Netherlands (NL), Poland (PL), Portugal (PT) and Slovenia (SI).

As can be seen, the patent was eventually granted in 12 countries. Next to the costs to build and maintain a patent portfolio, business and market development play an important role in the decisions to file patent applications in various countries. We assume that both the business strategy played an important role in the decision of the patentee to file patents in multiple countries thus anticipating that in these countries once the patents have been granted the technology will be commercialised either by direct sales or via licensees.

3.9.6 Granted patent for the Nereda technology

From the search report of the patent application WO 2004/024638 A it becomes clear that the examiner at the patent office identified five novelty destroying documents. The contents of these documents describe either partially or fully the nature of the invention as described in the 10 claims of this patent application. These documents have not only been identified for the sake of the patent granting process but have also been communicated to the applicant by January 2004 and registered in open access databases. Next via EP 1 542 932 A the patent attorney and the applicant continued to adapt claim 1. During that same period the applicant has made a request for a transfer of ownership of the patent to engineering company DHV ltd. In 2008 the EPO decides that the adapted patent application can be granted, which happened in 2009 after the term for opposition of 9 months has lapsed.

The adapted main claim 1 as described in EP 1 542 932 B now reads as follows, whereby the amendment texts for certain features are inserted in italics:

> A method for the treatment of waste water comprising an organic nutrient, wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge and the discharge of organic nutrient-depleted waste water characterised in that: in a first step the waste water is fed to sludge granules, *under anaerobic conditions*; after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step, *wherein the oxygen concentration is less than 5 mg/l* , with the granules being in a fluidised condition and *at the end of the second step or at the beginning of the third step sludge granules are removed*; in a third step, a settling step, the sludge granules are allowed to settle.

Two extra features have been added to the main claim. With these additional features the description of the Nereda technology is now clearly defined vs. yet known inventions and prior art in order to be concisely claimed.

You see that the scope of protection of the granted patent is reduced compared with first EP patent application (A1 document). This also indicates the importance of the dependent claims and of a sufficiently detailed and complete description. The claims can then be modified with additional features mentioned in the dependent claims or the description. With these additional features it is possible to overcome the objections to the granting of the patent. These features must already have been described in the patent application, as they can not be added later after the original filing of the application.

3.9.7 Patent family

You have seen from the example that a first patent application resulted in several equally granted patents in the different countries. These patent applications and granted patents have practically the same content. However, they are all published separately.

Most of these publications are included in the patent databases. However, when you are searching, you don't want to see every publication with the same content separately. That's not helpful. If you have seen one, you also know the content of the other publications.

In the patent databases, the publications are therefore grouped by family. A family of patents is therefore a collection of patent applications and patents that have the same content. The grouping is done automatically, using the relationship with the first filed application (the priority document) to group the documents. However, this may sometimes not be correct if a non-standard procedure has been followed.

3.10 After grant of the patent

It is only after the granting of the patent that it is clear what the exact scope of protection of the patent is. That is why the patent can only really be used to stop others using the invention once the patent has been granted. However, the work on the patent and also the costs and even risks are not over yet.

The following activities are still required:

1. You must discover potential infringement of your patent yourself. So you have to pay close attention to which competitor may be infringing.

2. You must also organize the stopping of a possible infringement yourself. Warn the potential infringer first and perhaps eventually even file a lawsuit. A lawsuit is not cheap. This will have to be taken into account when deciding on the strategy to be followed.

3. Even if your patent has been granted, you can still lose it. In the EP procedure, an opposition procedure is still possible within 9 months after the grant. During an opposition procedure, third parties can object to the granted patent. In that case, the patent may still be rejected. It is also possible that the patent needs to be modified. This is comparable to the examination of the patent application.

   The patent can also be attacked later through the courts by third parties. Also then is it possible that the patent will be declared invalid. This step is usually taken by third parties if they are accused of infringement.

4. To ensure that patent rights do not continue to exist for an unnecessarily long time, an annual maintenance fee must be paid. If payment is not made, the patent expires. If the patent does not have enough economic value, it is probably better not to maintain it any longer.

It is clear from the foregoing that the publications in the patent databases do not provide information about the status of a patent. This status must be looked up in the patent registers. Each country has its own patent register to administer this status. Some links to these registers can be found in section B.4.

Chapter 4

Using IP to make money with technical innovations

4.1 Introduction

In this chapter we will discuss the topic of strategic management and use of industrial property rights in companies. Copyrights do not belong to the industrial property rights, but they deserve a specific place in companies.

Here it is also important to distinguish ideas from inventions and innovations as they are often used throughout or amongst one another. We presented a working definition of inventions in section 3.4. While some ideas about new products and services may lead to new research and development and further product development and hence towards inventions, most of them will not be used in the process of innovation management. As such those ideas will not be translated into inventions incorporated into to valuable innovations in certain sectors of industry. Because, on the other hand an innovation is most often regarded as a new and tangible product or service which can be bought by customers in the market place thus creating economic growth.

In the next section we describe a number of common steps in a company's innovation process as the basis for the use of IP. In the following sections the use and exploitation of IP rights is discussed in the various steps throughout the innovation process.

4.2 Innovation process

Often innovation is a time and resources consuming process going through various phases from first idea, prototyping, validation to market entry of an novel product or process. Throughout that innovation process information about IP can be used in multiple ways. In figure 4.1 this innovation process is schematically pictured.

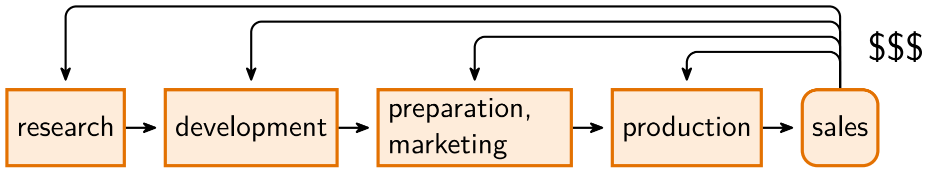

Figure 4.1: Proces from research to sale of product

Many companies start their innovation process by assigning market intelligence to one or more specialists. A state of the art research and necessary steps for product development may require significant time and resources depending on the sector of industry. For long term projects a company can decide to cooperate with a university for example for research ends working with scientists and PhD students. The goal of this phase in product development can be to ascertain proof of concept and bringing an idea for a novel product to the next stage.

At the development stage the product will be shaped towards the final version, although the manufacturing process at full scale is not yet determined. Since experts and engineers from various disciplines are involved in this stage, it can be time consuming and expensive.

Next, decisions about the output level of production and the layout of the factory have to be made during the production preparation phase before the start of a manufacturing process. Costs will usually depend on both the final product and sector of industry. For example building a construction plant for new cars can require initial investments of billions of euros.

Although marketing and sales do not seem a logical next step in an innovation process, they are of key importance. A successful market entry of new products will depend on sales to customers, thereby assuring that all investments and expenditures made earlier (like research and development, production engineering and marketing) will be earned back.

> Only the sales of the product generate revenues!

All steps in the innovation process prior to the stage of sales require adequate funding and investments. Those initial investments can be substantial while the return on these investments will be realised through sales. Using IP enables companies to create large enough margins when selling their innovative products to earn back those initial investments. Thus while IP contribute to the return on investment of companies, they can incentivize the market launch of their innovations at the same time. Conversely, intellectual properties only have value if a product is brought to market.

4.3 Using IP information for decision making throughout the innovation process

Using information from available intellectual properties in a timely manner is useful to avoid potential issues after market introduction of the product or to reduce certain costs throughout the innovation process.

In figure 4.2 the type of information that can be used and the moment of use is displayed.

We distinguish two kinds of analysis to retrieve and analyse such information;

1. patent landscape analysis

   a. Technical information about known solutions,
   b. Appropriated technical solutions with potential legal effect to take into account,
   c. A market analysis with names of competitors or potential partners

2. Freedom to Operate (FTO) analysis

   Information with potential infringement and risks assessment.

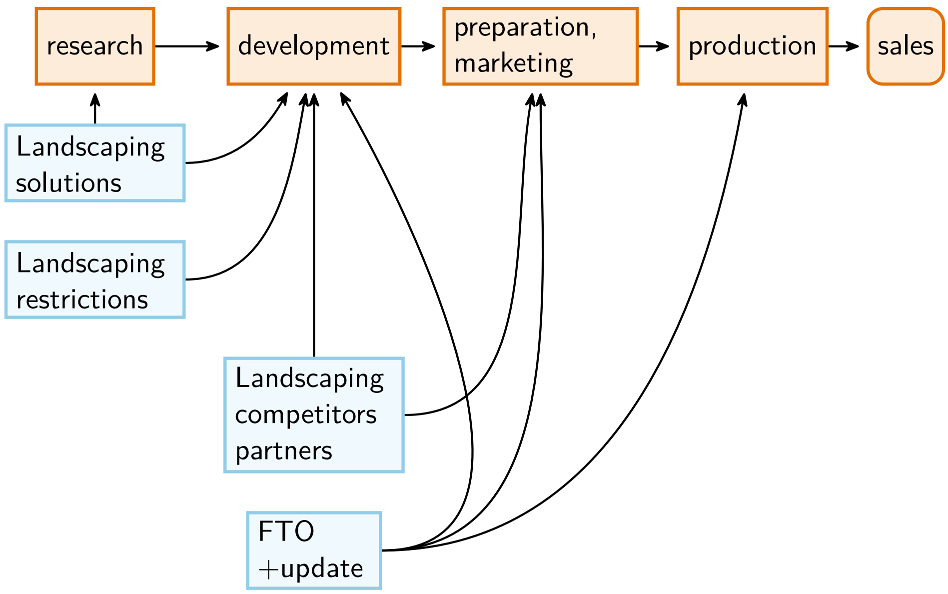

Figure 4.2: IP information in the process for a new product

4.3.1 Patent landscape analysis

In a global market companies and research organisations are surrounded by competitors and other actors. Using a patent landscape analysis one will acquire more information about them and about their technologies.

In a patent landscape analysis data can be analysed in three ways. Those three ways will generate useful data enabling easier decision making throughout different stages of the innovation process.

A. It is useful to create an overview of known technologies in order to be able to determine which problems and solutions need to be further analysed and developed within your organisation. For this analysis (technical) persons with knowledge of the subject-matter are necessary.

B. Prior to the decision to start developing a new product it is useful to study interesting technologies described by patents and pending patents. Search for possible technical solutions that may come close to the research and development of the organisation. Both technical and (legal) patent knowledge are required for these analyses. Analysing these data from a legal point of view may restrain your willingness to start a new innovation process. However, following decisions will depend on the business strategy of the organisation. Assuming that useful data have been retrieved and analysed one can decide to avoid potential litigation or infringement by redirecting the scope of research and development. A different strategy will be to license in the patents or start working as a partner of the patentee. These strategies will be further elaborated in next sections.

C. In addition to the technical and legal information from a patent landscape analysis, you can also obtain useful data for further market research. You can use this information to discover interesting countries, markets and possible partners for the sale of new products. It is also possible to analyze interesting markets in which you do not want or cannot be active yourself, but can become active through for example a partner.

4.3.2 Freedom to Operate (FTO) analysis

If the product reaches its final appearance at the end of the development phase, it could be useful to make an analysis about the risks to potential infringement of patents of third parties. An infringement of patents of third parties by may seriously hinder or even stop market introduction of a novel product or device. Such a risk assessment is called a Freedom to Operate analysis.

Throughout the patent landscape analysis one has analysed a first indication of potential infringement. But only when the the product is sufficiently specified and defined, an FTO analysis will be able to give sufficient certainty of the risks. Until the moment that your product will become part of the state-of-the-art for example through sales, a publication or a patent, it is still possible that others will get IP rights that will hinder sales of the products. Therefore it is useful to update the FTO analysis.

An FTO analysis requires both technical knowledge and legal IP expertise. Also knowledge about legal and financial risks is required. Due to that multidisciplinary character of such an FTO analysis costs are high. Therefore scope and nature of an FTO analysis better be aligned with the risks and business strategy of the company.

4.4 Strategic IP use

For companies it is important to determine which sort of IP rights are needed for launching successful innovations. Bigger companies and established firms have their own IP division with an IP strategy in place. In line with their strategy they usually start applying for a diversity of IP rights during the various stages of their innovation process. More in depth information about commonly used IP appropriation regimes by economic sector, products and process innovations can be found Cohen, Nelson, and Walsh [CNW00] and Scotchmer [Sco04], chapter 9.

We know that IP can enable companies to create enough margins once they sell their products to have a return on their investments thus incentivizing innovations. As IP proprietor the innovator may decide to stop competitors to bring the same product or process at the market price at lower costs or prices. Such mechanism is called a defensive IP strategy and is generally used by companies in the pharma sector. Economic literature about such a price mechanism enabled by product or process patents is described by Greenhalgh and Rogers [GR10] in chapters 1 and 2.

Figure 4.3 describes which kind of IP can be relevant in certain stages of the innovation process.

During research and development leading to technical innovations patents often are used. When publishing articles about scientific results at universities copyrights are important. Depending on the sector of industry in which a company is operational designs becomes relevant at the stage when the product will have a clearly defined outer shape and the shape needs to be easily recognizable by customers.

Brands are important for the marketing of products and services. In the interest of marketing designs can be used as well.

Know-how (secrets) about certain features in a manufacturing technology process, for example the use of parts are regarded as yet another intellectual property. If a company has a more offensive IP strategy patents can be used

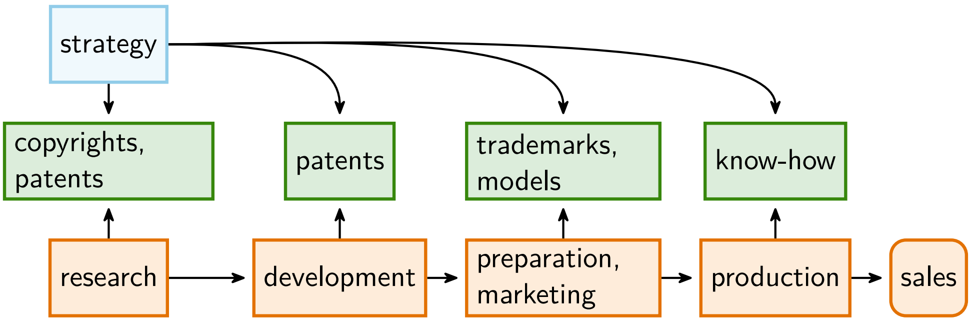

Figure 4.3: Generating IP with a new product

for (parts of) the manufacturing process. Such patented processes maybe out-licensed for example by companies in the chemical industry.

4.5 Purchasing and selling IP

In most economic sectors technologies are well developed at such a stage that many parts and processes are now available. Hence, there is no more reason to develop or manufacture those parts or processes. This is a huge difference compared with the upcoming economy at the start of the industrial revolution when manufacturers needed to have all parts and manufacturing processes in house by themselves. For example: the Ford Company wanted to have their own rubber plantations for the production of the tyres.

During the stage of research and development it is useful to analyse which technology, semi-finished products or parts can be purchased from others. Next the company can decide what needs further development by itself. Such strategy is also useful to identify interesting technologies developed by others which may solve technical problems and can be applied for further use. If these technologies have been appropriated in a patent portfolio of others they cannot be use as such without further analysis. Maybe there is a possibility to acquire ownership by assignment or come to terms in a license agreement.

4.5.1 Inlicensing patented technologies

A company may decide to obtain a license for a technology in order to start production and sales easier or faster. The results from a patent landscape analysis or Freedom to Operate may show that such a technology already exists or even that obtaining such a license agreement from a licensor is compulsory given the legal situation. Obviously, further information about the legal status on the validity of the patent in the country where the licensee

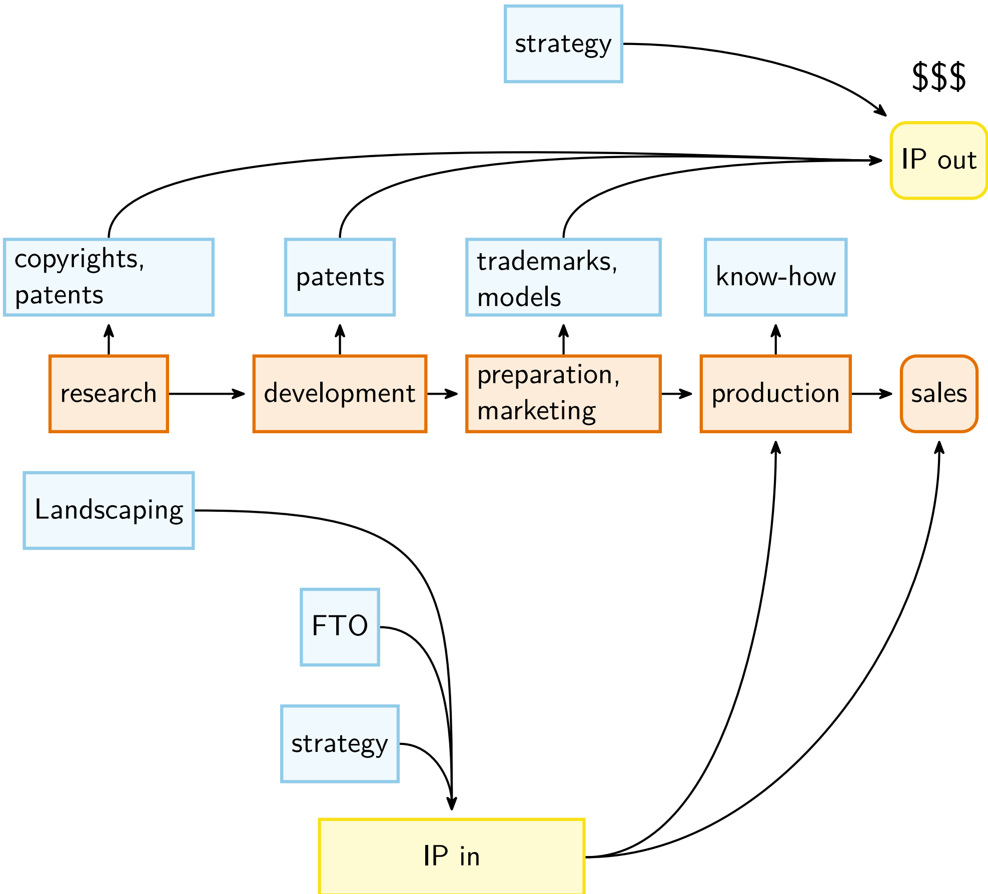

Figure 4.4: IE in and out

is operating is then required. For example if a Dutch manufacturer who is only working in the Netherlands needs certain technology the patent from the licensor should be valid in the Netherlands.

The business strategy and market perspectives are key in the decision making process to use licenses on technologies from third parties. But a patent landscape analysis is a useful business tool for companies with limited budgets for research and development. Next the company can contact the original patentee to start negotiations to obtain necessary patent licenses depending on its results. This is called inlicensing and presented as “IP in” in figure 4.4.

4.5.2 Outlicensing patented technologies

Usually a company decides to start production in a country or for a market by itself or by approaching others. Licensing technologies to others or franchising enables the patentee to do both. Such strategic decisions are often taken at central level of a multinational company or organisation and then followed up at decentral level.

But even if the patentee decides not to commercialise the technology itself, licensing to third parties remains an interesting option for example for organisations without production capacity in a particular country or market or a sales force. This is called outlicensing technologies and presented by “IP out” in figure 4.4. Outlicensing is often used successfully in cooperation with companies who are already active in certain markets and regions using the outlicensed technology to diversify their supply chain of products. Often the patentee is required to show successful sales records in an established home market for its patented technology.

4.5.3 Using patents in IP strategies

Depending on business strategy and use of IP a company can decide to outlicense their patent portfolio enabling others introducing new products or using manufacturing processes. Thereby allowing other companies to generate revenues without prior investments (in research and development, manufacturing, marketing, etc.) which were made by the patentee. This is called an offensive IP strategy which maybe more relevant for companies with products based upon a platform technology or compound with a large and diverse scope of applications.

On the other hand, companies may have a defensive IP strategy in the markets thereby stopping competitors selling look alike products to customers at lower prices. A large portfolio of nationally registered patented products in many countries is usually a prerequisite. Such a strategy may be relevant for companies with patented products based upon very narrowly defined technologies and compounds which can easily be copied or circumvented.

Which IP strategy a company can use will depend on its market position at present and foreseeable future versus those of competitors. A patent landscape analysis gives interesting insights and a global overview on certain technical developments over the years. Such information is useful to determine the market position as defined by patents and can contribute in the decision making process which IP strategy best be followed. At the same time with this analysis one can retrieve information about the patent strategy of competitors.

4.6 Strategic IP use of an academic patent

The University of Technology Delft and RHDHV started the development of the scaling up of Nereda technology based upon several patents. The first application with title 'Method of the treatment of waste water' is described in NL1021466C2. Next procedures as WO2004/024638A1 and EP1542932A1 followed. Patents for this technology has been registered in Canada (CA), China (CN), Japan (JP), Russia (RU), the United States of America (US), South Africa (ZA) and in Denmark (DK), Spain (ES), the Netherlands (NL), Poland (PL), Portugal (PT) and Slovenia (SI), see figure 3.6.

Next to costs building and maintaining a patent portfolio, business strategy and market development play an important role in the choice to file patent applications in various countries. National patent registrations enable RHDHV to commercialise their technology via direct sales or via licensees.

While the first patent was owned by the University of Technology Delft in 2005 granted patents via EP1542932B2 have been assigned to engineering company DHV (later Royal Haskoning DHV, or RHDHV). Meanwhile the title changed into 'Method of the treatment of waste water with sludge granules'.

4.6.1 Outlicensing the technology

After scaling up the Nereda technology has been installed at waste water treatment plants Veluwe, Rijn and IJssel and Rijnland in the Netherlands. Here, using the installed base of Nereda technology close to headquarters RHDHV acquired more know how and daily management expertise on operation and maintenance.

In a next step after 2010 market research was focussed on the application of the Nereda technology for water reuse in countries who suffer from recurrent periods of drought. As such RHDHV has been looking for cooperation with companies and contractors in countries such as Spain, Portugal and South Africa. This is possible using licenses agreements, franchises or via international public private partnerships.

Yet a different advantage of the Nereda technology, the reduction in footprint of a waste water plant necessary to treat municipal waste water, was then used for marketing and sales purposes. In large and growing cities where public space is limited and more waste water need treatment, the Nereda technology can be installed cost effectively during a revamp of an existing treatment plant. Even more so when effluent of these plants need to comply to strict environmental regulations. Likewise the Nereda technology has been installed in larger cities in Canada, China, Danmark, Poland, Slovenia, the USA and South Africa. For a Dutch engineering company like RHDHV it is almost impossible to market and install the technology by itself. In cooperation with regional or national companies who are already operational for example contractors and engineering companies these international markets can be serviced very well. For them the Nereda technology presents itself as an interesting opportunity to diversify their services.

In 2020 the Nereda technology was nominated as a breakthrough technology and commercially most valuable technology in the water sector.

4.6.2 Trademarks and logos

The application for registration of the European Union trademark (EUTM) for Royal HaskoningDHV was received at the EU IP Office on the 27th of June 2022. After examination of the trademark application it has been registered (with the number 018722758) and published on the 9th of September 2022. Next a time frame of possible opposition proceedings followed of another three months (till the 9th of December 2022). Then the EU trademark Royal HaskoningDHV was officially published with a minimum validity of 10 years starting from the application date (ic. 27th of June 2032).

The trademark Royal HaskoningDHV has been applied for with Nice classifications 9 (e.g. computer software), 35 (e.g. information and data compiling and analyzing for business management), 37 (e.g. installation and maintenance of water treatment installations, on-site construction and supervision of civil engineering works) and 42. (e.g. engineering services in the field of environmental technology).

Besides, the Nereda technology is registered in the three Benelux countries since 2018 (with the number 1371359). At the EU IP Office the Nereda technology has been registered since 2018 (with the number 017874261) for trademark protection in the 27 member states. The owner of these trademarks is Royal HaskoningDHV and the Nereda trademarks are listed in the Nice classifications 9, 11, 40 and 42.

Finally, according to the Global Brand Database of the WIPO, the Nereda technology received national and international trademark registrations via multiple application routes in some 25 countries (e.g. Australia, China, Czech Republic, Egypt, France, Germany, Italy, Japan, Malaysia, Poland, Romania, Russian Federation, Spain, Switzerland, Turkey, UK, United Arab Emirates, and the USA).

Chapter 5

Using IP for specific topics

5.1 Introduction

In this chapter the use of IP for specific topics is described. These topics are not linked to a specific activity as e.g. mentioned in chapter 4 and are of more general use.

Since software is nowadays very important in many parts of innovation and in society this topic is especially dealt with in section 5.2 and for open-source software in section 5.3.

5.2 Software

Computer programs are primarily protected by copyright.

Sometimes a patent can also be obtained on software-related inventions. Computer programs as such cannot be protected by patent law.

5.2.1 Copyright on software

Historically, there has been a long debate about whether software should be protected under patent law, copyright law or a separate legal regime. Ultimately, it was decided to protect software primarily under copyright law. This was a practical choice. Because software is written in programming language, it can be expressed as a kind of text. That is why computer programs are protected as literary works under copyright law. This principle is laid down in Article 10, paragraph 1, of the TRIPs Agreement and Article 4 of the WIPO Copyright Treaty.

Copyright protection of software relates to the concrete expression of the computer program, i.e. the specific form in which the programmer has expressed his intellectual creation in the source code. The source code concerns the instructions written by the programmer in a programming language and readable by humans. The target code is also subject to copyright protection. The object code comprises the binary, computer-readable and executable instructions generated from the source code by a compiler or interpreter. The object code is therefore in fact the translation of the source code into a computer-readable form.

The same conditions apply to copyright protection of software as to any other work. The source code and object code must demonstrate originality. They may not be derived from earlier software and the programmer must have made creative choices when writing the source code. If these conditions are met, the computer program is legally protected under copyright.[1]

Copyright does not protect an idea underlying a work. This means that the functionality, logic, method or purpose of a computer program and the processes, procedures, algorithms, programming languages and layout of data files that are used in the context of a computer program to be able to use certain functions of the program are not protected by copyright.

Copyright does not create a monopoly on the functionality of software. It grants the creator or right holder exclusive rights to permit or prohibit the reproduction (copying or editing) and publication (publishing, marketing, lending, renting or making available on demand) of a computer program. However, the creator or right holder cannot prohibit others from developing their own computer programs that pursue the same or similar purpose or functionality.

Copyright on software largely follows the same rules as those that apply to any other work. For example, the rules for authorship and legal succession are the same, right holders are entitled to the same broad exploitation rights and the term of protection is determined in the same way. However, there are a few special provisions concerning computer programs that are recorded in Chapter VI of the Copyright Act.

Based on the right of reproduction, the right holder may prohibit others from copying or taking over the computer program in whole or in part or from changing the source code. The law also stipulates that the right of reproduction also includes reproductions that are necessary for loading, displaying, executing, transmitting or storing the computer program. Someone who has lawfully obtained the software, such as the person who has purchased a computer program, may make these reproductions to the extent necessary

[1]Preparatory design material can also be protected by copyright, provided that no programming step with creative steps is needed to turn that material into a computer program.

for the use of the computer program. The lawful acquirer may also make a backup copy if this is necessary for the intended use.

In addition, the law permits the operation of software to be observed, studied and tested in order to discover the underlying ideas and principles. There is therefore an explicit authority to 'reverse-engineer' the software.

Furthermore, the 'decompilation' of a computer program, the reconstruction of a source code based on the target code, is permitted under certain circumstances. The law stipulates that a computer program may be decompiled, not in order to create a competing program that imitates the decompiled software, but to create compatible programs that can communicate with the decompiled software and are therefore interoperable. Furthermore, it follows from case law that decompilation is permitted to correct errors in the proper functioning of a computer program.

Graphical user interface and other elements

When executing a computer program on a computer, users are primarily confronted with the graphical user interface (GUI). These are the visual elements that enable the user to communicate with a computer program and thus instruct the program (software) to control the computer (hardware). Think of the various icons in the taskbar or the menu of a computer program.

However, the GUI itself is not a computer program. The special provisions regarding computer programs therefore do not apply to GUIs. A GUI can be independently protected by copyright, if the designer has made creative choices in the design of the interface. When decompiling a computer program for the purpose of interoperability or error correction, the source code may be reconstructed on the basis of the target code, but the GUI may not also be copied to the extent that it is protected by copyright. That would infringe the copyright on the GUI.

The same applies to the graphic and sound elements of, for example, video games. These can be independently protected by copyright if they are the creator's own intellectual creation, but do not themselves qualify as a computer program.

Video games

Video games generally consist of different types of works. In addition to software (source and target code), many video games contain a storyline, characters, images, animations, video, music and texts. Provided that the requirements are met, each of these works enjoys copyright protection. In principle, the copyright on the various works can lie with different creators. Sometimes hundreds of people can have made a creative contribution to a single video game. Because permission must be obtained from each rights holder for the release of the video game, the large number of rights holders can greatly hinder exploitation.

In practice, it is therefore arranged that all copyrights on the video game are, as much as possible, in the hands of the producer of the video game. The Copyright Act already provides for this to some extent. Insofar as creators have contributed to a video game under employment, the copyrights are in principle already held by the producer as employer under the law. For components of a video game that have been created by freelancers on assignment, the producer will usually have the copyrights contractually transferred to him. In addition, the producer can stipulate that the creator waives the right to mention his name, so that the rights are automatically granted to his/her company. For existing works that are included in a video game, such as the music that plays in the background of a video game, the producer will usually arrange permission by concluding a license agreement with the relevant copyright holders.

5.2.2 Software patent law

The starting point of patent law is that software as such cannot be patented, because computer programs are not considered inventions. However, the term invention contains the requirement of technical nature. A computer program that has a 'further technical effect' when executed on a computer, beyond the effect of the normal control of the computer, can therefore be patented. The computer program must provide a technical solution to a technical problem. Inventions with software must also meet the patent law requirements of novelty, inventive step and industrial applicability (see section 3.5).

Examples of computer programs that have a 'further technical effect' when executed on a computer are programs for controlling an anti-lock braking system (ABS) in cars, determining emissions from X-ray equipment, compressing data, encrypting electronic communications, restoring distorted digital images or training artificial intelligence. A 'further technical effect' can also concern the internal functioning or security of the computer. For example, programs for distributing the processor load, memory allocation or securing integrity during start-up offer a technical solution to a technical problem.

Patent protection is broader than copyright protection in the sense that patent law does grant a temporary monopoly on the technical functionality of the software-related invention. Patent law gives the holder the exclusive right to prohibit others from applying and using the patented invention for commercial purposes. It is therefore not permitted to market computer programs with the same 'further technical effect', or an effect that is more or less equivalent, during the period that the patent is valid.

5.2.3 Other ways to protect software

In addition to copyright protection of computer programs and patent protection of software-related inventions, software or parts thereof can also be protected by other intellectual property rights. For example, the source code of computer programs can be protected as a trade secret. Graphic features of computer programs, such as icons or pictograms of the graphic user interface, can be protected as drawings under design and model law, provided of course that the specific protection conditions are met.

In addition, the producer of software can of course contractually agree on additional protection with third parties, for example in license agreements.

Software can of course also be protected technologically, by security measures such as encryption methods and copy protection. The Copyright Act offers protection against circumvention of such technological protection measures.

5.3 Example of IP use in open source software

Open source software, or alternatively also called free software (free as freedom and not necessarily free as in a free beer), aims to make the software available to everyone and to be developed jointly.

Part of this software is in the public domain and another part is licensed. Well-known licenses are the GPL (GNU General Public License) or the BSD (Berkely Software Distribution) license. These licenses allow the use of the software under certain conditions. The user must therefore comply with those conditions and is not free to do everything.

Question:

> How can the terms of the open source licenses be enforced if the source code is publicly available? Click for answer.

Although the open source movement mainly originated in the academic world, there are now many large companies that develop open source software. These companies use the joint development to offer products and services around the open source software.

5.4 Example of IP use with standards

5.4.1 VESA (Video Electronics Standards Association)

Vesa is a non-profit corporation, which represents more than 300 companies. These companies are members of the corporation. It sets and supports interface standards for computers and consumer electronics.

The vision statement (from the website):

> VESA's vision is continual growth in technical standards development and evolution into an international trade association, with world-wide membership driving standards initiatives, product implementations, and market implementation.

5.4.2 Displayport

The displayport connection between a computer and a monitor is an important Vesa standard. The Vesa members are allowed to use the displayport logo on their products if these meet the requirements of the standard. In figure 5.1 the logo is displayed.

Figure 5.1: Displayport logo

Question:

> How can the use of the logo be limited to members who comply to the standard? Click for answer.

Appendix A

Glossary

A

academic patent

A patent where at least one of inventors is employed by a university or medical centre at the moment of the filing of the patent application. 11

B

BOIP

Benelux Office for Intellectual Property. The Benelux Office for Intellectual Property (dutch BBIE: Benelux-Bureau voor de Intellectuele Eigendom, french: Office Benelux de la Propriété intellectuelle) registers trademarks and designs for the Benelux. 58

breakthrough technology

Breakthrough technology is a new technology that will change a part of an industry significantly. 11, 45

C

claims

The claims are part of a patent to define the scope of protection. Usually, the set of claims consists of a main claim with several dependent claims. 22, 25

D

diversify

Diversification gives companies the opportunity to expand their range of products and services. 43

DPMA

Deutsches Patent- und Markenamt. The German Patent and Trademark Office is tasked with the granting of patents and trademarks for Germany. 58

E

EPC

European Patent Convention. A multilateral treaty to provide the legal system for granting European patents. Next to articles and rules for obtaining a patent, it also institutes the European Patent Organisation. In German: EPÜ, French: CBE. The European Patent Office is tasked with the granting of the European patents. 18, 54, 64

EPO

European Patent Office. The European Patent Office is tasked with the granting of the European patents according the EPC. Main seat in Munich with dependancies in Rijswijk, Berlin and Vienna. 18, 25, 28, 58

EUIPO

European Union Intellectual Property Office. The European Union Intellectual Property Office registers trademarks and designs for the EU. 58

examiner

The person working at a patent office, who will do the substantive examination (search report and grant) of a patent application. 27, 28

exhaustion

If a patent, trademark or design holder, or someone else with the permission of the holder, has sold a product, he can no longer use the patent, trademark or design right for that product. 19

F

Freedom to Operate

Freedom to Operate (FTO) is a study that analyzes potential risks of possible infringement of third party patents when introducing a new product to the market. 38, 39, 41

I

industrial property rights

Industrial property rights are all intellectual property rights except copyright. 36

innovation

Innovation is most often regarded as a new and tangible product or service which can be bought by customers in the market place. 36

intellectual properties

Intellectual property is a category of property that includes intangible creations of the human intellect. 6, 37, 38, 55

intellectual property rights

Intellectual Property Rights are the legal rights for creators over the creations of the minds. Intellectual property rights include patents, copyright, industrial design rights, trademarks, plant variety rights, trade dress, geographical indications, and in some jurisdictions trade secrets. 6, 55

IP

Intellectual Property. See also the description of intellectual properties and intellectual property rights in the glossary. 2, 6, 7, 9, 13, 37, 40, 43, 47, 55

IPR

Intellectual Property Rights are the legal rights for creators over the creations of their minds. See also the description of intellectual property rights and intellectual properties in the glossary. 6, 8, 9

J

JPO

Japan Patent Office. The Japan Patent Patent Office is tasked with the granting of patents and trademarks for Japan. 58

L

license

Meaning of license when used in IP: The right to commercially use a product or service to which another legal entity has intellectual property rights, on the basis of financial or material compensation. 41

O

Octrooicentrum Nederland

The Netherlands Patent Office is the patent office of the Netherlands. The Netherlands Patent Office is a department of the Netherlands Enterprise Agency, an agency of the Ministry of Economic Affairs and Climate Policy. The Netherlands Patent Office grants patents in the Netherlands and deals with European patents validated in the Netherlands. 18, 58

P

patent

A patent is an intellectual property right for an invention. 9, 17

patent landscape analysis

A patent landscape analysis provides a worldwide overview of patent holders who have technology in the economic sector of your organization. This gives you both market and product information of existing technology. With the help of this analysis, you can adjust research and development in time or decide to apply for a license from the patent holder for your market. 38, 39, 41, 44

PCT

Patent Cooperation Treaty. The Patent Cooperation Treaty is an international patent law treaty. It provides a unified procedure for filing patent applications to protect inventions in each of its contracting states. A patent application filed under the PCT is called an international application, or PCT application. 18, 25, 28, 30, 67

person skilled in the art

The term person skilled in the art, as used in patent law, is a constructed virtual person with knowledge and skill of a (broad) technical field. The person skilled in the art knows the entire state of the art, but has no inventive capacity. This constructed person skilled in the art is used in drawing up arguments, especially in the case of inventive step, sufficient disclosure and clarity of the patent application. 20–22

priority

A patent application can get right of priority from an earlier filing. This has the effect as if the patent application is filed on the date of the earlier filing. 31

R

ROW

National Patents Act 1995. Law for patents valid in the Netherlands, including the Caribbean, Curaçao and Sint Maarten. 18, 63

S

search report

The search report is prepared by the patent office where the patent application has been filed. It is used to assess novelty and inventive step during the examination of the patent. It therefore contains the most relevant documents that are used in the examination. 27–29

state of the art

The state of the art is formed by everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the patent application 20, 27, 37

U

USPTO

United States Patent and Trademark Office. The United States Patent and Trademark Office is tasked with the granting of patents and trademarks for the United States of America. 58

W

WIPO

World Intellectual Property Organisation. The World Intellectual Property Organization is one of the 15 specialized agencies of the United Nations (UN). WIPO administers 26 international treaties that concern a wide variety of intellectual property issues, ranging from the protection of audiovisual works to establishing international patent classification. WIPO currently has 193 member states and is headquartered in Geneva, Switzerland. 18, 28, 58

Appendix B

Links

B.1 National and international IP offices

Netherlands patent office (Octrooicentrum Nederland):
`https://www.rvo.nl/onderwerpen/innovatief-ondernemen/octrooien-ofwel-patenten`

Benelux Office for Intellectual Property (BOIP):
`https://www.boip.int/`

European Patent Office (EPO):
`https://www.epo.org/`

European Union Intellectual Property Office (EUIPO):
`https://www.euipo.europa.eu/`

World Intellectual Property Organisation (WIPO):
`https://www.wipo.int/`

German patent office (DPMA):
`https://www.dpma.de/`

United States Patents and Trademark Office (USPTO):
`https://www.uspto.gov/`

Japan Patent Office (JPO):
`https://www.jpo.go.jp/e/`

B.2 Additional information

ThatsIP E-learning Intellectuel Property:
`https://www.thatsip.nl/en/`
Netherlands patent office, videos explaining basics of patents:
`https://www.rvo.nl/onderwerpen/octrooien-ofwel-patenten/uitlegvideos`

UK Intellectual Property Office, videos on IP basic, case studies and others:
https://www.youtube.com/user/ipogovuk

Werkgemeenschap Octrooi-informatie Nederland (WON):
http://www.won-nl.org

B.3 Interesting publications from the WIPO

What is Intellectual Property?
https://www.wipo.int/publications/en/details.jsp?id=4528&plang=EN

Intellectual Property Basics: A Q&A for Students
https://www.wipo.int/publications/en/details.jsp?id=4410&plang=EN

Understanding Industrial Property
https://www.wipo.int/publications/en/details.jsp?id=4080&plang=EN

Inventing the Future
An Introduction to Patents for Small and Medium-sized Enterprises
https://www.wipo.int/publications/en/details.jsp?id=4350&plang=EN

Enterprising Ideas
A Guide to Intellectual Property for Startups
https://www.wipo.int/publications/en/details.jsp?id=4545&plang=EN

Guide to the International Patent Classification (2022)
https://www.wipo.int/publications/en/details.jsp?id=4593&plang=EN

International Patent Classification (IPC)
https://www.wipo.int/publications/en/details.jsp?id=4582&plang=EN

B.4 IP databases

Espacenet:
https://worldwide.espacenet.com/patent/

Espacenet pocket guide:
https://www.epo.org/espacenet-pocket-guide

Manual Espacenet (Dutch):
https://www.rvo.nl/sites/default/files/2021/03/Handleiding%20Espacenet_februari2021.pdf

European Patent Register:
https://register.epo.org/

European Patent Bulletin:
https://data.epo.org/expert-services/index.html

Google patents:
https://patents.google.com/

Depatisnet (DPMA):
https://depatisnet.dpma.de/DepatisNet/depatisnet

Patentscope:
https://patentscope.wipo.int/

The lens:
https://www.lens.org/

Trademark view and Design view:
https://www.tmdn.org/

EUIPO register (eSearch plus):
https://euipo.europa.eu/eSearch/

BOIP trademark register:
https://www.boip.int/en/trademarks-register

BOIP design register:
https://www.boip.int/en/designs-register

Register of the Netherlands patent office:
https://mijnoctrooi.rvo.nl/fo-eregister-view/

Register of the German patent office (DPMA register):
https://register.dpma.de/DPMAregister/pat/basis

UK Intellectual Property Office, online patent information and document inspection service:
https://www.ipo.gov.uk/p-ipsum.htm

Japan platform for patent information:
https://www.j-platpat.inpit.go.jp/

B.5 The patent classification schemes

CPC classification scheme at the USPTO (US patent and trademark office):
https://www.uspto.gov/web/patents/classification/cpc/html/cpc.html

CPC classification scheme in table to download scheme and definitions:
https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions/table

Appendix C

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[Sco04] S. Scotchmer. *Innovation and Incentives*. MIT Press, 2004. ISBN: 9780262195157. URL: https://mitpress.mit.edu/9780262693431/innovation-and-incentives/.

Appendix D

Parts of IP law

D.1 Parts of the Dutch patent law, Rijksoctrooiwet 1995 (in Dutch)

These are some of the most relevant parts of Dutch patent law (ROW).

- Artikel 53
  1. Een octrooi geeft de octrooihouder, behoudens de bepalingen van de artikelen 53a tot en met 60, het uitsluitend recht:
     a. het geoctrooieerde voortbrengsel in of voor zijn bedrijf te vervaardigen, te gebruiken, in het verkeer te brengen of verder te verkopen, te verhuren, af te leveren of anderszins te verhandelen, dan wel voor een of ander aan te bieden, in te voeren of in voorraad te hebben;
     b. de geoctrooieerde werkwijze in of voor zijn bedrijf toe te passen of het voortbrengsel, dat rechtstreeks verkregen is door toepassing van die werkwijze, in of voor zijn bedrijf te gebruiken, in het verkeer te brengen of verder te verkopen, te verhuren, af te leveren of anderszins te verhandelen, dan wel voor een of ander aan te bieden, in te voeren of in voorraad te hebben.
  2. Het uitsluitend recht wordt bepaald door de conclusies van het octrooischrift, waarbij de beschrijving en de tekeningen dienen tot uitleg van die conclusies.
  3. Het uitsluitend recht strekt zich niet uit over handelingen, uitsluitend dienende tot onderzoek van het geoctrooieerde, daaronder begrepen het door toepassing van de geoctrooieerde werkwijze rechtstreeks verkregen voortbrengsel. Het uitsluitend recht strekt zich evenmin uit tot de bereiding voor direct gebruik ten

behoeve van individuele gevallen op medisch voorschrift van geneesmiddelen in apotheken, noch tot handelingen betreffende de aldus bereide geneesmiddelen.

4. Het uitvoeren van de noodzakelijke studies, tests en proeven met het oog op de toepassing van artikel 10, eerste tot en met vierde lid, van Richtlijn 2001/83/EG tot vaststelling van een communautair wetboek betreffende geneesmiddelen voor menselijk gebruik (PbEG L 311) of artikel 13, eerste tot en met het vijfde lid van Richtlijn 2001/82/EG tot vaststelling van een communautair wetboek betreffende geneesmiddelen voor diergeneeskundig gebruik (PbEG L 311) en de daaruit voortvloeiende praktische vereisten worden niet beschouwd als een inbreuk op octrooien met betrekking tot geneesmiddelen voor menselijk gebruik, respectievelijk geneesmiddelen voor diergeneeskundig gebruik.
5. Is een voortbrengsel als in het eerste lid, onder a of b, bedoeld, in Nederland, Curaçao of Sint Maarten rechtmatig in het verkeer gebracht, dan wel door de octrooihouder of met diens toestemming in één der Lid-Staten van de Europese Gemeenschap of in een andere staat die partij is bij de Overeenkomst betreffende de Europese Economische Ruimte in het verkeer gebracht, dan handelt de verkrijger of latere houder niet in strijd met het octrooi, door dit voortbrengsel in of voor zijn bedrijf te gebruiken, te verkopen, te verhuren, af te leveren of anderszins te verhandelen, dan wel voor een of ander aan te bieden, in te voeren of in voorraad te hebben.
6. Een voortbrengsel als in het eerste lid, onder a of b, bedoeld, dat voor de verlening van het octrooi, of, indien het een Europees octrooi betreft, voor de dag, waarop overeenkomstig artikel 97, derde lid, van het Europees Octrooiverdrag de vermelding van de verlening van het Europees octrooi is gepubliceerd, in een bedrijf is vervaardigd, mag niettegenstaande het octrooi ten dienste van dat bedrijf worden gebruikt.

D.2 Parts of the European Patent Convention

These are some of the most relevant parts of patent law in the European Patent Convention (EPC).

- Article 52. Patentable inventions

  (1) European patents shall be granted for any inventions, in all fields of technology, provided that they are new, involve an inventive step and are susceptible of industrial application.

(2) The following in particular shall not be regarded as inventions within the meaning of paragraph 1:
   a) discoveries, scientific theories and mathematical methods;
   b) aesthetic creations;
   c) schemes, rules and methods for performing mental acts, playing games or doing business, and programs for computers;
   d) presentations of information.

(3) Paragraph 2 shall exclude the patentability of the subject-matter or activities referred to therein only to the extent to which a European patent application or European patent relates to such subject-matter or activities as such.

- Article 54. Novelty

  (1) An invention shall be considered to be new if it does not form part of the state of the art.
  (2) The state of the art shall be held to comprise everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the European patent application.
  (3) Additionally, the content of European patent applications as filed, the dates of filing of which are prior to the date referred to in paragraph 2 and which were published on or after that date, shall be considered as comprised in the state of the art.
  (4) Paragraphs 2 and 3 shall not exclude the patentability of any substance or composition, comprised in the state of the art, for use in a method referred to in Article 53(c), provided that its use for any such method is not comprised in the state of the art.
  (5) Paragraphs 2 and 3 shall also not exclude the patentability of any substance or composition referred to in paragraph 4 for any specific use in a method referred to in Article 53(c), provided that such use is not comprised in the state of the art.

- Article 56. Inventive step

  An invention shall be considered as involving an inventive step if, having regard to the state of the art, it is not obvious to a person skilled in the art. If the state of the art also includes documents within the meaning of Article 54, paragraph 3, these documents shall not be considered in deciding whether there has been an inventive step.

- Article 83. Disclosure of the invention

  The European patent application shall disclose the invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art.

- Article 84. Claims

  The claims shall define the matter for which protection is sought. They shall be clear and concise and be supported by the description.

- Article 87. Priority right

  (1) Any person who has duly filed, in or for
    (a) any State party to the Paris Convention for the Protection of Industrial Property or
    (b) any Member of the World Trade Organization,

    an application for a patent, a utility model or a utility certificate, or his successor in title, shall enjoy, for the purpose of filing a European patent application in respect of the same invention, a right of priority during a period of twelve months from the date of filing of the first application.

  (2) Every filing that is equivalent to a regular national filing under the national law of the State where it was made or under bilateral or multilateral agreements, including this Convention, shall be recognised as giving rise to a right of priority.

  (3) A regular national filing shall mean any filing that is sufficient to establish the date on which the application was filed, whatever the outcome of the application may be.

  (4) A subsequent application in respect of the same subject-matter as a previous first application and filed in or for the same State shall be considered as the first application for the purposes of determining priority, provided that, at the date of filing the subsequent application, the previous application has been withdrawn, abandoned or refused, without being open to public inspection and without leaving any rights outstanding, and has not served as a basis for claiming a right of priority. The previous application may not thereafter serve as a basis for claiming a right of priority.

  (5) If the first filing has been made with an industrial property authority which is not subject to the Paris Convention for the Protection of Industrial Property or the Agreement Establishing the World Trade Organization, paragraphs 1 to 4 shall apply if that authority, according to a communication issued by the President of the European Patent Office, recognises that a first filing made with the European Patent Office gives rise to a right of priority under conditions and with effects equivalent to those laid down in the Paris Convention.

- Article 88. Claiming priority

  (1) An applicant desiring to take advantage of the priority of a previous application shall file a declaration of priority and any other

document required, in accordance with the Implementing Regulations.

(2) Multiple priorities may be claimed in respect of a European patent application, notwithstanding the fact that they originated in different countries. Where appropriate, multiple priorities may be claimed for any one claim. Where multiple priorities are claimed, time limits which run from the date of priority shall run from the earliest date of priority.

(3) If one or more priorities are claimed in respect of a European patent application, the right of priority shall cover only those elements of the European patent application which are included in the application or applications whose priority is claimed.

(4) If certain elements of the invention for which priority is claimed do not appear among the claims formulated in the previous application, priority may nonetheless be granted, provided that the documents of the previous application as a whole specifically disclose such elements.

- Article 89. Effect of priority right

  The right of priority shall have the effect that the date of priority shall count as the date of filing of the European patent application for the purposes of Article 54, paragraphs 2 and 3, and Article 60, paragraph 2.

D.3 Parts of the Patent Cooperation Treaty

These are some of the most relevant parts of Patent Cooperation Treaty (PCT).

- Article 5. The Description

  The description shall disclose the invention in a manner sufficiently clear and complete for the invention to be carried out by a person skilled in the art.

- Article 6. The Claims

  The claim or claims shall define the matter for which protection is sought. Claims shall be clear and concise. They shall be fully supported by the description.

- Article 8. Claiming Priority

  (1) The international application may contain a declaration, as prescribed in the Regulations, claiming the priority of one or more

earlier applications filed in or for any country party to the Paris Convention for the Protection of Industrial Property.

(2) (a) Subject to the provisions of subparagraph (b), the conditions for, and the effect of, any priority claim declared under paragraph (1) shall be as provided in Article 4 of the Stockholm Act of the Paris Convention for the Protection of Industrial Property

(b) The international application for which the priority of one or more earlier applications filed in or for a Contracting State is claimed may contain the designation of that State. Where, in the international application, the priority of one or more national applications filed in or for a designated State is claimed, or where the priority of an international application having designated only one State is claimed, the conditions for, and the effect of, the priority claim in that State shall be governed by the national law of that State.

- Article 33. The International Preliminary Examination

(1) The objective of the international preliminary examination is to formulate a preliminary and non-binding opinion on the questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), and to be industrially applicable.

(2) For the purposes of the international preliminary examination, a claimed invention shall be considered novel if it is not anticipated by the prior art as defined in the Regulations.

(3) For the purposes of the international preliminary examination, a claimed invention shall be considered to involve an inventive step if, having regard to the prior art as defined in the Regulations, it is not, at the prescribed relevant date, obvious to a person skilled in the art.

(4) For the purposes of the international preliminary examination, a claimed invention shall be considered industrially applicable if, according to its nature, it can be made or used (in the technological sense) in any kind of industry. "Industry" shall be understood in its broadest sense, as in the Paris Convention for the Protection of Industrial Property.

(5) The criteria described above merely serve the purposes of international preliminary examination. Any Contracting State may apply additional or different criteria for the purpose of deciding whether, in that State, the claimed invention is patentable or not.

(6) The international preliminary examination shall take into consideration all the documents cited in the international search report.

It may take into consideration any additional documents considered to be relevant in the particular case.

- Rule 64. Prior Art for International Preliminary Examination

  64.1 Prior Art

  (a) For the purposes of Article 33(2) and (3), everything made available to the public anywhere in the world by means of written disclosure (including drawings and other illustrations) shall be considered prior art provided that such making available occurred prior to the relevant date.
  (b) For the purposes of paragraph (a), the relevant date shall be:
    (i) subject to item (ii) and (iii), the international filing date of the international application under international preliminary examination;
    (ii) where the international application under international preliminary examination claims the priority of an earlier application and has an international filing date which is within the priority period, the filing date of such earlier application, unless the International Preliminary Examining Authority considers that the priority claim is not valid;
    (iii) where the international application under international preliminary examination claims the priority of an earlier application and has an international filing date which is later than the date on which the priority period expired but within the period of two months from that date, the filing date of such earlier application, unless the International Preliminary Examining Authority considers that the priority claim is not valid for reasons other than the fact that the international application has an international filing date which is later than the date on which the priority period expired.

  64.2 Non-Written Disclosures

  In cases where the making available to the public occurred by means of an oral disclosure, use, exhibition or other non-written means ("non-written disclosure") before the relevant date as defined in Rule 64.1(b) and the date of such non-written disclosure is indicated in a written disclosure which has been made available to the public on a date which is the same as, or later than, the relevant date, the non-written disclosure shall not be considered part of the prior art for the purposes of Article 33(2) and (3). Nevertheless, the international preliminary examination report shall call attention to such non-written disclosure in the manner provided for in Rule 70.9.

64.3 Certain Published Documents

In cases where any application or any patent which would constitute prior art for the purposes of Article 33(2) and (3) had it been published prior to the relevant date referred to in Rule 64.1 was published on a date which is the same as, or later than, the relevant date but was filed earlier than the relevant date or claimed the priority of an earlier application which had been filed prior to the relevant date, such published application or patent shall not be considered part of the prior art for the purposes of Article 33(2) and (3). Nevertheless, the international preliminary examination report shall call attention to such application or patent in the manner provided for in Rule 70.10.

Appendix E

Documents

E.1 WO 2004/024638 A

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

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Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** METHOD FOR THE TREATMENT OF WASTE WATER WITH SLUDGE GRANULES

(57) **Abstract:** The invention relates to a method for the treatment of waste water comprising an organic nutrient. According to the invention, the waste water is in a first step fed to sludge granules, after the supply of the waste water to be treated the sludge granules are fluidised in the presence of an oxygen-comprising gas, and in a third step, the sludge granules are allowed to settle in a settling step. This makes it possible to effectively remove not only organic nutrients but optionally also nitrogen compounds and phosphate.

WO 2004/024638 A1

METHOD FOR THE TREATMENT OF WASTE WATER WITH SLUDGE GRANULES

The present invention relates to a method for the treatment of waste water comprising an organic nutrient, wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge particles and the discharge of organic nutrient-depleted waste water.

Such a method is known in the art, for example, from US 3,864,246. Waste water having a high rate of biological oxygen demand (BOD) is mixed with sludge flocs. The thus obtained sludge flocs-containing waste water is brought into contact with oxygen (air). The conditions chosen augment the growth of sludge flocs (that is to say biomass particles) that have improved settling properties. This reduces the time necessary for separating the microorganisms (in particular bacteria) that provide biological breakdown, from the waste water.

A drawback of the known method, despite the improved settling velocity, is that the implementation of the method requires a relatively large surface area, that is to say large-scale purification occupies an undesirable amount of space.

It is an object of the present application to improve the method, while occupying less space in comparison with the known method.

To this end the method according to the invention is characterised in that

- in a first step the waste water is fed to sludge granules,
- after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step, with the granules being in a fluidised condition and

- in a third step, a settling step, the sludge granules are allowed to settle.

This allows the method to be carried out in a relatively limited reactor volume. This may reduce the occupation of space down to a fifth. The reaction conditions chosen promote the formation of sludge granules (as opposed to sludge flocs) with excellent settling properties. Moreover, the conditions in the first step are oxygen-depleted, and in practice they are anaerobic, since there is no oxygen added. In the first step the sludge granules take up organic nutrients from the supplied waste water, and they are stored inside the microorganisms in the form of a polymer, such as polybetahydroxybutyrate. Should oxygen be supplied in the first step, this must not be in an amount that would prevent the storage of organic nutrient. In the second step, breakdown of the stored organic nutrients occurs under aerobic conditions. In addition, this aerobic second step may effect the breakdown of possibly present ammonium into nitrate. In the second step also the interior of the sludge granules is anaerobic and this is where the stored organic nutrients are broken down utilising nitrate. This produces nitrogen gas, resulting in an effective reduction of the N-content in the waste water. For the elimination of N-compounds to be broken down, the oxygen concentration in the second step is less than 5 mg/ml, and preferably less than 2 mg/ml. In this way the use of pre-positioned or post-positioned reactors for the removal of nitrogen compounds can be avoided, or their purifying capacity can be downscaled, which means a saving in costs. The present invention also makes it possible to eliminate phosphate. To this end, in a step that is not the first step, and preferably at the end of the second step or at the beginning of the third step, sludge granules are removed. Surprisingly it so happens, that under the conditions of the present invention phosphate accumulating microorganisms are not competed out. All the microorganisms needed for the method according to the invention are found in the sludge of purification plants. They do not need to be isolated, since the conditions specified ensure that these microorganisms constitute part of the sludge granules. The conditions according to the invention give rise to the formation of sludge granules that are significantly larger and have a higher density than the sludge flocs obtained according to the conditions as known from US 3,864,246 (see Fig. 1), having a settling velocity >10 m/h (as opposed to approximately 1 m/h for the known sludge flocs) and a sludge volume index <35 ml/g. The sludge volume index is the volume taken up by 1 gram of biomass after 1 hour's settling. For the purification of a subsequent portion of waste water the steps 1 to 3 (one cycle) are repeated. The invention is very suitable for the treatment of sewage water.

In the first step the waste water is preferably fed to a bed of sludge granules, and the sludge granules settle in the third step, forming a bed of sludge granules.

This allows the microorganisms to be exposed to a higher concentration of organic nutrient, which promotes granular growth.

According to a preferred embodiment, the waste water is fed to the bed of sludge granules at a rate such as to avoid fluidisation of the bed.

Since it is to a large extent avoided that present already treated waste water mixes with waste water to be treated, this allows the microorganism to be exposed to the highest possible concentration of nutrient which, as already mentioned, promotes granular growth. The term "to avoid fluidisation" is understood to mean that the bed does not fluidise, and/or that as a result of introducing the waste water, mixing occurs at most in up to 25% of the height of the bed. The waste water may, for example, be sprayed onto the bed directly or by using means for limiting the force with which the waste water can disturb the bed surface. In any case, mixing will occur at most in up to 25%, preferably in less than 15% of the height of the bed. Instead of introduction from the top side of the bed of sludge granules, the waste water may preferably be introduced from below. Especially in the latter case, the feed rate will be limited such that no fluidisation of the bed occurs. In both cases it is possible to displace and discharge purified water still present between the sludge granules from the bed in an effective manner, i.e. with little or no mixing of waste water and purified (nutrient-depleted) waste water, as will be discussed below. In principle it is also possible to introduce the waste water into the bed of sludge granules via pipes.

According to a preferred embodiment, at least a part of the nutrient-depleted waste water is discharged in the third step, after at least partial settling.

The removal of nutrient-depleted waste water prior to the addition of fresh waste water to be treated means that a smaller reactor volume is needed, and that the microorganism-comprising sludge granules come into contact with a highest possible concentration of nutrients. This is favourable for the formation of sludge granules. The height of liquid in the reactor is for example twice, and preferably 1.5 times or less, such as 1.2 times the height of the bed of settled sludge granules.

According to a preferred embodiment, at least a part of the nutrient-depleted waste water is discharged during the feeding of waste water to the bed of sludge granules in the first step.

In that case, the discharge of nutrient-depleted waste water is preferably the consequence of displacement due to waste water being fed to the bed of sludge granules.

Thus with one single action both the addition of fresh waste water, and the discharge of treated waste water is realised. This can be accomplished at a low capital outlay. Further savings are possible on control technology (fewer measurements are required) and operating costs. Furthermore, mixing of treated waste water with waste water to be treated is avoided, so that the concentration of nutrients to which microorganisms in the sludge granules are exposed is as high as possible, providing the previously mentioned advantage of growth in the form of sludge granules. The displaced treated waste water is preferably discharged at the top side of the bed. Due to the displacement, any flocs that may be formed are flushed out of the reactor. Therefore, the waste water is advantageously introduced via the bottom of the bed.

An important embodiment is one wherein the waste water is introduced in an amount of 50 to 110%, preferably 80 to 105% and most preferably 90 to 100% of the void volume of the bed.

In this way the biomass in the form of sludge granules is utilised optimally, at the smallest possible reactor volume.

The introduction of the waste water is preferably followed by an interval before commencing the second step.

This promotes the uptake of nutrients from the waste water, and contributes to the formation of sludge granules with good settling qualities. If desired, mixing may take place during the interval.

The interval is preferably sufficiently long for the removal of at least 50%, preferably at least 75% and most preferably at least 90% of the organic nutrient from the waste water.

This contributes the most to the formation of sludge granules with good settling qualities, while the purification of the waste water is optimal.

It is preferred for the waste water to be introduced in the third step, wherein sludge granules that settle more slowly are discharged from the reactor and sludge granules that settle more quickly remain in the reactor.

This further increases the pressure to select for granular growth. The introduction of waste water may be performed at a low flow rate during settling of the sludge granules, preferably after at least part the sludge granules have formed a granular bed but, as explained elsewhere, most preferably after the granular bed has formed. In the first two methods there is overlap between the first and third step. In the second and especially in the third method, light sludge flocs that have settled on the bed, or that would have the tendency to do so, are carried away by the flow of nutrient-depleted water displaced by waste water. As a consequence there is a pressure of selection resulting in maintaining the characteristics of the sludge in the form of granules. It is preferred for the discharge to take place in the third step via a discharge opening just above the final bed.

The invention will now be elucidated with reference to the following exemplary embodiment wherein

Fig. 1 shows a graph of the acetate, phosphate, ammonium, and NO_3^- + NO_2^- concentration during a cycle of the method according to the invention.

Figs. 2a and b show sludge flocs according to the prior art and sludge granules according to the present invention, respectively.

An air lift reactor (3 litre, height/diameter 20) was fed with 1.5 litres of waste water per cycle, which waste water represents an apropriate model for a domestic waste water. The composition was 6.3 mM sodium acetate; 3.6 mM ammonium chloride, 0.6 mM potassium phosphate, 0.37 mM magnesium sulphate, 0.48 mM potassium chloride and 0.9 ml/l standard solution of trace elements. The reactor was seeded with aerobic active sludge from a domestic wastewater purification plant. The reactor was operated in successive batch cycles. One cycle consisted of the following steps:

i) The introduction of 1.5 litres of model waste water at the bottom side of the reactor, for 60 minutes, so that there is a plug flow regime of waste water through the settled granular bed.

ii) Aeration for 111 minutes at a flow rate of 4 litres of air per minute.

iii) Settling of the granular sludge for 3 minutes after the termination of the aeration.

iv) Discharging the treated model waste water from the effluent outlet point at half the reactor height. Any biomass present at this moment above the effluent outlet point was removed from the reactor together with the treated waste water.

v) 1 minute interval, after which feeding with model waste water was recommenced.

By adding a base or acid, the pH in the reactor was maintained at 6.5 to 7.5 and the temperature was kept at 20°C. During the aerated phase ii) the concentration of dissolved oxygen was maintained at approximately 1.8 mg/ml. On the one hand this keeps the oxygen concentration sufficiently high for aerobic breakdown of nutrient in the external part of the sludge granules, and on the other hand only a low pumping capacity is required for the addition of air. After all, under these conditions, the transfer of oxygen from the air is very efficient. Consequently, there is also little energy required for the supply of oxygen. The breakdown of nitrogen compounds was shown to be optimal at these oxygen concentrations, with only minimal amounts of nitrate being found in the treated waste water.

In Table 1 the mean concentrations of the model waste water and the treated water are shown. The mean purification result is also given. Figure 1 shows the plot of the acetate (o), phosphate (Δ), ammonium (black diamond) and the sum of the nitrate and nitrite (open diamond) concentration during one cycle. Fig. 2b shows a photograph of the sludge granules obtained by the method. The obtained sludge granules were stable for at least 300 days, after which this experiment was stopped. The method according to the invention thus makes a reliable control of the operation possible. Fig. 2a shows typical sludge flocs having a settling rate as described in US 3,864,246. Although US 3,864,246 successfully combats the growth of filamentous organisms, which form so-called light sludge, the sludge flocs formed have a settling velocity of at best 1 m/h. In contrast, the sludge granules according to the present invention have very high settling velocities (>10 m/h), while the distance over which settling takes place may be relatively short.

Table 1 Concentrations of the untreated and treated model waste water

<table>
<tr><th>Mean values</th><th>Model waste water</th><th>Treated waste water</th><th>Removal Efficiency</th></tr>
<tr><td>Acetate (mM)</td><td>6.3</td><td>0</td><td>100%</td></tr>
<tr><td>NH_4^+ (mM)</td><td>3.6</td><td>0</td><td rowspan="3">97%</td></tr>
<tr><td>NO_3^- (mM)</td><td>0</td><td>0.1</td></tr>
<tr><td>NO_2^- (mM)</td><td>0</td><td>0</td></tr>
<tr><td>PO_4 (mM)</td><td>0.6</td><td>0.04</td><td>94%</td></tr>
</table>

One of the factors contributing to granular growth is feeding waste water with a highest possible nutrient concentration to the sludge granules. For this reason it is expedient to avoid mingling between treated waste water in the reactor and freshly supplied waste water. In those cases where a low nutrient concentration in the waste water prevails for many cycles, e.g. more than 10, nutrient may be added to the waste water if necessary. One option would be using liquid manure.

The present invention may be implemented in numerous ways. For example, instead of using one reactor it is propitious to use three reactors, the three reactors being operated out of phase. That is to say, while waste water is fed to one reactor, the aeration step is carried out in a second reactor, while in a third reactor settling takes place and possibly discharge of purified water. This keeps the capital outlay for pumps, especially with regard to their required maximum capacity, within limits. Treated waste water is released gradually and this is advantageous if this waste water needs to undergo a further treatment, since then also a smaller reactor for post-treatment suffices. Since compared with the above described experiment, reactors will in practice be relatively higher, settling will take longer. This means that feeding may take one third of the time, aeration and settling together two thirds of the time. A buffer tank for temporary storage of waste water to be treated is thus avoided and the three batch-operated reactors make continuous operation possible. The invention is illustrated by way of an air-lift reactor, but the invention may be embodied with any other type of reactor, such as a bubble column reactor.

CLAIMS

1. A method for the treatment of waste water comprising an organic nutrient, wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge particles and the discharge of organic nutrient-depleted waste water, **characterised** in that
- in a first step the waste water is fed to sludge granules,
- after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step, with the granules being in a fluidised condition and
- in a third step, a settling step, the sludge granules are allowed to settle.

2. A method according to claim 1, **characterised** in that in the first step the waste water is fed to a bed of sludge granules, and the sludge granules settle in the third step, forming a bed of sludge granules.

3. A method according to claim 2, **characterised** in that the waste water is fed to the bed of sludge granules at a rate such as to avoid fluidisation of the bed.

4. A method according to one of the preceding claims, **characterised** in that at least a part of the nutrient-depleted waste water is discharged in the third step, after at least partial settling.

5. A method according to one of the preceding claims, **characterised** in that at least a part of the nutrient-depleted waste water is discharged during the feeding of waste water to the bed of sludge granules in the first step.

6. A method according to one of the preceding claims, **characterised** in that the discharge of nutrient-depleted waste water is the consequence of displacement due to waste water being fed to the bed of sludge granules.

7. A method according to one of the preceding claims, **characterised** in that the waste water is introduced in an amount of 50 to 110%, preferably 80 to 105% and most preferably 90 to 100% of the void volume of the bed.

8. A method according to one of the preceding claims, **characterised** in that the introduction of the waste water is followed by an interval before commencing the second step.

9. A method according to claim 8, **characterised** in that the interval is sufficiently long for the removal of at least 50%, preferably at least 75% and most preferably at least 90% of the organic nutrient from the waste water.

10. A method according to one of the preceding claims, **characterised** in that a selection takes place in the third step, wherein sludge granules that settle more slowly are discharged from the reactor and sludge granules that settle more quickly remain in the reactor.

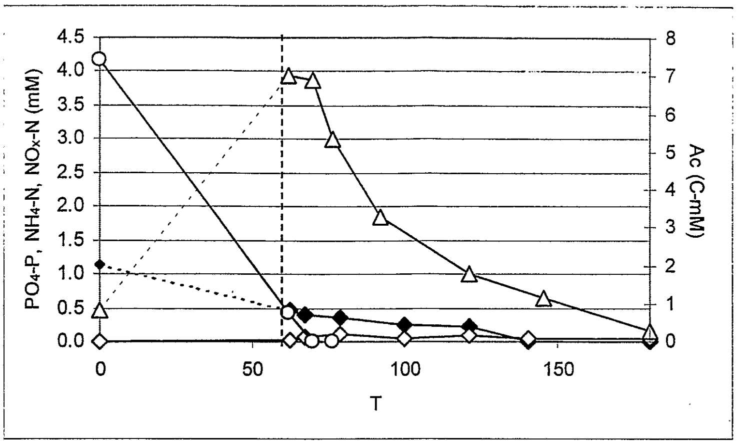

Fig. 1

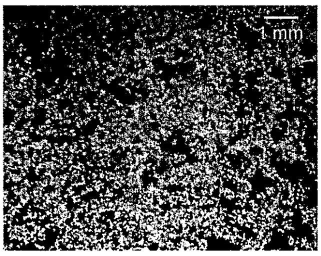

Fig. 2a

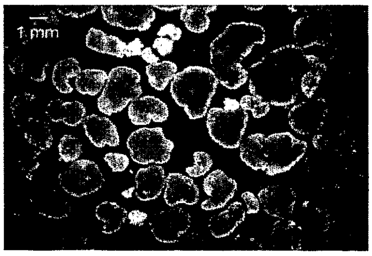

Fig. 2b

INTERNATIONAL SEARCH REPORT

Interna[tional A]pplication No
PCT/NL 03/00642

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C02F3/12 C02F3/26 C02F3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, BIOSIS, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BEUN J J ET AL: "Aerobic granulation in a sequencing batch airlift reactor" WATER RESEARCH, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 36, no. 3, February 2002 (2002-02), pages 702-712, XP004312290 ISSN: 0043-1354 page 703, right-hand column -page 704, left-hand column; figure 1 page 705, paragraph 3.1 - paragraph 3.2; figures 2,3 page 709, paragraph 4.1 page 710, paragraph 5 -page 711 ---	1-10

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 January 2004	19/01/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Glod, G

INTERNATIONAL SEARCH REPORT

Intern pplication No
PCT/NL 03/00642

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	DANGCONG P ET AL: "Aerobic granular sludge-a case report" WATER RESEARCH, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 33, no. 3, February 1999 (1999-02), pages 890-893, XP004151609 ISSN: 0043-1354 page 890, right-hand column page 892 -page 893	1-4,7,8, 10
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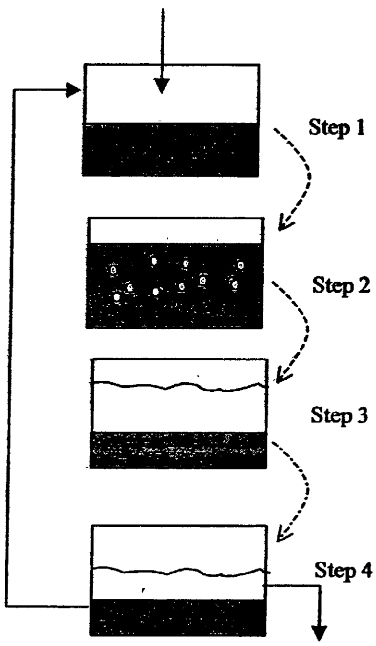
(54) Title: AEROBIC BIOMASS GRANULES FOR WASTE WATER TREATMENT



(57) Abstract: The method of producing aerobic biogranules for the treatment of waste water comprising the steps of: a) introducing waste water into a reactor; b) seeding the reactor with a active biomass material; c) supplying the oxygen-containing gas to the reactor to provide a mixing action to the suspension of biomass material in said waste water, the supply of oxygen-containing gas providing a superficial upflow gas velocity greater than 0.25 cm/s; d) initiating a period of nutrient starvation of the biomass material while continuing to supply oxygen-containing gas; e) allowing formed aerobic granules to settle in a settling zone in said reactor; f) discharging at least a portion of the waste water; g) repeating steps (a) to (f) until at least a portion of the biogranules in said settling zone are within a predetermined properties; and h) recovering said biomass granules within those predetermined properties.

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Aerobic biomass granules for waste water treatment

Background of the invention

1. Field of the invention

This invention relates to the production of the biomass of aerobic granules for the treatment of waste water.

In the treatment of waste waters by oxidative biological purification in aerobic granular sludge blanket (AGSB) reactors, waste water flows in an upward direction through an oxidation chamber in which micro-organisms are present. Movement of the suspension of waste water and micro-organisms within the waste water chamber is provided by the introduction of an oxygen-containing gas which also serves to mix the suspension of biological material and waste water. Within the reactors are inner zones of regulated settling which cooperate in the removal or accumulation of granules of a specified size range.

Other types of oxidative reactors which rely on the introduction of an oxygen-containing gas at the bottom of an oxidation chamber doubling up through waste water to be treated are generally referred to as uplift reactors. Such reactors are generally seeded with an active biological sludge which consumes contaminants within the waste water thus reducing the level of those contaminants and producing biomass which can later be removed from the reactor for recycle, or other uses, or disposal.

One such reactor is disclosed in US Patent No. 5,985,150 assigned to Biothane Systems International B.V. In this patent, there is disclosed an uplift reactor in which unsupported granular sludge is used to treat waste water. In this reference the sludge is introduced either as a supported or unsupported sludge into the reactor and waste water and an oxygen-containing gas supplied through the bottom of the reactor. The granular sludge is carried with the upwardly flowing gas into a settling region where a portion of the waste water is separated from the sludge and the remaining suspension returned to the oxidation chamber.

One problem with oxidative waste water treatment in reactors of this type is the lack of cohesion between the unsupported biomass thus making the handling of the biomass generally difficult. In particular, removing the biomass from the treated waste water and producing biomass which is suitably robust to be used as a seed for other reactors, has proved to be difficult.

However despite the difficulties in handling unsupported aerobic biomass granules it is recognised that the use of such granules over supported biomass granules generally has the potential to improve the purification efficiency of reactors thus allowing the use of smaller reactor systems. If the biomass of aerobic granules can also be produced to a commercially acceptable level, it is expected that the use will reduce suspension and mixing energy requirements and give rise to less erosion of equipment. However it has been difficult to produce the biomass of aerobic granules or biogranules of a sufficient size with adequate physical properties to be used effectively in aerobic uplift reactors.

It is an object of the present invention to provide a method of production of aerobic biogranules which can be used in the treatment of waste water.

Summary of the invention

The present invention is directed to a method of producing aerobic granules under controlled conditions for the treatment of waste water. The method comprising the steps of:

a) introducing waste water into a reactor containing an active biomass ;

b) supplying an oxygen-containing gas to the reactor to provide a mixing action and transfer of dissolved oxygen into the sludge in the waste water, the supply of oxygen-containing gas providing a superficial upflow gas velocity above 0.25 cm/s;

c) initiating a period of nutrient starvation in the reactor while continuing to supply oxygen-containing gas;

d) allowing formed aerobic granules to settle;

e) discharging and replacing at least a portion of the waste water;

f) repeating steps (a), (b), (c), (d) and (e) until the granules have predetermined physical properties; and

g) recovering biomass granules within those predetermined properties.

The applicants have found that aerobic granules suitable for uplift reactors and particular AGSB reactors may be formed under the above conditions without the need for the use of carrier materials.

It is believed that the starvation period in the reactor under shear conditions causes the biomass to agglomerate forming much more robust granules.

In another aspect of the invention, there is provided aerobic biogranules for waste water treatment having physical characteristics suitable for use in uplift reactors. Preferably these physical characteristics include a roundness aspect between 0.0 to 3.0, density between 1.004 to 1.85 g/cm^3, and average particle size between 100 and 10,000 µm.

Preferably the distance from any position within the biogranules to the outer surface of the biogranules is less than 800 µm. Thus for perfectly spherical biogranules the maximum diameter is 1600 µm.

Description of the drawings

Figure 1 is a schematic diagram of a column-type reactor used to perform the method of the invention;

Figure 2 is a process flow diagram of the method of the invention;

Figure 3 is a graph of a COD removal during waste water treatment;

Figure 4 is a graph of the changes in hydrophobicity of the cell surface over operation time; and

Figure 5 is a graph showing the changes in hydrophobicity as a function of starvation time.

Detailed description of the preferred embodiment of the invention

While the invention will now be described with reference to the production of aerobic biogranules in specific media, it would be readily recognised by those skilled in the art that the invention is applicable to the production of aerobic biogranules in any waste water system.

Due to the nature of bacterial degradation in waste waters, those bacteria which are best adapted to the particular media will proliferate while those without the ability to metabolise material in the media will not be dominant. Hence the inoculant for the process need only contain a range of bacteria.

In a typical method according to the invention, a reactor similar to Figure 1 is fed with waste water and an active biomass sludge. The preferred method as illustrated in Figure 2 involves initially step 1 of feeding the suspension of waste water and sludge without the supply of an oxygen containing gas.

The second step involves supplying an oxygen containing gas to cause the biomass to undergo oxidative respiration while under the shear conditions provided by the supply of gas.

The third step shown in Figure 2 involves stopping the supply of gas and allowing the biomass to settle, followed by the fourth step of discharging the supernatant and recycling the biomass to step 1.

Two column-type reactors 10 (1.2 m height) with a working volume of 2.4 l were used for sequential aerobic sludge blanket systems (both reactors had the same geometrical configuration, as shown in Figure 1, and the internal diameter of the reactor was 5 cm). The reactors were fed with waste water and started up by adding an active biomass sludge. In the examples 800 ml of municipal activated sludge (3000 suspended solids per litre) was added. Reactor 1 (R1) was fed with glucose as sole carbon source and reactor 2 (R2) with acetate as sole carbon source. Other operation conditions were kept the same for both reactors. Effluent was drawn at the middle port 12 of the column 10. The reactor was operated for 4 h per cycle with an hydraulic retention time (HRT) of 8 h and a substrate loading rate of 6.0 kg chemical oxygen demand (COD) m^{-3} per day was applied. The filling and withdraw time were each 5 min, the settling time was varied from 20 to 1 min and the remainder was the reaction time. No idling time was applied in the present research. The mean sludge retention time was 7 d in R1 and 9 d in R2. Sludge wastage was performed through effluent discharge. An oxygen containing gas which in the case of the examples was introduced through an air diffuser 11 by an air pump in the bottom of the column and controlled by a mass flow controller. An air flow rate of 3.0 l min^{-1} was applied. This gave a superficial gas velocity of 0.025 m s^{-1}

Media

The composition of the synthetic waste water was as follows: glucose, 1400 mg l^{-1}; peptone, 400 mg l^{-1}, meat extract (Laboratory-Lemco, Oxoid Ltd, Basingstoke, UK), 250 mg l^{-1}; NH_4CL, 200 mg l^{-1}; K_2HPO_4, 45 mg l^{-1}; $CaCl_22H_2O$, 30 mg l^{-1}, $MgSO_4$ $7H_2O$, 25 mg l^{-1}; $FeSO_47H_2O$, 20 mg l^{-1} and microelement solution, 1.0 ml l^{-1}. The carbon source was substituted by acetic acid (1875 mg l^{-1}) in R2. This gave a COD of 2000 mg l^{-1}. The microelement solution contained (g l^{-1}): H_3BO_3, 0.05; $ZnCl_2$, 0.05; $CuCl_2$, 0.03; $MnSO_4H_2O$, 0.05; $(NH_4)_6Mo_7O_{24}4H_2O$, 0.05; $AlCl_3$, 0.05; $CoCl_26H_2O$, 0.05 and $NiCl_2$, 0.05 (Tay and Yan 1996). The influent pH value was adjusted to 7.0 by the addition of $NaHCO_3$ and H_2SO_4.

The effluent was analysed for COD and the sludge sample for mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), sludge volume index (SVI) and specific oxygen utilization rate (SOUR) by following a standard method (APHA 1995) *Standard methods for the examination of water and waste water*, 19th edn, Washington DC: American Public Health Association. The granule size was measured by a laser particle size analysis system (MasterSizer Series 2600; Malvern Instruments Ltd, Malvern, Worcestershire, UK) when the size was less than 1880 μm or an image analysis system (Quantimer 500 Image Analyser; Leica Cambridge Instruments GmbH, Nubloch, Germany) when the size was greater than 1880 μm. Microbial observation was conducted by using either microscopy or image analysis (IA). The microbial compositions of granules were observed qualitatively with a scanning electron microscope (SEM) (Steriosan 420; Leica Cambridge Instruments). The granule samples were gently washed with phosphate buffer solution and allowed to settle naturally. The granules were then fixed with 4% paraformaldehyde and left for 4 h. The fixed granules were dehydrated by successive passages through 40, 60, 80 and 100% ethanol and then dried either by Freeze Dryer (Edwards, Crawley, West Sussex, UK) or Critical Points Dryer (E3000) (VG Microtech, East Grinstread, West Sussex, UK) and finally observed by SEM. The biomass density was measured by following the method of Beun *et al.* (1999), "Aerobic granulation in a sequencing bath reactor", *Water Research* 33,2283-2290. Cell hydrophobicity was determined by the method described by Rosenberg *et al* (1980), "Adherence of bacteria to hydrocarbons; a simple method for measuring cell-surface hydrophobicity", *FEMS Microbiology Letters* 9, 29-33. Hexadecane (0.25 ml) was used as the hydrophobic phase. The hydrophobicity was expressed as the percentage of cells adhering to the hexadadecene after 15-min partitioning. Granule strength was measured by following the method of Ghangrekar *et al.* (1996) Experience with UASB reactor start-up under different operating conditions, *Water Science and Technology* 34, 421-428 and expressed in terms of the integrity coefficient (%), which is defined as the ratio of the residual granule volatile suspended solid (VSS) and the total VSS after a certain period of shaking.

The evolution of aerobic granulation was monitored by means of optical microscopy, an IA technique and SEM during the operation of two sequential aerobic sludge blanket reactors fed with glucose and acetate, respectively. The physical characteristics and microbial activity of sludge in terms of SVI, settling velocity, size, hydrophobicity, SOUR, strength and roundness were also determined during the experiments.

Seed sludge

Microscopic examination of seed sludge taken from a local municipal waste water treatment plant showed a typical morphology of conventional activated sludge, in which filaments are observed. A SEM micrograph further revealed that the seed sludge had a very loose and irregular three-dimensional structure. The average floc size of the seed sludge was around 70 μm with an SVI value of 280 ml g^{-1}. As SVI values of activated sludge about 150 ml g^{-1} are typically associated with filamentous growth, , the seed sludge used seemed to be dominated by filamentous bacteria.

Characteristics of aerobic granules

The characteristics of aerobic granules at different stages and seed sludge were determined. Seed sludge had a mean diameter of 70 μm with an SVI value of 280 ml g^{-1}. Many filamentous bacteria were present in the seed sludge. One week after start-up, the SVI had decreased to 190 ml g^{-1} in R1 and 178 ml g^{-1} in R2 and compact aggregates were observed in both reactors (Fig. 2). One week later, the SVI had further decreased to 125 ml g^{-1} in R1 and 114 ml g^{-1} in R2 and the filamentous bacteria had disappeared in R2. Granular sludge at this stage had a much more compact and dense structure than seed sludge and 1-week old aggregates. With the operation proceeding, by the third week mature and round shaped granules with a clear boundary prevailed in the reactors and no visibly suspended biomass was present. After 1 min of settling, the mature granules had all settled, leaving a very clear supernatant fluid in the reactors. The SVI values of the mature granules were 51-85 ml g^{-1} in R1 and 50-80 ml g^{-1} in R2. These results clearly show that sludge settleability improves significantly as the granulation progresses.

The biomass concentration in the reactors gradually increased after start-up. After operation for 3 weeks, a stable concentration of 5.9 g MLSS l^{-1} in R1 and 8.6 g MLSS l^{-1} in R2 was reached. The mature granules from R1 still had filamentous bacteria extruding from the granule surface. However, the mature granules from R2 had a smooth surface as few filaments were observed. Glucose-fed granules had a mean diameter of 2.4 mm, with a range of 1.0 –3.0 mm, while granules grown on acetate had a mean diameter of 1.1 mm, with a range of between 0.5 and 1.5 mm. The microbial diversities of the glucose-and acetate-fed granules were different and the glucose-fed granules mainly consisted of coccoid bacteria in the internal part of the granule and some rod-like bacteria at the surface, with filaments tangled together; however, rod-like bacteria were predominant in whole acetate-fed granules.

The mature granules cultivated in R1 and R2 were found to have very good settleability. The settling velocity was 35 m h^{-1} for glucose-fed granules and 30 m h^{-1} for acetate fed granules. This settling velocity of aerobic granules is comparable with that of anaerobic granules cultivated in upflow anaerobic sludge blanket reactor (UASB). Results further showed that the mature granules had a dry biomass density of 41.1 g l^{-1} in R1 and 32.2 g l^{-1} in R2. The biomass densities of granules reached in R1 and R2 were relatively low compared with granules obtained in a sequencing batch airlift reactor (48 g l^{-1}). Higher settling velocity and biomass density of aerobic granules would result from the denser microbial structure. In biological systems, biomass serves as the biocatalyst for the degradation of organic matter. Obviously, a high retainable biomass in the reactor would ensure a faster and more efficient removal of organic pollutants, while excellent settling granules are essential for the good functioning of biological systems treating waste water.

The aerobic granules fed with glucose and acetate exhibited comparable microbial activity, in terms of SOUR, to conventional activated sludge, 69.4 mg $O_2 g^{-1}$ MLVSS h^{-1} for glucose fed mature granules and 55.9 mg $O_2 g^{-1}$ MLVSS h^{-1} for acetate-fed mature granules. In addition, the mature granules cultivated in both reactors had high physical strength and roundness. The roundness of a granule is calculated as 4πarea/perimeter^2 in which perimeter is the length of the granules outline. Aspect ratio is the ratio between the major axis and the minor aspect of an ellipse equivalent to the granule (0=line, 1=circle). The characteristic data of both glucose-and acetate-fed mature granules are summarized in Table 1. The systems were run very stably for more than 3 months before the experiments were stopped with a COD removal efficiency of around 97% at steady state when a loading rate of 6.0 kg COD m^{-3} d^{-1} was applied. The resulting aerobic biogranules are particularly well suited to use as seed in AGSB reactors.

TABLE 1

Characteristics of glucose- and acetate-fed mature aerobic granules

	Glucose	Acetate
Average diameter (mm)	2.4	1.1
SVI (ml g^{-1})	51-85	50-80
Settling velocity (m h^{-1})	35	30
Biomass concentration in reactor (g l^{-1})	5.9	8.6
Granule density (g l^{-1})	41.1	32.2
Granule strength (%)	98.2	97.1
Average aspect ratio*	0.79	0.73
SOUR (mg O_2 g^{-1} h^{-1})	69.4	55.9
COD removal efficiency (%)	97	98

*Roundness of the particle (0=line 1=circle)
SVI, Sludge volume index; SOUR, specific oxygen utilization rate;
COD.

The SBR system operates in a sequencing cycle of feeding, aeration, settling and discharging of supernatant fluid. As a result, micro-organisms growing in the SBR system are subjected to a periodical operation cycle.

The degradation time needed to reduce substrate concentration to a minimum was determined during SBR operation. The degradation time displayed a significant reducing trend with the increase in the operation cycles. In R2 fed with acetate, Fig. 3 shows that the time for COD reduction from 1000 to 100 mg l^{-1} decreased from 3 h at day 8 to 1 h at day 20. For a given aeration period, it appeared that a starvation phase existed during SBR operation. Thus, the aeration time period indeed consisted of two consecutive phases, a degradation phase in which the substrate was depleted to a minimum, followed by an aerobic starvation phase in which the external substrate was no longer available for micro-organisms. It is believed that 80% of the aeration period was in a state of aerobic starvation.

It is believed that under starvation conditions, bacteria became more hydrophobic which, in turn, facilitated microbial adhesion and aggregation. Aggregation can be regarded as an effective strategy of cells against starvation. Figure 4 shows changes in the hydrophobicity of the cell surface observed in R2 fed with acetate. As can be seen in Fig. 4, the seed sludge had a hydrophobicity of 39% and the hydrophobicity of the cell surface increased to 73% after the formation of aerobic granules at week 3. A similar trend was also observed in R1 fed with glucose. It is believed that the hydrophobicity of the cell surface is an important affinity force in the self-immobilization and attachment of cells.

Without wishing to be restricted to theory, in a thermodynamic sense, increasing the hydrophobicity of cell surfaces causes a decrease in the excess of Gibbs energy of the surface and further results in higher cell-to-cell interaction strength as well as a dense and stable structure. Consequently, starvation-induced changes in the characteristics of the cell surface and morphology seem to be in favour of the formation of strong microbial aggregation.

As mentioned above, the applicants believe periodical starvation in sequencing batch reactor (SBR) systems serves as a trigger for microbial granulation in activated sludge. However, the contribution of other operation conditions should preferably be controlled especially hydrodynamic shear and flow pattern in the reactor. Turbulence caused by upflow air aeration may act as the main hydraulic shear in a column-type SBR system, and can be approximately described by superficial air velocity.

In order to verify the effect of hydrodynamic shearing force on aerobic granulation, the SBR system of Fig. 1 fed with glucose was started up with two different superficial air velocities of 0.008 and 0.025 m s^{-1}, respectively. It was found that, when the SBR operated at a lower superficial air velocity of 0.008 m s^{-1}, no granules were observed in the system, but only fluffy flocs. However, regular shaped granules were successfully cultivated in the SBR operated at a high superficial air velocity of 0.025 m s^{-1} and preferably above 0.03 m s^{-1}. However, at a relatively high superficial air velocity of 0.041 m s^{-1}, granulation occurred and, because of the high shear strength, smooth, dense and stable aerobic granules were formed. According to the thermodynamic laws, the hydraulic shearing force in SBR, which is caused by upflow aeration, could force those periodical starvation-triggered denser aggregates to be shaped as regular granules, which have minimum surface free energy.

The microbial granules were cultured in a sequencing batch reactor with a medium containing glucose as the main source of carbon, as described earlier. Average diameter was 2.4 mm. Settling time was 2 min. Three 16S rRNA-targeted oligonucleotide probes were used to study the structure of the granules by FISH. The Eub338 probe with the sequence 5'-GCTGCCTCCCGTAGGAGT-3' was labeled with the fluorochrome CY2 and used to detect *Bacteria*. The Bacto1080 probe with the sequence 5'- GCACTTAAGCCGACACCT -3' was specific for *Bacteroides spp.* (as described in Sghir *et al.*, 2000) Quantification of bacterial groups within human fecal flora by oligonucleotide probe hybridization, *Applied and Environmental Microbiology* 66:2263-2266 and was labeled with the fluorochrome CY5. The Nsm156 probe contained the sequence 5'-TATTAGCACATCTTTCGAT-3' and was often used for the detection of ammonium-oxidizing bacteria from the *Nitrosomonas* cluster. This probe was labeled with tetrachlorofluorescein (TET). All probes were purchased from Research Biolabs, Singapore. Granules were cut with a cryomicrotome (Leica CM3050) and 50 μm sections were covered by 200 μl of hybridization solution for FISH (Kim and Ivanov, 2000). 10 μl of probe solution was added into the well. Final concentrations of the probes in the hybridization buffer were as follow: Eub338, 110 pmol·ml^{-1}; Bacto1080, 305 pmol·ml^{-1}, Nsm156, 130 pmol·ml^{-1}. The specimens were incubated for 4 h at 50°C, and the hybridization solution contained 50% formamide. These conditions have been optimized for the specific binding of Eub338 and Nsm156 probes (Kim and Ivanov, 2000). Because the Eub338 and Bacto1080 probes had similar melting temperature, FISH was performed simultaneously with these two probes. The probes were washed out after hybridization with 1 ml of washing buffer (hybridization buffer without formamide) for 2 h at 50°C because the recommended wash temperatures were 54°C for Eub probe, 50°C for Bacto1080 probe, and 48°C for Nsm156 probe.

To detect the exopolysaccharide (EPS) matrix in the granule, FITC-labeled lectin (ConA-FITC) from *Canavalia ensiformis* (Sigma, USA) was applied. A LIVE/DEAD® BacLight Bacterial Viability Kit (Molecular Probes, OR, USA) was used to detect dead cells. To detect channels and pores with diameters greater than 0.1 μm, granules were incubated for 4 h with a suspension of 0.1 μm TetraSpec Fluorescent Microsphere Standards (Molecular Probes, OR, USA). Final concentration of the microspheres was $2 \cdot 10^8$ particles·ml^{-1}.

The granule images were acquired by a Fluoview300 confocal laser scanning microscope (CLSM) (Olympus, Japan). Green and red fluorescence were excited by a 10 mW argon laser at 488 nm, separated with a 570 nm splitting filter and detected in channel 1 with a longpass filter 510 nm and in channel 2 with a bandpass filter 580nm - 640 nm. Red fluorescence from CY5 was excited by a helium neon laser at 633 nm and measured in channel 2 with a longpass filter 660 nm.

The edges of the granule were detected by analyzing the intensity of the light through the granule. The aerobic layer in the granule was detected by the presence of obligate aerobic ammonium-oxidizing bacteria *Nitrosomonas spp*. This layer was situated at a depth of 70-100 μm from the edge of the granule. Aerobic conditions in the interior of the granule were likely supported by the transport of oxygen through channels and pores. Channels and pores were detected in the granule and porosity values peaked at depths of 300 - 500 μm from the granule surface.

The anaerobic layer in the aerobically grown granule was detected by the presence of obligate anaerobic bacteria *Bacteroides spp*. This layer was situated at a depth of 800 - 900 μm from the surface of the granule. The layer of anaerobic bacteria was followed by a layer of dead microbial cells at a depth of 800 - 1000 μm from the surface of the granule. Anaerobiosis and cell death in the granule interior was probably promoted by the formation of polysaccharide plugs in the channels and pores. These plugs diminished the mass transfer rate of both nutrients and metabolites. Polysaccharide formation peaked at a depth of 400 μm from the surface of the granule.

Diffusion limitation in microbial aggregates may be overcome by the formation of channels and pores that interconnect the surface and the interior. The aerobic granules in these examples also contain channels and pores that penetrated to depths of 900 μm from the surface of the granule. The anaerobic layer formed when the porosity and channelling in the granule interior receded. Generally, the depth of the anaerobic layer depends on the microbial metabolic activity and transport of oxygen through the channels and the pores. Plugging of these channels and pores by polysaccharides will likely promote the formation of the anaerobic layer. The central core of the granule consisted of dead cells. Cell death was probably caused by diffusion limitation and could also be promoted by the plugging of the channels with polysaccharides.

The detection of an anaerobic layer in aerobically grown granules can have application in the size optimization of these granules. Large granules are likely to contain significant numbers of anaerobic bacteria, and the associated gases and organic acids produced during anaerobic fermentation can lead to the destruction of these granules. Therefore, the optimal diameter for the aerobic granules is proposed to be less than 1,600 μm. This is twice the distance from the granule surface to the anaerobic layer.

While the invention has been illustrated with reference to specific media, any liquid media can be treated to reduce the chemically and biologically oxidisable material therein.

CLAIMS

1. A method of producing aerobic biogranules for the treatment of waste water comprising the steps of:

a) introducing waste water into a reactor containing an active biomass sludge;
b) supplying an oxygen-containing gas to the reactor to provide a mixing action and transfer of dissolved oxygen into the sludge in the waste water, the supply of oxygen-containing gas providing a superficial upflow gas velocity above 0.25 cm/s;
c) initiating a period of nutrient starvation in the reactor while continuing to supply oxygen-containing gas;
d) allowing formed aerobic granules to settle;
e) discharging and replacing at least a portion of the waste water;
f) repeating steps (a), (b), (c), (d) and (e) until the granules have predetermined physical properties; and
g) recovering biomass granules within those predetermined properties.

2. The method of claim 1 wherein the starvation period in the reactor is at least 75% of the reaction cycle.

3. The method of claim 1 wherein the steps (b) to (d) are the equivalent of a single reaction cycle, the reaction cycle being repeated a plurality of times to produce biogranules of the predetermined size.

4. The method of claim 1 wherein the flow of oxygen-containing gas into said reactor creates turbulent flow within the reactor.

5. The method of claim 1 wherein the superficial upflow gas velocity is above 0.3 cm/s and less than 3.6 cm/s.

6. The method of producing aerobic biogranules for the treatment of waste water comprising the steps of:

a) introducing waste water into a reactor;

b) seeding the reactor with an acuve biomass material;

c) supplying oxygen containing gas to the reactor to provide a mixing action and oxygen to the suspension of biomass material in said waste water, the supply of oxygen-containing gas providing a superficial upflow gas velocity greater than 0.25 cm/s;

d) initiating a period of nutrient starvation of the biomass material while continuing to supply oxygen containing gas;

e) allowing formed aerobic granules to settle in a settling zone in said reactor;

f) discharging at least a portion of the waste water;

g) repeating steps (a) to (f) until at least a portion of the biogranules in said settling zone are within predetermined properties; and

h) recovering said biomass granules with those predetermined properties.

7. The method of claim 6, wherein the superficial upflow gas velocity is greater than 0.3 cm/s and less than 3.6 cm/s.

8. The method of claim 6 wherein steps (c) and (d) are the aeration stage of a single reaction cycle, the starvation period lasting at least 75% of the aeration stage.

9. The method of claim 6 wherein the predetermined physical property is a roundness aspect of 0.0 to 3.0.

10. The method of claim 6 wherein the predetermined physical property is a density of between 1.004 to 1.85 g/cm^3.

11. The method of claim 6 wherein the predetermined physical property is an average particle size of between 100 and 10,000 μm.

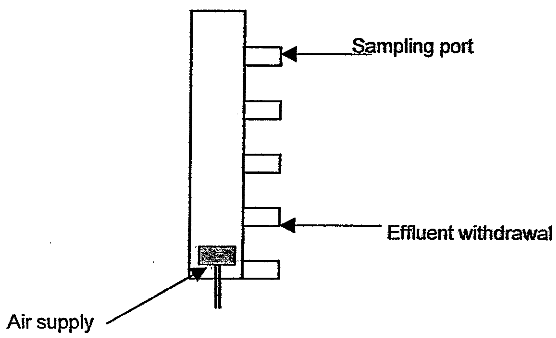
12. The method of claim 6 wherein the distance from any part of the formed biogranule to the nearest surface is less than 800 μm.

13. The method of claim 6 wherein the maximum diameter is 1600 μm.

14. The method of claim 6 wherein the settling zone is non-aerated.

15. The method of claim 6 wherein the ratio between the biomass of selected biogranules and suspended smaller particles of the biomass is between 0.001 to 0.20.

Figure 1



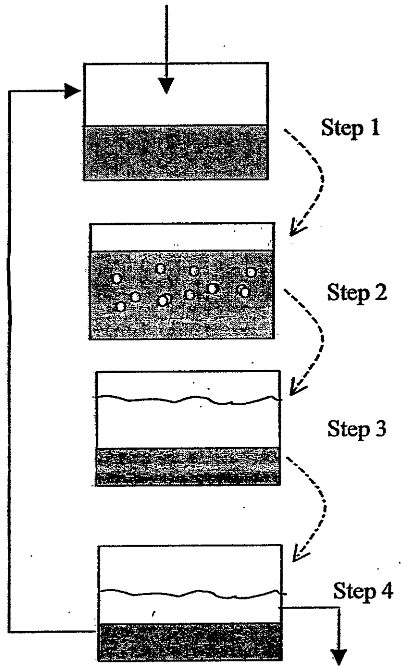


Figure 2

Figure 3

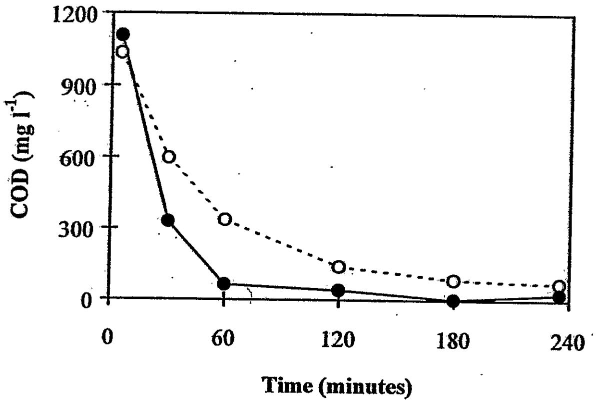


Fig. 3 COD removal curves at day 8 (o) and day 20 (•) in R2 fed with acetate.

Figure 4

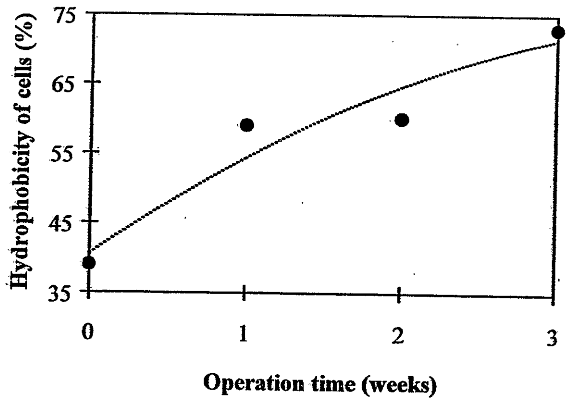
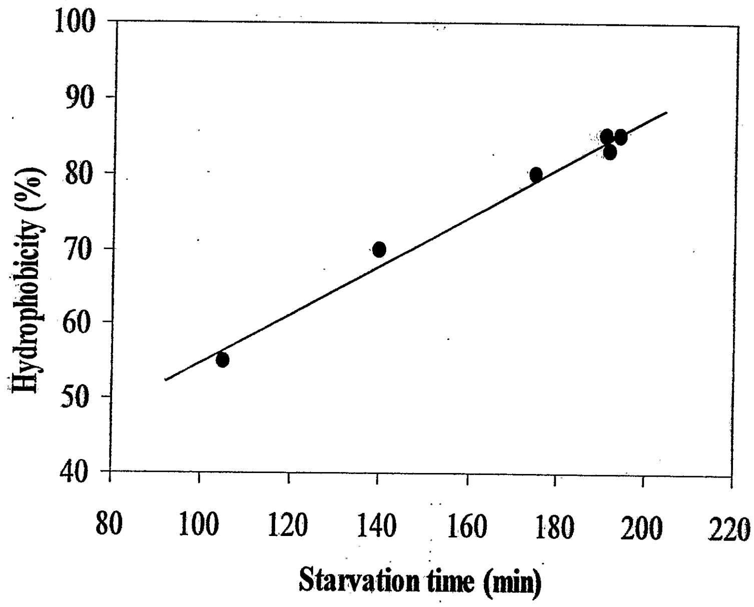


Fig. 4. Changes in hydrophobicity of cell surface with operation time in R2 fed with acetate.

Figure 5


100
90
80
70
60
50
40
Hydrophobicity (%)
80
100
120
140
160
180
200
220
Starvation time (min)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG03/00017

A.	**CLASSIFICATION OF SUBJECT MATTER**
Int. Cl. 7:	C02F 3/26, 3/00, 11/00
According to International Patent Classification (IPC) or to both national classification and IPC	
B.	**FIELDS SEARCHED**
Minimum documentation searched (classification system followed by classification symbols) REFER DATA BASE CONSULTED	
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI IPC C02F 3/26, 3/00, 11/00 & Key words (granul, biogranul, oxygen)	

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98/37027 A1 (TECHNISCHE UNIVERSITEIT DELFT) 27 August 1998 whole document	1-15
X	WO 93/15025 A1 (SANKYO COMPANY LTD) 5 August 1993	1, 6
A	Derwent Abstract Accession No.92-044885/06, Class D 15, JP 3288593 A (EBARA INFILCO Kk) 18 December 1991	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 26 March 2003	Date of mailing of the international search report 09 APR 2003
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **ASOKA DIAS-ABEYGUNAWARDENA** Telephone No : (02) 6283 2141

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	WO 02/18563 A1 (COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH) 7 March 2002	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SG03/00017

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
WO	9837027	EP	964831		
WO	9315025	AU	33670/93	JP	5261385

END OF ANNEX

E.3 EP 0 776 864 A

(19) Europäisches Patentamt
European Patent Office
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Remarks:
A request for correction under Rule 88 EPC for the purpose of the additional designation of Finland was received on 11.11.96.

(54) **Process for the aerobic biological purification of water**

(57) The invention is directed to a process for the aerobic purification of waste water in a reactor containing unsupported granular active sludge. In the figure there is a reactor (1) having two compartments, (2 and 3). At the bottom of compartment (2) air is introduced through (4). The mixture of gas, sludge and waste water has an upward flow in compartment (2) due to the airlift action of the air introduced in the bottom. The mixture of gas, sludge and waste water flows over the upper rim of the separation wall (5) between the two compartments (2 and 3). In the alternative it may flow through suitable openings provided in the wall (5) at a level below the water level in both compartments.

In compartment (3) a three phase settler (6) has been provided, which settler separates gas, sludge and water. Part of the water, which is substantially free from suspended sludge is removed from the ractor (1) as effluent.

The sludge is removed from settler (6) and is returned to the reactor, in compartment (3). The sludge and the waste water have a downward flow in this compartment (3). In this compartment the waste water is introduced through line (8). The resulting mixture flows to compartment (2) underneath the separation wall (5). It is to be remarked that alternatively the waste water may be introduced in compartment (2).

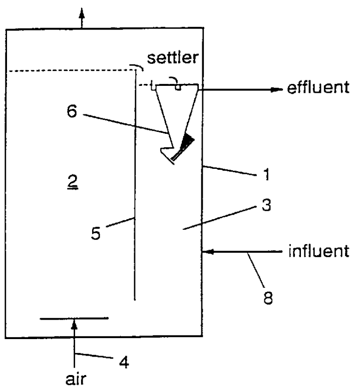

FIG. 1

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Description

Field of the invention

The present invention is directed to a process for the aerobic biological purification of water in a reactor containing active sludge. More in particular, the invention is directed to purifying drinking water, process water, and, most importantly, waste water.

Background of the Invention

In European patent application 24758, a process for oxidative biological purification of waste water is is disclosed, whereby the waste water flows in an upward direction through an oxidation chamber in which microorganisms are present, attached to an insoluble carrier. The function of the carrier is to support the active sludge by providing a surface for sludge to grow on and/or to increase the density of the sludge-carrier particle. Separation of the purified waste water from the supported active sludge bakes place at the top of the reactor and separated sludge is returned to the reactor.

In these type of reactors, also known as airlift reactors, movement of the suspension in the oxidation reactor is provided by introduction of oxygen, air or oxygen enriched air. At the top of the oxidation chamber the three phase mixture, consisting of water, gas and supported sludge is separated in a three phase separator.

Part of the recirculating waste water is separated from the supported activated sludge and is removed from the reactor as effluent. All, or at least a majority of the sludge is reeirculated to the reactor, usually in a compartment in which there is a downward flow. This may be, but is not necessarily an anaerobic or anoxic zone.

It is an object of the invention to provide an improved process or system for the aerobic purification of waste water of the type described herein above.

Summary of the Invention

The present invention is directed to a process for the aerobic biological purification of waste water in a reactor containing unsupported granular active sludge. The process comprises the steps of introducing waste water and a first gas containing oxygen into the reactor, where the first gas is introduced into the reactor at such a place that the first gas provides a mixing action, also called a turbulence, within the reactor. The method also comprises removing purified waste water from the reactor.

Another aspect of the invention is a reactor that is useful in the above-summarized process. The reactor provides for the aerobic purification of waste water, and comprises at least one first zone and means for creating an upward flow of waste water through the first zone, and at least one second zone having a downward flow of waste water through the second zone. The reactor also has means for transferring the waste water from the first zone to the second zone at the top of the reactor, and means for transferring the waste water from the second zone back to the first zone at the bottom of the reactor. In addition, the reactor has a separator, preferably a three-phase separator, located in the second zone, where the separator has means for recirculating separated sludge by gravity to the second zone and means for removing water free from sludge. The reactor further has means for aerating, mixing and transporting waste water in the first zone.

Brief Description of the Drawinga

The foregoing summary, as well as the following detailed description of the preferred embodidiment of the invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there are shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown. In the drawings:

Fig. 1 is a schematic drawing of a preferred reactor of the invention including a separator; and

Fig. 2 is a schematic drawing of an expanded view of the separator and nearby features of the reactor of Fig. 1

Detailed Description of the Preferred Embodiments

The present invention is directed to a process for is the aerobic biological purification of water in a reactor containing unsupported granular active sludge, the oxygen necessary for maintaining aerobic conditions being provided in the form of an oxygen containing gas at such a place in the reactor that the oxygen-containing gas at least partly provides for the necessary mixing action in the reactor.

The present invention is based on the surprising discovery that the use of unsupported granular sludge is possible in an airlift reactor for aerobic biological purification. One of the important advantages of the use of unsupported granular sludge lies in the absence of the need to continuously supply a support material to the reactor, which is important in view of the cost of the material and the handling, and the ease in the further processing of the excess sludge. In addition thereto it can be remarked that the use of unsupported granular sludge generally improves the purification efficiency of the reactor, which leads to the possibility of using smaller reactor systems. Adhesion of the sludge to the support, which may present problems with certain types of sludge, no longer plays a role. Further, it is to be noted that the energy required for suspending and mixing the sludge is generally less than the amount of energy necessary in the conventional systems based on sand, glass or basalt. Finally the use of unsupported sludge has the distinct advantage that the unsupported sludge gives rise to less erosion of the equipment.

The present invention is in the area of the aerobic, biological purification of water, preferably waste water such as industrial and/or domestic waste water. Depending on the impurities present in the waste water, and in particular the presence of nitrogenous impurities, either a conventional biological oxidation of organic impurities to carbon dioxide and water is provided for or also nitrification, optionally a combination with denitrification in an anoxic zone of the reactor is possible. Depending on the type of waste water, the composition of the micro-organisms in the unsupported granular sludge will vary.

An important aspect of the present invention is the use of unsupported granular sludge. As is well-known in the art, unsupported granular sludge comprises biologicallyactive sludge granules containing either no or substantially no externally added support material, and having a density greater than about 1000 kg/m^3. There are various ways of making sure that the sludge in a reactor is unsupported. An easy way is to start-up an installation with supported aerobic sludge and let this sludge gradually become unsupported by simply recirculating only a part of the sludge and not supplying any support material to the reactor. Due to the growth of micro-organisms in the course of time the amount of support will gradually decrease. In the alternative, one can take an amount of granular anaerobic sludge from an existing system. Generally this sludge will then become gradually aerobic due to increase of the amount of aerobic microorganisms.

Of course it is also possible, once one or more installations using the process of the present invention have become operational, to use unsupported, aerobic granular sludge from such an installation to start-up a new installation.

Once the system is operating properly under steady-state conditions, no specific actions are necessary to keep the sludge in a proper condition. In this respect it is preferred to keep the mean residence time of the water in the system within the range of 0.3 to 20 hours, preferably between 0.5 and 10 hours, and most preferred between 0.5 and 5 hours.

In this respect it is to be noted that the term "unsupported" does not exclude the presence of minor, solid impurities in the granular sludge. Due to its very nature, waste water may be contaminated with sand or other small solid particles, which might be captured by the sludge. However, the granular unsupported sludge may be characterized by the fact that no, or substantially no, separate solid support particle is present in the majority of the granules. No external support is added during the process.

In order to operate properly, it is preferred that the amount of sludge present in the reactor range from about 5 to about 100 kg/m', preferably from about 15 to about 60 kg/m^3. The sludge is suspended in the liquid and is kept in suspension mainly by introduction of an oxygen-containing gas at an appropriate place in the reactor, usually at the bottom of the aerobic zone. This oxygen-containing gas is preferably air, oxygen or oxygen enriched air, and most preferably is air.

The reactor is generally divided into at least two zones, which zones are connected to each other at the top and the bottom, whereby in at least one of said zones, denoted the first zones, the waste water has an upward velocity due to the action of the oxygen-containing gas, and whereby at the top of the first zones the suspension flows into at least one second zone, wherein the waste water has a downward velocity. The second zones may be operated at very low dissolved oxygen concentration, but this is not necessarily the case.

In the prior art it is customary to recirculate the waste water from one zone to another in such a way that it flows over the top of the separation wall between the two zones. In such a situation the rate of recirculation increases almost exponentially with the increase in the water level, once it has risen to a level above the top of the separation wall.

The reactor of the present invention is provided with means for recirculating waste water from the first, also known as the aerobic zone, to the second zone, which means are preferably of such a construction that the rate of recirculation is approximately directly proportional to the level of water in the aerobic zone, when the level of water in the second zone is constant.

An easy way to construct a reactor that meets the criteria of directly proportional recirculation rate is to provide a separation wall which extends to a level above the usual water level in neighboring zones and to provide openings in the separation wall at a level below the level of the water in both zones, which openings have a sufficient cross-sectional area to provide a suitable recirculation.

It is also possible that the opening is below the water level in the first zone and above the water level in the second zone. The reactor is preferably provided with a separator, also sometimes called a settler, for example such as disclosed in EP-A 90,450, EP-A 311,215, EP-A 311,216 and/or EP-A 315,233. The entire disclosure of EP-A 315,233, which describes a preferred separator for use in the present invention, is incorporated herein by reference.

The separator provides for the gas, sludge and water to be separated from each other. The separated water is partly recirculated and partly removed as product water. The unsupported granular sludge will generally be recirculated for the major part, preferably to the second zone in which the waste water has a downward velocity. As the granular sludge may easily be disturbed by application of excessive shear forces, it is preferred to recirculate the sludge under the influence of gravity, for example using the system as disclosed in EP-A 24,758.

In a preferred embodiment, the separator is placed in the second zone of the reactor, wherein the waste water has a downward velocity. In order to prevent problems with capturing of air in the downward flowing water, it is preferred that the downward velocity of the waste water in this area will not exceed about 0.25 m/s, preferably not exceed about 0.20 m/s.

The actual construction of the separator, and in particular the number of partitions thereof (see feature 12 in Fig. 2) will depend at least partly on the gas load of the reactor. It has been found that in the application of the present type of separator, the number of partitions to be used should preferably be at least 1, whereas with gas loads of over 3 $Nm^3/m^2 \cdot h$ the number of partitions should be

$$P \geqq 1+\left|\frac{V\text{-}3.0}{3}\right|$$

wherein P is the number of partitions, and V is the gas load of the separator, expressed as $Nm^3/m^2 \cdot h$.

According to one embodiment it may be advantageous to supply a gas, for example an oxygen-containing gas or nitrogen, to the second zone wherein the waste water has a downward velocity. This supplying of gas may, in case it is oxygen-containing, improve the purification efficiency of the system, together with improving the efficiency of the sludge separation.

According to a preferred embodiment, the waste water that recirculates from the aerobic zone to the second zone is partly introduced into the separator located in the second zone. It is preferred to direct the water flow in such a way that the waste water has an upward direction before it enters the separator. This has the unexpected and surprising advantage that the separation efficiency is greatly increased.

In order to obtain this upward flow of the waste water in the second zone wherein the flow is mainly downward, it is possible to provide an additional separation wall at some distance from the separation wall between the first and second zones, preferably substantially parallel thereto and extending to a level below the entrance of the separator, said additional partition wall creating a separate downward flow compartment.

In an alternative embodiment, the separator may be constructed in such a way that it creates a separate compartment for downward flow, for example, by extending the separator across the entire width of the downward flow compartment. It is to be noted that in customary systems, the separator is constructed in such a way that the water can pass around the separator and accordingly the water will have an upward flow when reaching the entrance of the separator.

According to the invention, the mixing and suspending of the granular unsupported sludge is at least partly provided for by the introduction of an oxygen-containing gas. However, it is also possible to introduce all or part of the waste water through the bottom of the reactor, whereby the upward flow thereof aids in suspending the sludge and mixing the system. Finally, the airlift system may be assisted by some mechanical mixing.

According to the invention, the residence time of the waste water is generally from about 0.2 to about 20 hours, whereas the temperature range is from about 5°C to about 65°C, preferably from about 2O°C to about 45°C. The load of the reactor may be between about 0.2 and about 20 kg $COD/m^3 \cdot d$, optionally in combination with up to about 20 kg $Kjehldal\text{-}N/m^3 \cdot d$.

For a complete removal of both the organic as well as the nitrogen compounds, the COD/N ratio should preferably be at least 3. As the waste water to be purified will not always meet the minimum value it may be necessary to add an external COD source. This will depend mainly upon the degree to which the impurities have to be removed. Sometimes it may be useful to add nutrients to provide sufficient growth of sludge in the system. The external COD-source and/or nutrients can be added in various forms, such as solid, liquid or gaseous form. The COD-source can be added at various locations such as below the settler.

The invention is also directed to a reactor that is suitable for use in the process of the invention, the reactor comprising at least one first, also known as is aerobic, compartment provided with means for creating an upward flow of waste water, and at least one second compartment for downward flow of waste water, said compartments being provided with means for recirculating the waste water from the aerobic compartment to the second compartment at the top thereof and with means for recirculating the waste water from the second compartment to the aerobic compartment at the bottom thereof, and means for aerating, mixing and transporting waste water in the aerobic compartment. The reactor also comprises a separator, preferably placed in the compartment for downward flow, said separator having means for recirculating separated sludge by gravity to the compartment for downward flow and means for removing water free from sludge. A preferred reactor has a gap present between (a) the wall separating the first and second zone and (b) the wall of the separator.

According to a preferred embodiment, the separator is a three phase separator, whereas the means for recirculating the waste water from the aerobic compartment to the second compartment may be provided by openings in a separation wall between the aerobic compartment and the second compartment.

When applying the embodiment, wherein the waste water has an upward flow when entering the three phase separator, an additional separation wall is present between the means for recirculating the waste water from the aerobic compartment to the second compartment and the separator,

The reactor to be used in the present invention preferably has the separator in the second zone, i.e., the compartment with downward water velocity. The main advantage thereof is that the function of the separator is not, or almost not, disturbed by the large amount of air which is brought into the reactor. Furthermore, by restricting the downward velocity as indicated above, the action of the separator is improved because the liquid flow in the second compartment will not be hampered by gas, resulting in lower energy use.

The reactor to be used in the present invention preferably has a ratio of reactor height to reactor diameter of at least about 0.5, more preferably the ratio is from about 1 to about and 25, and most preferably the ratio is from about 2 to about 5.

In Fig. 1 a reactor 1 is shown, having two compartments or zones, 2 and 3. At the bottom of compartment 2, air is introduced through 4. The mixture of gas, sludge and waste water has an upward flow in compartment 2 due to the airlift action of the air introduced in the bottom. The mixture of gas, sludge and waste water flows over the upper rim of the separation wall 5 between the two compartments 2 and 3. In the alternative it may flow through suitable openings provided in the wall 5 at a level below the water level in both compartments. It is also possible that the opening is below the water level in the first zone and above the water level in the second zone.

In compartment 3 a three phase separator 6 has been provided, which separator separates gas, sludge and water. Part of the water, which is substantially free from suspended sludge, is removed from the reactor 1 as effluent.

The sludge is removed from separator 6 and is returned to the reactor in compartment 3. The sludge and the waste water have a downward flow In this compartment 3. In compartment 3, the waste water is introduced through line 8. The resulting mixture flows to compartment 2 underneath the separation wall 5. It is to be remarked that alternatively the waste water may be introduced in compartment 2.

In Fig, 2, a three-phase separator 6 suitable for use in the invention is illustrated. Separator 6 is provided in the compartment having a downward flow of water.

The separator 6 has a chamber 15 bounded by walls 10 and 11, of which wall 10 extends across the compartment, forcing the gas/sludge/waste water flowing from compartment 2 to compartment 3 downward between separation wall 5 and compartment wall 10. The gas/sludge/water mixture flows along wall 10 and guide plate 13, and enters the separator 6 at the upper side (right-hand aide as shown in Fig. 2) of the partitions 12. The mixture flows in a downward direction between the partitions, during which time the gas separates from the gas/aludge/water mixture. At the lower end of the partitions (12) (left-hand side as shown in Fig. 2) already a first separation takes place between sludge on the one hand and water/reBidual gas an the other hand. At least part of the sludge moves downward due to gravitational forces along the inner side of guide plate 12 and is returned to compartment 3. The remainder of the sludge-containing mixture travels upward and enters the chamber 15.

The effluent is recovered from the separator as it flows over the top of wall 11 into final effluent collection trough 14, from where it is removed from the reactor. The ns gas is collected in the overhead gas chamber and removed from the reactor (see Fig. 1).

The invention will now be illustrated in more detail by the following non-limiting example, which demonstrates the advantageous properties of the present ;invention.

EXAMPLE

Waste water having a COD content of 725 mg/l and a flow or 100 m^3/h was introduced in a system as illustrated in Fig. 1, having a settler as in Fig. 2. The reactor height was 9.0 m and its capacity was 200 m^3. The residence time was 2 hours and the reactor load was 8.7 kg COD/$m^3 \cdot$d The concentration of unsupported suspended granular sludge in the reactor was about 400 m/l, or about 35 g/l.

In order to oxidize the COD introduced into the reactor, 2500 m^3/h of air is required. This amount results in a residence time in compartment 2 of 6 minutes with an upward velocity of 90 m/h. In compartment 3, and particularly in the channel formed by the separation wall 5 and the separator wall 10, the downward velocity was about 0.18 m/s. The upward velocity of the water in the separator 6 was about 14 m/h.

From the separator, purified water was recovered having a COD content of 50 mg/l. The oxygen content of the gas recovered from the overhead gas compartment was 19% by volume.

It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular meodiments disclosed, but it is intended to cover modifications within she spirit and scope of the present invention as defined by the appended claims.

Claims

1. A process for the aerobic biological purification of waste water in a reactor containing unsupported granular active sludge comprising the steps of introducing waste water and a first gas containing oxygen into the reactor, where the first gas is introduced into the reactor at such a place that the first gas provides a mixing action within the reactor, and removing purified waste water from the reactor.

2. The process according to claim 1, wherein the sludge is present in the reactor in an amount of from about 5 to about 100 kg/m^3.

3. The process according to claim 1, wherein the sludge is present in the reactor in an amount of from about 15 to about 60 kg/m^3.

4. The process according to claim 1, wherein the first

gas is selected from the group consisting of oxygen, air and oxygen-enriched air.

5. The process according to claim 1, wherein the reactor is provided with at least one first zone and at least one second zone, where at least one first and at least one second zone are in fluid communication both at the top and at the bottom of the reactor, where waste water has an upward velocity in each first zone and a downward velocity in each second zone.

6. The process according to claim 5 wherein at least one second zone is operated under anoxic conditions.

7. The process according to claim 5 wherein the upward velocity is at least partly provided by the introduction of the first gas.

8. The process according to claim 5, further comprising a separator in fluid communication with the reactor, said separator providing for the continuous separation of purified water from granular sludge, said granular sludge thereafter being at least partly recirculated.

9. The process according to claim 8 wherein the unsupported granular sludge is recirculated back into a second zone.

10. The process according to claim 9, wherein the unsupported granular sludge is recirculated under the influence of gravity.

11. The process according the claim 8, wherein the separator is located inside the reactor and is a three phase separator.

12. The process according to claim 8, wherein the separator is located in a second zone of the reactor.

13. The process according to claim 8, wherein the waste water containing unsupported granular sludge has an upward velocity as it enters the separator.

14. The process according to claim 5 wherein the downward velocity of the waste water in the second zone does not exceed about 0.25 m/s.

15. The process according to claim 5, wherein the downward velocity of the waste water in the second zone does not exceed about 0.20 m/s.

16. The process according to claim 5, wherein a second gas is supplied to at least one second zone.

17. The process according to claim 16, wherein the second gas is an oxygen-containing gas.

18. The process according to claim 5, wherein the waste water has a first height in a first zone and a second height in a second zone and wherein the reactor is constructed in such way that the waste water recirculates at a rate approximately directly proportional to the difference between the first and second heights.

19. A reactor for the aerobic purification of waste water, suitable for use in the process of claim 1, said reactor comprising at least one first zone, a means for creating an upward flow of waste water through the first zone, at least one second zone having a downward flow of waste water through the second zone, a means for transferring the waste water from the first zone to the second zone at the top of the reactor and means for transferring the waste water from the second zone to the first zone at the bottom of the reactor, a separator located in the second zone, said separator having means for recirculating separated sludge by gravity to the second zone and means for removing water free from sludge, said reactor further having means for aerating, mixing and transporting waste water in the first zone.

20. The reactor according to claim 19, wherein the separator is a three phase separator.

21. The reactor according to claim 19, wherein the means for transferring the waste water from the first to the second zone is provided by openings in a wall separating the first and second zones.

22. The reactor according to claim 19 wherein a gap is present between the wall separating a first and second zone and the wall of the separator.

23. The reactor according to claim 19, additionally comprising means for introducing a second gas into the second zone at a level below the lowest part of the wall separating the second zone from the first zone.

24. The reactor according to claim 19, having a ratio of reactor height to reactor diameter of at least about 0.5.

25. The reactor of claim 24, wherein the ratio is from about 1 to about 25.

26. The reactor of claim 24, wherein the ratio is from about 2 to about 5.

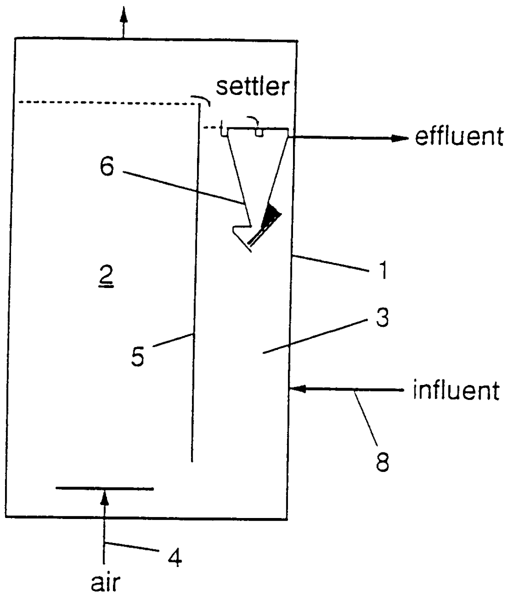
settler
effluent
6
2
1
3
5
influent
8
4
air

FIG. 1

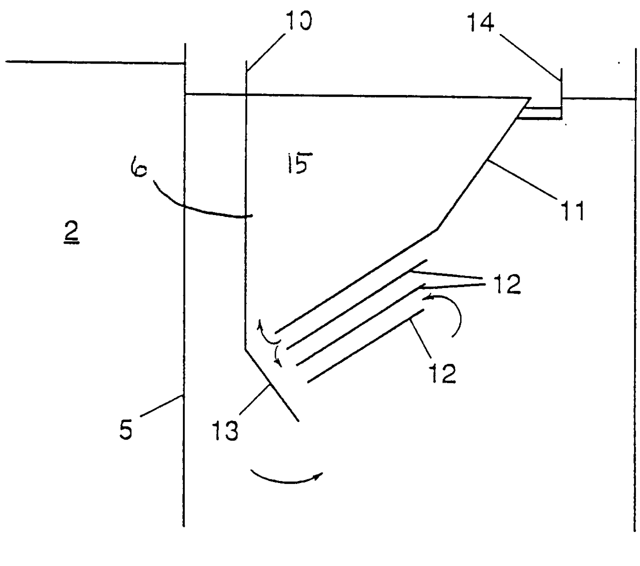
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FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 20 1932

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	NL-A-9 301 791 (BIOTHANE SYSTEMS INTERNATIONAL) * page 2, line 23 - page 5, line 23 * * page 6, line 34 - page 7, line 26 * * page 8, line 28 - page 9, line 4 * * page 10; claims 1,4,6-8 * ---	1-10	C02F3/22 C02F3/12 C02F3/30 B01J8/22
X	NL-A-9 301 792 (BIOTHANE SYSTEMS INTERNATIONAL) * page 2, line 33 - page 4, line 2 * * page 6, line 35 - page 7, line 19 * * page 9, line 8 - page 10, line 5 * * page 11; claims 1,2,4-6,8-10,12,13,15; figures * ---	1,4-11, 13,14	
A	EP-A-0 191 483 (SMITH & LOVELESS) * page 31; claims 1,3 * ---	1,6, 13-16	
D,A	EP-A-0 024 758 (GIST-BROCADES NV) * page 6; claims 1,2 * -----	1,4	TECHNICAL FIELDS SEARCHED (Int.Cl.6) C02F B01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 October 1996	Gonzalez Arias, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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E.4 EP 1 542 932 B

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(54) **METHOD FOR THE TREATMENT OF WASTE WATER WITH SLUDGE GRANULES**

VERFAHREN ZUR ABWASSERBEHANDLUNG MIT SCHLAMMPARTIKEL

PROCEDE DE TRAITEMENT D'EAUX USEES PAR DES GRANULES DE BOUE

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- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 176 (C-1183), 25 March 1994 (1994-03-25) & JP 05 337492 A (MITSUBISHI KAKOKI KAISHA LTD), 21 December 1993 (1993-12-21)**

Remarks:
The file contains technical information submitted after the application was filed and not included in this specification

EP 1 542 932 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to a method for the treatment of waste water comprising an organic nutrient wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge particles and the discharge of organic, nutrient-depleted waste water.

[0002] Such a method is known in the art, for example, from US 3,864,246. Waste water having a high rate of biological oxygen demand (BOD) is mixed with sludge flocs. The thus obtained sludge flocs-containing waste water is brought into contact with oxygen (air). The conditions chosen augment the growth of sludge flocs (that is to say biomass particles) that have improved settling properties. This reduces the time necessary for separating the microorganisms (in particular bacteria) that provide biological breakdown, from the waste water.

[0003] BEUN J J ET AL disclosed an aerobic granulation in a sequencing batch airlift reactor, wherein an aerobic granular sludge was cultivated while intensely mixed.

[0004] DANGCONG P ET AL discloses the observation of aerobic granular sludge in a sequencing batch reactor in which a synthetic urban wastewater containing sodium acetate as an organic substrate was fed, and dissolved oxygen (DO) was controlled at low concentration.

[0005] MORGENROTH E ET AL discloses the culturing of granules in a laboratory scale sequencing batch reactor (SBR) under aerobic conditions.

[0006] BEUN J J ET AL relates to N-Removal in a granular sludge sequencing batch airlift reactor.

[0007] EP-A-0 776 864 discloses a process for the aerobic biological purification of water.

[0008] A drawback of the known method, despite the improved settling velocity, is that the implementation of the method requires a relatively large surface area, that is to say large-scale purification occupies an undesirable amount of space.

[0009] It is an object of the present application to improve the method, while occupying less space in comparison with the known method.

[0010] To this end the method according to the invention is characterised in that

- in a first step the waste water is fed to sludge granules, under an aerobic conditions
- after the supply of the waste water to be treated an oxygen-comprising gas is introduced in a second step, wherein the oxygen concentration is less than 5mg/ml with the granules being in a fluidised condition and at the end of the second step or at the beginning of the third step granules are removed.
- in a third step, a settling step, the sludge granules are allowed to settle.

[0011] This allows the method to be carried out in a relatively limited reactor volume. This may reduce the occupation of space down to a fifth. The reaction conditions chosen promote the formation of sludge granules (as opposed to sludge flocs) with excellent settling properties. Moreover, the conditions in the first step are oxygen-depleted, and in practice they are anaerobic, since there is no oxygen added. In the first step the sludge granules take up organic nutrients from the supplied waste water, and they are stored inside the microorganisms in the form of a polymer, such as polybetahydroxybutyrate. Should oxygen be supplied in the first step, this must not be in an amount that would prevent the storage of organic nutrient. In the second step, breakdown of the stored organic nutrients occurs under aerobic conditions. In addition, this aerobic second step may effect the breakdown of possibly present ammonium into nitrate. In the second step also the interior of the sludge granules is anaerobic and this is where the stored organic nutrients are broken down utilising nitrate. This produces nitrogen gas, resulting in an effective reduction of the N-content in the waste water. For the elimination of N-compounds to be broken down, the oxygen concentration in the second step is less than 5 mg/ml, and preferably less than 2 mg/ml. In this way the use of pre-positioned or post-positioned reactors for the removal of nitrogen compounds can be avoided, or their purifying capacity can be down-scaled, which means a saving in costs. The present invention also makes it possible to eliminate phosphate. To this end, in a step that is not the first step, and preferably at the end of the second step or at the beginning of the third step, sludge granules are removed. Surprisingly it so happens, that under the conditions of the present invention phosphate accumulating microorganisms are not competed out. All the microorganisms needed for the method according to the invention are found in the sludge of purification plants. They do not need to be isolated, since the conditions specified ensure that these microorganisms constitute part of the sludge granules. The conditions according to the invention give rise to the formation of sludge granules that are significantly larger and have a higher density than the sludge flocs obtained according to the conditions as known from US 3,864,246 (see Fig. 1), having a settling velocity >10 m/h (as opposed to approximately 1 m/h for the known sludge flocs) and a sludge volume index <35 ml/g. The sludge volume index is the volume taken up by 1 gram of biomass after 1 hour's settling. For the purification of a subsequent portion of waste water the steps 1 to 3 (one cycle) are repeated. The invention is very suitable for the treatment of sewage water.

[0012] In the first step the waste water is preferably fed to a bed of sludge granules, and the sludge granules settle in the third step, forming a bed of sludge granules.

[0013] This allows the microorganisms to be exposed to a higher concentration of organic nutrient, which promotes granular growth.

[0014] According to a preferred embodiment, the waste water is fed to the bed of sludge granules at a rate such as to avoid fluidisation of the bed.

[0015] Since it is to a large extent avoided that present already treated waste water mixes with waste water to be treated, this allows the microorganism to be exposed to the highest possible concentration of nutrient which, as already mentioned, promotes granular growth. The term "to avoid fluidisation" is understood to mean that the bed does not fluidise, and/or that as a result of introducing the waste water, mixing occurs at most in up to 25% of the height of the bed. The waste water may, for example, be sprayed onto the bed directly or by using means for limiting the force with which the waste water can disturb the bed surface. In any case, mixing will occur at most in up to 25%, preferably in less than 15% of the height of the bed. Instead of introduction from the top side of the bed of sludge granules, the waste water may preferably be introduced from below. Especially in the latter case, the feed rate will be limited such that no fluidisation of the bed occurs. In both cases it is possible to displace and discharge purified water still present between the sludge granules from the bed in an effective manner, i.e. with little or no mixing of waste water and purified (nutrient-depleted) waste water, as will be discussed below. In principle it is also possible to introduce the waste water into the bed of sludge granules via pipes.

[0016] According to a preferred embodiment, at least a part of the nutrient-depleted waste water is discharged in the third step, after at least partial settling.

[0017] The removal of nutrient-depleted waste water prior to the addition of fresh waste water to be treated means that a smaller reactor volume is needed, and that the microorganism-comprising sludge granules come into contact with a highest possible concentration of nutrients. This is favourable for the formation of sludge granules. The height of liquid in the reactor is for example twice, and preferably 1.5 times or less, such as 1.2 times the height of the bed of settled sludge granules.

[0018] According to a preferred embodiment, at least a part of the nutrient-depleted waste water is discharged during the feeding of waste water to the bed of sludge granules in the first step.

[0019] In that case, the discharge of nutrient-depleted waste water is preferably the consequence of displacement due to waste water being fed to the bed of sludge granules.

[0020] Thus with one single action both the addition of fresh waste water, and the discharge of treated waste water is realised. This can be accomplished at a low capital outlay. Further savings are possible on control technology (fewer measurements are required) and operating costs. Furthermore, mixing of treated waste water with waste water to be treated is avoided, so that the concentration of nutrients to which microorganisms in the sludge granules are exposed is as high as possible, providing the previously mentioned advantage of growth in the form of sludge granules. The displaced treated waste water is preferably discharged at the top side of the bed. Due to the displacement, any flocs that may be formed are flushed out of the reactor. Therefore, the waste water is advantageously introduced via the bottom of the bed.

[0021] An important embodiment is one wherein the waste water is introduced in an amount of 50 to 110%, preferably 80 to 105% and most preferably 90 to 100% of the void volume of the bed.

[0022] In this way the biomass in the form of sludge granules is utilised optimally, at the smallest possible reactor volume.

[0023] The introduction of the waste water is preferably followed by an interval before commencing the second step.

[0024] This promotes the uptake of nutrients from the waste water, and contributes to the formation of sludge granules with good settling qualities. If desired, mixing may take place during the interval.

[0025] The interval is preferably sufficiently long for the removal of at least 50%, preferably at least 75% and most preferably at least 90% of the organic nutrient from the waste water.

[0026] This contributes the most to the formation of sludge granules with good settling qualities, while the purification of the waste water is optimal.

[0027] It is preferred for the waste water to be introduced in the third step, wherein sludge granules that settle more slowly are discharged from the reactor and sludge granules that settle more quickly remain in the reactor.

[0028] This further increases the pressure to select for granular growth. The introduction of waste water may be performed at a low flow rate during settling of the sludge granules, preferably after at least part the sludge granules have formed a granular bed but, as explained elsewhere, most preferably after the granular bed has formed. In the first two methods there is overlap between the first and third step. In the second and especially in the third method, light sludge flocs that have settled on the bed, or that would have the tendency to do so, are carried away by the flow of nutrient-depleted water displaced by waste water. As a consequence there is a pressure of selection resulting in maintaining the characteristics of the sludge in the form of granules. It is preferred for the discharge to take place in the third step via a discharge opening just above the final bed.

[0029] The invention will now be elucidated with reference to the following exemplary embodiment wherein

Fig. 1 shows a graph of the acetate, phosphate, ammonium, and NO_3^- + NO_2^- concentration during a cycle of the method according to the invention.
Figs. 2a and b show sludge flocs according to the prior art and sludge granules according to the present invention, respectively.

[0030] An air lift reactor (3 litre, height/diameter 20) was fed with 1.5 litres of waste water per cycle, which waste water represents an apropriate model for a domestic waste water. The composition was 6.3 mM sodium acetate; 3.6 mM ammonium chloride, 0.6 mM potassium phosphate, 0.37 mM magnesium sulphate, 0.48 mM potassium chloride and 0.9 ml/l standard solution of trace elements. The reactor was seeded with aerobic active sludge from a domestic waste-water purification plant. The reactor was operated in successive batch cycles. One cycle consisted of the following steps:

i) The introduction of 1.5 litres of model waste water at the bottom side of the reactor, for 60 minutes, so that there is a plug flow regime of waste water through the settled granular bed.
ii) Aeration for 111 minutes at a flow rate of 4 litres of air per minute.
iii) Settling of the granular sludge for 3 minutes after the termination of the aeration.
iv) Discharging the treated model waste water from the effluent outlet point at half the reactor height. Any biomass present at this moment above the effluent outlet point was removed from the reactor together with the treated waste water.
v) 1 minute interval, after which feeding with model waste water was recommenced.

[0031] By adding a base or acid, the pH in the reactor was maintained at 6.5 to 7.5 and the temperature was kept at 20°C. During the aerated phase ii) the concentration of dissolved oxygen was maintained at approximately 1.8 mg/ml. On the one hand this keeps the oxygen concentration sufficiently high for aerobic breakdown of nutrient in the external part of the sludge granules, and on the other hand only a low pumping capacity is required for the addition of air. After all, under these conditions, the transfer of oxygen from the air is very efficient. Consequently, there is also little energy required for the supply of oxygen. The breakdown of nitrogen compounds was shown to be optimal at these oxygen concentrations, with only minimal amounts of nitrate being found in the treated waste water.

[0032] In Table 1 the mean concentrations of the model waste water and the treated water are shown. The mean purification result is also given. Figure 1 shows the plot of the acetate (o), phosphate (Δ), ammonium (black diamond) and the sum of the nitrate and nitrite (open diamond) concentration during one cycle. Fig. 2b shows a photograph of the sludge granules obtained by the method. The obtained sludge granules were stable for at least 300 days, after which this experiment was stopped. The method according to the invention thus makes a reliable control of the operation possible. Fig. 2a shows typical sludge flocs having a settling rate as described in US 3,864,246. Although US 3,864,246 successfully combats the growth of filamentous organisms, which form so-called light sludge, the sludge flocs formed have a settling velocity of at best 1 m/h. In contrast, the sludge granules according to the present invention have very high settling velocities (>10 m/h), while the distance over which settling takes place may be relatively short.

Table 1 Concentrations of the untreated and treated model waste water

Mean values	Model waste water	Treated waste water	Removal Efficiency
Acetate (mM)	6.3	0	100%
NH_4^+ (mM)	3.6	0	97%
NO_3^- (mM)	0	0.1	
NO_2^- (mM)	0	0	
PO_4 (mM)	0.6	0.04	94%

[0033] One of the factors contributing to granular growth is feeding waste water with a highest possible nutrient concentration to the sludge granules. For this reason it is expedient to avoid mingling between treated waste water in the reactor and freshly supplied waste water. In those cases where a low nutrient concentration in the waste water prevails for many cycles, e.g. more than 10, nutrient may be added to the waste water if necessary. One option would be using liquid manure.

[0034] The present invention may be implemented in numerous ways. For example, instead of using one reactor it is propitious to use three reactors, the three reactors being operated out of phase. That is to say, while waste water is fed to one reactor, the aeration step is carried out in a second reactor, while in a third reactor settling takes place and possibly discharge of purified water. This keeps the capital outlay for pumps, especially with regard to their required maximum capacity, within limits. Treated waste water is released gradually and this is advantageous if this waste water needs to undergo a further treatment, since then also a smaller reactor for post-treatment suffices. Since compared with the above described experiment, reactors will in practice be relatively higher, settling will take longer. This means that feeding may take one third of the time, aeration and settling together two thirds of the time. A buffer tank for temporary storage of waste water to be treated is thus avoided and the three batch-operated reactors make continuous operation possible. The invention is illustrated by way of an airlift reactor, but the invention may be embodied with any other type of reactor, such as a bubble column reactor.

Claims

1. A method for the treatment of waste water comprising an organic nutrient, wherein the waste water is brought into contact with microorganisms-comprising sludge particles, an oxygen-comprising gas is fed to the sludge particles, and the method further comprises the settling of the sludge and the discharge of organic nutrient-depleted waste water, **characterised in that**

   - in a first step the waste water is fed to sludge granules, under anaerobic conditions;
   - after the supply of the waste water to be treated an oxygen- comprising gas is introduced in a second step, wherein the oxygen concentration is less than 5mg/ml with the granules being in a fluidised condition and at the end of the second step or at the beginning of the third step sludge granules are removed.
   - in a third step, a settling step, the sludge granules are allowed to settle.

2. A method according to claim 1, **characterised in that** the waste water is introduced in an amount of 50 to 110%, preferably 80 to 105% and most preferably 90 to 100% of the void volume of the bed.

3. A method, according to claim 1 or 2, **characterised in that** the introduction of the waste water is followed by an interval before commencing the second step.

4. A method according to claim 3, **characterised in that** the interval is sufficiently long for the removal of at least 50%, preferably at least 75% and most preferably at least 90% of the organic nutrient from the waste water.

Patentansprüche

1. Verfahren zur Behandlung von einen organischen Nährstoff enthaltendem Abwasser, wobei das Abwasser mit Mikroorganismen enthaltenden Schlammpartikeln in Kontakt gebracht wird, den Schlammpartikeln ein Sauerstoff enthaltendes Gas zugeführt wird und das Verfahren des Weiteren die Sedimentation des Schlamms und die Ableitung des Abwassers, welches an organischem Nährstoff abgereichert ist, umfasst,
   dadurch gekennzeichnet, dass

   - das Abwasser in einem ersten Schritt unter anaeroben Bedingungen einem Schlammgranulat zugeführt wird,
   - nach der Zufuhr des zu behandelnden Abwassers ein Sauerstoff enthaltendes Gas in einem zweiten Schritt,

   in welchem die Sauerstoffkonzentration weniger als 5 mg/ml beträgt, eingeleitet wird, wobei sich die Granulatkörner in einem fluidisierten Zustand befinden, und
   am Ende des zweiten Schritts oder zu Beginn des dritten Schritts Granulatkörner entfernt werden und

   - sich die Granulatkörner in einem dritten Schritt, einem Sedimentationsschritt, absetzen.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** das Abwasser in einer Menge von 50 bis 110 %, vorzugsweise in einer Menge von 80 bis 105 % und besonders bevorzugt 90 bis 100 %, des Zwischenkornvolumens des Bettes eingeleitet wird.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** auf die Einleitung des Abwassers ein Zeitintervall folgt, bevor mit dem zweiten Schritt begonnen wird.

4. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** das Zeitintervall ausreichend lang ist, damit wenigstens 50 %, vorzugsweise wenigstens 75 % and besonders bevorzugt wenigstens 90 %, des organischen Nährstoffs

aus dem Abwasser entfernt werden können.

Revendications

1. Procédé pour le traitement d'eaux usées comprenant une substance nutritive organique, dans lequel les eaux usées sont amenées en contact avec des particules de boue comprenant des micro-organismes, un gaz comprenant de l'oxygène est amené aux particules de boue, et le procédé comprend en outre la sédimentation de la boue et la décharge des eaux usées appauvries en substance nutritive organique, **caractérisé en ce que**

   - dans une première étape, les eaux usées sont amenées à des granules de boue, sous des conditions anaérobiques ;
   - après l'amenée des eaux usées devant être traitées, un gaz comprenant de l'oxygène est introduit lors d'une deuxième étape, la concentration d'oxygène étant inférieure à 5 mg/ml, les granules étant dans un état fluidisé et, à la fin de la deuxième étape ou au commencement de la troisième étape, les granules de boue sont enlevés,
   - dans une troisième étape, une étape de sédimentation, on laisse les granules de boue sédimenter.

2. Procédé selon la revendication 1, **caractérisé en ce que** les eaux usées sont introduites en une quantités de 50 à 110 %, avantageusement 80 à 105 % et le plus avantageusement de 90 à 100 % du volume vide du lit.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** l'introduction des eaux usées est suivie d'un intervalle avant le commencement de la deuxième étape.

4. Procédé selon la revendication 3, **caractérisé en ce que** l'intervalle est suffisamment long pour l'élimination d'au moins 50 %, avantageusement d'au moins 75 % et le plus avantageusement d'au moins 90 % de la substance nutritive organique des eaux usées.

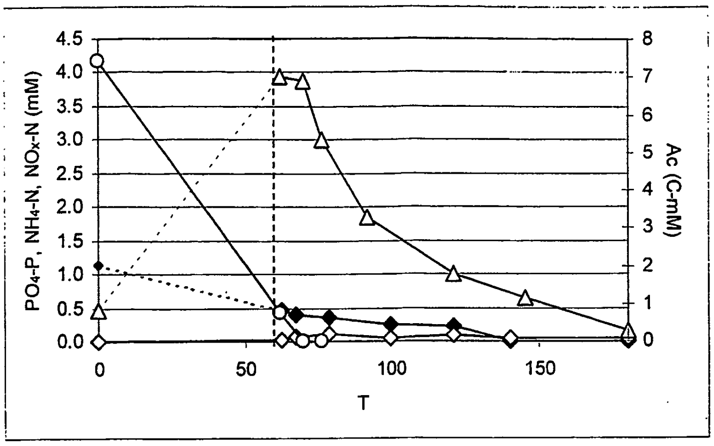

Fig. 1

Fig. 2a

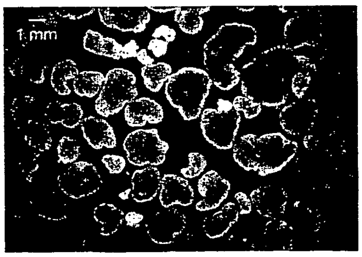

Fig. 2b

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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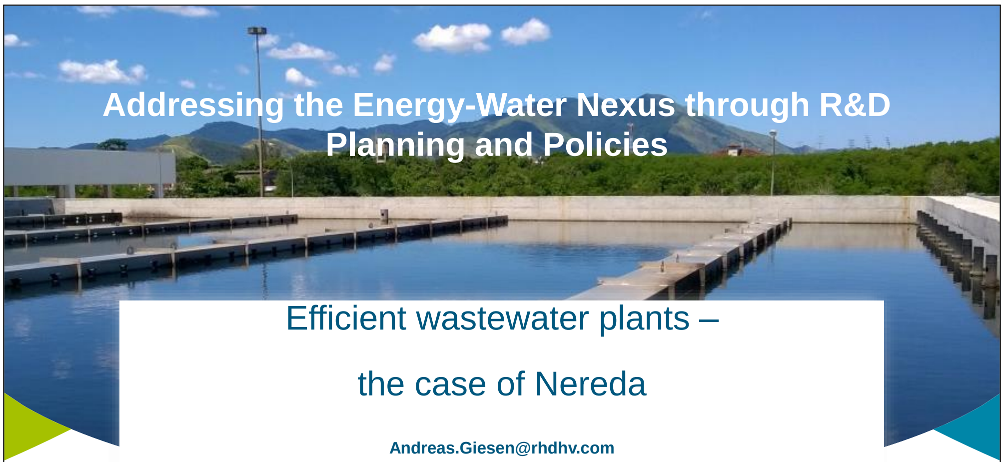
- EP 0776864 A **[0007]**

E.5 Efficient wastewater plants - the case of nereda



Addressing the Energy-Water Nexus through R&D Planning and Policies

Efficient wastewater plants – the case of Nereda

Andreas.Giesen@rhdhv.com

29 May 2018

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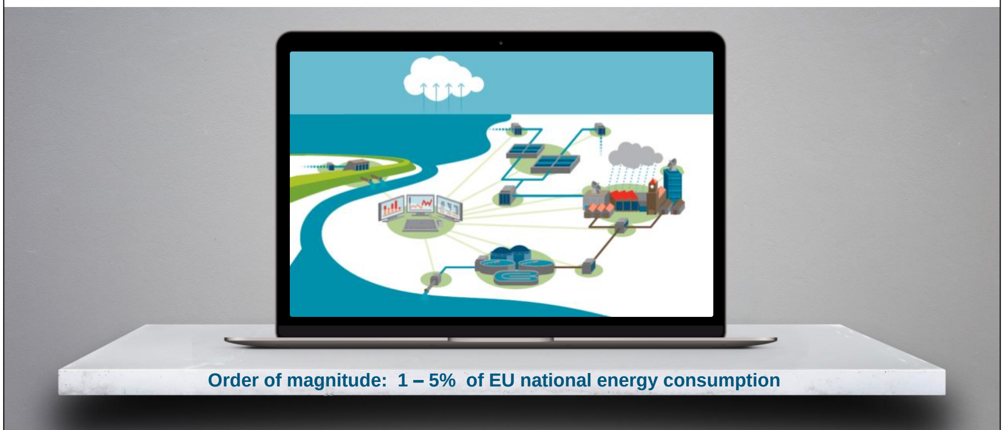
Workforce of **6,500** in more than **150** countries

One of the **top independently owned** engineering companies

Our Organisation

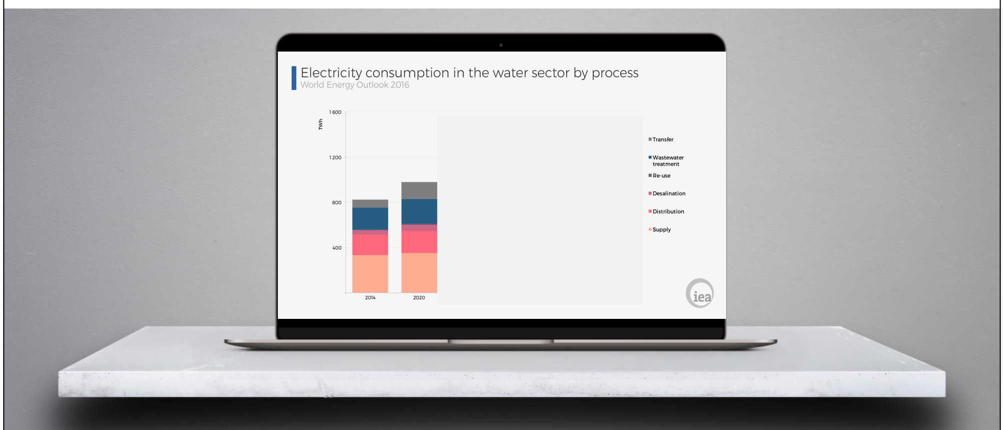
Covering the whole water cycle

Energy consumption urban water cycle



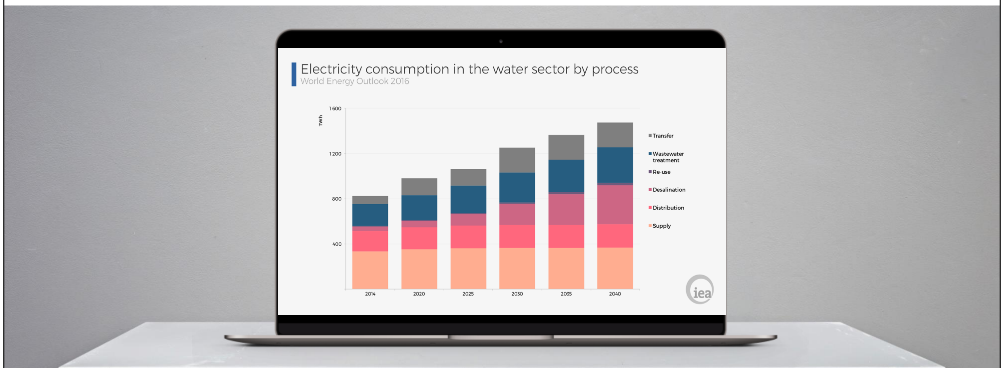
Order of magnitude: 1 – 5% of EU national energy consumption

Significant part for wastewater treatment



And major part for biological treatment

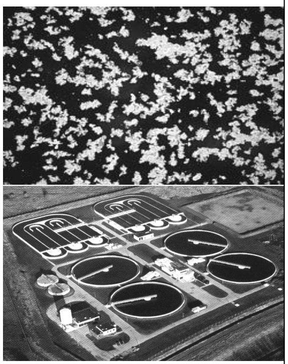
Growing consumption



Increase in desalination and sanitation

Conventional wastewater treatment

- Activated sludge state of art since 1914
- Good effluent quality
- Poor sludge settling quality
- Low biomass concentrations
- Significant footprint
- High energy consumption
- Often high chemical consumption
- Excess activated sludge can be digested to reduce waste and improve energy efficiency of treatment
- Current aim: energy neutrality….but sofar mainly achieved by “importing organic waste” into the “wastewater plant” digester



Wastewater treatment with Nereda®

- Natural way of treating wastewater using aerobic granular sludge with excellent settling properties

GRANULES

8 g/l or more
$SVI_5 \approx SVI_{30}$

FLOCS

4 g/l
$SVI_5 > SVI_{30}$

Due to excellent settling properties

GRANULES

8 g/l or more
$SVI_5 \approx SVI_{30}$

Compact → lower CAPEX

Easy to operate → lower OPEX

Sustainable → lower energy/chemical consumption

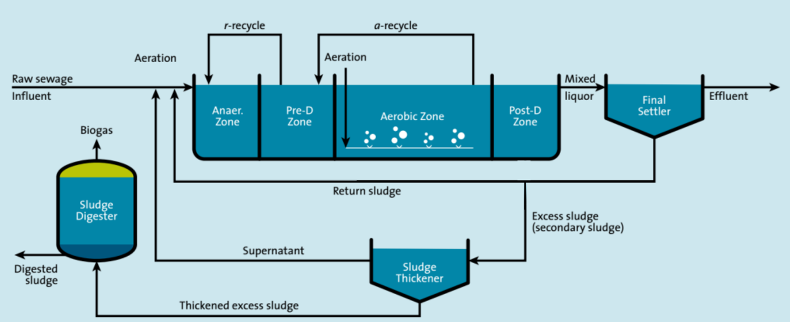
FLOCS

4 g/l
$SVI_5 > SVI_{30}$

Conventional Activated Sludge Process

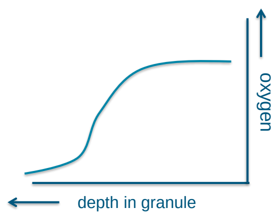
Biological nutrient removal in activated sludge requires many compartments and circulation flows

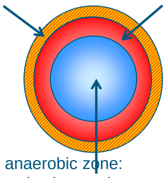
Carbon, Nitrogen and Phosphorus removal in UCT configuration



Nereda® granule – BNR in the granules

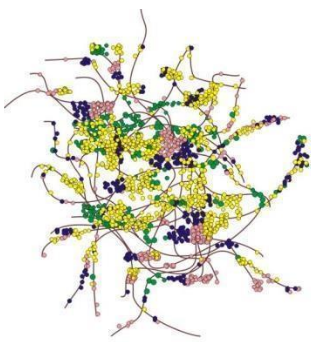
Oxygen gradient in granule
Simultaneous removal of COD, P and N
Transport by diffusion, not by pumping



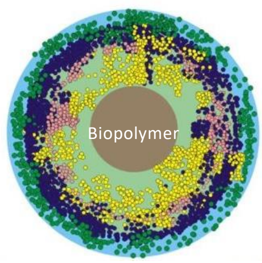


Micro-organismen in the granule

Activated sludge



Aerobic granular biomass

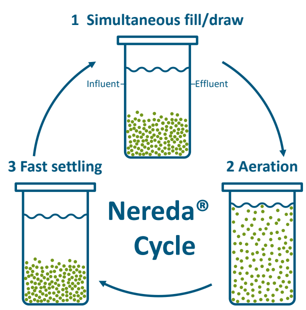


- Nitrifiers
- Denitrifiers
- Phosphate Accumulating Organisms (PAO's)
- Glycogen Accumulating Organisms (GAO's)

Courtesy Delft University of Technology

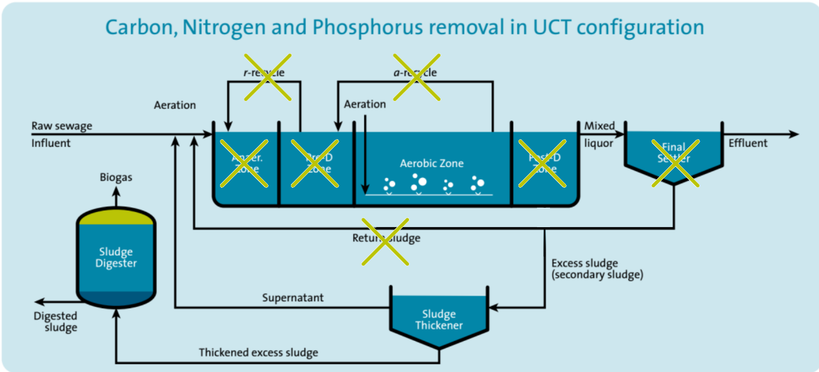
Nereda® process cycle

- Simple one-tank concept
- No clarifiers
- No moving decanter
- No mixers
- Extensive biological COD, N- and P-removal
- Low energy consumption
- Easy operation
- Low totex



Nereda® compared to Conventional

Biological nutrient removal in activated sludge requires many compartments and circulation flows



Energy efficiency example

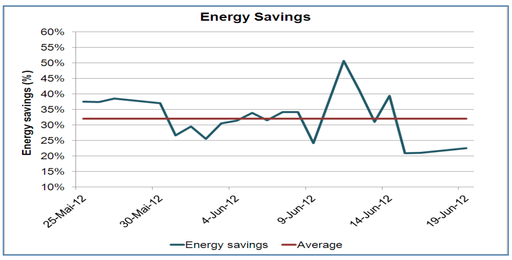
Municipal wastewater | full BNR | 100,000 pe

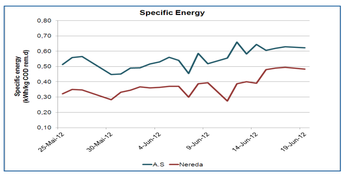
Equipment	CAS		NEREDA	
	kWh/d	%	kWh/d	%
Influent pumping station	150	3%	262	10%
Screening & Sand Removal	73	1%	73	3%
Biological reactor	4.972	86%	1.798	67%
mixers anaerobic section	192	3%		
mixers predenitrifiation	318	5%		
internal circulation for BNR	648	11%		
propulsors aerobic section	848	15%		
aeration	2.534	44%	1.798	67%
final settling tanks	60	1%		
sludge return pumping station	372	6%		
Other equipment	338	6%	348	13%
Cable and frequency converter losses	266	5%	189	7%
TOTAL ENERGY CONSUMPTION	5.799	100%	2.670	46%

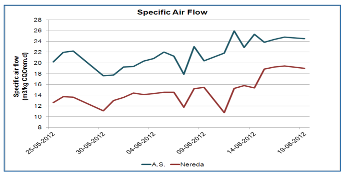
Note that is an example based on a specific plant in Dutch climate achieving full BNR and that energy consumption for both technologies depends on wastewater characteristics, targeted effluent quality, design and equipment selection.

Aeration efficiency Nereda® vs CAS

@ETAR Frielas, Portugal







- Approx. 30% less aeration than parallel operated CAS.
- Up to 50% less energy considering also savings on settler and recirculation pumps

Advantages

SMALL FOOTPRINT
Up to a factor 4 smaller

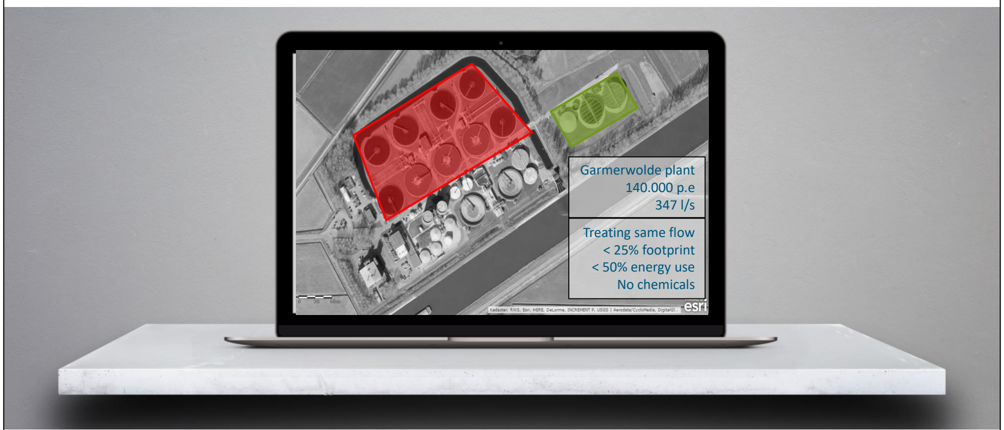
SUSTAINABLE
30-50% energy savings
No/minimal chemicals

EXCELLENT EFFLUENT QUALITY
Including biological nutrient removal N/P

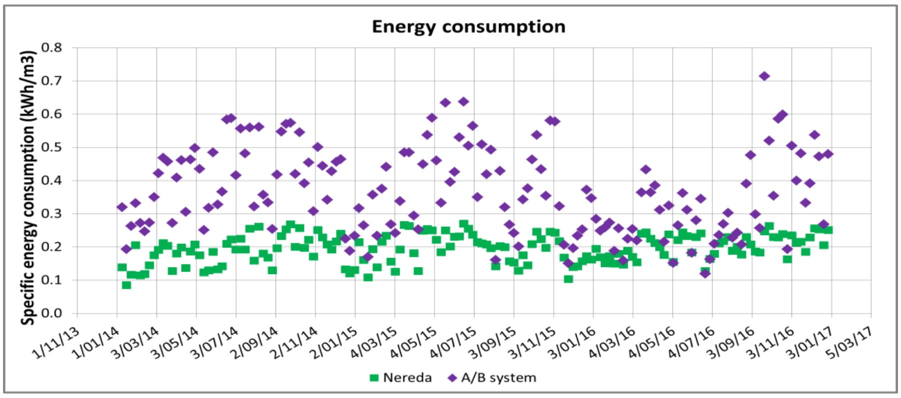
COST EFFECTIVE
Lower CAPEX & OPEX

EASY TO OPERATE
Automated & robust

Footprint Nereda® Garmerwolde



Energy – Garmerwolde



History & current status

Aerobic Granular Biomass Technology

Scientific inspiration and transpiration

- It all started with a good discussion and collaboration between two professors at an October Fest in the 90s

Prof. Peter Wilderer
TU Munich

Prof. Mark van Loosdrecht
TU Delft

History and development

- From lab scale experiments to full scale application

Start R&D at Delft University of Technology

Large pilot research at Ede STP

Demos in RSA and Portugal

Feasibility study carried out by Royal HaskoningDHV

Breakthrough Nereda® Technology

Royal opening plant Epe, The Netherlands

1993 | 1999 | 2000 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2010 | 2012 | 2013

Cooperation Delft with Royal HaskoningDHV (formerly: DHV)

Start-up industrial launching customer

Start-up 1st full scale municipal plant in the Netherlands

Granule formation stable at lab scale

National Nereda Development Program Public Private Partnership

Scale-up meets world largests SBR tank volume

From municipal pilot to industrial applications

- Prototype
- Scale-up
- Learn and create confidence

History and development

- From lab scale experiments to full scale application

1993 – Start R&D at Delft University of Technology

1999 – Cooperation Delft with Royal HaskoningDHV (formerly: DHV)

2000 – Feasibility study carried out by Royal HaskoningDHV

2002 – Granule formation stable at lab scale

2003 – Large pilot research at Ede STP

2004 – Start-up industrial launching customer

2005 – Breakthrough Nereda® Technology

2007 – National Nereda Development Program Public Private Partnership

2008 – Demos in RSA and Portugal

2010 – Start-up 1st full scale municipal plant in the Netherlands

2012 – Royal opening plant Epe, The Netherlands

2013 – Scale-up meets world largests SBR tank volume

Nereda® Frielas – Lisbon – Portugal

CLIENT
Agua de Portugal – Simtejo

WASTEWATER TYPE
Municipal & Industrial

CAPACITY
12,000 m^3/day | 44,000 p.e.

PEAK FLOW
1,850 m^3/hour

Nereda® Gansbaai – South Africa

CLIENT
Overstrand Municipality

WASTEWATER TYPE
Municipal

CAPACITY
5,000 m^3/day | 63,000 p.e.

PEAK FLOW
400 m^3/hour

PRE-TREATMENT
Screening and sand & grit removal

POST TREATMENT
Water reuse pond, reed bed infiltration

History and development

- From lab scale experiments to full scale application

1993	Start R&D at Delft University of Technology
1999	Cooperation Delft with Royal HaskoningDHV (formerly: DHV)
2000	Feasibility study carried out by Royal HaskoningDHV
2002	Granule formation stable at lab scale
2003	Large pilot research at Ede STP
2004	Start-up industrial launching customer
2005	Breakthrough Nereda® Technology
2007	National Nereda Development Program Public Private Partnership
2008	Demos in RSA and Portugal
2010	Start-up 1st full scale municipal plant in the Netherlands
2012	Royal opening plant Epe, The Netherlands
2013	Scale-up meets world largests SBR tank volume

Nereda® Epe – The Netherlands 2011

CLIENT
Water Authority Veluwe

WASTEWATER TYPE
Municipal & Industrial

CAPACITY
8,000 m^3/day | 41,000 p.e.
(inclusive 13,750 p.e. from industrial discharges)

PEAK FLOW
1,500 m^3/hour

PRE & POST TREATMENT
screening, sand trap and oil & grease removal (slaughterhouse emissions) & sand filtration

History and developme

■ From lab scale experiments to full scale

Start R&D at Delft University of Technology

resea

RSA
gal

Feasibility study carried out by Royal HaskoningDHV

Royal opening plant Epe, The Netherlands

1993 | 1999 | 2000 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2010 | 2012 | 2013

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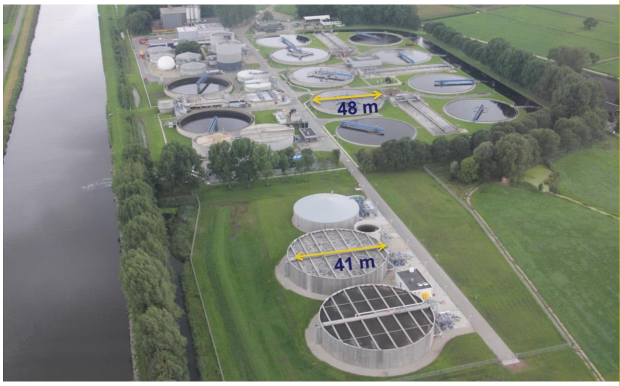
Scale-up meets world largests SBR tank volume

Nereda® Garmerwolde – The Netherlands, 2013



CLIENT
Water Authority Noorderzijlvest

WASTEWATER TYPE
Municipal

CAPACITY
30,000 m³/day | 140,000 p.e

PEAK FLOW
4,200 m³/hour

Implementation progress

2005: Vika, The Netherlands, 5,000 p.e.

Today: Ringsend Dublin, PPS2, first cell; Ultimate capacity 2,670,000 p.e.

Nereda® plants

Operational plants:

Vika, Ede	NL
Cargill, Rotterdam	NL
Smilde, Oosterwolde	NL
STP Gansbaai	RSA
STP Epe	NL
STP Garmerwolde	NL
STP Vroomshoop	NL
STP Dinxperlo	NL
STP Wemmershoek	RSA
STP Frielas, Lisbon	PT
STP Ryki	PL
Westfort , IJsselstein	NL
STP Clonakilty	IRL
STP Carrigtwohill	IRL
STP Deodoro, Rio de Janeiro	BR
STP Kingaroy	AUS
STP Simpelveld	NL
STP Cork Lower Harbour	IRL

Operational plants:

STP Highworth	UK
STP Ringsend	IRL
STP Jardim Novo, Rio Claro	BR

Plants under construction:

STP Hartebeestfontein	RSA
STP Alpnach	CH
STP Faro, Olhão	PT
STP Zutphen	NL
STP Utrecht	NL
STP Österröd, Strömstad	S
STP Inverurie	UK
STP Kendal	UK
STP Great Dunmow	UK
STP Morecambe	UK
STP Barston	UK
STP Breskens	NL
STP Kloten	CH

Plants under design:

STP Tatu, Limeira	BR
STP São Lourenço, Recife	BR
STP Jaboatão, Recife	BR
STP Jardim São Paulo, Recife	BR
STP Tijuco Preto, Sumaré	BR
STP Lontra, Araguaína	BR
STP Região Sul de Palmas	BR
STP Radcliffe	UK
STP Walsall Wood	UK
STP Failsworth	UK
STP Newham	UK
STP Dungannon	UK
STP Blackburn	UK
Sappi, Lanaken	BE
STP Vriezenveen	NL
STP Altena	GE
STP Stonewater Creek	US
STP Wolf Creek	US
STP Fleury	FR

Global Nereda® roll-out

Nereda: an exciting or boring story?

- Game changing technology:
  - Significant lower energy consumption
  - Facilitating energy neutrality
  - Significantly lowering CAPEX and OPEX
  - Better treated water quality
  - Compact and suitable for upgrading of existing infrastructure
- 10 years from scientific inspiration to first pilot → fast
- 2 years from pilot to first industrial full-scale → fast
- Working within a Public Private Partnership with Dutch Water Authorities as co-developpers and launching customers
- Exciting !

Nereda: an exciting or boring story?

- 6 – 8 years from pilot to first municipal applications → ?
- plus 6 – 8 year from first municipal application to "modern standard in The Netherlands" → ?
- Similar confidence building process in most other markets → slow
- 8 - 10 years after first European full-scale a (small) first Nereda in Germany and France
- Boring slow !

Nereda | Royal HaskoningDHV

Key messages for discussion

- The Nereda example shows that scientific research can significantly contribute to develop game-changing and truly sustainable wastewater treatment technology
- The PPP National Nereda Development Program and roll-out of the technology is recognized in The Netherlands (just like the technology itself) as best-practice
- Whereas society would benefit from a fast implementation and valorization of successful research, the international adaptation of "elsewhere proven" game-changing wastewater treatment technologies is very slow.
  And maybe within the EU even slower than in Asian and Latin-American markets.
- How to catalyze European implementation?
- How to minimize hurdles in EU public tenders for "elsewhere proven" modern and superior solutions?

Royal HaskoningDHV
Enhancing Society Together