ObservatoryNANO

Economic Analysis of Nanotechnology for Environmental Applications

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Executive Summary

This report looks at the impact of nanotechnology for environmental applications. The two applications that are considered in more detail are nanotechnology for water purification and for air pollution control.

The water industry includes the supply of fresh water through purification or desalination, and the removal and processing of wastewater. In the developing world, the primary challenge is widening access to clean drinking water – 13% of the global population still get water from unimproved sources. Other drivers for innovation include increases in water demand, over exploitation of existing sources, and an aging water infrastructure.

The impact of nanotechnology is to introduce new technologies for water treatment, including photocatalytic methods or nanofiltration. Given the limited number of companies that currently have products available, the size of this market is believed to be in the sub-100 million range. Biwater reported a combined market size of 2.5bn in 2005 for nanofiltration and reverse osmosis (though reverse osmosis is still the dominant technology of the two)[1].

Air pollution control is driven by regulation, such as the European Union's Air Quality Directive. This tends to impact owners of facilities that generate emissions, such as power plant and factories, though this has also led to the introduction of catalytic converters for vehicles.

The functional requirements of air pollution control technologies include Removal of Carbon Dioxide and Removal of particulate matter. Equipment for emissions reduction or capture must be capable of being used in a demanding operational environment; a CO2 scrubber should have the capacity to deal with the substantial quantities of emissions from a power plant, for example. A 2006 report by BCC Research placed the value of nanotechnologies for environmental remediation – which includes other applications beyond pollution removal – in the low tens of millions (USD) at that time. Given the few companies with identified commercial products in this area, this is felt to be a realistic assessment of current market size.

1 http://www.envirolinknorthwest.co.uk/Envirolink/Events0.nsf/0/8025739B003AADE380257409004C149F/$file/02%20-%20Biwater%20-%20Martin%20Hind.pdf

1. Methodology

1.1. Definition

For the purposes of this report, nanotechnology is defined as "the study of phenomena and fine-tuning of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale."[2]

The specific focus of this report is on applications of nanotechnology for environmental remediation. These include mitigation of air pollution or removal of particulate matter, CO2 and other substances from emission, cleaning of polluted soil, purification and desalination of water, and wastewater treatment.

1.2. Methodology for Preparing the Report

The development of this report has been a three stage process. Desk research using publicly available sources of information was used to produce a first version of this report. Input and feedback is then sought from experts, via questionnaires, interviews and discussions, and from the ObservatoryNano symposium which takes place in March 2009. A final report is then produced, which synthesises the desk research and external expert input.

1.3. Methodology for Quantitative Assessment

Quantitative assessments of market size, growth rates, and the current market shares of nanotechnology enabled products are developed using external data sources such as market research providers, industry groups, and individual experts. Estimates and market size projections that are made by the authors of this report are clearly marked as such.

All forward looking estimates are necessarily a projection, and are therefore subject to error within the market models themselves, as well as to unforeseen external events. In particular, the current economic crisis has forced countries and companies to significantly adjust their growth forecasts – in most cases, this will not have been taken into account in projections which date from before 2008.

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[2] Introduction to Nanotechnology, http://ec.europa.eu/nanotechnology/index_en.html

2. General Market Description

2.1. Brief Market Description

This report considers applications of nanotechnology for environmental applications; specifically in the areas of water and air purification. These should more accurately be considered as two separate markets, each with their own players and dynamics.

The commonality is that both markets involve solutions to contamination of a shared resource; the atmosphere or the water supply. Both also demonstrate 'tragedy of the commons'-like effects, in which the consequences of action (such as releasing sulphur from power station) affects a whole community, rather than just the actor responsible for this harm. Because of this, government has a central role in establishing common standards for emissions or water cleanliness, and sanctioning individual violations.

2.1.1. Water

Simply put, the water industry involves the supply of fresh water, and the removal and processing of wastewater. The water supplied may come from surface water (lakes and rivers) ground water (from wells) or from the sea (using desalination to render seawater drinkable). Processing wastewater involves the removal of contaminants so that the water can be reused.

Water can also be categorised by use. Globally the majority of water (70%) is used for agriculture. This is followed by 20% for industrial use and 10% for domestic use.[3] The distribution of water usage in Europe is somewhat different, with 50% consumed by agriculture.

In the majority of countries, ensuring a supply of fresh water and the treatment of waste water is the responsibility of public utilities. 54% of the world's population has a piped connection for drinking water, and a further 33% have an 'improved' source: public taps, boreholes, springs and rainwater collection.[4] This still leaves 13% of the global population – 884 million people – with an unimproved source.

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[3] http://www.sam-group.com/downloads/studies/waterstudy_e.pdf

[4] http://www.who.int/water_sanitation_health/monitoring/water.pdf

One of the Millennium Development Goals established at the beginning of the decade was that the number of people without access to clean drinking water should be halved by 2015. The World Health Organization reports that this target is likely to be met globally, but that there are still a number of individual countries which are not track, mainly in Oceania and Sub-Saharan Africa.

A recent trend in developed countries is for water services to be provided by a private company given some form of exclusive licence. Countries are also increasingly open to public/private partnerships between utilities and private companies. This has created a substantial market for water services, provided by companies like Veolia Environnement, Suez Environnement and RWE. Revenues from Veolia's water business were EUR 12.6 in 2008.

The water industry's capital intensity and relatively steady returns have also made utilities an attractive takeover target; Thames Water was purchased for GBP 8bn in 2006 by Macquarie, and Australian investment bank[5].

Where the water supply has been privatised, the role of government is typically to establish standards for drinking and waste water, and to monitor compliance with these standards by inspections and sanctions if appropriate.

2.1.2. Air

Standards for air quality are set by national or multinational bodies. The most important efforts in this area include the European Union's Air Quality Directive (1992)[6] which defines a policy framework for the control of a number of pollutants. The UK's Department for Environment, Food, and Rural Affairs (DEFRA) has developed an Air Quality Strategy for England, Scotland, Wales and Northern Ireland in line with this directive. This has the aim of reducing the effects of air pollution, which it states "is currently estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months." Ten pollutants are monitored, which are:

- Particulate Matter, which is categorised by size. The most common source of particulate matter in the UK was fuel combustion.
- Oxides of Nitrogen are commonly produced by road transport and electricity production.

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[5] http://www.telegraph.co.uk/finance/2949111/Macquarie-buys-Thames-Water-in-8bn-deal.html

[6] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0062:EN:HTML

- Oxone is created by interactions between air pollutants (including oxides of nitrogen) and volatile organic compounds.
- Sulpher Dioxide is produced by burning coal and heavy oil in power stations and oil refineries
- Polycyclic aromatic hydrocarbons (PAHs) are produced by domestic coal and wood burning.
- Benzene is produced by combustion and transport.
- 1,3-butadiene is produced by petrol combustion.
- Carbon Monoxide is created by incomplete fuel combustion
- Lead is emitted by iron and steel combustion
- Amonia is produced by livestock manure and fertilisers.

European and national standards are often brought in line; for example, the UK strategy follows the European directive is setting a target for Nitrogen Dioxide that concentrations of $200\mu g.m^{-3}$ are not to be exceeded more than 18 times a year.

These standards then directly influence environmental restrictions. Whilst these don't tend to affect the individual consumer, they are important for facilities such as power plants, which have a duty to manage their emissions. A fossil fuel power plant will emit CO2, particulate matter, Sulphur dioxide and Oxides of Nitrogen. To some extent these can be mitigated by technologies which remove harmful matter from emissions.

Companies which produce technology for scrubbing emissions include Siemens, GE Energy, Belco (a DuPont subsidiary) and Ahlstom. Many of these companies also produce other equipment for power plants, including boilers, turbines and control systems.

2.2. Nanotechnology Impact

A wide range of research work is being carried out to solve the challenges of providing clean drinking water, of improving waste water recycling, and desalinating sea water. The environment technology sector report described these technologies in more detail at http://www.observatorynano.eu/project/document/184/.

Nanotechnology-based methods for treating drinking water, wastewater recycling and ground water remediation include photocatalysis using Titanium Dioxide nanoparticles, nanofiltration using nonporous membranes, electrochemical oxidation, redox reactions and adsorption using carbon nanotubes (CNTs). This latter technology takes advantage of the hydrophobic nature of CNTs' internal surfaces and the potential for chemical functionalisation. These methods are being designed to increase the effectiveness of water filtration by increasing flow and reducing fouling, and to enhance the ability of filtration systems to remove a range of toxic materials.

Nanotechnologies for air purification include using photocatalytic materials (such as TiO2) as building coatings or road surfaces. Interaction between the Ti02 and Nitrogen Dioxide causes the reduction of the latter substance, enabling cleaner air.

2.3. Drivers and Barriers to Innovation

2.3.1. Drivers

Demand for water.

A number of dynamics increase the demand for water; growing populations, urbanisation, and economic growth). Water consumption has a close relationship to population growth: approximately 4000 km2 of water were consumed globally in 2000, and this is expected to rise to over 5000 km2 by 2025, mirroring projections of growth in the world's population. (http://www.sam-group.com/downloads/studies/waterstudy_e.pdf).

With up to 60% of the worlds population expected to live in cities by 2030 (presently 50%), there is pressure on water systems not only to deliver fresh water, but also to remove and process substantial quantities of wastewater safely. Energy production is another driver of water usage. The WaterCAMPWS indicates a number of regions in the North-Eastern and Mid West United States in which electricity generating power plants account for over 50% of all water used.[7]

The effects of water shortages can already be seen; drought in Australia's Murray Darling Basin forced the Federal Government to establish a new coordinating body to manage the water supply.

To increase access to water, new supplies have to be enabled. One of the ways of doing this is to recycle a greater proportion of wastewater. Veolia Environnement projects that wastewater

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[7] http://watercampws.uiuc.edu/index.php?menu_item_id=145

recycling capacity will increase by 10-12% per year to 2015. This will result in a recycling capacity of 55 million m3 per day. New technologies are needed to provide more cost-effective means of large scale wastewater remediation.

For areas in which aquifers are being depleted or surface water is scarce, desalination may provide an answer. Global desalination capacity is expected to increase from 51 million m3 to 109 million m3 per day by 2016, representing a potential market of €5bn per year. Desalination is a particularly popular approach in the Middle East and California, driven also by a drop in cost enabled by reverse osmosis technology. Continued improvements of desalination technology are required to reduce costs in order to make desalinated water cost competitive with ground water sources.

Demand for Clean Water Supplied in the Developing World

The Millennium Development Goal of halving the number of people without access to clean water by 2015 has resulting in increasing development aid targeted to this problem. The NGO Water Aid estimates that USD 14 billion is being spent annually on increasing access to clean water – though they believe that this would need to increase to USD 30 billion for the target to be met. [8]

Increasing access to clean water in the developing world requires the development of technologies which are effective, inexpensive, and suitable for use in a developing world context; one which is likely to be lacking a mains power supply, advanced technical skills, and access to replacement parts.

Water Contamination

Water supplies are also becoming increasing contaminated, driving new technologies which are capable of large-scale water purification. Contamination may occur as a result of run-offs of pesticides, phosphates and other agricultural chemicals, and leeching of radioactive materials. Contamination may affect aquifers as well as surface water. Even after use of a chemical has been

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[8] http://www.wateraid.org/uk/about_us/frequently_asked_questions/4469.asp

phased out, contamination may continue, as in the case of polychlorinated vinyls (PCVs) – a banned industrial coolant which persists in the US water supply.[9]

Improving Water Infrastructure

Water infrastructure in the developed world is aging, which means either that systems can no longer cope with increased demand, or that performance becomes inefficient due to a lack of capacity or excess leakage. London's aging water system has prompted the local water supplier, Thames Water, to carry out one of the countries largest and most expensive civil engineering projects, the London Tideway Tunnels. This is intended to prevent the overflow of London's sewers and the release of wastewater into the River Thames. The WaterCAMPWS argues that a one trillion dollar investment programme is required to upgrade the United States' existing water infrastructure.

This presents a driver for the development of more cost effective technologies, given that large scale infrastructure projects are unable to win taxpayer approval in light of the current economic contraction.

Regulations

The primary driver of development in air purification technology is regulation. An emissions regulation – such as limiting the amount of NOx that can be produced – compels a company to introduce technology which is capable of satisfying this requirement. There are also instances in which recycling flue gas can improve an energy production process, but this is very much a secondary motive.

2.3.2. Barriers to Innovation

Local Monopolies in Water Supply

To some extent the industrial structure of the water industry mitigates against innovation. Water supply contracts are typically local monopolies, generating no incentive for improvements in excess of those mandated by law. The impetus to improve performance by enhancing water quality or preventing leakage comes from a regulatory body which grants these contracts, but this

[9] http://watercampws.uiuc.edu/index.php?menu_item_id=148

is externally imposed rather than organic to the utilities themselves. However, when winning new contracts, water supply companies do have an incentive for technological and performance improvement, as this may provide cost or other advantages in competitive bidding.

Lack of Customer Drivers

As stated above, regulation provides the main driver for companies to invest in air purification equipment to remove particulate matter and other substances from their emissions. Because this is perceived as essentially being a matter of regularly compliance, there is little strategic interest in developing air purification technologies; it is a cost, rather than an opportunity to achieve a cost saving.

2.4. Relevant Sector Segmentation and Applications

For the purposes of this report, nanotechnology applications for the provision of clean water and clean air will be considered Nanotechnologies for soil remediation will be considered in a future report.

2.5. Possible Future Products and Time Range

Application	**Commercially Available**	**1-3 years**	**3-5 years**	**5+ years**
Water Purification	Nanofiltration systems	Nanostructured membranes for purification	Ion precipitating bacterium. Titanium dioxide based methods	
Air Pollution Control	Nanoscale titanium dioxide additives		Nanostructured membranes for CO_2 removal	

3. Application Profiles

3.1. Improving Air Quality

3.1.1. Short application description

European regulations have established a number of regulatory restrictions on air pollution (limiting the amount of particulate matter in air at <0.005gm/km, for example). The flue gases from a power plant contain CO_2 and particulates, including ash, sulphate and nitrate. Therefore, industrial facilities are therefore often required to filter their emissions.

Three methods are currently used to reduce particulate matter; a bag house, electrostatic precipitation and a cyclone collector. Bag houses are a relatively simple method which used fabric bags as filters. The bags need to be cleared periodically. Electrostatic filters employ an electrostatic charge to separate out particles from a flowing gas. Cyclone separators spin aerosol streams causing the separation of particulate matter.

Scrubbers are typically used to remove Carbon Dioxide, and have a variety of modes of operation. Amine/liquid scrubbers flow gases through solutions, in which amines absorb CO_2 or hydrogen sulphide. The amine is run through a regenerator, which removes the gas enabling some of the amine to be reused. Other techniques which are being investigated include pressure swing adsorption (PSA), in which adsorption of a gas – such as CO2 – by a porous material occurs at high pressure. When pressure is reduced, the gas is desorbed and the material can be reused.[10] Scrubbers are typically large, costly installations.

Three primary nanotechnology-impacted approaches to air purification are photocatalysis, using a photo-active substance such as TiO2; catalytic traps, and static filters. Nanoscale particles of TiO2 (which are too small to reflect light, and therefore appear to be transparent) are used in paints and coatings. Pollutants such as nitrogen oxides bind to the TiO2 particles, which absorb sunlight, converting the nitrogen oxide to nitric acid, which is the washed away by rain.[11]

Another approach is to use membranes to remove CO_2. The NANOGLOWA project is developed a range of nanostructured membranes which would replace the need for a scrubber and would

[10] http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/3b3.pdf

[11] http://www.newscientist.com/article/dn4636

significantly reduce carbon dioxide in emissions.[12] GE is also developing nanostructured membranes which, with the correct adsorption and surface transport properties, could be used for precombustion CO2 capture[13]. Precombustion capture is required in so-called 'clean coal' systems, in which coal is gasified and then has pollutants removed before it is used as a fuel.

3.1.2. Functional requirements

Removal of Carbon Dioxide

Given the impact of global warming, the most important function that a scrubber could provide is the removal of CO2. The most polluting power plant in the United States produces 25.3 million tonnes of CO2 per year, with power generation accounting for 25% of global CO2 emissions[14].

Removal of particulate matter

Particulate matter in emissions – often ash – reduces air quality and can be linked to health problems. Directive 2008/50/EC of 21 May 2008 on ambient air quality and cleaner air for Europe proscribes an upper limit values for the amount of particulate matter in air (a limit value of 35 µg/m3, not to be exceeded more than 35 times in any calendar year).[15] New power plant facilities would need to demonstrate compliance with this limit, and existing power plants may need to be retrofitted with pollution control equipment.

Net positive environmental impact

Emission reduction processes should have a net positive environmental impact. A process which captures CO2 removes it from gaseous emissions but it must still be extracted from the scrubber in some form. Similarly, the process should require as little new material input as possible; if nanoporous membranes become unusable after a period of time and require replacement, the environmental impact of producing the replacement should be exceeded by the benefits – in the form of CO2 reduction – which the membrane is able to achieve.

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[12] http://www.nanoglowa.com/

[13] http://www.grcblog.com/?p=574

[14] http://www.sciencedaily.com/releases/2007/11/071114163448.htm

[15] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0050:EN:NOT

3.1.3. Boundary conditions

Equipment for emissions reduction or capture must be capable of being used in a demanding operational environment; a CO_2 scrubber should have the capacity to deal with the substantial quantities of emissions from a power plant, for example. This is particularly important when a CO_2 capture process is used for gasified coal, before its use as fuel.

Cost is a very important factor. Because companies are primarily motivated by complying with regulations, there is little advantage to be gained by performance which substantially exceeds the regulatory requirements.

3.1.4. Product examples

Nanobreeze Room Air Purifier

The Nanobreeze Room Air Purifier was manufactured by NanoTwin Technologies Inc (though the website of the company is unavailable, so it may have ceased to exist). The nanotechnology element of this device was a coating containing TiO_2 on UV lamp, which then demonstrated photocatalytic degradation of organic pollutants. This was designed for home use.[16]

Green Envirotec Inc. Wall Coatings

The company Green Envirotec offers a service of coating interior walls with TiO_2 in a liquid solution, which would then break down organic pollutants – sold primarily as a means to reduce odour[17].

3.1.5. Economic Information and Analysis

A 2006 report by BCC Research placed the value of nanotechnologies for environmental remediation – which includes other applications beyond pollution removal – in the low tens of millions (USD) at that time. Given the few companies with identified commercial products in this area, this is felt to be a realistic assessment of current market size.

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[16] http://www.voyle.net/Nano%20Products%202005/Products%202005-0003.htm

[17] http://www.greenenvirotek.com/green_cleaning-4.shtml

3.1.6. Selected Key Companies Profiles

CO2 Solution

CO2 solution is based in Quebec, Canada and is listed on the TSX Venture Exchange under the Symbol CST. The company recorded revenues of CAD 590 000 (approx € 350 000) in nine months to March 31 2008. The company is producing an enzyme which is used in a scrubber and which converts CO_2 to a bicarbonate in water solution.

Siemens

Siemens Power Generation business supplies a full range of equipment for power plants, from turbines to control systems. The company also sells air pollution control systems, for control of particulates (with fabric filter and electrostatic precipitation systems) and SO_2.[18]

Ahlstom Power

Like Siemens, Ahlstom sells a full range of power plant equipment. Air pollution control systems include a range of flue gas desulphurisation (FGD), as well as fabric filters, electrostatic precipitation systems, and mercury control.[19]

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[18] http://www.powergeneration.siemens.com/products-solutions-services/products-packages/environmental-systems/

[19] http://www.power.alstom.com/home/equipment___systems/ecs/36904.EN.php?languageId=EN&dir=/home/equipment___systems/ecs/

Drinking Water Treatment

3.1.7. Short application description

Drinking water treatment commonly involves a five stage process after the water has been transported from its source to holding reservoirs. The water alkalinity or acidity is first adjusted (possibly with the addition of additives like lime) so that it becomes slightly alkaline. This reduces the likelihood that water dissolves heavy metals from water pipes.

A clarification process is then used to remove turbidity or colour from the water. This process uses a flocculation agent which binds to particles in the water, causing the agglomeration of a precipitate which can be filtered out. The agents used may include iron hydroxide or a polymer called PolyDADMAC.

The flocculate is removed during stage 3, a sedimentation process in which a slow water flow allows particulate matter to sink to the bottom of sedimentation basins. The matter which settles on the bottom of the tank (called 'sludge'!) must then be removed and treated.

The fourth stage of water treatment is filtration, in which the remaining particles are removed. One of the most common methods employs sand and a layer of activated carbon or coal to remove organic compounds. Filtration systems should be designed and monitored to prevent clogging, in which no water can pass through the filter material.

Finally the filtered water is then disinfected to eliminate pathogens which have withstood the earlier processes. Chlorine is the most commonly used disinfectant agent, in the form of sodium hypochlorite which forms chlorine in contact with water. Additional steps may also be taken, such as the addition of fluoride to improve the dental health of water users.[20]

Uses of Nanotechnology

Nanotechnologies may be used to destroy bacteria (disinfection) or to reduce pollutants in water (filtration). This is of particular interest for regions which do not have access to a reliable supply of clean drinking water. These may also be responses to emergency situations, such as when a natural disaster like a flood or typhoon disrupts the water supply.

[20] http://www.epa.gov/ogwdw/consumer/pdf/hist.pdf

Technologies which would be employed at the flocculation stage include an ion precipitating bacterium, which precipitates pollutants such as arsenic faster than non-catalysed oxidation.

Photocatalytic methods employ solar activated reactions to destroy pollutants and micro-organisms. These include the use of Titanium Dioxide (TiO2) nanoparticles which may be coated on various substrate materials. The TiO2 particles have been demonstrated to remove organisms like Clostridium perfringens, which is resistant to chlorine.

Filtration membranes are another interesting application area for nanotechnology. Membrane pores which are as small as 1nm can block organic matter (such as pesticide molecules) whilst allowing water to pass through. The challenge is that the filtered material can start to block the membrane, reducing flow and eventually requiring cleaning or replacement. Multiple membranes could be arranged in a cascade, in which each membrane layer is designed to remove a specific material type from water. Nanofiltration improves on reverse osmosis as the membrane pores are larger, requiring lower water pressure.

3.1.8. Functional requirements

Removal of harmful substances

Water purification and disinfection should remove harmful substances from water, such as bacteria, viruses, parasites, and other substances. No single approach removes all such substances; chlorine, which is very effective against bacteria, is unable to remove organisms such as cryptosporidium. Another distinction should be drawn between processes – such as UV purification – which remove harmful substances at a single point, and additives such as chlorine which remain in the water and prevent further contamination.

Resistance to fouling

Fouling occurs when a filter becomes clogged with the substance it is designed to be filtering out. In some cases fouling can be cleared by reversing a system; flushing water back through a filter to clear blockages, for example.

Capacity is sufficient for use

The capacity of a purification system should be appropriate for its use. A system which is used to provide clean water for a village should have the capacity to purify sufficient water to satisfy all consumption needs, without users having to resort to using impure sources.

3.1.9. Boundary conditions

Technologies which are intended to increase access to water in the developing world must suit the context in which they will be used. A technology designed for use by a village in sub-Saharan Africa should demonstrate high (cost-) effectiveness, to have a relatively simple mode of operation, and to have a sufficient lifetime without requiring replacement parts. Total lifetime cost is an important factor in encouraging adoption; water treatment systems may be purchased by charities or international development agencies.

The primary boundary condition for this and all other environmental nanotechnologies is that any negative effectives from the technology used should not outweigh the harm caused by the original pollutant.

3.1.10. Product examples

Boca Raton Nanofiltration Membrane Treatment Plant

The UK company Biwater has developed two nanofiltration membrane water treatment plants in the US. The first of these opened in Boca Raton, Florida, in March 2003 and is designed to remove solids from shallow ground water.[21] The company received an order for a plant in Jupiter, Florida in December 2007.[22] The plant was planned to have a daily capacity of 14.5 mega gallons.

Matrikx

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[21] http://www.biwater.com/casestudies/detail.aspx?id=41

[22] http://www.biwater.com/news/news.aspx?id=69

KX Technologies' Matrikx water filters remove disease organisms from water. They have previously been described as employing a nanotechnology-based filtration method, but no further details are currently available.[23]

NanoCeram® Filter Cartridges / Disruptor™

These filter cartridges are produced by Argonide and utilised electrostatic attraction and adsorption to achieve high removal efficiency with a low power drop. It is designed for use in laboratory or industrial settings which require ultra pure water. According to Argonide, the filtration media is sold by Ahlstrom under the product name Disruptor™. Ahlstrom is targeting the product for home applications at the point of use or point of entry (at which the water supply enters the home).

3.1.11. Economic Information and Analysis

Given the limited number of companies that currently have products available, the size of this market is believed to be in the sub-100 million range. Biwater reported a combined market size of 2.5bn in 2005 for nanofiltration and reverse osmosis (though reverse osmosis is still the dominant technology of the two)[24].

3.1.12. Selected Key Companies Profiles

Kx Technologies

Kx Technologies develops a number of water filtration technologies, including a large production facility for carbon filters.[25] The company is now a subsidiary of Marmon Water, with that firm's Separation Technologies Group.

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[23] http://www.kxtech.com/Technology/Matrikx.aspx

[24] http://www.envirolinknorthwest.co.uk/Envirolink/Events0.nsf/0/8025739B003AADE380257409004C149F/$file/02%20-%20Biwater%20-%20Martin%20Hind.pdf

[25] http://www.kxtech.com/Index.aspx

Veolia Environnement

Companies operating in this industry include Veolia, the global leader in water services. Veolia Environnement, which was originally a water utility created on the order of Napoleon III, became independent in 2002. The company recorded revenues of 36 billion Euros in 2008, of which 12.6M was accounted for by the water business. Veolia Water has 82,900 employees and provides water to 132 million people.[26]

Aquaporin

Aquaporin (http://www.aquaporin.dk/) is a Danish company which was founded in 2005. The company develops Aquaporin membrane technology for water purification, primarily targeting the ultra pure water (UPW) market, which includes medical and industrial applications.

RWE

Germany's RWE, which had previously owned a number of water companies, is gradually exiting this market, organising an IPO for subsidiary American Water. The full implementation of this divestment by IPO was delayed due to the financial crisis.[27]

Biwater AEWT

Formed after the acquisition of Advanced Environmental Water Technologies (AEWT) by Biwater in 2005, Biwater AEWT is a supplier of reverse osmosis and nanofiltration treatment plants. The company is responsible for a full range of activities, from designing plants, managing sourcing and installation, and post-start up troubleshooting and support.

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[26] http://www.veolia.com/en/group/activities/water-management.aspx

[27] http://www.rwe.com/web/cms/mediablob/en/204612/data/33914/Annual-report-2008-PDF-Download-.pdf

4. References

Nanotechnology in Environmental Applications, BCC Research

http://www.bccresearch.com/report/NAN039A.html

Report from the Workshop on Nanotechnologies for Environmental Remediation, JRC Ispra 16 17 April 2007, David Rickerby and Mark Morrison, http://www.nanowerk.com/nanotechnology/reports/reportpdf/report101.pdf

5. Appendix 1: Expert Engagement

Input to this report is comes partially from an expert session on nanotechnologies for clean water provision, held during Nanotech Northern Europe 2008. Speakers at this session included:

Mark A. Shannon

Director, The WaterCAMPWS (The Centre of Advanced Materials for the Purification of Water with Systems)

Claire Weill

Institute du développement durable et les relations internationales

Bruce Jefferson

Senior Lecturer, Cranfield University, UK

Nano-enabled water supply facing post-industrial challenges: the case of Russia

State University School of Economics, Russia

David Rickerby

Senior Scientific Officer, European Commission Joint Research Centre

Maggy Momba

Tshwane University of Technology

Kevin M. McGovern

McGovern Capital Inc.

Tony Byrne

Nanotechnology and Integrated BioEngineering Centre, University of Ulster