Long-term planning tools for water purification sector: roadmapping for nanotechnologies in Russia

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Abstract

One of the most important issues for the world society in the XXI century is a task to provide pure water for citizens. As evidenced results of expert survey, made by the Higher School of Economics significant part of water sources for drinking water in Russia doesn’t meet necessary requirements. And one of the most adequate solutions to meet this challenge is using the nanotechnologies in processes of water purification that can solve the set of problems such as polluted sources, obsolete equipment, increased risk of diseases etc.

Roadmap “Applying Nanotechnology to Water Treatment” was launched by summarizing opinions of expert community participants both national and foreign regarding the most significant nanotechnologies and products made with their help which are used or can be used for water treatment and purification purposes. The aim of the research is to make special innovation routes R&D-technologies-products-markets that could be used by federal and regional authorities and Russian companies working in the field of water purification. The roadmap becomes the first large-scale national foresight exercise in the area of nanotechnologies for water purification.

Keywords: Water purification; Foresight; Roadmapping; Long-term planning tools.

Introduction

Roadmaps as a long-term planning tool instrument in the sphere of water purification

There are strong evidence that for effective management of the innovation process it is an urgent need in providing a link between a demand for innovative products and its supply. In international practice way of meeting this challenge is employing Foresight and especially it’s core — roadmaps. Roadmaps are widely used both in government and corporate sector for formulating innovation policy as a whole and providing special plans of new products and technologies implementation (1, 3, 8, and 9).

One of the most significant challenges currently facing government policy and business community is the development of nanotechnological sector. Inclusion of nanotechnology in the priorities of economic policy requires an assessment of long-term prospects of this sector, correct goal setting for its development, choosing the most effective points of focus. Roadmaps can serve to solve this problem (5-7).

Description of the roadmap “Applying Nanotechnology to Water Treatment”

Roadmap “Applying Nanotechnology to Water Treatment” was developed by HSE for Russian Corporation of Nanotechnologies (Rusnano). It was launched by collecting opinions of experts regarding the most important nanotechnologies and products made with their help which are used or can be used for water treatment and purification purposes. The aim of the research is to identify and to make foresight assessment of markets for future-oriented nano-enabled products in the sphere of water purification. The roadmap is the first large-scale national foresight exercise in the field of nanotechnologies for water purification (2, 4).
The roadmap evaluates nanotechnology’s potential to increase water treatment and purification efficiency in various segments, including centralised and decentralised water purification, industrial water treatment, and treatment of industrial and municipal waste water. The goal of the paper is to suggest an effective instrument for long-term planning in the field of water purification that provides a set of special plans of implementation of new technologies and commercialization of innovation products in this area (5-7).

**Context**

Issue of providing pure water for citizens has obvious significance for modern society. This issues considers as urgent task almost in every country in the world. And Russia isn’t an exception case. According to the results of expert survey made by the Higher School of Economics (HSE), about 20% of surface and underground water sources used for centralised supply of drinking water in Russia do not match relevant standards and requirements (see Figure 1).

**Figure 1.** Need for water treatment innovations

Expert community considers nanotechnologies in processes of water purification as an important decision that can solve the range of problems such as polluted sources, obsolete equipment, increased risk of diseases etc. (Figure 2).
Clean water supply is one of the major challenges societies around the world are facing. Thus far water treatment for general public and industrial purposes and wastewater treatment are not sufficiently resolved technological challenges. According to a recent social survey done by the HSE the problem of water quality hence the closely related problem of water purification remains one of the deepest concerns expressed by 35 per cent population of Russia and dominating other social and domestic/household problems. These challenges increasingly raise the awareness of a wide range of technology specialists and policy-makers. The paper develops an integrated roadmap to detect and leverage the potential of nanotechnologies for water supply and waste treatment (2, 4, 5-7).

Thus, the main driving forces for development of nanotechnological water treatment and purification solutions include the following:

- pollution of surface and underground water sources;
- significant wear and tear of water supply and sewage infrastructure;
- increasingly stringent requirements to water quality (5).

**Methods**

**Scenario-based roadmapping for long-term planning of Russian water purification market**

Roadmap was based on a wide range of experts and involved representatives of key firms of the field of water purification both producers and consumers, and research institutions.

Roadmapping allows researchers to consider alternative ways to obtain strategic goals and choose the most effective one. It provides market and production prospects estimations and helps to construct an innovative technological chain from R&D up to entry into market. The main feature of this roadmap is its scenario-based approach. The scenarios provided the framework for roadmapping by constructing the socio-economic «skeleton» of future society and by formulating the future challenges of the sphere of nanotechnologies in water treatment. The roadmap provides a special plan of implementation of new technologies and products taking into account three scenarios — pessimistic, moderate and optimistic (4-6).

The logic of roadmap development required an implementation of a wide range of Foresight methods in a strict succession (Fig.3).
There were a lot of evidence-based methods (benchmarking, bibliometrics, patent analysis etc.) aimed at analysis of existing works in the field of nanotechnology in water purification, expert methods (workshops, interviews, panel discussions) that provides a retrieval of “tacit knowledge”. Besides there are a set of creative methods. The most obvious example of it is wild cards and weak signals methods. It represents a possible future actions or events with low probability but high potential effect.

**Regional approach to solve problems in the field of water treatment**

Potential for applying new water treatment technologies for centralised and decentralised water supply (which defines marketing strategies for various markets), largely depends on such characteristics as coverage of centralised water supply systems; wear and tear of distribution networks; and water treatment plants’ equipment adequacy to the actual quality of source water in various Russian regions. Groups of similar regions were identified to develop promotion strategies, with similar problems in the water treatment and purification field.

The regions were divided into two groups, on the basis of centralised water supply systems’ coverage:
1) Group A: more developed centralised water supply networks (over 73% of the total area is covered);
2) Group B: less developed centralised water supply networks (73% or less of the total area is covered).

The following factors were identified as the most important ones for Group A:
- quality of water sources used by the centralised water supply networks, and adequacy of water treatment plants’ equipment;
- pollution level of water supplied to consumers (which among other things depends on the state of distribution networks).

On the basis of the above approach, 4 groups of regions were identified:
- A-1: relatively problem-free regions
- A-2, A-3: average regions
- A-4: relatively problematic regions

For Group B – regions with lower coverage of centralised water supply systems – the following factors were noted as key ones:
- quality of water in sources used for decentralised water supply;
- quality of water in centralised water supply systems.

The quality of water in centralised water supply systems was estimated by two indicators:
- quality of water sources used by centralised water supply networks, and adequacy of water treatment plants’ equipment to source water quality;
- pollution level of water supplied to consumers (which among other things depends on the state of distribution networks) (5).
Results and discussion

According to the experts, the most promising segment of water treatment and purification nanotechnologies is membrane technologies including baromembrane processes; electromembrane processes; membrane bioreactors; membrane degassing. Prospective supplementary technological solutions include the following nanoproducts: carbon nanotubes and fullerenes; dendrimers; zeolites; catalysts. Efficiency of traditional water purification technologies (such as coagulation, sorption, flotation) can also be significantly increased by applying nanotechnologies (4, 5).

According to the expert poll results, by 2015 (under the optimistic scenario) the following segments will have the highest demand for water treatment and purification technologies (in value terms) in Russia: centralised and decentralised water treatment; municipal waste water treatment; industrial water treatment.

There are a set of innovation strategies for using nanotechnologies for water treatment in different Russian regions with taking into account such conditions as level of development of decentralised and centralised water purification, state of distribution networks etc (2, 5, 6).

Current state of Russian R&D and production capacities

According to the experts, in terms of R&D results Russian membrane technology is on the whole on a par with the world leaders (the USA, Japan and South Korea), but commercialisation of these results is less successful yet.

Experts note that Russian R&D of certain kinds of sorbents are quite comparable with international analogues, and Russian products are second to none in terms of consumer properties and performance characteristics.

According to the expert poll results, new kinds of coagulants are currently being developed, which could replace certain other water treatment stages; this would make possible using them in treatment installations in areas not covered by centralised water supply systems, or where water quality is unstable (and worsening) – i.e. where water treatment and purification facilities must be especially flexible. Furthermore, certain industrial technological solutions already exist, ready for large-scale application to treat industrial and drinking water (5).

Production chain resources Russia lacks

According to the expert survey, all resources needed to develop nanomembrane processes are available in Russia. However, purchasing advanced foreign-made equipment could speed up commercialisation of this product, and would allow making products with improved consumer properties.

As one of the major obstacles hindering development of mass production of cutting-edge sorbents, the experts named lack of government funding: most of R&D and prototype production are undertaken at Russian universities or research institutes. Accordingly, other major problems identified by the experts included insufficient level of laboratory equipment and poor infrastructure.

Russia currently lacks sufficient production capacities for making coagulants (including those that could be considered as nanoproducts), i.e. to move developed innovative products on to the mass production stage. This is a problem of both industrial companies and centralised drinking water supply systems (5).

Visualization of the roadmap

Visual representation of the Roadmap includes five main layers:

- Technological development aims
- Processes and technologies which employ nanocomponents
- Promising nanoproducts
- Dynamics of market segments
- Alternative innovation technologies and traditional processes and technologies

A brief description of the sections’ content is given below.

Section 1: Technological development objectives

This section lists key objectives which must be accomplished to apply membrane and other nanocomponents-based technologies to water treatment and purification.
Section 2: Promising processes and technologies which use nanocomponents

In this section are described processes used for water treatment and purification purposes, which potentially may include (or already include) use of nanotechnologies. The section describes not just membrane-based processes but also other ones, whose potential for application of nanotechnologies is still being examined.

Section 3: Products needed to apply promising water treatment and purification technologies

Depending on specific water treatment objectives, and basic characteristics of water sources, various water treatment processes may be used, each requiring specific kinds of membranes. Section 3 illustrates interconnection between promising water treatment processes and relevant products.

Section 4: Market segments

This section describes segments of water treatment and purification market. It includes forecasts of each segment’s potential in Russia and globally for three fixed points: 2010, 2015, and 2020. Each forecast includes three scenarios: pessimistic, moderate (average) and optimistic.

Section 5: Alternative (new) and traditional processes and technologies

In this section alternative technologies are described, either traditionally used for water treatment and purification, or those which can potentially be used in future. Advantages and disadvantages are listed for each alternative, compared with nanocomponents-based technologies.

Conclusion

To conclude the roadmap determines a range of strategic goals for nanotechnological markets, connected with water treatment and provides special measures to achieve them choosing from alternative ways. Roadmap also provides concrete coordination mechanism of stakeholder’s actions necessary to be done for achievement of strategic goals.

The roadmap also describes possible strategies for developing water treatment and purification nanotechnologies including aggressive, active and passive ones. Besides the roadmap provides a set of innovation strategies in water purification for Russian regions. The roadmap has promising practical application for investment project-making and project appraisal in the field of water treatment as it provides both technological and commercial validation of alternative chains «R&D – technology – product – market».

In the final analysis roadmap could help the government to set strategic priorities for its research and technology policy in the field of water treatment considering scenario-related international, national and industrial technological and market developments.

References

(1). Desalination and Water Purification Technology Roadmap, US Bureau of Reclamation and Sandia National Laboratories 2003
(3). Foresight of Water Resources and Management in Egypt, Center for future studies, 2006
(6). Karasev O., Vishnevskiy K., Strategies of nanotechnology development in water purification in russia on the basis of integrated roadmaps, EMEC 12, The 12th European Meeting on Environmental Chemistry


(8). Water and Wastewater Industry Energy Efficiency: A Research Roadmap, Awwa Research Foundation, 2004