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# NANOTECHNOLOGY IN THE FUNCTION OF SUSTAINABLE WATER USE

*Svetlana Stevović[1], Žarko Nestorović[2], Neđo Đurić[3]*

[1] University of Belgrade, Innovation Center of Faculty of Mechanical Engineering, Kraljice Marije 16, Belgrade, Serbia
[2] JP EPS Đerdap 1, Trg kralja Petra I, Kladovo, Serbia
[3] Academy of Sciences and Arts of the Republic of Srpska, Bana Lazarevića 1, 78000 Banja Luka, the Republic of Srpska

**Abstract:** Nanotechnology, as contemporary field of research in forming of materials and devices on the level of molecule and atoms, is founding broad utilization in different scientific and engineering domains. The influence of nanotechnology on the development of contemporary human society has got a significant potential in domains as economy, environment protection, health and improvement of the quality of life. The need for fresh water as a necessary resource for living world, as well as the economic activity on the level of humanity is growing in the conditions of increasing population, increasing economic activities and increasing pollution. In that sense the conventional methods for water treatment may become ineffective for providing sustainable utilization of water resources in the future. Nanotechnology as a contemporary scientific and engineering field is considered efficient and potentially, the only solution for sustainable utilization of fresh water in the future. The efforts in nanotechnology utilization for sustainability of fresh water resources mean comprehensive approach and clarity in defining goals as well as the ways for their realization. The basic expectations of nanotechnology in the sense of fresh water resources utilization are directed to enhancement of fresh water availability, increase of efficiency of fresh water delivery and enabling next generation systems for fresh water quality monitoring. The increase of fresh water availability by nanotechnology means development of filtering systems and development of membrane systems, inverse osmosis for water desalinization and catalysts for water treatment. Efficiency of fresh water delivery based on nanotechnology means reducing energy necessary for its transportation, developing system of pipes and components which are easier, stronger and which will last longer as well as to provide cheap materials which improve energy efficiency for heating and cooling. All these processes for nanotechnology development aiming to provide sustainable fresh water resources utilization require significant efforts on scientific and engineering level in order to be utilized in everyday life. This paper aims to research the state of the art of nanotechnology development in the domain of sustainable utilization of fresh water resources.

**Keywords:** Nanotechnology, fresh water resources, sustainability.

## 1. INTRODUCTION

Water is essential resource for life on the planet Earth. According to [1] the total volume of water in the oceans, ice caps, lakes, rivers, groundwater, atmospheric water and all other existing water in the world is about 1,386,000,000 cubic kilometers (km$^3$). The volume of liquid fresh water (ground water, lakes, swamp water, and rivers) is about 10,633,450 (km$^3$), while the volume of water in lakes and rivers is about 93,113 (km$^3$). Despite the relatively high volume of fresh water the need for it is expected to rise as well as the level of its deterioration [2]. The reasons are on the one side the rising world population, and on the other side the rise of its deterioration is caused by its pollution. The sources of water pollution are numerous and there is almost no human activity which does not pollute the water. For example, the agricultural production is inseparable from using fresh water but in literature it is possible to find the next statement: "*Agriculture disrupts all freshwater systems hugely from their*

* Corresponding author: svetlanas123@gmail.com

*pristine states*" [3]. This statement is supported by the fact that agricultural production consumes more fresh water than any other human activity [4].

The classical concept of water supply could be described in the following way: "*The new water supplies are likely to appear as a result from conservation, recycling, reuse and improved water use efficiency rather than from large development projects.*" [4]. This approach, even though it is right on the abstract level, does not include the new technologies for water cleaning, but indicate the need for responsible utilization of existing water resources rather than engagement of new ones. In the aforementioned situation where water, as a limited resource, is utilized at the level where there is little or no possibility to access a new source, the only solution is to refine utilized water and increase efficiency of its use. The classical approach has also numerous limitations. The classical technology is quite expensive, resource and time demanding what requires a completely new approach and technological solution.

The main problem of water use in the future could be pointed out as how to face with its rising demand, sustainable use as inevitable deterioration. Rising demand for water is possible to solve with the increase of its accessibility, sustainable use with invention of materials which are more durable and with less pollutant potential and deterioration of water could be solved with efficient wastewater treatment. All these processes must be provided with as maximal energetic efficiency as possible. The nanotechnology in the last few decades appeared as a promising solution. Figure 1 illustrates the relation between problems of rising need for water, water as a limited resource and its rising deterioration and nanotechnology.

Nanotechnology is defined in various ways. One among definitions focuses the size in which the nanotechnology is situated: "*Nanotechnology is the ability to control and restructure the matter at the atomic and molecular levels in the range of approximately 1–100 nm, and exploiting the distinct properties and phenomena at that scale as compared to those associated with single atoms or molecules or bulk behavior.*" [5]. Aforementioned definition is set out in Nanotechnology Research Directions [6]. Other approaches are broader and encompass more general view making difference between nanoscience and nanoengineering. "*Nanoscience deals with the measurement and characterization of the nano and microscale structure of cement-based materials to better understand how this structure affects macroscale properties and performance through the use of advanced characterization techniques and atomistic or molecular level modelling*." [7]. Some characteristics of nanotechnology engineering are given on the example of concrete: "*Nano-engineering encompasses the techniques of manipulation of the structure at the nanometer scale to develop a new generation of tailored, multifunctional, cementitious composites with superior mechanical performance and durability potentially having a range of novel properties such as: low electrical resistivity, self-sensing capabilities, self-cleaning, selfhealing, high ductility, and self-control of cracks. Concrete can be nano-engineered by the incorporation of nanosized building blocks or objects (e.g., nanoparticles and nanotubes) to control material behavior and add novel properties, or by the grafting of molecules onto cement particles, cement phases, aggregates, and additives (including nanosized additives) to provide surface functionality, which can be adjusted to promote specific interfacial interactions.*" [8]. The significance of accepting scientific definition of nanotechnology is also questioned in literature and stressed as very important because of scientific and commercial reasons. The significance of delineating the boundaries of emerging technology is considered as central to obtaining understanding of the technology's research paths and commercialization prospects and nowhere is this more relevant than in the case of nanotechnology given its current rapid growth and multidisciplinary nature [9].

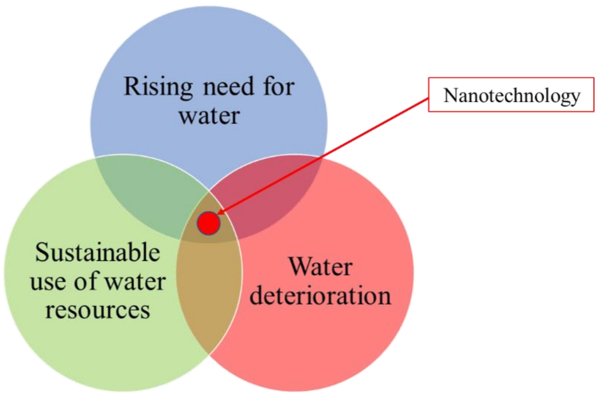


*Figure 1. The relation between main water problems and nanotechnology*

The societal aspects of nanotechnology are also researched in the beginning of its development. Point out the idea that nanotechnology shall extending the limits of sustainable development and human potential this was formulated in following way: "*The main reason for developing nanotechnology is to advance broad societal goals such as improved comprehension of nature, increased productivity, better healthcare, and extending the limits of sustainable development and of human potential.*" [10].

The idea of utilization of nanotechnology in solving water problems appears in the first decade of twentieth century. "Dr Alan Smith of the UK government's Micro Nanotechnology Network explains that nanotechnology is making waves in the water treatment industry." [11]. "Wilhelm Barthlott of the University of Bonn in Germany, the discoverer and developer of the "lotus effect," has a vision of a self-cleaning Manhattan, where a little rain washes the windows and walls of skyscrapers as clean as the immaculate lotus." [12].

In paper [13] the use of catalytically self-propelled microjets (dubbed micromotors) for degrading organic pollutants in water via the Fenton oxidation process is described. The figure 2 illustrates self-propelled microjet. Paper [14] presents the idea of oil/water separation by using polybenzoxazine (PBZ) and titanium dioxide (TiO2) nanoparticles. "*Two important properties—the low surface free energy of polybenzoxazine (PBZ) and the photocatalysis-induced self-cleaning property of titanium dioxide (TiO2) nanoparticles—are combined to develop a promising approach for oil/water separation. They are integrated into a multifunctional superhydrophobic and super oleophilic material, PBZ/TiO2 modified polyester non-woven fabrics (PBZT), through a simple dip coating and subsequent thermal curing method*."

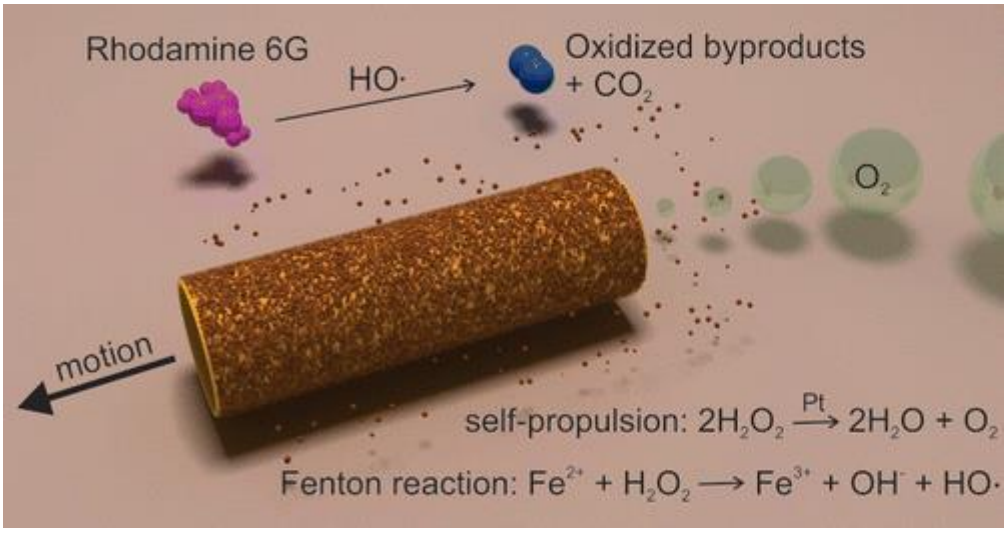


*Figure 2. Self-propelled microjet*

In USA the white paper of water sustainability through nanotechnology was introduced [14]. The reason for introducing this paper was found into the arguments that "… *significance of water bridges many critical areas for society: food, energy, security and the environment*." "*In 2012, droughts affected about two-thirds of the continental United States, impacting water supplies, tourism, transportation, energy, and fisheries – costing the agricultural sector alone $30 billion. In addition, the ground water in many of the Nation's aquifers is being depleted at unsustainable rates, which necessitates drilling ever deeper to tap groundwater resources. Finally, water infrastructure is a critically important but sometimes overlooked aspect of water treatment and distribution. Both technological and sociopolitical solutions are required to address these problems."* It is obvious from the exposed data that there is economic justification for development of nanotechnology in water resources providing. The nanotechnology is viewed as a tool for taking advantage of the unique properties of engineered nanomaterials to generate significant breakthroughs in addressing Nation's water challenges. This is the example of initiative of developing new generations of knowledge with the goal to solve rising problems of water scarcity.

Despite the fact of benefits of nanotechnology, a numerous papers investigate the dangers of nanotechnology. The dangers are in the domain of influences to environment and as well as the possible influences on people's health. Today, the thousands of nanoparticles are known but well-defined guidelines for evaluating their potential toxicity and control their exposure are not fully provided [15]. Characteristics of nanoparticles such as chemistry, ability to enter in different environments where they never existed before could have unpredictable impacts and consequences. Unpredictable behavior of nanoparticles is especially dangerous where they may influence human health. Almost every organ of human body may be exposed to negative influence of specific nanoparticles [15].

Despite the fact that rapidly developing nanotechnologies offer many benefits they also could be toxic [16]. The toxicity of nanoparticles may differ depending on their reactivity, retention time, and the distribution in human body. Also there is imbalance between rising number of nanoparticle types and applications and studies about their negative effects after exposure and potential toxicity.

The ideas for nanotechnology utilization vary from focusing on benefits only [17] to fear of negative effects of it and calling for a moratorium on the deployment of nanomaterials [18]. The development of nanotechnology and it's dramatic increase in the last two decades (including applications and scientific research) supports the idea of optimistic opinion that nanotechnologies' advances overcome the potential dangers.

Nanotechnology also opens a lot of questions connected with people's privacy and ethics. The gap between ethical and scientific issues in the case of nanotechnology seems to be unsolvable. The development of nanotechnology, and its possibilities opened also the questions connected with ethics [19]:

– Who will benefit from advance in nanotechnology (is there a balance between developed and less developed countries)?

– Ability of nanotechnology to improve surveillance devices and new weapons producing. How is it possible to protect individual privacy when near-invisible microphones, cameras, and tracking devices become widely available? "Will these new technologies increase security or add to the arsenal of bio- and techno- or even nano-terrorism?"

– Environmental issues are also not known because of new created nanomaterials and

– Implementing nanomaterials in human bodies with implanted computer chips opens the questions about acceptability of this implementations and its consequences.

These questions are the questions about use and misuse the advances of nanotechnology and if the society is able to control its misuse.

Contemporary approaches in solving water problems by utilization of nanotechnology seem to be highly specialized i.e. orientated on certain problems. Also the different strengths and shortcomings of Nano technological solution are recognized and researched.

The problems of fluoride in drinking water and its negative influence on human health as well as possibilities of nanotechnology, inspired different solutions for its removal, but experimental results are valid under specific parameters including pH, other ions presence, initial fluoride concentration, temperature, etc. [20].

The nanoparticles as photo catalysts are used in the process of degradation of Reactive Blue 19 (RB-19) and Reactive Red 76 (RR-76) dyes pollutant in the industrial waste water using $TiO_2$, C-doped $TiO_2$ TiO2(C-TiO2), S-doped TiO2 (S-TiO2) and C,S co-doped TiO2 (C,S-TiO2) [21]. The dyes degradation was investigated under several experimental parameters such as pH, catalyst load, dye concentration, shaking speed, and irradiation time and catalyst recovery. Also the toxicity and biological activity of the treated and untreated waste water on artemia and *Vibrio parahaemolyticus* were investigated. The conclusion of this research was that: "*The treated wastewater doesn't possess toxicity against rotifer and artemia marine organisms*." Also the conclusion was that degradation efficiency was high. These results show that in controlled conditions there were no toxic consequences and the high efficiency was reached by using nanoparticles.

Theoretical approach in processes of water desalination was used in order to research possibility of using Sweeping Gas Membrane Distillation (SGMD) technique [22]. The valuable results of this approach are that the predictions show a small error of 3.6% with the experimental data reported in literature. This example shows that theoretical results for prediction of some nanotechnology utilizations may be used in the process of certain solutions evaluation. The SGMD model is developed as follows [22]:

$$Q_h = h_f(T_b - T_1) \tag{1}$$

where $h_f$ represents the coefficient of convective heat transfer given by formula

$$h_f = 1.86k_l\left(\frac{RePr}{d_h^2}\right) = 0.116k\left(Re^{\frac{2}{3}} - 125\right)Pr^{\frac{1}{3}}\left[\frac{1+\left(\frac{d_h}{L}\right)^{\frac{2}{3}}}{d_h}\right] \tag{2}$$

The parameters have the following meanings:

– $Q_h$ - heat flux which is provided by the circulative hot feed to the membrane surface;

– $T_b$ and $T_1$ are the bulk and the membrane's surface temperatures, respectively;

– $k_l$ - is the feed thermal conductivity;

– $d_h$ - is the feed channel hydraulic diameter and

– $L$ - is the module length.

The Nusselt number $N_u$ is calculated as follows:

$$N_u = 0.13Re^{0.64}Re^{0.38} \qquad Re < 2100 \tag{3}$$

$$N_u = 0.13Re^{0.8}Pr^{0.33} \qquad Re > 2100 \tag{4}$$

$$Re = \frac{\rho v d_h}{\mu}$$

$$Pr = \frac{C_\rho \mu}{k_l} = \frac{v}{a}$$

where $\rho$, $v$ and $d_h$ are the fluid density, velocity and hydraulic diameter of the feed in hot channel of the SGMD module, respectively. the viscosity of hot fluid in the feed channel is denoted by $\mu$, and $a$ and $C_\rho$ are the thermal diffusivity and the specific heat capacity, respectively.

The sweeping gas heat transfer coefficient could be expressed as follows:

$$h_a = 0.206\left(\frac{k}{d_h}\right)(Re\ cos\ \alpha)^{0.63}Pr^{0.36} \tag{5}$$

where $\alpha$ is the yaw angle, which can change from 0° to 90° for pure cross-flow to parallel flow, respectively.

Since there is no heat generation or consumption through the SGMD module, the total heat transfer could be written as:

$$h_f(T_{bf} - T_f) = J\lambda + \frac{\varepsilon K_g + (1-\varepsilon)k_m}{\delta}(T_f - T_a) = h_a(T_{ba} - T_a) \tag{6}$$

where $T_f$, Tbf , $T_a$, $T_{ba}$ are representative temperatures in the feed channel, i.e. on the membrane surface, in the feed bulk, in the distillate side and on the surface of the membrane, and in the sweeping gas bulk, respectively. The λ symbol shows the latent heat of water, and J is the distillate flux. This brief outline of the SGMD model shows that complex knowledge is possible to transfer into a relatively simple model which is in good concordance with reality.

Modifications of some natural materials could also be used in the wastewater treatment. "*The natural and Cobalt Hexacyanoferrat modified zeolites were characterized by FTIR and SEM techniques and were employed as an adsorbent for removal Cd(II) ions from aqueous solution.*" [23]. The results show that the nanoparticles have effective potential for the adsorption of Cd(II) from the wastewater. The results were nearly two times greater than adsorption capacity of non-modified zeolite. This is an example for increasing the capacities for wastewater treatment of natural materials with nanotechnology.

Energy efficiency obtained by nanotechnology is also one of the drivers of its utilization. Nanotechnology is in the middle of the attention for providing different benefits for human society including sustainable energetic supply. The expectations in academic community as well as among the investors are great [24]. The significant breakthroughs in energy sector provide electricity with smaller influence on the environment and with the better utilization of renewable sources of energy. This makes possible efforts to strive to realize the ideal of green and sustainable energy. "*Nanotechnology, in particular nanophotonics, is proving essential to achieving green outcomes of sustainability and renewable energy at the scales needed.*" [25]. This approach implies the nanostructures involved in all components of energy efficient buildings together with solar cells.

A public perception about nanotechnologies is also very important issue in its utilization and the potential for development. The importance and influence of public perception is best seen in the case of genetically modified food and effects on its sale. The research provided in USA reported that Americans' initial reaction to nanotechnology is "*thus far generally positive, probably rooted in a generally positive view of science overall.*", but it was identified "*loose of privacy to tiny new surveillance devices*" as the most important risk to avoid [26]. In the Switzerland the survey of perception for nanotechnology utilization in the food production and food packaging was provided. "*Results suggest that affect and perceived control are important factors influencing risk and benefit perception. Nanotechnology food packaging was assessed as less problematic than nanotechnology foods. Analyses of individual data showed that the importance of naturalness in food products and trust were significant factors influencing the perceived risk and the perceived benefit of nanotechnology foods and nanotechnology food packaging.*" [27]. The wider research about cultural cognition of the risks and benefits of nanotechnology [28]. The findings were that subjects did not react in a uniform, much less a uniformly positive manner, but rather polarized along lines consistent with cultural predisposition toward technological risk generally. Finding also does not support for the "familiarity hypothesis" (which holds that support for nanotechnology will likely grow as awareness of it expands) "*the study instead yielded strong evidence that public attitudes are likely to be shaped by psychological dynamics associated with cultural cognition.*" The provided research about public perception proves that clear public attitude about nanotechnology is not formed yet. This is probably because, on the one side, the expectations of new technologies to solve the human problems are great and, on the other side, the fear of the unknown still exists. "*The applications for engineered nanomaterials and nanotechnology are developing exponentially, along with the awareness in government, industry and public groups of nanosafety issues. There is also growing public concern caused by negative perceptions among some high profile groups that nano-enabled products are proliferating uncontrollably and being released without adequate testing of their safety.*" [29]. The statement that nanomaterials and nanotechnology are developing exponentially and that public concern about safety utilization is growing is the crucial for developing method of nanotechnology evaluation in this paper.

Aforementioned examples and results are a small set of dramatically increased research in nanotechnology utilization and new possibilities and ideas for providing sustainable water use. The benefits of nanotechnology, at this stage of its development, are unquestionable. But important questions still remain for discussion. Before all the questions about possible influences of nanotechnologies' in the future. It is probably impossible to predict the possible mutual reaction between different nanoparticles when they meet themselves in the natural environment. Will the reaction between them be positive for environment or not? Bearing in mind the different experiments based on different ideas, their modifications and possible failures it is real that risks exists. On the other side nanotechnology may be the only solution for providing the necessary conditions for life (in this case: fresh water) the nanotechnology appears as an imperative for investigation. Those conflicting questions could be essential in future. Bearing in mind the intentions in the world it is obvious that nanotechnology and nanoscience are developing regardless to risks they produce. In that case it is only possible to investigate the methods for estimating risks and benefits from nanotechnology and to research possibilities for eliminating the threats and dangers of nanotechnology in future. In this paper the basic assumption is that nanotechnology development will continue in the future. The basic methods for analysis of risks in this paper are based on the descriptive techniques of analysis because there is not enough data and knowledge for reliable models. Adopting assumption that water is the best media for nanoparticles transportation and existence it immediately follows that water is most vulnerable resource with nanoparticles' negative influences.

## 2. MATERIALS AND METHODS

Analyzing nanotechnology and its influence on environments and humanity shall include two main dimensions. The first one is the benefit and the second one is the risk. Benefits of nanotechnology could be measured in different ways, but risk measurement is almost impossible. The benefits of nanotechnology utilization could be measured by the economic effect; number of lives saved the number of problems solved etc., while the risks of nanotechnology are difficult to predict and could be known only after accidents happen. Some assumptions, however, could be made and analysis provided in advance. In this paper we discuss some methods for evaluating nanotechnology and position them into different dimensions.

The next methods are proposed and described in this paper for nanotechnology solution evaluation:

- "Benefits - Dangers" method and
- "Benefits - Risk" method.

The "Benefits - Dangers" method is based on numerical expression of benefits and dangers coming from a certain nanotechnology product. Depending on the number of benefits and dangers a certain nanodevice is evaluated and the decision of its development could be made. The "Benefits - Dangers" method for evaluating a nanodevice is shown on the Table 1.

The 1st quadrant: dangers of a certain solution are numerous and benefits of the solution are numerous. In this case the development of nanotechnology solution should be done very carefully or it should be avoided depending on the perception of the dimensions (dangers or benefits) that will prevail in the future.

The 2nd quadrant: dangers are numerous and there are only a few benefits of nanotechnology solution. In this case development of nanotechnology solution should be avoided until the dangers are reduced to the acceptable level.

The 3rd quadrant: few dangers and few benefits. According to the logic of this method the development should be postponed.

The 4th quadrant: few dangers and numerous benefits. In this case the development of nanotechnological solution should be encouraged.

*Table 1. The "Benefits-Dangers" method for nanotechnology solution evaluation*

| | | Benefits | |
|---|---|---|---|
| | | Numerous | Few |
| Dangers | Numerous | Develop it carefully or avoid development | Avoid Development |
| | Few | Encourage development | Postpone development |

The limitation of "Benefits - Dangers" method is in its simplicity i.e. in implicit assumption that both benefits and dangers are of the same weight. That means: there are no existing dangers in nanotechnological solution which could escape out of the control or to make unrepairable damages to humanity and/or environment. This method could be extended and improved but in this paper only an illustration of it is given. Also this method does not include the risks connected with nanodevices. Actually, the risk (probability of occurrence of unwanted events) may be acceptable even in the case of numerous dangers.

To avoid the simplifications and limitations of "Benefits - Dangers" method, the "Benefits - Risk" method is developed. This method encompasses the level of risk and benefits of nanotechnological solution and connected strategies for its development accordingly. Table 2 illustrates the "Benefits – Risk" method.

The 1st quadrant: risk of a certain solution is high and benefits of the solution are great. In this case the development of nanotechnology solution should be postponed till the risk is reduced to the acceptable level.

The 2nd quadrant: risk is high and benefits of nanotechnology solution are small. In this case development of nanotechnology solution should be avoided until risk is reduced to the acceptable level and the benefits increase (if possible).

The 3rd quadrant: risk is low and benefits are small. According to the logic of this method the development should be postponed if there are no capacities for improving benefits.

The 4th quadrant: low risk and great benefits. In this case the development of nanotechnological solution should be encouraged.

*Table 2. The "Benefits-Risk" method for nanotechnology solution evaluation*

| | | Benefits | |
|---|---|---|---|
| | | Great | Small |
| Risk | High | Reduce risk before developing | Avoid Development |
| | Low | Encourage development | Postpone development |

The "Benefits-Risk" method in this interpretation also has some limitations and could be improved. Improvements could be based on the space and time horizons: the risk and benefits distribution in space and time. The distribution of risk in space means if it is of global or local character while the distribution in time means the period of time in which the unwanted event could occur. The further development of this methods for nanotechnological solutions evaluation overcame this paper's aims.

## 3. RESULTS AND DISCUSSION

The analysis of nanoparticles and nanodevices with proposed methods according to expectations connected with fresh water solutions was obtained as follows.

The results of analysis of the systems for enhancement of fresh water availability by nanotechnology utilization mostly generate the numerous benefits and only a few (if any) dangers. The only questioned are the catalysts and microjets which, despite the numerous benefits, could behave in uncontrolled manner. The results obtained by "Benefits-Dangers" method are shown in Table 3.

The analysis of the enhancement of fresh water availability by nanotechnology provided by "Risk-Benefits" methods that risks are low and benefits are great. The results are shown in Table 4.

*Table 3. The results of systems for enhancement availability of water by nanotechnology utilization obtained by "Benefits-Dangers" method*

| | | Benefits | |
|---|---|---|---|
| | | Numerous | Few |
| Dangers | Numerous | Catalysts<br>Microjets | |
| | Few | - Inverse osmosis<br>- Nano filters<br>- Membranes | |

*Table 4. The results of systems for enhancement availability of water by nanotechnology utilization obtained by "Benefits-Risks" method*

| | | Benefits | |
|---|---|---|---|
| | | Great | Small |
| Risk | High | | |
| | Low | - Inverse osmosis<br>- Nano filters<br>- Membranes<br>- Catalysts<br>- Microjets | |

The analysis of nanotechnology systems for enhancement of water availability slightly differ depending on the method used. The utilization of "Benefits-Dangers" method exposed catalysts and microjets as potentially dangerous because of their unknown behavior among possible variations. "Benefits-Risk" method, however, showed that all systems are of low risk because catalysts and microjets are of limited volume and, if they produce pollution it would be recognized immediately because of the character of water.

The nanotechnology utilization in efficiency of fresh water delivery by means of reducing energy necessary for its transportation, developing system of pipes and components which are easier, stronger and longer lasting as well as to provide cheap materials which improve energy efficiency for heating and cooling could only provide the benefits with only few (if any) dangers because the classical systems also produce some influences on environment. The nanotechnology utilization in this segment of sustainable water use could only reduce the existing influence of classical systems.

Concluding the discussion about benefits, dangers and risks of nanotechnology utilization in sustainable water use it is possible to say that the main strategy should be to encourage development. The character of water reduces some risks because every deviation in its quality will be immediately noticed by increase in health problems among population. It is assumed that all products were tested enough before commercialization on the necessary levels to avoid any uncontrollable damages.

## 4. CONCLUSION

Water is not only crucial for life it is also necessary condition for humans' economic activities. Growing population with growing economic activities causes water resources depletion. Especially vulnerable, in that life's and economic processes, is fresh water which is of very limited volume and most exposed to pollution. The classical strategies for fresh water providing (reuse, water treatment, recycling) including new development projects are almost at their limits to meet the needs. The only new promising possibility for fresh water providing is to include nanotechnology solutions.

Nanotechnology solutions are seen in the directions of sustainable fresh water use by enhancing possibilities for fresh water availability, increase of efficiency of fresh water delivery and enabling next generation systems for fresh water quality monitoring.

Bearing in mind that new technologies (including nanotechnologies) have unknown influences on human lives and environment there is a need to evaluate their dangers and benefits in order to make decision about their development. Treating nanotechnology as relatively new phenomenon which has been developing dramatically (according to certain authors-"exponentially"), it is very difficult to forecast the possible unwanted consequences. That is because the nanotechnology products are of very small dimensions which allow them to overcome existing biological barriers more easily and enter into humans' and other living organisms in different ways which are almost unpredictable. Also the potential mutual combination of nanoparticles as well as the combinations with some living organisms could have unpredictable consequences. In order to evaluate the possibilities in this paper the two methods are proposed: "Benefits-Dangers" and "Benefits-Risk" method. Despite the limitation of these methods they are reliable for decision making about further development of nanotechnology.

The results of these methods utilization on the nanotechnological systems for the sustainable water use showed that there is a slight difference in evaluating nanotechnological solutions obtained by “Benefits-Dangers” method and “Benefits-Risk” system. Nanotechnology solutions development for sustainable water use (inverse osmosis, membranes and nanofiltering) should be encouraged by both “Benefits-Dangers” and “Benefits-Risk” methods. Other two nanotechnological solutions (catalysts and microjets) are evaluated as to be carefully developed by “Benefits-Dangers” method and that should be encouraged to develop by “Benefits-Risk” method. The possibilities of numerous unknown dangers are compensated by low risk of their appearance.

Nanotechnology is still developing and is the promising solution for sustainable water use in the future. The numerous benefits, small risks and huge resources invested in its development open the perspective of its economic sustainability.

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НАНОТЕХНОЛОГИЈА У ФУНКЦИЈИ ОДРЖИВОГ КОРИШЋЕЊА ВОДА

**Сажетак:** Нанотехнологија, као савремено поље истраживања начина формирања материјала и уређаја на нивоу атома и молекула, налази све ширу примену у различитим научним и инжењерским областима. Утицај нанотехнологије на развој савременог друштва има велики потенцијал у доменима економије, заштите животне средине, здравља и унапређења нивоа квалитета живота. Потреба за водом, као ресурсом неопходним за одржање живота уопште, али и економске активности на нивоу човечанства, све више расте у условима повећања становништва, економских активности и све већег загађења животне средине. У том смислу конвенционалне методе пречишћавања вода у будућности могу постати недовољно ефикасне за обезбеђивање одрживог коришћења водних ресурса. Нанотехнологија као савремена научна и инжењерска област сматра се ефикасним и потенцијално јединим решењем проблема одрживог коришћења водних ресурса у будућности. Напори у коришћењу нанотехнологије за одрживост водних ресурса подразумевају свеобухватан приступ и јасно дефинисање циљева и начина за њихову реализацију. Основна очекивања од нанотехнологије у смислу коришћења водних ресурса усмерена су на повећање расположивости воде, повећање ефикасности испоруке воде и омогућавање наредне генерације система за мониторинг квалитета вода. Повећање расположивости воде применом нанотехнологије обезбеђује се кроз филтрацију и развој мембранских система, инверзију осмозе за десалинизацију воде и катализатора за третман воде. Ефикасност испоруке воде применом нанотехнологије треба да смањи количину енергије потребне за њен транспорт, обезбеђивање система водоводних цеви и компоненти које су лакше, јаче и трајније као и да обезбеди јефтине материјале који унапређују енергетску ефикасност воде при хлађењу и грејању. Сви ови процеси развоја нанотехнологије за одрживо коришћење вода захтевају значајне напоре на научном и инжењерском плану како би нашле примену у свакодневној употреби. Овај рад бави се истраживањем стања развоја нанотехнологије у области одрживог коришћења водних ресурса.

**Кључне речи:** Нанотехнологија, водни ресурси, одрживост.

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