Water Security Risk – Part One

Nanobubbles in the Water, Health, Food, and Trade Crisis

Amirhossein Khodaei – Researcher

Nanobubble Technology: A Technological Solution for Public Health, Biological Threat Management, and Water Security in Iran

Iran is located in one of the world's sensitive and arid geopolitical regions, where water-related crises, including declining rainfall, land subsidence, depletion of groundwater aquifers, and contamination of surface and groundwater resources, have posed serious threats to the country's biological and economic security. In this context, the use of advanced and indigenous technologies, including nanobubble technology, can provide a scientific and effective response to these challenges. This analytical note examines the role of nanobubbles in public health, environmental protection, improving water-use efficiency, and the executive and legal requirements for developing this technology in Iran.

Iran Is Among the Countries with Nanobubble Technology

Iran is currently one of the few countries, alongside Japan and the United States, possessing industrial nanobubble technology. This technological capability, which is the result of efforts by domestic knowledge-based companies, can, through targeted and planned development, become a global competitive advantage in the fields of water, health, agriculture, and the environment.

What Are Nanobubbles and What Makes Them Unique?

Nanobubbles are bubbles with a diameter of less than 200 nanometers that, unlike ordinary bubbles, remain stable in liquids and do not rise to the surface. This characteristic gives them unique properties, including:

- A significant increase in dissolved oxygen
- Generation of free radicals with disinfecting properties
- Oxidation of organic pollutants and heavy metals
- Reduction of surface tension and improved water penetration into soil
- High stability in aquatic environments and the ability to function over extended periods

Applications of Nanobubble Technology in Iran and the World

Public Health and Pharmaceuticals

- Disinfection of drinking water by reducing chlorine use by up to 60% and removing odors, color, and microbial agents such as *E. coli*, Salmonella, and hepatitis A virus, thereby significantly improving public health.
- Improving the quality of herbal medicines and radiopharmaceuticals by increasing the permeability of medicinal substances and the stability of active compounds, resulting in greater therapeutic effectiveness and immunization.
- Improving immunity in the body through enhanced absorption and stability of active pharmaceutical substances.
- Using nanobubbles as drug carriers and contrast agents in medical imaging and cancer treatment.

Wastewater Treatment and the Environment

- Reducing the microbial load by more than 90% and optimizing aeration systems, thereby reducing energy consumption and costs.
- Oxidizing organic and inorganic pollutants and improving wastewater quality for reuse and reducing environmental pollution. An industrial example: in a dairy factory, BOD, COD, and suspended solids were reduced by 10.6%, 5.77%, and 16.5%, respectively, while dissolved oxygen increased by 134%.
- A chemical-free wastewater treatment project in the food and beverage industry improved wastewater quality and compliance with environmental standards.
- Cleaning surface waters, lakes, and rivers by controlling harmful algae and preserving ecosystems without the need for harmful chemicals.

Agriculture, Horticulture, and Food Security

- Saving up to 30% in water consumption and reducing fertilizer and pesticide use by up to 30%, helping preserve water resources and soil health.
- Increasing agricultural crop yields, such as an 18% increase in tomatoes and an 8% increase in rice, as well as improving product grain size and quality.
- Controlling soil-borne diseases and using moderately saline water without contamination, thereby improving food security.
- Enhancing plant immunity against diseases by improving oxygenation conditions in the soil.

Livestock, Poultry, and Aquaculture

- Disinfecting drinking water for livestock and poultry and reducing the use of antibiotics, improving animal health and the quality of animal products.
- Increasing dissolved oxygen in aquaculture and improving the health and growth of algae-eating species.
- Helping increase immunity and reduce diseases in aquatic animals and other animals by improving biological conditions.

Industry, Services, and Construction

- Improving washing and cleaning processes with minimal chemical use in the food, pharmaceutical, textile, and paint industries.
- Reducing scaling and corrosion and increasing the service life of equipment and machinery in industrial and service facilities.
- Saving 20–30% in water consumption in residential, administrative, and healthcare buildings by using nanobubbles in water supply and treatment systems.
- Creating a healthier environment and reducing building and equipment maintenance costs.

Swimming Pools and Water Sports

- Reducing chlorine consumption by 40–60%, improving water clarity and quality, and reducing algae growth and skin diseases.
- Reducing the frequency of swimming-pool water replacement and improving the user experience in water sports.
- Improving users' overall health and protecting the environment by reducing harmful chemicals and increasing cooling efficiency.

Environment, Surface Waters, and Lakes

- Effective control of harmful algae, improving water clarity and preserving ecosystems in natural water resources.
- Cleaning and treating contaminated water without using chemicals, helping reduce pollution and preserve biodiversity.

Military and Security Applications

- Treating and disinfecting water in critical situations and military areas, increasing water-supply security.
- Enhancing the food security of military personnel by improving the quality of water and food through the use of nanobubbles.

- Reducing biological risks and increasing safety in field and emergency conditions.

Oil, Gas, and Recovery Industries

- Increasing oil production and improving water-oil separation without the need for chemicals or hydraulic fracturing.
- Improving the efficiency of oil and gas recovery through the use of nanobubbles in extraction processes.
- Increasing the safety of transmission lines by preventing blockages, scaling, and microbial growth in pipes and tanks.

Specialized and Research Applications

Medicine and Medical Imaging: Use of nanobubbles as drug carriers, contrast agents for improving the accuracy and quality of ultrasound imaging, cancer treatment, and wound healing.

Advanced Industrial Treatment: Removal of the inhibitory effects of fats and substances in the food and beverage industries.

Power Plants, Industrial Cooling Towers, and Water Towers: Increasing efficiency and improving heat transfer, preventing pipe blockages, controlling and removing biofilm growth, and reducing operating costs by up to 30%.

Plating and Surface Treatment: Removing rust without chemicals and improving anti-corrosion effects through free radicals (ROS).

Automotive Applications, Fuel Savings, Water Cooling, and Cooling Systems

Improving Engine Cooling Efficiency: Using nanobubble water in vehicle cooling systems increases heat transfer, reduces engine temperature, and extends component life.

Fuel Savings: Optimizing engine operating temperature and reducing friction in the cooling system can reduce fuel consumption and increase vehicle efficiency.

Reducing Corrosion and Scaling in Water Circuits: Nanobubbles prevent rust and scale accumulation and extend the service life of cooling systems.

Applications in Heavy and Agricultural Machinery: Improving cooling efficiency under harsh environmental conditions, reducing wear, and saving energy.

HVAC Systems: Increasing the effectiveness of heat exchangers and reducing energy consumption.

Production, Transmission, and Improving the Efficiency of Various Gases

Fuel Gases (LPG, Natural Gas): By increasing the contact surface between liquids and gases, nanobubbles optimize gas separation and purification processes, increase production efficiency, and reduce waste.

Industrial Gases (Oxygen, Nitrogen, Hydrogen, etc.): Nanobubbles help improve the transfer and dissolution of these gases in liquids, which has extensive applications in industries including medicine, electronics, and chemicals.

Increasing Safety in Transmission Lines: Preventing microbial growth, reducing deposits and blockages in pipelines and tanks, and increasing the safety and efficiency of gas storage and transmission systems.

Applications in Catalytic and Chemical Processes: Nanobubbles improve the efficiency of catalytic reactions by providing suitable conditions for gas transfer.

Role in Safety and Immunity

Increasing Biosafety: Disinfecting water and work and living environments, reducing pathogens, and improving sanitary conditions.

Creating Biological Immunity in Agricultural and Livestock Products: Reducing the need for antibiotics and pesticides and increasing resistance to diseases.

Enhancing the Safety of Industrial and Urban Systems: Preventing blockages, corrosion, and microbial contamination in water and gas transmission lines.

Preventing Biological Hazards in Critical Conditions: Providing clean and safe water for military and emergency uses.

Export Potential and Foreign-Exchange Generation

With its nanobubble technology, Iran has the potential to export equipment, technical and engineering services, and implementation consulting to countries facing water crises, particularly in the Middle East, Central Asia, and North Africa.

Exporting this technology can both generate foreign exchange directly through the sale of technology and equipment and replace imports with domestic production and reverse engineering, ultimately contributing to the growth of the knowledge-based economy.

Knowledge-Based Companies and the Democratization of Technology

One of the key approaches to developing and commercializing nanobubble technology in the country is to expand and diversify knowledge-based and technology-oriented companies in this field. This path can be accelerated through government support and legal facilitation.

To achieve this goal, simple, implementable, and practical measures in Iran are essential, including:

- Development of laboratory infrastructure and specialized research centers.
- Establishment of a cooperation network among universities, industry, and government.
- Specialized training and empowerment of human resources.
- Implementation of pilot projects in agriculture, healthcare, pharmaceuticals, biotechnology, food, various industries, and environmental sectors.
- Granting facilitating licenses and supporting relevant startups and innovative companies.
- Public awareness-building and information dissemination about the benefits.
- Incorporating nanobubble technology into national development programs and policymaking.
- Tax exemptions for nanobubble companies.
- Including nanobubble technology in the official list of priority areas for knowledge-based financing facilities.
- Joint investment by the government, private sector, and Innovation Fund in major projects.
- Developing the domestic market through pilot projects in provinces facing water stress and along the routes of water consumption for drinking water, agriculture, and other industries.

Necessity of Facilitation and Issuance of Supportive Regulations

For the sustainable development of this technology, it is necessary for Parliament and the government to provide legal facilitation, including:

- Adoption of a law supporting new water-oriented technologies, with an emphasis on nanobubbles.
- Reforming and facilitating regulations governing the issuance of activity licenses for water technology companies.
- Requiring government organizations (municipalities, the Ministry of Energy, the Ministry of Agriculture, and the Ministry of Health) to utilize nanobubble technology and making it a condition for obtaining any permit and issuing completion certificates for new projects.
- Establishing export incentives for equipment and technical services in this field.
- Providing facilities and land for the establishment of accelerators specializing in nanowater technology.

- Making the transfer and issuance of deeds for agricultural land and various water-consuming facilities, as well as obtaining any permit, conditional on the inclusion of a mechanization plan aimed at saving water.

Diverse and Implementable Financing Solutions for the Development of Nanobubble Technology in Iran

Corporate Social Responsibility Budgets

Large industrial, petrochemical, oil, banking, and major industrial companies can allocate part of their social responsibility budgets to the development of new technologies such as nanobubbles. Due to its direct impact on health, water, the environment, and food security, this source should be given the highest investment priority.

Investment by Private and State-Owned Enterprises

Large enterprises active in the water, agriculture, pharmaceuticals, power, construction, and energy industries can invest directly or through their subsidiaries in projects with economic and biological returns. This participation accelerates the commercialization and expansion of the technology.

Green Securities and Bio-Based Technologies

Issuing green bonds and technology participation bonds, as instruments for attracting national and international capital, can be an important policy-level option for projects related to reducing water consumption, reducing pollutants, and biological security.

Venture Capital (VC) and Angel Investors

Startups in the nanobubble technology sector can use financing from venture capital investors and so-called angel investors. By accepting risk, these investors can support startups in exchange for an equity stake, from the prototyping stage through market entry.

Government and Research Budgets

The Ministries of Science, Agriculture, Energy, Industry, Health, and even Defense provide financial support for technological and academic projects through research and development (R&D) programs and technology-oriented projects. This support can lead to the advancement of technical knowledge and the localization of technology.

Innovation and Prosperity Fund

This fund is specifically intended for knowledge-based companies and provides facilities such as low-interest loans, equipment grants, bank guarantees, technology export insurance, and export facilities. The role of this fund in providing infrastructure support and promoting technological growth is vital.

Grace-Period Financing Facilities

Government and private banks can reduce the cost of implementing water-saving and nanobubble projects through employment-generation loans, green credit lines, and long-term financing facilities with grace periods.

People-Centered Economic Governance

Furthermore, by prioritizing economic groups (deciles), the use of people-centered economic models, including crowdfunding (collective micro-financing), local micro-funds, and public shareholding schemes, makes it possible to attract the direct participation of people in technology development. These approaches strengthen the sense of social belonging and the sustainability of investment.

Public-Private Partnerships (PPP)

By designing joint projects between the government, municipalities, and the private sector, project implementation can be accelerated. This model reduces risk and increases the effectiveness of investment in the fields of water, the environment, and healthcare.

Attracting Foreign Investment and International Cooperation

Signing memoranda of understanding with international companies experienced in nanobubble technology, attracting financial resources from development institutions, and implementing joint research projects are part of the path toward the rapid expansion of this technology within the country.

Sale of Carbon Credits and International Environmental Support

Through its role in reducing energy and water consumption and pollutants, nanobubble technology can qualify for carbon-credit sales and receive financial support from international environmental and sustainable-development institutions.

Support from Provincial and Regional Development Funds

Provinces, free-trade zones, and industrial parks can allocate development budgets to local technology companies, creating the conditions for the expansion of nanobubble projects at the local and provincial levels.

Other Diverse Methods

These include utilizing technological support from the Vice Presidency for Science, Technology and Knowledge-Based Economy, facilities from the Cooperative Development Bank, attracting international assistance, cooperation with universities, and making use of charitable resources in the fields of healthcare and the environment.

Conclusion

Nanobubble technology is a technological, indigenous, and multidimensional strategy for Iran today; from improving public health, reducing diseases, and preserving vital water resources, to addressing biological threats, increasing agricultural productivity, and developing technology-based exports.

The expansion of this technology through support for knowledge-based companies, formulation of development policies, targeted investment, and legal facilitation can become one of the country's most effective lines of defense against the water crisis, food crisis, and health crisis...