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# TOWARD THE 21$^{ST}$ CENTURY NUCLEAR-SCIENCE TECHNOLOGY

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## ABSTRACT

Energy security is vital for the steady growth of the world's welfare and economy and although many novel non-nuclear energy sources are being explored, much less attention is given to nuclear energy. In developing this source, safety, environment protection, and non-proliferation are essential considerations. I have proposed establishing deep underground nuclear parks where not only energy production, but also the processing and transportation of fuel can be carried out in a well protected small area; in the near future they might be operated under international supervision to ensure non-proliferation. The quantum physics on which modern technologies such as nanotechnology, and biotechnology are based, offer a sound foundation. The mathematical and physical technologies developed in the fields of nuclear engineering will provide the fundamental educational basis for such 21$^{st}$ century science and technology.



KEYWORDS

Deep underground nuclear park; Nanotechnology; Quantum physics; Weak interactions; Non-Proliferation

## 1. INTRODUCTION

To promote the use of nuclear energy for the 21st century we must overcome the many obstructions that were generated over the last decade. These are issues about the nonproliferation of nuclear material and the disposal or elimination of radioactive waste; they might be solved without large surgery of our nuclear energy system. To get public support for the development of nuclear energy, we should expand the uses of radioactive material, such as in medicine, and as tools for scientific research. So far our nuclear engineer mostly have concerned on the energy problem; we must pay more attention to the benefits of products created by weak interactions. A fission reactor can be operated safely in a critical condition by employing delayed neutrons; without these, the fission reactor can be operated in sub-critical condition by providing spallation neutrons created by injecting medium- energy protons into a heavy metal target, as I previously proposed. However, beta decay due to weak interactions creates long-lived radioactive materials that will be hazardous for human activity in future. Beta decay has been studied so far in the rather simple Fermi theory; a more fundamental physical theory has to be developed through high-energy physics and the astronomical physics of super nova and neutrino oscillation. Then, it might have be possible in future to deal with these weak interactions and utilize them in a more beneficial way for future generations. In this paper, reflecting my special work in the field of reactor physics, I would like to speculate on the future of nuclear energy and the associated science and technology in the 21 century, including quantum physics, quantum computation, and biology.

## 2. THE DEEP UNDERGROUND NUCLEAR PARK CONCEPT

Before discussing the science and technology in 21 century, I would like to discuss the concept of establishing deep underground nuclear parks, which is a more urgent and realistic problem facing us in the near future. To maintain our form of human civilization, the energy security is essential, and nuclear energy provides the most reliable present source, although many alternative sources have been proposed. However, many problems such as those involving radiation hazards and the proliferation of fissile materials have to be deal with it, and wisely resolved.

I proposed the concept of building deep underground nuclear parks (Takahashi, 2000a; Takahashi, 2004) an idea that has gained support over the last few years, although it is politically provocative. This has many advantages over the conventional nuclear reactor described in the reference paper. Here, I would further propose that such an international nuclear-fuel-processing and nuclear park can be operated under international supervision by, for example, the IAEA. Under international supervision, and collaboration, a steady supply of the nuclear fuel could reduce the risk of proliferation of fissile material. This is very naïve proposal presently, but we have now reached the proper time to discuss on this important political problem seriously. When I proposed the installation of an accelerator-driven reactor in the Northern Islands (whose ownership was disputed by Japan and Russia) at the Gudawri workshop for ADS workshop 15 years ago at Georgia in Caucasus to Prof. Chuviro from the Institute of Theoretical and Experimental Physics (ITEP) at Moscow, he rejected this idea. But seeing the present-day world, I believe that the proposal for an international nuclear park is worthwhile considering more seriously than ever before. Although placing a nuclear park deep underground in a volcanic island is questionable, the Rokkasho site that is now Japanese proposal site of fusion reactor might be reasonable.

In the past, building a reactor underground was considered, and studies carried out, in Sweden, and Russia. Also, the Kansai-electric power company (KEPCO) studied PWR construction underground, but abandoned the idea due to the high costs. The latter versions of the PWR, and the more or less present-day versions of PWR plants might be sited under the earth without any major change in their configurations, thereby incurring no further high investments in figuring out how to optimize their economy. My proposal of a deep underground reactor involves embedding the reactor and coolant ducts by incasing these components into smaller sized casings, and then embedding them deep into the earth. In so doing, the pressure vessel can be thin, and so able to be transported into a small place in underground without requiring a large transporter. By using an embedding material such as sand or salty material between the casing and the vessel or coolant ducts, the components can be accessed and repaired without high cost.

The idea has been criticized because of the high cost of constructing underground, but, if properly designed, the power plants' construction costs can be minimized. There are many facilities underground worldwide, such as the Large Hadron Collider (LHC) in Geneva, Switzerland, the Homestake Goldmine in the United States, and Tokyo Electric Power Company's (TEPCO's) Kanagawa hydraulic power plant. There are many underground railroad and traffic tunnels, and by modifying and detouring some of these, we might find many candidate sites for installing a nuclear park in many layers, similar to the Yuka mountain projects and the JNC study.