Nuclear Desalination: A Solution For Water Crises

Basavaraj.V.Meti

Lecturer in Physics, S A College & P G Centre Naregal, District: Gadag, State:Karnataka -582111
basavarajvmeti12@gmail.com

I. ABSTRACT

Water is a critical renewable resource that is not evenly distributed around the world, and over-exploitation has altered the water cycle, not allowing to be restored. Since several previous decades, the need for drinking water per year has been increased at a staggering rate. This need has been palliated through desalination processes to obtain potable water from seawater and brackish water, desalination has been based on thermal methods like MED and MSF and the use of membrane processes like the reverse osmosis. These methods require the use of energy that has been provided mostly by fossil plants. Unfortunately, the gases emitted freely to the atmosphere are favoring pollution all over the world, despite international agreements to avoid it. Nowadays, it is necessary to include clean technologies, like nuclear, gathering attractive characteristics as being: (a) base load, (b) competitive costs, (c) friendly with the environment, and (d) producing as much drinkable water as an integrated water desalination power plant (IWPP) may produce. It is necessary to understand the pros and cons of nuclear desalination as an alternative to be considered by a country where potable water and electricity are needed. The integrated process of desalination and electricity generation offers a better energy use and in this regard exergoeconomic analysis provides a multiobjective tool to improve energy efficiency keeping the integrated process being economical competitive. In particular, the coupling of nuclear and desalination plants are modeled and analyzed through this book along with their competitiveness, sustainability, and the description of the licensing process that must be fulfilled to be able to have a nuclear desalination plant in operation.

II. Water Availability For Human Beings

Access to freshwater is vital for human life; around 70% of the world is covered by water, but only 3% of this water is fresh; the other 97% is brackish and seawater. No more than 0.03% is accessible to human consumption, 2.07% is in glaciers, and 0.90% is underground. In addition, water is not distributed evenly over the earth's land; there are a lot of arid and semiarid regions. Freshwater is a renewable resource; the amount of water has been quantified to be around 93,100,000 million of m3 , it has remained constant through millions of years, and it has been recycling through water cycle or hydrologic cycle; however, population has growth increasing the demand and not allowing performing the natural cycle and in some cases polluting it. In November 2019, there are about 7.8 billion of people living that require water to cover their vital needs and also to develop living and industrial activities. Freshwater is not distributed evenly; there are regions plenty of freshwaters; meanwhile, others are suffering water stress or even scarcity due to natural factors as geography or climate or by political or social factors as engineering or regulation. According to the United Nations studies by 2025, people living in water-stressed regions will amount to 66% of the total population, and around 1.8 billion humans will be in water scarcity regions. As a result of human population growth there is an increase demand for freshwater, in addition the interruption of the natural freshwater cycle reduce the availability of this resource. Human beings, to cope with this problem, must use, manage, distribute, and recover the natural freshwater available efficiently and look for additional resources. Among the means to get additional resources is through seawater desalination, but it must be done sustainably to avoid unforeseeable damage to marine life and the environment. Water desalination is a mature technology that is developed through two main principles, thermal desalination and membrane desalination. Thermal desalination using multistage flash distillation and multiple- effect distillation started commercially in the 1930s; meanwhile, reverse osmosis (membrane process) started in the 1960s. Currently, there are 15,906 desalination plants worldwide with different capacities from tiny ones of less than a 100 m3 /d up to huge ones, being the largest with a 1,036,000 m3 /d capacity.

Currently the total installed desalination capacity is 95.37 million m3 /d that produces 34,810 million m3 annually. This amount is only 0.037% of the total available freshwater in the world; seawater desalination has a significant potential to make a difference in the access to potable water. However, one of the main barriers to exploit this technology entirely is the associated desalted water cost and several environmental concerns. In most of the desalination plants in operation, the energy source is fossil power plants. These plants are emitting greenhouse gases. For the desalination process the pollution currently amounts to around 76 million tons of CO2 per year, and that is increasing year after year with the incorporation of more desalination plants powered by fossil sources. The use of clean energy sources as nuclear power or renewable energy could additionally reduce the environmental impact because these sources are not emitting greenhouses gases. If only the electricity production process is considered, nuclear and renewable sources do not emit CO2; in comparison, CCGT plants emit around 0.422 ton/MWh and coal plants around 0.980 ton/MWh; thus a 1000-MWe installed capacity plant with an 80% capacity factor will produce 8,760,000 MWh/year, and if it is produced by using a CCGT, it will emit 3.696 million of ton of CO2 per year, but using a coal plant, it will emit 8.584 million of ton of CO2 per year. Nuclear desalination is an alternative that can meet the requirements to be considered sustainable at the difference with the IWPP using fossil power. However, in this effort, it is essential to point out that the current participation of nuclear power plants represents a negligible amount; only 15 out of 15,906 operational desalination plants are powered by nuclear energy, and renewable sources provide almost a negligible capacity; fossil fuels power the others. Since the 1960s nuclear desalination started; in most cases to provide makeup water for reactor uses, the type of coupling was mostly with thermal processes. The coupled desalination plants had a capacity below 3,000 m3 /d because the purpose and use of the desalted water. Coupling with membrane processes has also happened but at small-scale production. One exceptional case was the Kazakhstan BN-350 nuclear reactor coupled to MED and MSF processes with a 120,000 m3 /d total capacity, and it operated for more than 20 years. Nuclear desalination can be made with any size of the reactor. Large units compose the current generation of nuclear reactors with power outputs between 1100 and 1600 MWe; this type of project is capital intensive posing an economic and financial risk because of construction delays and unexpected regulatory challenges. To overcome this financial risk, a new reactor design in a smaller size, less than 300 MWe, has been launched. By the size of these reactors, they can be allocated in remote regions of large cities, in isolated places, and in the rural sector. This type of reactor can be suitable candidates for the coupling of desalination plants, and it can be affordable by developing countries.

Designers of tomorrow39;s nuclear power plants are more closely eyeing the developing world, by crafting reactors that can serve a dual purpose – to produce electricity and economically turn seawater into fresh drinking water. The twin production system is known as quot;nuclear desalinationquot;.

Economics holds the key to the future of nuclear desalination, experts say, with advanced reactor designs now promising reduced costs in turning seawater into freshwater. For developing countries facing water crises, it is a major drawing card.

At an international conference on nuclear desalination, held in Morocco, 16-18 October 2002, specialists from more than 35 countries assessed global developments, including the prospects for nuclear plants. Participants heard that

advanced High-Temperature Gas-Cooled Reactor designs were a competitive, safe and cleaner alternative to conventional fossil-fueled plants. As well as generating electricity, when coupled with a desalination facility the reactors could produce freshwater for about a dollar for two cubic meters. The IAEA39;s Mr. Mabrouk Methnani, a technical officer in the IAEA Section on Nuclear Power Technology Development, said in the past, designers of nuclear reactors did not account for the developing world. quot;No emphasis was made to coupling a desalination unit with the reactor. The picture is changing, with small and medium reactors being developed for this purpose,quot; he said. India aims to have its demonstration desalination plant being built at Kalpakkam in the southeast of the country, operating by March 2003. The jury is still out on its cost effectiveness, as it uses an older model heavy water reactor. It will, however, provide training and research in finding solutions to the freshwater shortages facing the people of southern India.

III. Nuclear Desalination in India

As a part of our national programme to improve the quality of life of our large population by systematic induction of nuclear energy, Bhabha Atomic Research Centre (BARC) has been engaged in research and development activities on desalination since 1970s. The desalination activities were part of a programme of setting up a number of demonstration plants for the energy intensive processes such as desalination of seawater, electrolytic production of hydrogen and electrothermal production of phosphorus. These activities are presently termed by IAEA as 'Non-electrical Application of Nuclear Energy'. The development work done at BARC has generated capability to design, fabricate, commission and operate large and small size desalination plants indigenously for large scale deployment and providing opportunities for the socio-economic development of water scarcity areas and large coastal arid zones in the country.

IV. Nuclear Desalination Demonstration Project (NDDP)

Based on decades of operational experience of MSF(multi-stage flash) and RO(reverse osmosis) plants at Trombay, BARC has undertaken setting up of the Nuclear Desalination Demonstration Project (NDDP) at Kalpakkam. NDDP consists of a hybrid MSF-RO desalination plant of 6.3 million litres per day (MLD) capacity (4.5 MLD MSF and 1.8 MLD RO) coupled to 2 x 170 MWe Madras Atomic Power Station (MAPS), Kalpakkam. The requirements of seawater, steam and electrical power for the desalination plants are met from MAPS I II. The hybrid plant has provision for redundancy, utilization of streams from one to another and production of two qualities of products for their best utilization. The RO plant may use the cooling sea water of the MSF plant as feed which is about 8C higher than the ambient temperature. The higher temperature operation of RO gives high throughput. It is also possible to use reject sea water from RO plant as feed for MSF plant. It saves the chemical pretreatment for the MSF feed. The SWRO plant which is already commissioned in 2002, draws sea water from the outfall of Madras Atomic Power Station, whose temperature is about 2-3 deg.C higher than that of the normal sea water, which is an added advantage for the RO plant. The plant incorporates necessary pretreatment and an energy recovery system and produces potable water of about 500 ppm total dissolved solids (TDS) resulting in lower water cost. The plant operates at relatively lower pressure to save energy, employs lesser pre-treatment chemicals (because of relatively clean feed water from MAPS outflow) and aims for longer membrane life. It is expected that these membranes will last for five years. The potable water produced is supplied to nearby areas. The MSF plant which is in advanced stage of construction is designed for higher top brine temperature with Gain to Output Ratio (GOR) of 9:1 and utilizes less pumping power (being long tube design). The desalination plant can meet the fresh water needs of around 45,000 persons @ 140 lpcd. There is a provision for augmentation of product water capacity by blending the low TDS product water of MSF plant with brackish ground water/ moderate salinity permeate from SWRO plant. This will then serve the need of larger population. The scheme has been appreciated by International Atomic Energy Agency (IAEA). BARC (India) is a front runner in nuclear desalination as per IAEA. A part of high purity desalted water produced from MSF plant will be used as the make up demineralised (DM) water after necessary polishing for the power station. Blending of the product water from RO and MSF plants would provide high quality drinking water (about 200 ppm TDS). The RO plant operation can continue to provide water for drinking purposes even during the shut down of the power station. "The Nuclear Desalination Demonstration Plant (NDDP) located at Kalpakkam [off Chennai], Tamil Nadu, is the world's largest hybrid seawater desalination plant coupled to an existing nuclear power plant," says Dr. P.K Tewari, Head, Desalination Division, BARC, Mumbai. This desalination facility is coupled to the Madras Atomic Power Station (MAPS), and deploys both multi-stage flash (MSF) evaporation and reverse osmosis (RO) membrane separation technologies. The total capacity of NDDP is 6.3 million litres per day (MLD). Multi-Stage Flash (MSF) evaporation plant produces 4.5 million litres per day of distilled quality water and Reverse Osmosis (RO) plant produces 1.8 million litres per day of potable-quality water. The desalination plant meets the entire pure water requirement of Madras Atomic Power Station (MAPS). "The multi-stage flash technology works on the principle of flash evaporation wherein the temperature of water is increased under pressure and then flash evaporated by reducing the pressure gradually in multiple stages," said Shri. M.M. Rajput, Plant Superintendent, NDDP, BARC Facilities, Kalpakkam.

V. REFERENCES

1. Sciencedirect: https://www.sciencedirect.com/science/article/pii/B9780128200216000016

2. IAEA prospectus: https://www.iaea.org/newscenter/news/prospects-nuclear-desalination

3. The Hindu December 06/2012 :https://www.thehindu.com/sci-tech/science/Hybrid-desalination-plant-at-Kalpakkam/article15617418.ece

4. A report of "Advances in Nuclear Desalination in BARC (India)" by D.S. Shukla and P.K. Chemical Engineering Technology Group Bhabha Atomic Research Centre Trombay, Mumbai