Comparison between LTTD and RO process of sea-water desalination: an integrated economic, environmental and ecological framework

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Sea-water desalination has emerged as the key alternative to overcome demand–supply gap of potable water, worldwide. This paper aims to carry out a technology review of sea-water desalination, technologies in an integrated framework of economic, environmental and ecological analyses. The economic analysis here refers to a project/technology development effort analysis in the context of national economy. The cost per unit output from this perspective is the economic cost. In an environmental analysis, the higher specific energy consumption in a process vis-à-vis the best technology option in the project area is measured in terms of certified emission reduction. In ecosystem analysis, the accent is to find out whether the technology disrupts the existing eco-system. Such a disturbance entails a huge ecological cost. The cost quantified per unit output is arrived at as the reduction in GDP in the project affected area due to the direct and indirect effects of adverse ecological effects; these effects are deduced using specifically developed *I–O* tables 'with and without' technology options, for the project area. The choice of technology is the one with the minimum composite cost per unit output. The composite cost in the context is the sum of economic cost, the environmental cost and the ecological cost per unit output. The framework is applied in the technology review of low-temperature thermal desalination process and its impact on project areas of Lakshadweep islands and Thoothukodi district vis-à-vis the alternative RO process of sea-water desalination technology.

Keywords: Economic, environmental and ecological factors, reverse osmosis, sea water, thermal desalination.

FRESHWATER consumption increased by six times between 1900 and 1995, more than double the population growth rate[1]. Nowadays the availability of potable water is a worldwide problem due to the steep increase in demand for water not matched by recharge. Roughly one-third of worldwide population of 6.8 billion lives in water-scarce areas. Analysts estimate that by 2025 two-thirds will be living in water-scarce areas, making this a critical problem equivalent to climate change. Under this global situation, solutions such as water transfer or dam construction are not sufficient; sea-water desalination with an installed capacity of 63 million cubic metre per day has emerged as the key alternative. The major questions being posed with regard to desalination are high environmental cost due to high energy consumption and the environmental impact of large plants dumping their concentrate waste stream into the oceans (ecological cost). This article aims to carry out a technology review of the low-temperature thermal desalination (LTTD) process developed by the National Institute of Ocean Technology (NIOT), Chennai which has a mandate to develop technologies to harness the vast potential of the sea. The review would use an integrated economic (price per litre of desalinated water to yield an internal rate of return (IRR) equivalent to the social discount rate), environmental (specific energy consumption per litre of desalinated water vis-à-vis the best technology option) and ecological (cost due to the disturbance in the ecosystem measured as the change in GDP in the project catchment area per litre of desalinated water due to the introduction of a particular technology) analysis of setting up LTTD plants for sea-water desalination.

The unit of analysis is not technology, but the 'project area'. This implies that we will not evaluate technologies to rank them universally, but evaluate all technology options for each project area in terms of composite cost of economic, environmental and ecological components. The analysis would be carried out here for two domestic locations to illustrate the methodology. To bring out implications, the LTTD composite cost (economic and ecological cost) would be compared with the results for the next best technology option.

Comparison of desalination technologies

The principal desalination technologies can be classified by the separation mechanism into thermal and membrane desalination technologies. Thermal desalination separates salt from water by evaporation and condensation, whereas membrane processes use semi-permeable membranes and driving forces like pressure to separate salt

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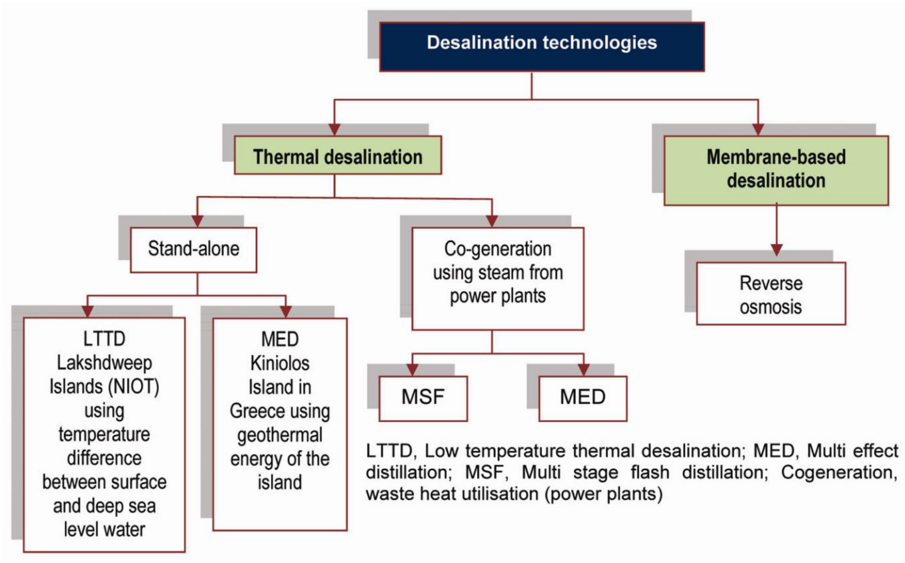

Figure 1. Desalination technologies. Source: Ref. 10.

from water. An overview of the currently available and applied commercial desalination techniques is shown in Figure 1.

Understanding desalination technologies

A comparison of the LTTD process with reverse osmosis (RO) process, multi-stage flash distillation (MSF) and multi effect distillation (MED) in terms of principle of operation, and environmental and ecological effects can help us in understanding the implications of technology choice.

Principles of operation

RO is a membrane process, where water at high pressure is made to pass through a porous membrane having pores of 0.5–1.5 nm size. The dissolved solids are left behind. This is carried out in stages as described below:

Stage 1: First, sea water is pre-treated in order to make it suitable for RO application.

Stage 2: Subsequently, the pre-treated feed water has to be pressurized before entering the polymeric RO thin-film composite membranes.

Stage 3: In the RO membrane unit, salt is separated from water with a rejection of 98–99.5% depending on the membrane in use.

Stage 4: Due to the fact that RO permeate has extremely low levels of dissolved salts, limestone ($CaCO_3$) bed, lime ($Ca(OH)_2$) or caustic soda (NaOH) may be added to increase hardness, alkalinity, pH and to cause the formation of calcium bicarbonate. This reduces corrosion problems in the water distribution system. Moreover, RO permeate contains dissolved carbon dioxide which needs to be removed because it may be transformed in carbonic acid, making water corrosive.

Stage 5: Finally, RO retentate has to be disposed. Several disposal options are available, and the most frequently employed option is discharging into the sea. The discharged brine may damage the existing ecosystem.

LTTD works on the principle of utilizing temperature gradient between two water bodies to evaporate the warmer water at low pressure and condense the resultant vapour with the colder water to obtain freshwater.

MED was the first process used for sea-water desalination. It is based on heat transport from condensing steam to sea water or brine in a series of stages or effects. It is a distillation process where the evaporation of sea water is obtained by the application of heat delivered by compressed vapour inside horizontal tubes.

MSF is an important thermal desalination process. The principle of operation in MSF is based upon a series of flash chambers where stream is generated from sea water at a progressively reduced pressure. In MSF, heated water flashes inside a low-pressure chamber and the steam generated is condensed in a sequence of stages.

A detailed review on the technologies is available in the literature[1–3]. However, the scope of the present article is restricted to a comparison of LTTD technology with the RO process-based desalination.

NIOT developed and installed a commercial LTTD plant at Kavaratti islands, Lakshadweep, in response to the ‘dire need’ expressed by the residents. They wanted good quality of drinking water and appropriate quality of soft water for other purposes such as cattle rearing, bathing, etc. The households in the islands were not able to use the contaminated groundwater for these purposes. The islanders were particular that if a desalination process is to be adopted to source good quality water, it should not disturb the fragile marine ecosystem of coral islands. The technology so developed had to be maintenance-free or one that could be easily maintained by the unskilled labour skill set available within the islands. Earlier attempts to develop commercially viable RO-based systems had completely failed to operate under the trying conditions and for want of skilled labour in the islands. Besides, the RO-based technology was perceived by the islanders as one that could disturb the marine ecosystem in Lakshadweep. NIOT responded to the aspirations of the islanders and developed the LTTD technology and installed a lakh litre per day desalination plant in the year 2005.

In 2012, the National Council of Applied Economic Research (NCAER) was to elicit the perceptions of the islanders on the utility of such a plant in their day-to-day life. The research institution was also asked to review the technology in terms of economic cost per unit output vis-à-vis other commercially available and competing technologies and to briefly comment on how alternative technologies, including LTTD could affect the marine ecosystem and review whether this parameter is given adequate importance. This article is based on such a review of the LTTD plant at Lakshadweep. It also carries out an analysis for NIOT's proposed LTTD plant for Thoothukodi Thermal Power Station in Tamil Nadu utilizing waste heat recovered from condenser discharge.

Environmental and ecological factors to be considered in shaping technology policy

Adoption of technologies for desalination can have adverse environmental and ecological effects. For instance, adoption of certain technologies can cause considerable damage to ecology and environment in a number of ways including (i) Uncontrolled discharge of concentrated brine that can contaminate water aquifers and damage aquatic ecosystems[4]. The brine discharge may also contain pre-treatment chemicals, corrosion materials, nuclear contaminants (if attached to nuclear power plants), etc. (ii) Desalination plants use the thermal energy from an attached power plant from the waste water discharge of the condenser unit. The electrical energy used in the process of desalination emits carbon dioxide, which results in environmental pollution. Generally, the lesser the energy requirement by desalination technology, the lesser this indirect environmental impact is going to be. (iii) Desalination plants may cause noise pollution, gaseous emissions and chemical spills. In the case of discharged concentrate, total dissolved salts (TDS), temperature and specific weight (density) of the discharge are of critical importance as they result in damage to the aquatic environment. TDS discharge is directly proportional to the recovery ratio of the plant. The increased temperature can also harm the aquatic life. The increased density results in the sinking of the discharge, termed as desertification of seas, causing harm to certain parts of the ecosystem.

Ecological effects and technology options

The most important ecological impact associated with the desalination process arises due to brine discharge into the sea, which causes 'sea desertification' and 'imbalance to the marine eco-system'[5]. Brine discharge may also contain pre-treatment chemicals, corrosion materials, etc. In the case of LTTD, sea desertification is negligible, while the same from an RO plant is very high. RO has very high chemical discharge and causes eco-system disturbance, while the same is negligible in the case of LTTD, MSF and MED. As a result, the adverse impact on fishermen involved in activities such as ornamental fishing is minimal from the LTTD, MSF or MED plant vis-à-vis the RO alternative.

Technology choice – methodology outline

The choice of technology was reviewed on the basis of the composite cost of providing 1 litre of desalinated water. The composite cost was arrived at as the cumulative cost of the following:

(i) Price per litre of desalinated water that would yield a 12% IRR on investments in the desalination plant, assumed as the base cost. The test discount rate of 12% used is the social discount rate (SDR). SDR is often set as the real rate of return in economic prices on the marginal unit of (public sector) investment in its best alternative use[6]. This is the logic in assuming a SDR of 12%. A lower SDR would result in sub-optimal projects being undertaken initially, while the deserving ones are starved for funds which arrive for approval later. While a very high SDR would result in non-utilization of surplus funds.

(ii) Environmental cost per litre of desalinated water is arrived at on the basis of additional energy consumption per litre of desalinated water over the technology option with the least specific energy consumption. In the Indian context, one megawatt hour (MWh) energy consumption is assumed to imply a tonne of carbon dioxide emission. If a process involves reduction of specific energy consumption by one MWh, it is assumed to have earned one certified emission reduction (CER). For further details on this, readers can refer to the Central Electricity Authority, Website, Homepage[7].

(iii) Ecological cost per litre of desalinated water is arrived at as the change in GDP per litre of desalinated water in the 'project catchment area' due to the introduction of a particular technology. The reduction/increase in final output is arrived at by evolving an input–output table for the project catchment area along with both direct and indirect effects of the introduction of technology from the Leontief inverse table.

The composite cost was arrived as the sum of base cost, environmental cost and ecological cost per unit output of desalinated water. Economic interpretation of Leontief inverse table is briefly explained below as an understanding is crucial to estimate the ecological cost per litre of desalinated water. In a simple and refined form an input–output coefficient table, originally designed by Leontief, represents in each of its columns a technique of production.

$$AX + Y = X, \tag{1}$$

Equation (1) is the basic input–output system of equations. Matrix A is called the input–output coefficient matrix, vector X is the vector of output and vector Y is the vector of net final demand.

Mathematically, the vector of output X in the system of eq. (1) can be solved as follows:

$$X - AX = Y, \quad (I - A)X = Y, \quad X = (I - A)^{-1}Y, \tag{2}$$

where I stands for the identity matrix, which is a square matrix where all the diagonal elements are equal to one and all the other elements are equal to zero. $(I - A)^{-1}$ is the Leontief inverse which can be calculated.

The input structures represented by the A-matrix show the type and amount of various inputs each industry requires in order to produce one unit of its output, but tell nothing about indirect effects. For example, the effect of the production of a motor vehicle does not end with the steel, tyres and other components required. It generates a long chain of interactions in the production process since each of the product used as input needs to be produced and will, in turn, require various other inputs. The production of tyres, for instance, requires rubber, steel and cloth, etc. which, in turn, require various products as inputs, including the transport service provided by motor vehicles that necessitates the production of motor vehicles in the first place. One cycle of input requirement requires another cycle of inputs which, in turn, requires another cycle. This chain of interaction goes to infinity. However, the sum of all these chained reactions is determined from the value of the Leontief inverse[8].

Categories of LTTD plants developed by NIOT

NIOT has been working extensively in the field of LTTD and has established plants of various capacities. NIOT started working with LTTD applications in 2004 and established various plants. Some of successful demonstrations of LTTD technology are mentioned below.

(i) Land-based plant in Kavaratti Island, Lakshadweep, with capacity of 100 m^3/day (2005). (ii) Power plant condenser reject water-based LTTD cogeneration plant at NCTPS, Chennai with capacity of 150 m^3/day (2009), and Thoothukodi (proposed). (iii) Barge-mounted experimental plant off Chennai coast, with capacity of 1000 m^3/day (2007; currently dismantled after successful demonstration).

Scope of the present review

Here, we analyse stand-alone Kavaratti Island LTTD plant as well as the proposed Thoothukodi co-generation LTTD plant in terms of the composite cost of base cost of the process of desalination, and environmental as well as ecological cost per unit output of desalination. We also discuss the perceptions of the islanders on the impact of clean water supply to Kavaratti in the last five to six years.

LTTD process – stand-alone and co-generation units

While the ocean with its temperature variation across depth presents a scenario of two water bodies for an island-based stand-alone LTTD plant, a coast-based thermal power plant discharging huge amounts of condenser reject water into the nearby ocean represents an alternative co-generation application of LTTD process. In the technology review the former case of LTTD application, viz. a stand-alone desalination plant in Kavaratti islands was studied (Lakshadweep case study). For the latter, LTTD co-generation thermal desalination unit case study at the proposed Thoothukodi district was studied (Figures 2 and 3). The main components of the LTTD plant are the evaporation chamber, condenser, pumps and pipelines to draw warm and cold water, and a vacuum pump to maintain the plant at sub-atmospheric pressures.

Composite cost of desalinated water

(i) Price per litre of LTTD water that would yield a 12% IRR on investments: The capital cost, excluding interest

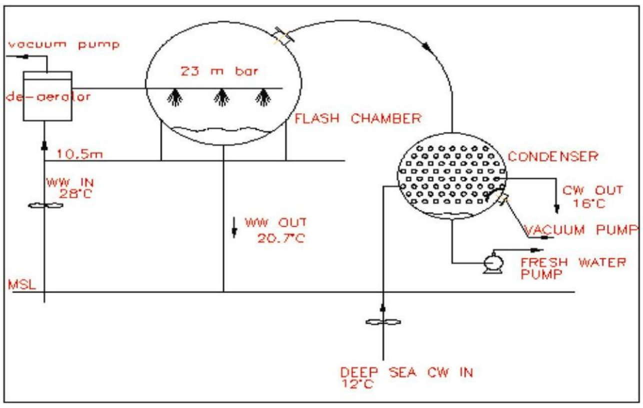

Figure 2. Schematic of LTTD process for Karavatti. WW, Warm water; CW, Cold water. Source: NIOT, Chennai.

Table 1. Price per litre of LTTD water that would yield 12% economic IRR (stand-alone case study)

Particulars	Amount (Rs)
Price per litre of LTTD water that would yield 12% economic IRR	0.75
Impact on ecology	Negligible, hence the interests of fishermen – major stakeholders in the coral islands – are protected.
Environmental impact	Higher energy requirement for operation of the plants means there is an environmental impact. This works out to 0.23 paise per litre

Source: Ref. 10.

Source: NIOT

Figure 3. A view of the installed Kavaratti desalination plant.

during construction incurred in setting up the plant was Rs 1752 lakhs, the annual operating cost, including wages, salaries, electrical energy consumption and repair and maintenance incurred is around Rs 46.83 lakhs[9]. The price per litre of LTTD water that would yield 12% economic IRR on capital investments works out to Rs 0.75 per litre (Table 1).

(ii) Environmental cost per litre of LTTD water over the best technology choice: In terms of incurring the least environmental cost per litre, the RO process stands out as a better option than the LTTD process. In terms of specific energy consumption, the LTTD plant consumes around 10 kWh of electrical energy per cubic metre (1000 l) vis-à-vis is the RO process which claims to consume only around 4.5 kWh per cubic metre. Since a reduction of 1 MWh specific energy consumption per unit output is valued at 1 CER, and as 1 CER is traded at six Euros, we can value the additional environmental cost per litre assuming that the exchange value of unit Euro at around Rs 70. The additional environmental cost works out to a negligible 0.23 paise per litre.

(iii) Ecological cost pet litre of desalinated water: Ecological cost per litre of LTTD desalinated water is negligible as it does not disturb the marine ecosystem. The RO system-based desalination could entail a huge ecological cost, even if it operates successfully as the ornamental fishing activity in coral islands would not have taken off.

Perceptions of islanders

Based on interviews with experts and field visits to desalination plants as part of the study, it was observed that LTTD was perceived as the best technology by residents of Kavaratti islands because of many interconnected factors. RO which was tried earlier was not suitable because of various reasons, such as high brine discharge and the consequent disturbance in the ecosystem affecting the livelihood of fishing households in the islands, corrosion of mechanical parts and requirement of skilled labour. The reasons behind the preference of LTTD can be summarized as follows:

- An LTTD plant uses higher energy for its operation compared to the membrane-based RO technology. In spite of this, LTTD is the preferred technology for coral islands since it is eco-friendly. This is because it does not disturb the marine ecosystem as there is no discharge of brine solution into the sea.
- LTTD does not necessitate storage of chemicals in the islands unlike RO.
- LTTD process does not require skilled labour for its operation.
- LTTD is a stand-alone technology.

Socio-economic impact of using LTTD technology

The study attempted to understand the perception of the people in the island on changes in their lives since the introduction of LTTD process. Most of the study population (93%) confirmed that there has been some change in their day-to-day lives because of using LTTD technology for desalination. The kind of changes reported by the study population range from regular access to good quality water, reduction in the prevalence of low blood pressure, better health conditions, reduction in water-borne diseases such as jaundice and diarrhoea, and reduction in hardness of water.

Standard of living

The study enquired of the people whether introduction of LTTD technology has made a change in their standard of living. More than 60% of the surveyed population also ‘strongly agreed’ that their standard of living has changed for the better after introduction of LTTD technology. Figure 4 presents the survey findings.

Water-borne diseases

We also attempted to understand if there was prevalence of water-borne diseases in the area before the introduction of the LTTD process. While more than half (53%) of the study population replied in the affirmative, the remaining 47% responded negatively. Dysentery (88%), typhoid (13%), amoebiasis (6%) and cholera (6%) are the common water-borne diseases reported in the survey area before the introduction of LTTD. In contrast, almost a negligible (2%) share of the study population reported that water-borne diseases are prevalent in their area even after the introduction of LTTD. Thus it can be concluded that the LTTD process for desalination has impacted the people living in the surrounding areas of the desalination plant in a positive way by reducing water-borne diseases.

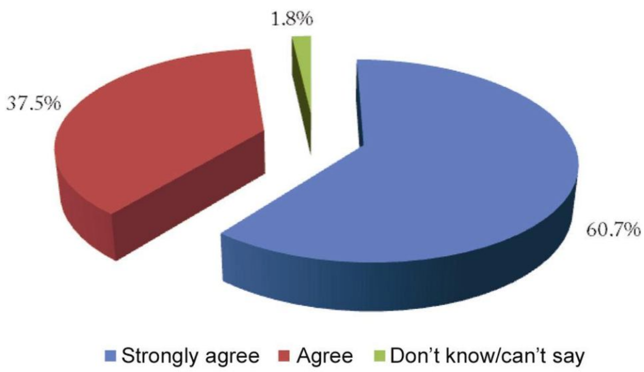

Figure 4. Perception of study population regarding changes in standard of living since introduction of LTTD in Kavaratti Island, Lakshadweep. Source: Primary Field Survey, NCAER, April 2012.

Figure 5. Thoothukodi Thermal Power Station. Source: NIOT.

Healthcare treatment

As part of the survey, an effort was made to look at the availability of options for healthcare and treatment of water-borne diseases in the area before the introduction of LTTD. Most of the study population (98%) reported that the existing number of government healthcare staff was sufficient. They also reported that doctors are generally available at the government healthcare facilities.

NIOT’s LTTD unit as a co-generation plant in power plants

North Chennai Thermal Power Station (NCTPS)

It can be seen from LTTD plants that a temperature difference and adequate vacuum levels should be sufficient for generation of freshwater. One aspect of LTTD is that it transfers the available heat from warmer water to colder water while generating freshwater from the warm water. This aspect could, therefore, be aptly used in thermal power plants resulting in the double benefits of cooling the reject water from the condenser and generating freshwater. A small temperature gradient of about 8–10°C, as is the case with most power plants, would be sufficient to utilize the concept. With the idea of demonstrating application of an LTTD plant in a coast-based thermal power plant, with the co-existence of warm power plant condenser rejected water and the nearby surface sea water with a gradient of about 8–10°C, NIOT set up the LTTD plant NCTPS and is in the process of setting up an LTTD co-generation unit in Thoothukodi.

Thoothukodi Thermal Power Station (TTPS)

It is situated near the new port of Thoothukodi on the sea shore of the Bay of Bengal, Tamil Nadu (Figure 5) and spread over an area of 160 ha. The units are all coal-based. Coal is transported by sea through ships from Haldia, Paradeep and Vizag ports to TTPS. Generation and plant load factor (PLF) for the year 2010–11 was 7113.696 MU and 77.33% respectively. TTPS has a total installed capacity of 1050 MW, comprising five units of 210 MW each.

Thoothukodi city is in a water-shadow area and facing severe water shortages, and the water demand is heavily increasing. The plant requires about 1.5 MLD (million litres per day) DM water with quality less than 1 ppm and 4 MLD of 100–200 ppm, in addition to domestic water for the township and plant. The water requirement for the plant is currently met from river sources, which is scarce

Table 2. Base cost of a two MLD plants in Thoothukodi (Rs in lakhs) in constant prices

Year	Capital cost excluding IDC (interest during construction)	Operating cost salaries and wages	Operating cost electricity	Repair and maintenance cost	Travel, insurance and rent	Water output in lakh litres
1	2541.6					
2	635.4	46	241	27	34	3650
Years 3 through 26		46	241	27	34	7300
Present value (Rs)	2,775.82	360.78	1,890.20	211.76	266.67	53,995.99
Price per litre (Rs) to yield 12% IRR	0.051	0.007	0.035	0.004	0.005	0.102

Price to be recovered per litre to yield 12% IRR = 10 paise. Source: Ref. 10.

in summer. Also, other potential power stations are explored for implementation of future plants. The second unit of TTPS and a few private power plants are also getting commissioned. In order to meet the demand for clear desalinated water, NIOT has proposed a desalination plant in TTPS. LTTD has proposed considering the possibility of producing high-quality water utilizing the condenser discharge.

Application of LTTD in mainland (power plant): Cost based on LTTD project in Thoothukodi

Based on the project cost and operating and financial expenses, the estimated price of desalinated water per litre from the project in Thoothukodi to yield 12% IRR is given in Table 2.

In the discounted cash flow (DCF) analyses, inflation is not factored in and the analysis is carried out on base-year prices. The analysis period is restricted to 26 years (including the gestation period) as it represents the useful life of the LTTD plant.

Ecological cost of adopting RO technology in Thoothukodi

The possible impact of the choice of RO technology for desalination on the economy of Thoothukodi district, as a whole has been analysed.

Gross district domestic product

The gross district domestic product (GDDP) for Thoothukodi district has been estimated for the year 2009–10, using the available official data on GDDP for the year 2008–09 and the gross state domestic product (GSDP) of Tamil Nadu for the years 2008–09 and 2009–10, as available from the Directorate of Economics and Statistics, Tamil Nadu.

Input–output tables

In order to assess the linkages between industries and to facilitate impact analysis of induced final demand, input–output (*I–O*) table for 2009–10 has been constructed for Thoothukodi district, based on the above GDDP estimates and the *I–O* coefficients available from the all-India *I–O* transaction tables compiled by CSO. Compilation of *I–O* table requires preparation of supply and use tables of domestic output of Thoothukodi district. Impact analysis has been carried out for the following activities.

Fishing

The total value of output of fishing activity in Thoothukodi district for the year 2009–10 at factor cost has been estimated at Rs 473.67 crores. However, at market prices, the value of output of fishing is Rs 832.24 crores. The difference between the market prices and factor cost of fish output is accounted by trade and transport (Rs 365.90 crores) and net indirect taxes (Rs 7.34 crores).

According to the information provided, if RO technology, which includes the consequent discharge of brine, is used, the fish catch would decrease by about 30% (based on telephonic interviews with experts). This implies that there would be loss of Rs 142.10 crores (30% of Rs 473.67 crores) in fish output at factor cost. Consequently, at market prices, the loss would be Rs 109.77 crores in trade and transport services (30% of Rs 365.90 crores, Rs 58.50 crores in trade activity and Rs 51.28 crores in transport activity). It is assessed that these losses will be in the final consumption of households and exports; thus the entire loss will be in final demand.

Impact on the Thoothukodi district economy if RO technology is adopted

The loss on account of adopting RO technology in Thoothukodi has been assessed at Rs 142.10 crores in fish output, Rs 58.50 crores in trade activity and Rs 51.28 crores in transport activity. This is the direct impact on the economy of Thoothukodi district and is purely on account of brine discharge following the adoption of RO technology. However, decrease in output of the district in fishing, trade and transportation will also indirectly affect

Table 3. Estimates of fall in output in Thoothukodi district due to adoption of RO technology (Rs in lakhs)

Sectors	Present estimates: Final demand	Present estimates: Gross output	Loss in output: Final demand	Loss in output: Gross output	Per cent decrease: Direct effect	Per cent decrease: Direct and indirect effects
Agriculture, livestock and forestry	59,111	231,680	0	–1,253	0.0	–0.5
Fishing	46,039	47,367	–14,210	–14,464	–30.0	–30.5
Mining, manufacturing, electricity, construction	539,796	1,413,453	0	–5,833	0.0	–0.4
Trade, hotels and restaurants	146,571	410,845	–5,850	–7,856	–1.4	–1.9
All other services	709,049	1,059,754	–5,128	–7,831	–0.5	–0.7
Total at factor cost	1,500,565	3,163,099	–25,187	–37,237	–0.8	–1.2

Source: Ref. 10.

Table 4. Cost of LTTD versus RO plant in Thoothukodi

Particulars	Amount (paise per litre) for LTTD	Amount (paise per litre) for RO process
Price per litre to yield 12% IRR on Thoothukodi LTTD plant investments	10	Not available
Environmental cost	0.05	0
Ecological cost	0	43 paise, if 30% catch is affected; 14 paise, if 10% catch is affected

Source: Ref. 10.

other industries due to the inter-industry linkages in the economy.

For estimating the indirect impact, the static Leontief model (based on Leontief inverse) is used. The estimated direct and indirect impacts on account of RO technology in Thoothukodi are shown in Table 3.

For Thoothukodi district as a whole, the fall in output will be 1.2% if direct and indirect effects are taken into account as a result of brine discharge if RO technology is introduced in the district. In absolute terms, the direct loss will be Rs 251.87 crore and indirect loss will be another Rs 120.50 crores, bringing the total loss to Rs 372.37 crores.

The total loss in output in Thoothukodi would be Rs 372 crores, if the traditional crafts' catch are affected due to the desertification of sea. Since traditional crafts contribute to 30% of overall catch, a reduction of catch by 30% maximum entails a staggering ecological cost, if the existing ecosystem is disturbed due to adoption of RO in Thoothukodi power plants; even a 10% reduction in traditional crafts' catch can entail a staggering ecological cost per litre as shown below.

The loss in output translates to GDDP loss of Rs 316 crore. If the district power plants set up around 20 million lpd plants to cater to power plants as well as to meet the drinking water requirements for the townships, the ecological cost per litre works out to 43 paise per litre.

The ecological cost of 14 paise per litre is enormous even if the catch is affected by a very marginal 10 per cent. The 2 million lpd LTTD plant in Thoothukodi is expected to consume around 6 kWh per cubic metre power vis-à-vis the specific consumption rate of 4.5 kWh/cubic metre of RO. This would translate into a very negligible environmental cost of around 0.05–0.06 paise per litre. Details are presented in Table 4.

In the case of Thoothukodi power projects, adoption of RO process for desalination would entail a huge ecological cost (ranging from 140% to 430% of basic processing cost), affecting the livelihood of traditional fishermen. It could range from 14 to 43 paise per litre. Thus LTTD emerges as the best alternative due to the eco-friendly nature of the technology.

Concluding remarks

Water is a unique natural resource as it is life-sustaining. The projected water requirement in India by 2025 is 973–1180 BCM, which exceeds the projected supply. Therefore, desalination of sea water for household consumption and industrial use is gaining importance as a measure to augment India's water resources. In this context, the policy for choice of desalination technology becomes quite relevant. This choice must include considerations of cost, efficiency, as well as environmental and ecological side effects of the technology.

There are two main variants of desalination technology – thermal technology (encompassing LTTD, MED and MSF) and membrane-based RO technology. The analysis reveals that LTTD technology is the way forward in coral islands, in spite of higher energy consumption vis-à-vis RO. Thermal desalination should also be the preferred technology for the coast-based power plants, iron and steel plants, and paper and pulp industry.

In the medium and small-scale category industries, including dyes and chemicals and the leather industry would call for the use of thermal desalinated water in the coastal areas and RO-based desalinated water in the interiors.

Introduction of LTTD has significantly improved the standard of living of the inhabitants of Kavaratti, according to an NCAER survey. An overwhelming 93% of respondents agreed with this assessment. They also reported that there was no discharge of chemicals that had an adverse effect on ornamental fish available as a wild variety in the coral island. Incidence of water-borne diseases has also decreased, according to the results of the same survey. Besides, this involves minimal efforts towards maintenance, often accomplished by unskilled labour. There is a case to incentivize adoption of LTTD or penalize adoption of alternative technologies.

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