Mahasagar-Bulletin of the National Institute of Oceanography, 19 (2) 1986, 113-118

ESTIMATION OF SALINITY POWER POTENTIAL IN INDIA

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ABSTRACT

Salinity gradient as a source of energy has much potential, but this has been recognized only recently. The energy density of this source is equivalent to about 250 m water head for a salinity difference of 35 ppt. This source exists at the estuaries where freshwater flows into the sea or wherever sources of different salinities exist. In India, the total freshwater discharge from rivers and streams flowing into the seas around amounts to about 23 x 10^3 m^3/sec which could provide a power potential of about 54.8 x 10^3 MW. Additional sources are done available in the form of salt deposits or salt pans. Only very little work has been on the techniques of extraction of power from salinity gradient.

Key-words: Salinity power, energy potential, salinity gradient.

The rapid spread of industrialization along with the population explosion and modernisation of life style is putting more and more pressure on conventional energy sources. In this context it is prudent to look for alternative energy sources. Salinity gradient, as a source of energy, has been recognised only recently and unfortunately only very little scientific research has been done in developing this energy as a source for power generation (Levenspiel and de Nevers, 1974; Loeb, Bloch and Issac, 1978; Norman, 1974; Olsson, Wick and Issacs 1979; Weinstein and Leitz, 1976; Wick, 1978; and Lacey, 1980). Salinity power extraction refers to the conversion of mechanical or electrochemical potential in the salinity difference between two solutions. So far, four methods have been proposed for the extraction of power from salinity gradient. These techniques are based on-1) osmotic pressure difference, 2) vapour pressure difference, 3) reverse electrodialysis and 4) mechano-chemical engines using collagens (NIO, 1981).

The salinity gradient energy source exists in the estuaries where fresh water flows into the sea water. Its energy density can be measured mechanically in terms of osmotic pressure difference between two different saline solutions. Osmotic pressure difference between freshwater and sea water (35 ppt. salinity) is about 25 atmospheres, equivalent to about 250 m water head. This is a renewable resource owing to the continuous turning of hydrological cycle, and is, therefore, an indirect form of solar energy. Wick (1978) estimated the extractable salinity power on a global scale as about 2.6 x 10^{12} from river run-off alone which exceeds the extractable ocean thermal energy. And it is even much more when other sources like salt domes, hypersaline waters and salt pans are also considered.

In this paper an attempt has been made to evaluate the power potential resulting from the river discharge and other likely sources in India.

River discharge data has been taken from Rao (1979) and Unesco (1971) for the Indian rivers discharging on both the east and west coasts of India. The power potential has been calculated following the method suggested by Wick (1978). The salinity power resources could be divided into two broad classes : 1) renewable such as estuaries, salt pans and dried lagoons etc. and 2) non-renewable such as salt domes, sub-terranean salt deposits etc.

In an electrolytic solution such as sea water, which contains a number of ions in moderately high concentration, there exists an interaction between the solute and solvent molecules. The solvent (water) molecules are arranged in an orderly fashion around the inorganic species; the extent of extraction depends upon the extent of dilution, the regular arrangement of water around the species will tend to break down, resulting in the liberation of energy. This process occurs naturally at the river mouths but the released energy is lost irrecoverably since it is consumed in entropy increase. Hence, in theory, any two solutions of different salinities brought together for interaction should yield energy. The power potential may vary with the different techniques mentioned earlier.

River run-off : The river discharge and the power potential resulting from the discharge for different rivers on the east coast of India are given in Table I. Total discharge of rivers draining into the Bay of Bengal along the east coast of India amounts to about 16.6 x 10^3 m^3/sec. In this case, the osmotic pressure is assumed to be about 24 atmospheres, as the surface salinity in the Bay of Bengal is generally less than 34‰. The power potential is estimated to be about 39.9 x 10^3 MW (Table I). The river discharge into the Arabian Sea along the west coast of India is about 5.9 x 10^3 m^3/sec. and the corresponding salinity power is estimated to be about 14.9 x 10^3 MW (Table II). The osmotic pressure is assumed to be 25 atmospheres, since the average surface salinity is nearly 35‰ It is obvious from the estimations that the power potential is more on the east coast than on the west coast. The availability of fresh water varies seasonally and annually. This may cause a handicap in considering salinity power as a firm source. However, this problem can be overcome if the river water is impounded for use during lean season.

There are a few other sources like subterranean brines, salt deposits, brine springs, salt lakes and salt pans in India. However, due to the lack of quantitative data on these deposits and related sources, and on the availability of fresh water in those regions, the power potential of these sources could not be evaluated.

Other sources : Millions of tonnes of pure rock salt deposits produced by evaporation of sea water in enclosed basins occur embedded in the sands of the Rann of Kutch and in the alluvial tract southeast of Sind (Gujarat). Salt beds of considerable size occur in Mandi (Himachal Pradesh) which have been mined

Table I : Power potential resulting from river discharge on the east coast of India

River	Aveg. annual discharge m³/sec	Power potential (MW)
Hooghly*	6228	14947
Subarnarekha	252	605
Brahmani	580	1392
Mahanadi	2112	5069
Godavari	3327	7985
Krishna	2145	5148
Pennar	103	5148
Cauvery	664	247
Medium rivers		1594
Rushikulya	57	137
Vamsadhara	111	266
Nagavali	76	182
Sarda	22	53
Yeleru	29	70
Gundlakamma	32	77
Musi	9	31
Paleru	10	38
Muneru	14	26
Kunleru	13	134
Swarnamukhi	16	24
Kortaliyar	11	122
Palar	56	65
Gingee	10	58
Ponnaiyar	51	24
Vellar	27	36
Vaigai	24	41
Varshalli	10	103
Gundar	15	
Vaippar	17	494
Tamarpani	43	742
Minor rivers — state wise		125
West Bengal and Orissa	206	
Andhra Pradesh	309	19
Tamil Nadu	52	24
Total	16630	34

*Assumed 50% flow from Farakka point, Source Unesco (1971).

for the extraction of salt (Wadia, 1975). A few salt lakes are known to exist in the northern states of India. Of these, the Sambar Lake in Rajasthan is known to have large reserves of salt estimated to be about 50 million tonnes (Wadia, 1975). In the coastal states of India, salt is extracted from sea water and the salt pans can be used as a source. In the coastal areas where large scale salt deposits and salt pans are available, salinity power potential exists owing to the proximity of sea water which can be used as a dilute solution creating a salinity gradient. However, salt and brine resources in the interior regions in India could be considered as sources, if fresh water or brackish water is available in proximity.

Table II. Power potential resulting from river discharge on the west coast of India

River	Aveg. annual discharge m³/sec	Power potential (MW)
Sabarmati	101	253
Mahi	269	673
Narmada	1290	3225
Tapi	570	1425
Shetrungi	9	23
Bhedra	11	28
Dhadhar	21	53
Burhabalang	69	173
Baitrani	182	455
Purna	35	88
Ambika	40	100
Vaitarna	138	345
Ulhas	96	240
Savitri	47	118
Mandavi	42	105
Kalinadi	207	518
Gangavati	156	390
Sharavati	144	360
Netravati	146	365
Ghaliar or Beypore	165	413
Bharatpuzha	279	698
Periyar	390	975
Pamba	200	500
Minor rivers — Statewise		
Gujarat	37	93
Karnataka, Goa & Maharashtra	31	74
Kerala	1270	3175
Total	5945	4865

Principles of energy conversion

Pressure Retarded Osmosis : This method uses the 'principle of direct osmosis. If fresh water (or low saline water) and sea water (or high saline water) are separated by a semi-permeable membrane, fresh water will permeate through the membrane, thus diluting the sea water and creating hydraulic pressure. Power can be generated when the water flux which is a mixture of permeated fresh water and sea water with the resulting pressure is released through a hydroturbine generator.

If the hydraulic pressure is applied on the sea water side, the permeate flow decreases and the flow stops when the applied pressure equals the osmotic pressure difference between the fresh water and the sea water. If the applied pressure is between zero and the osmotic pressure, Pressure Retarded Osmosis occurs. Loeb, Bloch and Issacs (1978) and Wick (1978) have experimented with this method and indicated that maximum power can be obtained at 50% of efficiency at hydraulic pressure head equal to half the osmotic pressure difference.

Reverse Electrodialysis : In concept, this is the reverse of the conventional electrodialysis process for desalination of water. When saline and fresh water pass through alternate compartments separated by alternately arranged cation and anion exchange membranes, a voltage is generated across each membrane. The generated voltage is due to diffusive flow of anions and cations through respective membranes. These voltages are additive and establish a flux of electric charges between the electrodes placed in the two end compartments. These electrodes can be connected to an external load to which power can be delivered (Lacey, 1980; Loeb, Bloch and Issacs, 1978; Weinstein and Leitz, 1979). This is also called Dialytic Battery.

Reverse Vapour Compression : This is the reverse process of the vapour compression desalination. An advantage of this method is that no membrane is required as in the cases of the methods described earlier. If saline and fresh water flow through separate compartments in an evacuated chamber, water vapour transfers from the fresh water chamber to saline water chamber due to the lower vapour pressure of the saline water. When vapour transfers from fresh water chamber to salt water chamber, it carries energy in the form of latent heat of vaporization. During condensation, an equal amount of energy is released. This released energy should be supplied back to fresh water chamber, otherwise the process of vaporization ceases to occur. This can be accomplished through effective heat exchangers. If the vapour that is being transferred from fresh water chamber to saline water chamber is allowed to pass through a turbine, power can be generated (Loeb, Bloch and Issacs, 1978; Olsson, Wick and Issacs, 1979).

Mechanochemical Engines : These are analogous to heat engines. Using fibres, which swell in fresh water either in one or two dimensions and contract in saline water, salinity gradient energy can be converted into mechanical power. With the swelling and contraction of the fibres by flushing of fresh water and sea water respectively, a piston can be moved to and fro. The piston can be connected to a rotating flywheel, facilitating power extraction (Emren, 1979).

All the methods, at present, are either in the conceptual or experimental stage and are not economically viable as compared to the conventional power production. However, the first three methods described earlier are receiving more attention from the standpoint of commercial applications. The major factors determining the application of pressure retarded osmosis or reverse electrodialysis will be the improvement in membrane technology and low membrane cost. High salt rejection or ion selection of the membranes used in the desalination are not well suited for use in the salinity power plants. For example, high salt rejection of membranes result in low flux of water. Moreover, the sediments or particulate matter in the input stream will cause deterioration of the membrane and reduce the efficiency. Hence, the solutions need pretreatment. Also problems like bio-fouling and environmental concerns need to be tackled. In the vapour pressure difference technique, basic problems remain of large size turbines, large scale circulation rates and large capital expenditure on heat exchangers. Although membranes and pretreatment of solutions are not required, it is subject to thermal limitations. Therefore, major advances in technology, careful optimization of operating conditions, proper assessment of environmental impact are required to make large scale production of salinity power a reality.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. V. V. R. Varadachari, Director and Dr. J. S. Sastry, Deputy Director, for encouragement and guidance.

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