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DISTRIBUTION OF TEMPERATURE IN THE VICINITY OF A CONDENSER OUTFALL IN KALPAKKAM COASTAL WATERS

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Abstract

This paper discusses the distribution of temperature around the condenser outfall of a nuclear power plant, Madras Atomic Power Station (MAPS) located 60 km south of Madras. The distribution of temperature is strongly influenced by the seasonally reversing coastal currents at this location. The thermal plume moves to the north hugging the coast when the currents are northerly during the southwest monsoon period (June - September) and moves to the south when the currents are southerly during the northeast monsoon period (October-February). There are also situations, particularly during the transition from northeast to southwest monsoon, when the thermal plume showed a movement towards the intake resulting in recirculation of heated effluents. It is observed that following the commencement of station operation there has been a general warming up of coastal waters resulting in an increase in temperature of about 1° C in April / May and 2° C in June / July. The paper makes an assessment of the significance of the observed temperatures in the context of power plant operation and ecology of coastal waters.

Introduction

The Temperature distribution studies in coastal waters of Kalpakkam assumed significance with the commissioning of two 235, MW (e) each, nuclear power plant during the period 1983-85. Earlier studies had established the seasonal distribution of surface temperature during the pre-operational period (Nair, 1985; Nair and Ganapathy, 1983). The present paper discusses data on variations in surface temperatures in the vicinity of the seawater intake system after the commissioning of the plant and data on the distribution of temperature in the thermal plume from the condenser discharges.

We acknowledge with thanks the invaluable help of our colleague Shri P. Murugan in the collection of a part of the data.

Description of Intake and Discharge System

The MAPS, consisting of two units of 235 ME (e) each is located at Kalpakkam on the east coast of India 60 km south of Madras. Unit-1 reactor went operational on 23rd July, 1983 whereas Unit-2 reactor went operational on September 18, 1985. The two reactors use seawater as a secondary coolant and the total requirement of seawater for cooling is about 35 cubic metre per second. The seawater is drawn through a submarine tunnel, the seaward end of which lies 420 m away from the shore (Fig. 1). The intake structure is connected to the shore through an approach jetty. Seawater flows by gravity into the fore-bay and pump house located ashore adjacent to the reactors. From the fore-bay the seawater is pumped through the condensers and discharged onshore adjacent to and to the north of the approach jetty.

General hydrographic features

The shoreline at Kalpakkam is open to the Bay of Bengal. The mean tidal range is 0.3 to 1.5 m. The coastal current at Kalpakkam has a seasonal character. NE monsoon (October - February) and SW monsoon (June - September) winds cause a southerly and northerly littoral drift respectively along the coast. During the southwest monsoon period the discharge from the condenser flows in the form of a canal on the shore towards north ranging from 100 m to 500 m length and then mixes with the coastal waters, whereas during the northeast monsoon period the discharge from the condenser flows directly into the coastal waters.

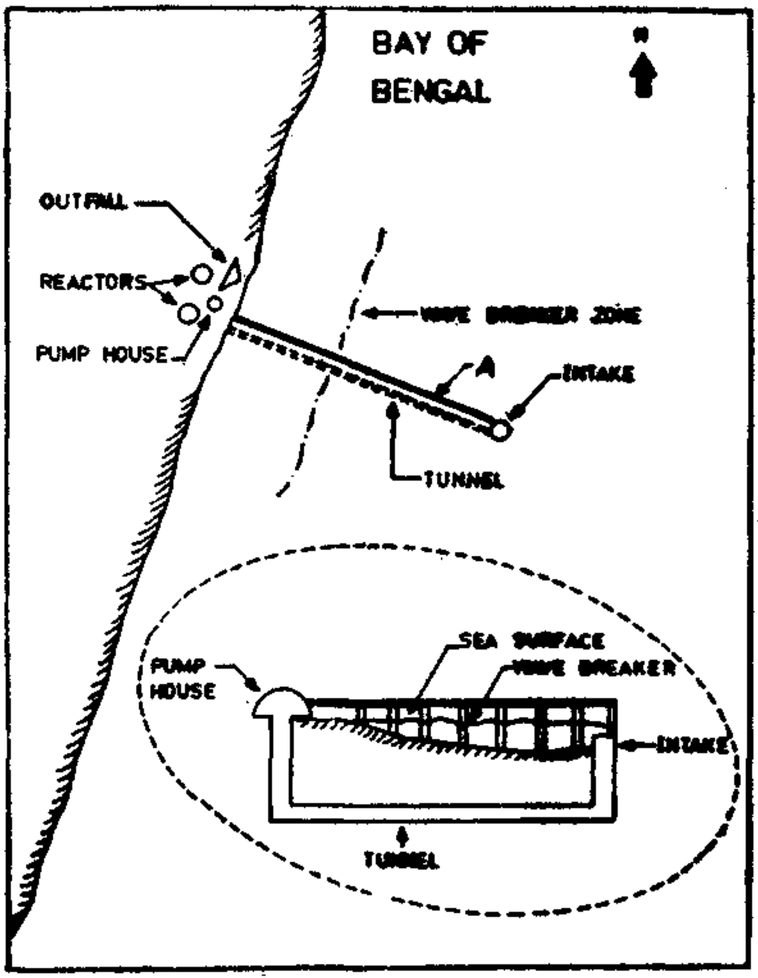

Fig. 1. A schematic diagram showing the reactor, seawater intake system and the outfall structure.

Material and Methods

Surface temperature measurements were carried out at weekly intervals during the period 1981-'84 from a point 400 m away from the shore on the approach jetty by taking a surface sample in a polythene bucket and using a thermometer which reads to 0.1° C. Similar measurements were also carried out to the north and south of the outfall-point and along the jetty. Vertical distribution of temperature at the end of jetty were also measured on two occasions using reversing thermometers.

during this period. Similarly measurements were made towards south from the outfall point during the NE monsoon period as the coastal currents are southerly during this period.

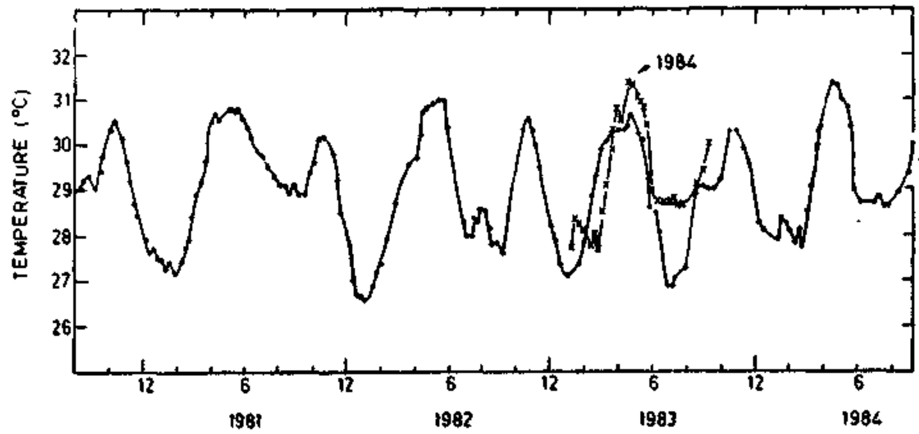

Fig. 2. Moving average of surface water temperature in coastal waters.

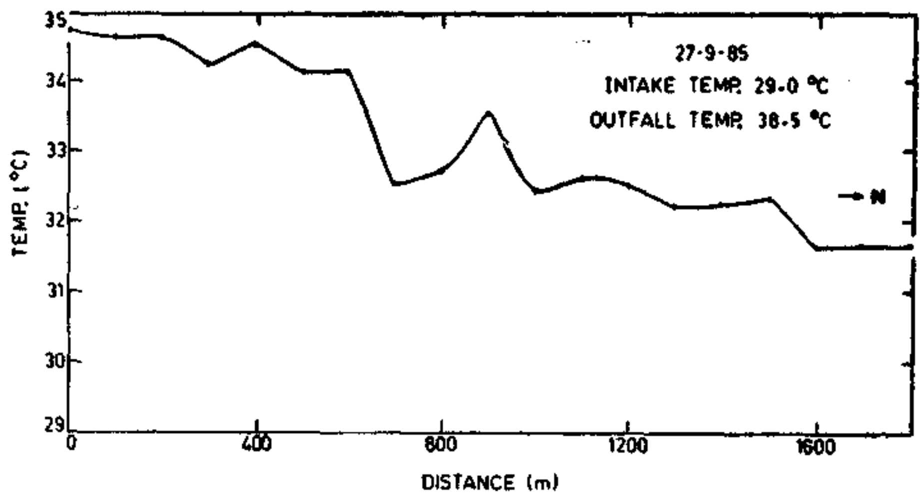

Fig. 3. Surface temperature in shore water towards north Kalpakkam on 27.9.1985.

Since coastal currents are directed north during the SW monson period (Nair *et al.*, 1983) temperature measurements were carried out towards north from the outfall point

Results

Weekly surface temperature data collected at a point (A) on the jetty, 400 m away from the shore have been converted into moving averages and the data are given in Fig. 2. A summary of data on the intake and outfall temperatures, temperature at a distance from the outfall and data on the direction of coastal currents during SW and NE monsoon seasons are given in Table 1.

to SW monsoon are given in Figs. 5 and 6 respectively. Vertical distribution of temperature at point (A) is given in Fig. 7. The difference between intake and outfall temperature (Δt) during the period of study ranged from 6.9°C to 10°C with the maximum Δt being recorded when both the reactors were operating nearly

TABLE 1. *Seasonal differences in the intake and outfall temperatures and the direction of coastal currents at Kalpakkam*

Date	Power level of reactors MW (e)		Temperature (°C) at different locations.				
	R (I)	R (II)	Intake	Outfall	(Δt)	Away from outfall***	Direction of currents
28.2.86	220	200	26	35	9.0	28.5 (1.6)	S
14.2.86	230	210	28	37.5	9.5	29.0 (1.1)	S
13.2.86	230	180	28	36.6	8.6	28.5 (1.0)	S
8.2.86	160	S/D*	27.4	34.3	6.9	28.4 (1.7)	S
23.1.86	230	S/D	25.8	33.8	8.0	28.0 (1.6)	S
10.1.86	217	220	25.5	35.5	10.0	26.6 (1.6)	S
24.12.85	225	**	27.1	34.1	7.0	28.5 (1.6)	S
27.9.85	225	–	29.0	38.5	9.5	31.6 (1.9)	S
20.8.85	106	–	28.0	36.5	8.5	28.9 (1.6)	N
12.8.85	73	–	27.6	34.6	7.0	28.3 (1.3)	N
9.8.85	50	–	28.5	37.0	8.5	29.5 (2.0)	N

*S/D Reactor shutdown; ** Reactor II was commissioned only in September 1985.
*** distance in km in parenthesis. Δ t = outfall – intake.

Data on the distribution of temperature along the coast both to the north and to the south of the outfall during SW and NE monsoon seasons are given in Figures 3 and 4 respectively. The distribution of temperature along the jetty during the SW monsoon season and the period of transition from NE monsoon season on full power. When the coastal currents are southerly during the northeast monsoon period, the heated effluents moved towards south registering sometimes a Δt of upto 1.5° C, 1.6 km south of the outfall point. When the coastal currents were northerly the heated effluents moved towards north recording a Δt of upto only 2.5°C, 1.6 km to the north of the outfall.

Moving averages of surface temperature

Moving averages of surface temperature (Fig. 2) clearly shows two annual maxima one in April/May and the other in Sept./Oct. and two minima one in July and the other in January. As the Madras Atomic Power Station unit I has become operational in July 1983, an attempt has been made to superimpose 1984 data on 1983 data to evaluate the temperature change following station operation. A general warming up is evident from the 1984 curve. The temperature maximum in April/May has been elevated by 1° C and temperature minimum in June / July has also been similarly elevated by 2° C.

SW monsoon

The data on the variation of temperature with distance towards north is given in Fig. 3. Distance zero indicates the point of mixing of the effluents with coastal waters. However, the effluents travel as a canal parallel to the water line for some distance (about 0.5 - 0.8 km) before mixing with the sea. At the point of mixing the temperature was 34.8° C and decreased to 31.5° C at a distance of 2.0 km, which is 2.5° C more than the intake temperature, indicating the movement of thermal effluents towards north. This is also evident from the relatively low temperature observed towards the south on the same day.

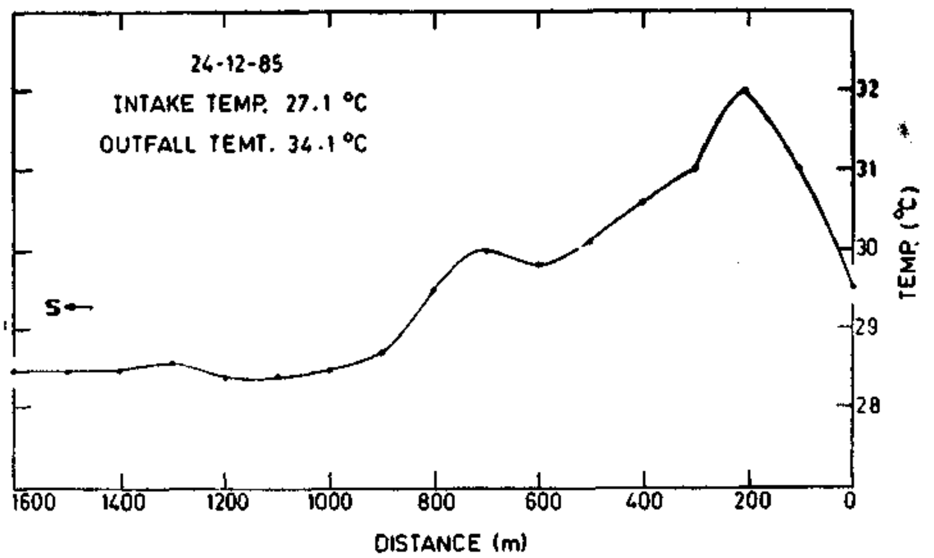

Fig. 4. Surface temperature in shore water towards south at Kalpakkam on 24. 12. 1985.

Temperature measurements along the jetty (Fig. 5) do not show any significant variation of temperature with distance from the shore during this period. Thus the shore water around the intake structure is not influenced directly by the hot plume. This is largely due to the movement of the heated effluents from the condenser outfall as a stream parallel to and separated by a sand bar from the sea, eventually mixing with the coastal waters 0.5 - 0.8 km to the north of the outfall area. Moreover, strong coastal currents prevalent at this time takes the hot plume towards north.

NE monsoon period

Data on the variation of temperature with distance towards south is given in Fig. 4. Distance zero indicates the point of mixing. During this period the condenser discharges mixed with the coastal waters adjoining the outfall structure without moving as a canal as it was the case during SW monsoon season. It was found that the temperature from the mixing zone first increased from an initial value of 29.5° C at the mixing zone to a maximum of 31.9° C at 200 m and then decreased to 28.6° C at 1.6 km which was 1.5° C higher than the intake temperature.

The increase to a maximum at about 200 m from the point of mixing, instead of at the point of mixing can be explained on the basis that the high momentum of discharged water, the buoyancy effect of the hot plume and the direct entry of the plume into the adjoining waters pushes the plume into the sea for some distance (about 50 m) across the direction of coastal currents. Coastal currents during NE monsoon period is not as strong as that during SW monsoon period. Once the momentum is reduced after a travel of about 50 m, southerly current predominants over the velocity of the condenser discharge and the plume starts moving in the direction of the current as a result of which maximum is observed at 200 to 300 m from the point of mixing.

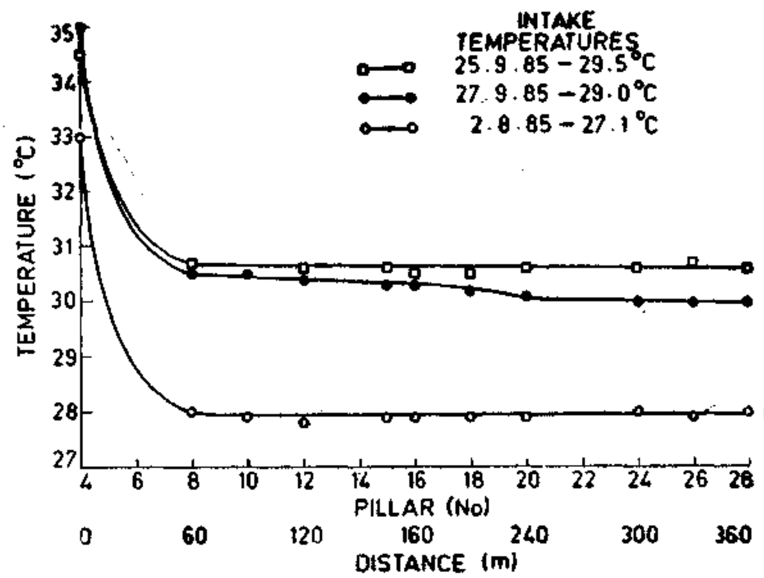

Fig. 5. Surface temperature along the jetty during SW monsoon period.

Data on measurements of temperature along the jetty during the transition from NE monsoon period to SW monsoon (Fig. 6) shows that the heated effluents moved towards the intake and resulted in some recirculation affecting adversely the performance of condensers. This is also corroborated by the vertical distribution of temperature at the end of the jetty on two occasions (Fig. 7) which indicates thermal stratification.

Discussion

When the condenser water is discharged into a receiving body, the discharge spreads out to form a plume in which the temperature decreases steadily from a maximum at the discharge point to reach the normal ambient temperature of the surrounding water at a distance. The shape, volume and temperature characteristics of the thermal plume depend upon the nature of the discharge design as well as the hydrographic characteristics of the receiving waters. Two situations are often considered (1) a completely stratified system and (2) a well mixed system.

The plume spreads depending upon the direction of currents and the temperature of the near surface water. Because of the dissipation of the heat to the atmosphere by evaporation, convection and radiation, the temperature comes down to the intake level a few km downstream in the direction of the current. Surface cooling and mixing eventually cause the plume to lose its identity. In the process, the whole receiving body in the vicinity gets warmed up slightly for a distance of a few kms in the direction of the current. In the present instance this warming up is felt to a distance of 2 km to the north along the shore during the southwest monsoon period and to a similar distance to the south during the northeast monsoon period. A comparison of moving averages of surface temperatures during 1983 with those of 1984 also shows

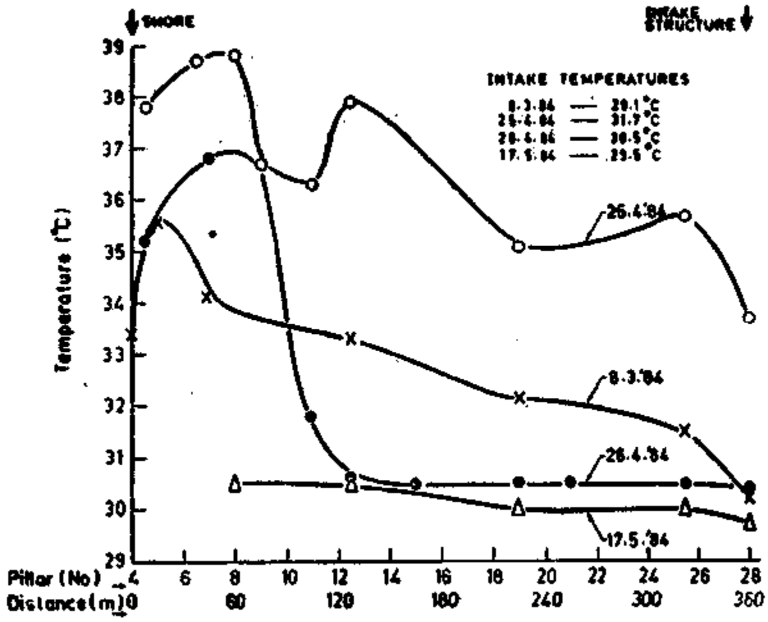

Fig. 6. Surface temperature along the jetty during the transition period from NE to SW monsoon.

very clearly the general warming up of the coastal waters in the vicinity of the discharge.

The results clearly indicate that the movement of heated effluents is governed by the direction and velocity of seasonal currents. Recirculation of heated effluents is found to be occurring to a limited extent during the transition from NE to SW monsoon period.

The results of the study will serve as a basis for future work on the effect of thermal discharge on different species of marine life. From ongoing studies on the density of fouling biomass in coastal waters before and after 1983 there are indications that the intensity of fouling has increased in the post-operational period. These results will also be of importance in the context of minimising recirculation of heated effluents in power plants operating and proposed on the east coast of India.

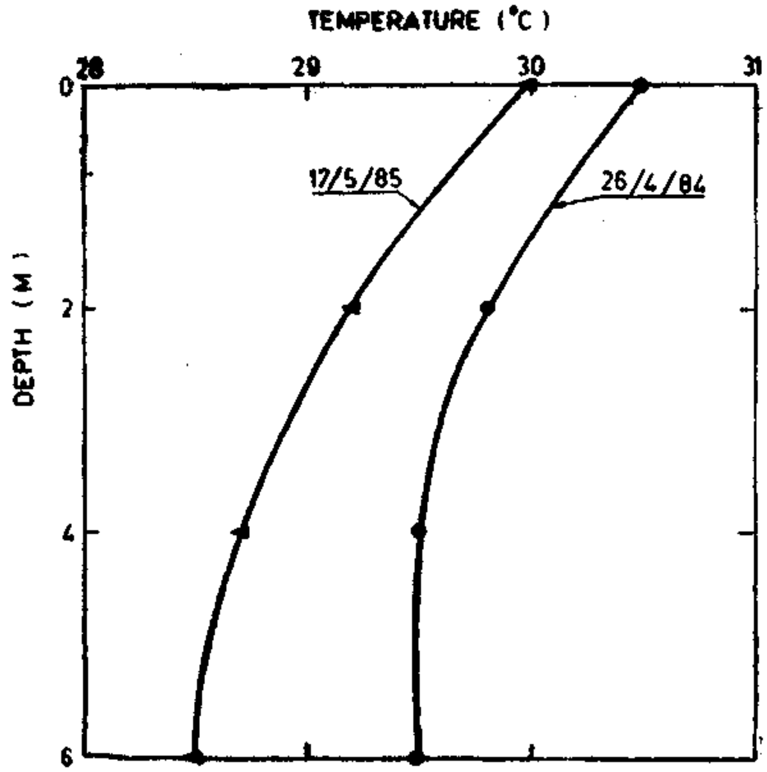

Fig. 7. Vertical stratification of temperature at a station near the intake.

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