Jellyfish ingress: A threat to the smooth operation of coastal power plants

Coastal areas are often preferred for setting up power stations due to the easy availability of sea water for condenser cooling. In such coastal power stations, there are instances of plant shutdown due to excessive accumulation of fouling debris inside the cooling circuits. In one of the power stations in UK, the quantity of fouling debris removed was about 40 tonnes per year and this was at times as high as 130 tonnes[1]. Recently, there have been a few instances, when jellyfish in large numbers entered the sea water cooling system of the Madras Atomic Power Station (MAPS) at Kalpakkam, causing plant shutdown[2]. While moderate ingress of jellyfish leads to a reduction in the plant efficiency, large arrivals may even lead to forced shut down of a power plant[2–4]. The present study deals with the ingress of jellyfish in MAPS cooling water system and its impact on the power plant operation.

MAPS consisting of two units, each of 235 MW(e) capacity is located at Kalpakkam (12°33′N and 80°11′E), 65 km south of Chennai (Figure 1) on the east coast of India. The power plant uses sea water as its condenser coolant. The sea water intake is located 420 m away from the shore and is connected through an approach jetty (Figure 1). Sea water enters the cooling water system through 16 windows (3.2 m height and 2 m width) located radially in the intake structure. From the intake point, water flows into the forebay by gravity. The sea water travels through the Travelling Water Screens (TWS) at the forebay before 12 pumps (6 for each unit) draw the sea water for condenser cooling as well as for cooling the process water heat exchangers. The TWS is made up of stainless steel mesh (20 mm pore size) with a platform to collect debris attached at an angle of 90° (Figure 1). The TWS moves vertically and takes about 12 min to complete a rotation.

Jellyfish arriving at the TWS were collected in the forebay during the period from January 1995 to December 1996. During collection, individuals arriving for a period of one hour, every alternate day were pooled. They were separated into different species and weighed using a common balance. From these data jellyfish landing was calculated and expressed as tonne/month.

Jellyfish-induced water blockage in the conduit was assessed by determining the water level difference between the forebay and the intake (head loss). The measurement was done from the platform at the respective places using a lead and line.

Three species of jellyfish were observed during the study period, namely *Crambionella stuhlmanni*, *C. buitendijki* and *Dactylometra quinquicirrha*. Among these three species, *D. quinquicirrha* was the dominant one. In 1995 and 1996, the percentages of each species of the jellyfish to the total jellyfish collected were: *D. quinquicirrha* 45 and 40%, *C. buitendijki* 34 and 36%, *C. stuhlmanni* 21

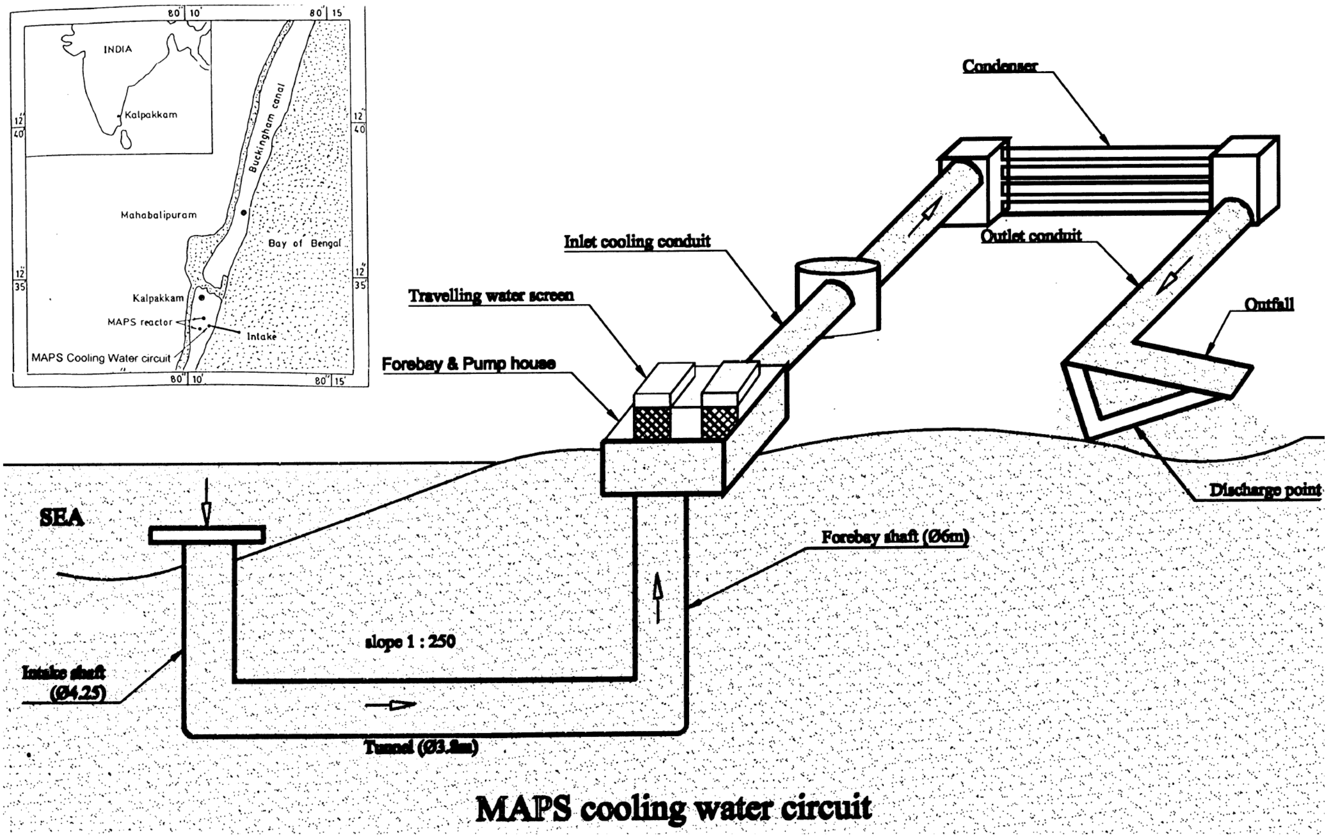

Figure 1. Map showing the submarine tunnel at the Madras Atomic Power Station (MAPS).

and 24%, respectively. Jellyfish arrived in large quantities during April to July and October (Figure 2 *a*). The maximum quantity of jellyfish arrival was found to be 17.54 tonnes in October 1996. Jellyfish were not observed during January to March, November and December. Data showed that the peaks in jellyfish arrivals on the TWS coincided with the reversal of the coastal water currents observed during the two monsoon seasons.

The maximum head loss recorded was 3.8 m during October 1996 and the minimum was 1.4 m in December 1996 (Figure 2 *b*). Figure 3 shows the correlation between head loss and arrival of jellyfish in the TWS. There is a positive correlation between the head loss and arrival of jellyfish in the TWS (P = 0.0002).

Being largely passive drifters in the sea, the arrival of jellyfish in the Kalpakkam coastal waters is closely linked to the current pattern observed along the coast[4,5]. The important observation in the present study is the relationship between head loss and the jellyfish ingress. The data on head loss at the forebay clearly indicate that head loss is directly proportional to the arrival of jellyfish (Figure 3). The ingression of jellyfish into the cooling water circuits resulted in the plant shutdown[2]. The revenue loss resulting from such unscheduled temporary plant outages is very high (about Rs 5.5 million/day). The increase in head loss leads to an increase in back pressure in the turbine as well as a reduction in the heat transfer efficiency in the heat exchangers, resulting in the reduction of power production. 1 m increase in head loss in the forebay is often responsible for 7 mm Hg backpressure in the turbine. An increase of 10 mm Hg back-pressure in the turbine results in a loss of Rs 0.11 million/day. In comparison, results from the present study recorded a head loss of a maximum of 3.8 m which would result in a two-fold increase in back-pressure in the turbine, resulting in a huge monitory loss to the power plant. Furthermore, jellyfish are often responsible for the damage of intake screens due to impingement, causing an estimated loss of about Rs 0.4 million/season.

Information on the control strategies for jellyfish ingress into power plant cooling systems is limited. In Japan, power stations use 'bubble curtain' around the intake point generated by compressed air. Jellyfish attempting to cross this curtain are lifted upward so that they do not disturb the intake screen. This method would fail in the event of large-scale ingress of jellyfish. Hence an alternative strategy for controlling jellyfish ingress is proposed. This problem may be minimized by removing the jellyfish by the use of netting around the intake area before they enter the cooling water circuit. The cost–benefit analysis of this method has not been worked out. However taking into consideration the losses incurred by plant outage due to jellyfish ingress, adopting this preventive method would prove to be economical. In addition, the use of remote sensing technology to track the movement of large masses of jellyfish in the oceanic waters could help in forecasting their arrival at a specific power plant site.

Large-scale ingress of jellyfish in power plant cooling water systems, as those observed at Kalpakkam, leads to the choking of the TWS. Hence modifications in the TWS structure in the forebay

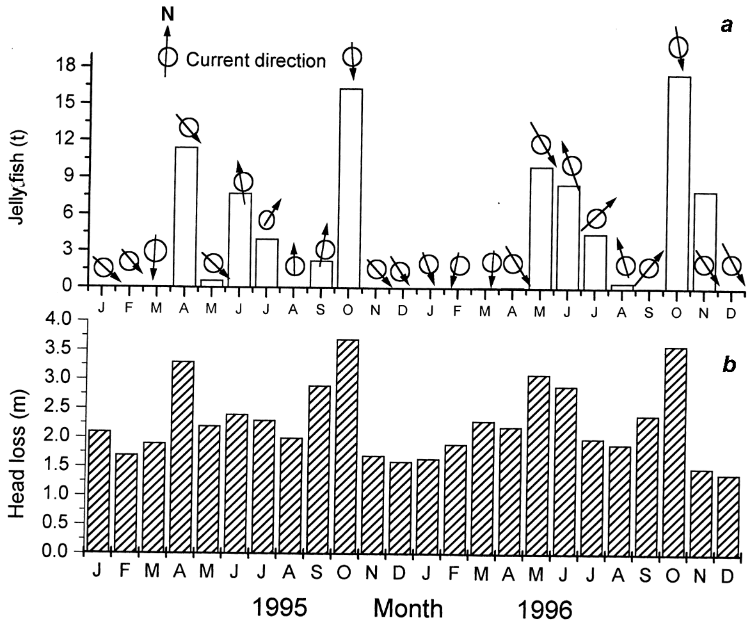

Figure 2. ***a***, Monthly arrival of jellyfish on travelling water screens of MAPS with the direction of coastal water currents; ***b***, Monthly observation of head loss in the forebay of MAPS.

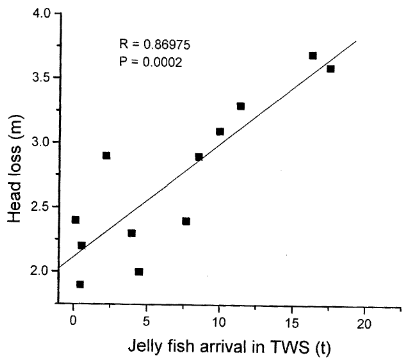

Figure 3. Correlation between jellyfish ingress and head loss

can also minimize the problem. At present, the orientation of TWS platform is at 90° and takes about 12 min for a complete rotation. When the jellyfish arrive in large numbers, they can be effectively removed from the forebay by changing the angle of orientation of the TWS platform to below 90° (to retain the jellyfish impinging on the screens, which can be easily collected upon surfacing) and by increasing the speed of rotation. This will result in a better removal rate of these organisms and thus would help in continuing plant operations. However further simulated studies in this direction would help in alleviating this problem and lead to the smooth operation of the plant.

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