

Total dissolved copper concentrations in coastal waters of Kalpakkam

¹ correspondence as we have been monitoring the sea at Kalpakkam coast since 1979, as part of our coastal water-monitoring programme. He has directly implicated the condenser cooling water discharge from Madras Atomic Power Station (MAPS) into the coastal waters as the sole cause for the elevated levels of Cu and Hg (the values reported have already been contested²) in the Kalpakkam coastal waters. It also has many factual errors and needs to be corrected.

A cruise was made to collect sea water samples from Kalpakkam coastal water to estimate dissolved copper. In the present endeavour, copper could be estimated whereas Hg could not, due to operational difficulties. Thus the discussion here pertains to Cu only, although both Cu and Hg have been discussed by Selvaraj. Kalpakkam is situated at 12°34'N lat. and 80°11'E long. on the east coast of India. MAPS, consisting of two pressurized heavy water reactors (PHWR), each of 235 MW(e) capacity, is located on this coast. Unit-1 reactor went operational on 23 July 1983, whereas Unit-2 went operational on 18 September 1985. Sea water at a rate of about 35 m³/s is used for cooling the condenser and other auxiliary systems when both the units are operational. Sea water is drawn through a submarine tunnel of 468 m length, built 53 m below the seabed. The tunnel is connected at the landward end to the pumphouse through a vertical shaft called forebay. After extracting heat, sea water is discharged on the shore to the north of the reactor. MAPS uses aluminium brass (an alloy of Cu and Zn) as a condenser as well as process water heat exchanger material. Details of the site and MAPS are given elsewhere³. Water samples were collected from four stations located along the coast stretching over a length of about 8 km and about 600 m into the sea. These stations are located in the same area from where Selvaraj had also collected his samples. The sampling locations were chosen such that stations 2, 3 and 5 are not influenced by MAPS condenser discharge, whereas station 4 is influenced by the discharge (Figure 1), so that a comparison could be made between results from influenced and non-influenced areas. Water column at the four stations

varied from 7 to 9 m. Four surface (1 m below the sea surface) and bottom (1 m above the bottom) water samples were collected using Nansen water sampler of 1.5 l capacity during post-monsoon period (March 2006). Precautions were taken during sample collection to avoid contamination, following the procedure described by Schmidt⁴. Samples were acidified using 2 ml HNO₃ per litre of sample to prevent deterioration and were defreezed until analyses (analyses were completed

within 7 days from the date of sampling). Samples were analysed for dissolved copper by an IRIS intrepid II inductively coupled argon plasma optical emission spectrophotometer, which uses E chelle optics and a unique charge injection device solid-state detector. The Thermo Electron Validated Analysis software controls all operations. The temperature of the plasma torch is about 10,000 K. Results of Cu analyses along with water quality parameters are given in Table 1.

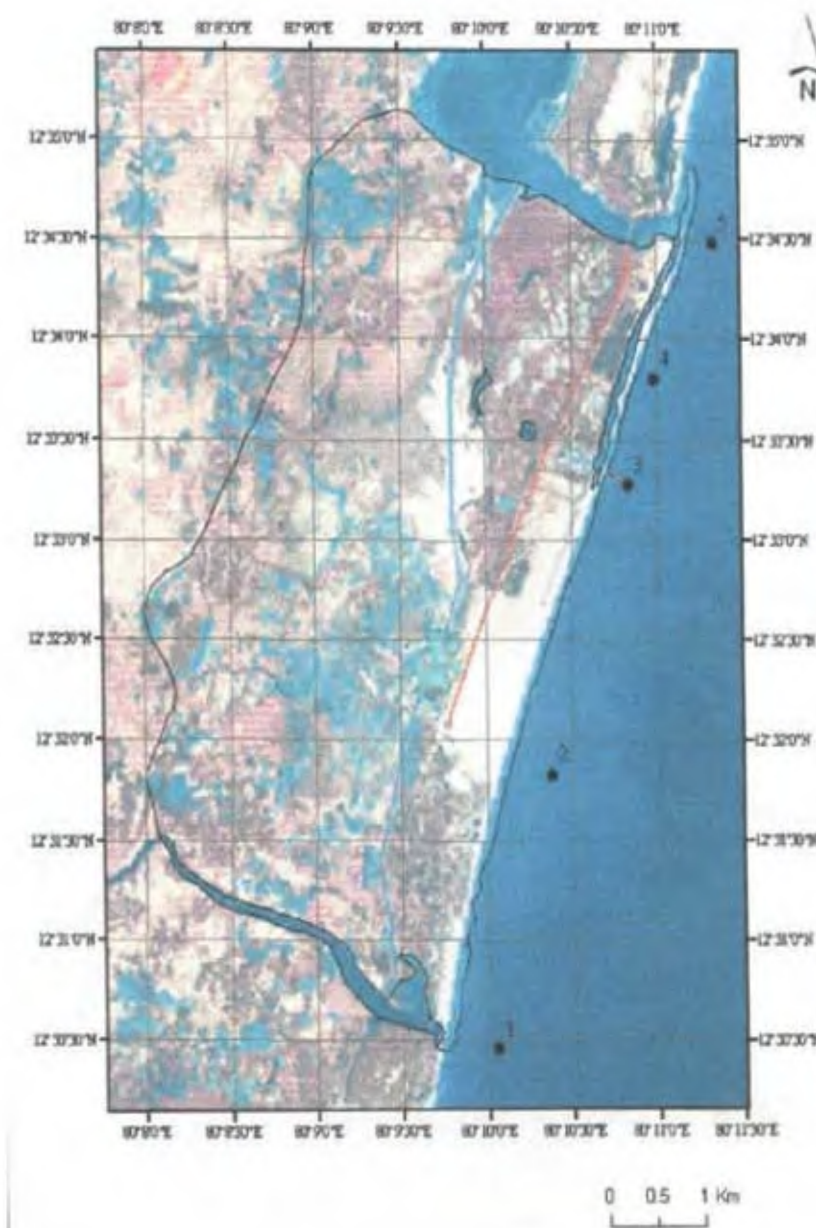


Figure 1. Study area showing sampling location.

Table 1. Temperature, pH, DO, salinity and dissolved copper in coastal waters of Kalpakkam

Location	Longitude	Latitude	Temperature (°C)	pH	DO (mg/l)	Salinity (PSU)	Cu (µg/l)
2S	80°10'117"	12°31'063"	28.5	8.22	6.1	35.75	49
2B	–	–	28.2	8.20	5.9	35.86	52
3S	80°10'876"	12°33'063"	27.5	8.23	5.5	35.97	43.5
3B	–	–	27.1	8.16	5.2	35.2	35
4S	80°10'063"	12°33'347"	28.5	8.22	5.6	35.59	34
4B	–	–	28.2	8.18	5.2	35.2	49.5
5S	80°11'310"	12°34'051"	28.5	8.23	5.4	35.04	46
5B	–	–	28	8.21	5.2	34.98	50
Average	–	–	–	–	–	–	44.5

Sea water is used in MAPS as the condenser cooling water⁵ and not as the secondary coolant as mentioned by Selvaraj. The secondary coolant in MAPS is demineralized water. It is incorrectly reported by Selvaraj that dissolved Cu has been estimated for the first time from Kalpakkam coast. However, the same had been estimated way back in 1984 (ref. 6) and in 1987 (ref. 7). The average value reported by Iyengar *et al.*⁶ is 1.7 µg/l. The values of total dissolved Cu reported by others⁷ ranged from 0.8 to 4.5 µg/l, and the average value was 2.6 µg/l over a period of one year. Results obtained during the present study ranged from 34 to 52 µg/l, and the average value was 44.5 µg/l. There was hardly any variation in the Cu concentration between any two stations, except for the fact that stations 2, 4 and 5, the bottom samples showed marginally higher values than that of surface samples. In the present study, station 4, which is close to MAPS condenser discharge, showed Cu concentration similar to that of the other three stations. Although the present values are higher than the reported values^{6,7}, they are much lower than those reported by Selvaraj (554.5 and 571.2 µg/l for surface and bottom samples respectively, during the post-monsoon period). The marginal increase in Cu concentration observed in the present study compared to the earlier reported values^{6,7} could be attributed to the general increase in pollution from various sources over a period of 20 years. Moreover, the present studies were carried out (March, 2006) after the tsunami (December, 2004), which has brought almost all the sediments from the bottom to the coastal waters. Possibly this has helped in the increase in the concentration of Cu in the coastal waters of Kalpakkam, which experienced the fury of the tsunami.

It is difficult to understand how the Cu concentration went up as reported by Selvaraj, and therefore, it goes without saying that something was seriously wrong with the result. It is not clear as to how the author came to the conclusion that the high values of Cu in the coastal waters of Kalpakkam (even if correct, notwithstanding the contest²) were due to input from the coastal industries; only an atomic power plant, i.e. MAPS exists and no other industry exists in and around Kalpakkam. Moreover, such conclusion is drawn without knowing the content of discharge. The above conclusion could have been dialectical had the MAPS outfall water been analysed for Cu. The report that antifouling paints containing Cu being used in the sea water intake pipe structures of MAPS to combat biofouling resulted in its increase in the coastal waters is factually wrong, as there are no antifouling paints used in the condenser cooling water submarine tunnel. Only coal tar epoxy paint is used for the trash racks and intake screen. Selvaraj has reported that to control biofouling and bio-corrosion, chlorine has been used intermittently – a distorted fact as only low dose continuous chlorination⁸ is in vogue at MAPS since 1988. Similarly, the source of chlorine is not through electrolytic chlorination process as mentioned by Selvaraj, but through liquefied gaseous chlorine cylinder⁹. Selvaraj has also attributed corrosion of copper alloys (condenser tube material in MAPS) to the elevated levels of Cu in coastal waters. Taking this clue that corrosion of condenser tube of MAPS has resulted in the rise in Cu levels in Kalpakkam coastal waters, the total amount of Cu in Kalpakkam coastal waters and that of Cu present in the condenser system was calculated. Based on the report by Selvaraj, the total amount of Cu in the Kalpakkam

coastal waters amounts to 84 tonnes in a volume of 0.2 cubic km. [The length considered is 4 km into the sea (according to the bathymetry data available¹⁰, to get a depth of about 50 m at Kalpakkam coast, one has to go more than 5 km into the sea), breadth considered is 2 km parallel to the coast (as evident from the traverses mentioned by Selvaraj), an average depth of 25 m (calculated from table 1 of Selvaraj) is taken and the average Cu concentration taken is 420 µg/l (calculated from table 1 of Selvaraj). Total Cu in Kalpakkam coastal waters of 0.2 cubic km volume is = volume (l) × concentration (µg/l) = 0.2 cubic km × 420 µg/l = 84 tonnes.] Similarly, the total amount of Cu present in the condenser system (based on the total surface area, thickness, density and percentage of Cu in the condenser tube alloy¹¹) amounts to 154 tonnes. [The total amount of Cu present in the entire condenser cooling system = available volume (l) × density of tube (g/cc) × % of Cu in the alloy = 19233 sq. m (area) × 1.25 mm (thickness) × 8.44 g/cc × 0.76 = 154 tonnes.]

The above two calculations show that more than 50% of Cu from the condenser tube system could have been eroded by the year 1995–96 (the year in which Cu content was estimated). Considering the fact that the sea is a dynamic environment and no other industry is located in and around Kalpakkam coast due to the prevailing sea water current, the water mass (containing Cu) would be moving out to other areas and fresh Cu from the source (MAPS condenser cooling water) has to enter the coastal milieu so that the reported¹ values could be sustained. In that case, by this time, i.e. (10 years later) the entire condenser system would have been eroded and the condenser tubes would have been replaced 2 to 3 times en masse. However, this has not

happened. Thus, it is axiomatic that the report published¹ has factual errors and has unscientifically implicated MAPS using erroneous results². The results of the present study clearly show that discharge from the MAPS condenser does not contain elevated levels of Cu. It not only gives credence to the comment by Kureishy², but also parleys with him.

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Received 8 May 2006; revised accepted 29 June 2006

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A comment on Gula and Gulate megaspores

Heterospory – a necessary step in the evolution of seed habit in vascular land plants, is the production of two kinds of spores, viz. micro and megaspores. Megaspores are the female gametophytes producing reproductive units of heterosporous plants. In fossil conditions where the nature of the gametophytes produced by the spores is not known, the two kinds of spores are differentiated on the basis of their respective sizes. Generally, spores larger than 200 µm are considered as megaspores¹.

Dispersed megaspores are classified as Azonate, Zonate and Gulate/Lageniculate by various workers^{2–4}. In the Azonate group megaspores have uniformly distributed surface ornamentations, whereas in the Zonate group the exoexine extends to form a thin zona all round the body and the dense ornamentation is found between the contact area and the zona. The third group – Gulate/Lageniculate – includes megaspores with gula. In these megaspores, the triradiate contact area extends apically to form a cone/tube/neck-like structure, which is invariably devoid of ornamentation.

Though Lageniculate megaspores were first reported by Bennie and Kidston⁵, the term ‘gula’ was introduced by Potonié and Kremp² when they proposed Unterabteilung Lagenotriletes – a new subturma under abteilung Triletes⁶. The spores included in this group are trilete, ‘Der apex exrhebt sich meist auf einer ‘Gula’, das heißt auf einem Hals (=höherem Deheszenzkegel)’. The term ‘Gula’ was described as ‘Wenn die tecta (namentlich im näheren Bereich des apex) sehr hoch werden, entsteht ein Dehiszenzkegel, der als Gula, be zeichnet wird. Man vergleiche die Diagnose der 2. Unterabteilung Lagenotriletes, zu denen die Gattung Lagenicula gehört’⁷, meaning thereby that gula is a neck-like projection/outgrowth in the apical region of the megaspore. Bharadwaj⁸ instituted a new series Gulati for ‘the trilete spores with a dehiscence cone in which the tecta more or less in the neighbourhood of the apex, are vertically raised forming a ‘vestibule’⁹ (pp. 27–28) or ‘gula’⁷ (p. 12)’. Thus, this structure has been variously termed/described as ‘vestibule’⁹, cone-shaped neck-like projection which

projects out from the body of spore¹⁰ (p. 10), and ‘apical prominence’¹¹. Zerndt¹² used the name *Lagenicula* as a genus for dispersed megaspores with gula. At present, nine Gulate/Lageniculate genera are known from Devonian¹³, Carboniferous^{14–18}, Permian^{3,4,19–24} and Triassic²⁵. From Indian Gondwana, five Lageniculate genera are described, viz. *Lagenicula* (Bennie & Kidston) Potonié & Kremp 1954 (refs 3, 4, 24, 25), *Satpura-spora*²³, *Maithyspora*²², *Dizkstraea*²² and *Setosisporites*²⁴.

Chaloner¹¹ described some megaspores in fertile fructifications of two Carboniferous lycopods – *Lepidostrobus monospora* and *Lepidostrobus dubius*, i.e. *in situ* megaspores and placed them under the genus *Triletes horridus*. According to him, ‘The sporophylls of these cones composed of a proximal horizontal sporangium-bearing portion and a distal sporophyll lamina. The abaxial half of the sporangium is occupied by one fertile and three abortive megaspores’. Further, description of the fertile megaspores by Chaloner¹¹ includes ‘apex (abaxial pole) of the spore bearing a prominence, which