ond phase slag particles appear to have slightly enhanced the dissolution tendencies, which could probably be due to galvanic coupling action of the Cu matrix with the slag inclusions. It is to be noted that the sulphides are electrically conducting and they aid in the establishment of local galvanic cells. The effect of the inclusions was not significant because the volume fraction of inclusions was relatively low and, moreover, they were not interconnected but widely dispersed.

As the electrochemical behaviour of ancient coppers is almost similar to that of modern copper, it implies that ancient and modern Cu samples are almost similar chemically. As the ancient Indian copper samples have successfully withstood corrosion under *unplanned* soil burial conditions for such a long time, it indicates that modern-day *planned* burial of copper must also behave similarly. The corrosion of copper exposed to the soil environment will be the critical factor. As ancient Indian copper has proved that it can withstand corrosion in Indian soil conditions over a long period of time, it must be seriously considered as the material of construction of outer canisters for long-term underground storage of nuclear wastes.

Additionally, information about long-term corrosion processes can be also obtained from characterization of surface patina on ancient Indian coppers. This will help in validating long-term corrosion models. For example, XRD patterns obtained from the surfaces, as a function of depth, help in understanding the sequence of formation of corrosion products. The results of XRD analysis conducted on ancient Indian copper[6] revealed that the first product to form was cuprite, followed by the formation of sulphates and oxysulphates, due to the presence of S in the environment.

A significantly large amount of ancient Indian copper objects are presently locked up in Indian museums and archaeological storerooms, waiting to be analysed. The interaction and co-operation of people skilled in metallurgical knowledge with archaeologists will greatly benefit in creating a knowledge database on ancient Indian copper. This will aid in material selection of high-level nuclear waste storage canisters.

1. Balasubramaniam, R., *Curr. Sci.*, 2002, **82**, 1357.
2. Balasubramaniam, R., *Corros. Sci.*, 2000, **42**, 2103.
3. Dunn, D. S., Pensad, O., Brossi, C. S., Cragnolin, G. A., Sridhar, N. and Ahn, T. M., In Proceedings of the International Workshop on Prediction of Long Term Corrosion Behaviour in Nuclear Waste Systems (eds Feron, D. and Macdonald, D. D.), European Federation of Corrosion Publications, Number 36, The Institute of Materials, Minerals and Mining, London, 2003, pp. 261–279.
4. Rosborg, B., Karnland, O., Quirk, G. and Werme, L., *ibid*, pp. 287–304.
5. Laha, T., Shankar, J., Balasubramaniam, R., Prabhakar, V. N., Sharma, D. V. and Banerjee, D., *Indian J. Hist. Sci.*, 2002, **37**, 321.
6. Srivastava, A. and Balasubramaniam, R., *Bull. Mater. Sci.*, 2003, **26**, 593.

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Do lichens still grow in Kolkata City?

Kolkata is India's largest metropolis. It is one of the fastest growing cities in eastern India. During the last few decades it has become overcrowded by the population explosion. Increased urbanization, industrialization and heavy vehicular traffic have resulted in deterioration of air quality in the city. Lichens among the plant group have long been recognized as sensitive indicators of environmental condition. The decline of lichens around the city centre due to air pollution is well studied throughout the world[1]. Lichens show their sensitivity to air pollution in different ways such as decline in diversity, absence of sensitive species and morphological, anatomical and physiological changes[2]. Thus to get an idea about the change of lichen diversity in relation to the increased urbanization in the Kolkata, a field survey was attempted both in and around Kolkata and Howrah (Indian Botanic Garden (IBG)) cities. The collection was made in the same localities from where earlier records of the lichens were available.

The identification of specimens revealed the occurrence of 25 species of lichens belonging to 11 genera and 10 families. Among the different localities, IBG exhibits the maximum diversity of lichens represented by 15 species. The boundary areas of Kolkata city have scarce growth of few lichens, while the heart of the city is devoid of lichens[3].

Das *et al.*[4] during 1986 studied the frequency of lichens in 25 streets of Kolkata ('Calcutta') city in relation to traffic load and reported the occurrence of only *Parmelia caperata*, a pollution-tolerant species on the trees in the streets. Frequency of occurrence of lichens from 13.4% to 93.3% on roadside trees withstanding a traffic load of 23.6 to 0.4 vehicles per minute was reported. However, in the present study it has been noticed that no tree vegetation exists in the streets. The few avenue trees that were present on the roadside do not host lichen growth.

The available oldest record of lichen collection in IBG belongs to Kurz, who made intensive lichen collection in the year 1865, out of which 53 species (19 new) for Kolkata were described[5]. During the sixties of the last century, Awasthi attempted to recollect one of the endemic, monotypic taxon (*Pyrgidium bengaliense* Krempelh.) in the type locality (IBG) on the same habitat (bark of *Ravenela madagascariensis)* but had been unsuccessful[6]. The comparison of the present lichen flora of IBG with the situation around 1865 clearly exhibit the extent of the loss of lichen flora in the area. The present record of lichens will provide a basis for further (experimental) research concerning the influence of air pollution and urbanization on the lichens.

The perceptible decline in the vegetation cover, the loss of species-specific habitats over the years, the increase in industrial areas and growth of large urban areas are some of the leading factors resulting in the loss and change of diversity of lichens in India[7]. Another factor with a potential influence in the natural distribution of

the lichen species are the climate, microclimate, eutrophiation, rain-water tracks and dust-accumulation. Apart from the abiotic factors, the phorophyte type, structure of bark, bark-wounds and water-holding capacity of bark also influence the epiphytic lichens. The loss of species-specific habitats leads to removal of pollution-sensitive species[8].

A comparative account of the lichen flora between the past and present studies clearly indicates that in the last hundred forty years the lichen flora of the IBG has changed significantly. Out of the 53 species earlier reported in 1867, only five species are common in the past and present enumeration. The species of lichen genera *Lecanora*, *Thelotrema*, *Verrucaria* and *Pyrgidium*, appear to be more sensitive to the environmental changes and are therefore extinct. Similar to the study carried out in Lalbagh garden of Bangalore[9], among the different growth forms of lichens, the IBG exhibit dominance of crustose lichens (21 out of 25 species), which are more tolerant to air pollution followed by foliose and fruticose forms[10]. Further, pollution-tolerant crustose lichens act as pioneer colonizer in a new environment and replace sensitive species.

Das *et al.*[11] in the year 1986 indicated that the central zone of the IBG holds a congenial atmosphere for healthy growth of diverse lichen species in comparison to the heart of Kolkata city. In the present study only eight species of lichens are reported from boundary areas of the Kolkata city, while the IBG area exhibits the maximum diversity of lichens represented by 15 species. The dense tree vegetation, together with its situation along the Hoogly river and less vehicular traffic load provide the garden area a more moist habitat suitable for many lichen taxa to grow. The westerly winds from the moisture laden sea breeze are cleaner and support a variety of lichens taxa to colonize on different substrates. The lichen flora of Kolkata exhibit similarity to the lichens of the nearby eastern Himalayan and Sundarban areas with exuberance of graphidaceous and pyrenocarpous lichens.

It is interesting to note that recently the SO_2 and NO_2 pollution levels are down in the Kolkata city. The SO_2 and NO_2 content in the air have shown reduced trends (SO_2 from 7.0 $\mu g/m^3$ to 4.0–2.75–3.5 $\mu g/m^3$; NO_2 from 79 $\mu g/m^3$ to 68–42.25–31 $\mu g/m^3$) during the year[12] 2001–2004.

Under the condition of falling SO_2 levels, recolonization of lichens starts due to species returning. Significant enhancement in the lichen flora on trees, including the reappearance of foliose and fruticose species can be used to determine the speed at which mean SO_2 and NO_2 levels in an area have fallen[13]. However, in the case of Kolkata species return cannot be expected as the city streets are almost devoid of trees while one hopes that in future IBG may re-host the lost species. The present number and distribution of lichen species in Kolkata will be a baseline record for carrying out future biomonitoring studies in the area.

1. Richardson, D. H. S., *Pollution Monitoring with Lichens*, Richmond Publishing Co Ltd, England, 1992, p. 76.
2. LeBlanc, F. and Rao, D. N., *Bryologist*, 1973, **76**, 1–19.
3. Upreti, D. K., Nayaka, S., Tandon, J. and Bajpai, A., *Phytotaxonomy*, 2005 (in press).
4. Das, T. M., Guha, N., Majumdar, S., Samim, K. A., Roy, S., Das, G. and Das, A. K., *Indian Biol.*, 1986, **18**, 26–29.
5. Nylander, W., *Flora*, 1867, **50**, 3–9.
6. Awasthi, D. D., *Catalogue of the Lichens from India, Nepal, Pakistan and Ceylone*, Beihefter zur Nova Hedwigia, Heft 17, Weinheim Verlag Von J. Crammer, Germany, 1965, p. 137.
7. Upreti, D. K., *Environ. Conserv.*, 1996, **22**, 362–363.
8. DeWitt, T., *Epiphytic Lichens and Air Pollution in The Netherlands*, Biblio. Lichen. 5. J. Crammer, Germany, 1976, p. 226.
9. Nayaka, S., Upreti, D. K., Gadgil, M. and Pandey, V., *Curr. Sci.*, 2003, **84**, 674–680.
10. Gilbert, O., in *The Lichens* (eds Ahmadjian, V. and Hale, M. E.), Academic Press, New York, 1973, pp. 443–472.
11. Das, T. M., Roychowdhury, K. N. and Roy, S., *Indian Biol.*, 1986, **18**, 1–10.
12. *Times of India*, Industrial Pollution Down in Kolkata, 7 February 2003.
13. Hawksworth, D. L., *Bot. J. Linn. Soc.*, 1989, **100**, 99–109.

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