mental pollution of the Kolar gold field area.

About 6 years ago, an Australian company came up with a project of recovering the residual gold (0.75 g/tonne) from the mill tailings by *in situ* heap leaching technology. However, due to the proximity of these dumps to the dwellings of workers, etc. the project did not materialize.

Now that BGML has abandoned its mining and metallurgical operations since January 2000, there is nothing anybody can do. The people in and around Kolar gold fields have to coexist with the dumps and tolerate its nuisance until a new solution is found. The Building Research Institute at Roorkee may have some answer for the utilization of these sands.

1. Gowda, A. M. S. and Shenoi, B. V., Bharat Gold Mines Ltd (BGML), Centenary Souvenir, 1980, pp. 43–45.
2. Devaraj, V. G., BGML Centenary Souvenir, 1980, pp. 104–106.
3. Ganapathi Prabhu, K. in National Seminar on Recent Development in Exploration, Exploitation of Minerals in India, Mining, Geological and Metallurgical Institute of India, 1990, pp. 165–166.

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Response

Para 1 of the article by J. V. Subbaraman confirms the prevalence of environment pollution hazard. It also substantiates the same, not only on the mine workers, but also on the local population living at a considerable radius surrounding the mining area, where the mill tailings are heaped as dumps.

Para 2 identifies pneumoconiosis (lung diseases), which is invariably associated with the respiratory system of all living beings. As far back as from 1917, various miners' diseases resulting from the gold mining by milling process are being studied and identified by the National Institute of Miners' Health founded at site in the Kolar Gold Field.

Afforestation efforts towards retarding the environment pollution hazard, affirm the pollution hazard – a very expensive scheme, but not yet a permanent remedy. The major constituents of the mill tailings being about 55 to 60% of silica dust and the balance also of other amphibole minerals, establish the fact that lung diseases are caused by inhalation of the silicious dust. (ref: Souvenir of the 50th year of Independence – 1997).

Coming to bulk productive utilization of the tailings, the technical feasibility of developing the puzzolonic characteristics is in consonance with our scheme. Only the research and experimentations are conducted in the wrong direction by the Cement Research Institute of India, with support from Bharat Gold Mines Ltd, as a S&T project. As far back as in 1974 we had suggested the scheme for the same, since fast-consumption of the tailings is the only permanent solution.

The statement that the total mill tailings generated over the past 120 years is only 35 million tonnes, of which only one million tonne is lost by denudation, is not correct. The historical gold production data of the Kolar gold mines are: 51.124 million tonnes of ore are milled and gold produced is 800.3 tonnes, as furnished by the Indian Bureau of Mines for the total period of a little over 120 years, ending on 31 March 2000.

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Musical notes from a veena

The musical notes produced on stringed instruments like the veena, are based on the physical and mathematical formulations associated with the vibrations of stretched strings. Such instruments operate over a vibrational frequency range of perhaps 60 to 1000 Hz in the fundamental, spanning over about four octaves. An octave is a range over which the frequency doubles, for example, 60 to 120 Hz, 120 to 240 Hz and so on, and in a veena, twelve notes are placed within an octave. The frequency span of 60 to 1000 Hz is covered with four tensed wires spread along the length of the veena.

The layout of a veena and a schematic of each of its wires are as shown in Figure 1 *a* and *b*, respectively. The wires rest over a curved metallic surface called the bridge, located on a resonator on the right and over a cross bar, fret, on the left. There are additional twenty-four frets spread out over ¾ length of the wire and their mutual separations-geometrically decrease to the right. Pressing the wires against any of these frets and plucking them on the resonator side produces a distinct musical note. l_0 is the total length of the wire; l_1, l_2, etc. are lengths to the 1st, 2nd, etc. frets, respectively, as shown in Table 1 (row 1). Lengths up to l_{12} only are included here for clarity.

Any book on musical science[1] states that the total length of the wire, l_0, when properly tensed and plucked, will produce the fundamental musical note Sa; l_1 will produce Ri$_1$; l_2 will produce Ri$_2$ and so on, as shown in Table 1 (row 3), with l_{12} producing Ṡa, which incidentally happens to be same as the second harmonic associated with Sa of l_0. The notes between l_{12} and l_{23} are designated by Ṡa Ṙi$_1$ …Ṅi$_3$, etc. Notes lower than Sa are designated by Ṣa, Ṛi, etc.

The values of the lengths of the wires l_o to l_{12} can be calculated[1] using a mathematical relation

$$l_{n+1} = (l_n/2^{1/N}) = \{l_0/2^{(n+1)/N}\}, \qquad (1)$$

where N is the number of subdivisions interposed between Sa and Ṡa, or the number of notes contained in an octave and n are corresponding integer numbers. Table 1 (row 2) lists these values for l_0 = 100 cm and $N = 12$.

The following 'approximate' relations between the various lengths are readily verifiable:

$$l_{12} = l(\dot{\text{S}}\text{a}) = 0.5\ l_0 = (1/2)\ l_0 \qquad (2)$$

$$l_6 = l(\text{Ma}_2) = (l_0 l_{12})^{1/2} \qquad (3)$$

$$l_7 = l(\text{Pa}) = 0.67\ l_0 = (2/3)\ l_0 \qquad (4)$$

$$l_5 = l(\text{Ma}_1) = 0.75\ l_0 = (3/4)\ l_0 \qquad (5)$$

$$l_4 = l(\text{Ga}_3) = 0.8\ l_0 = (4/5)\ l_0 \qquad (6)$$

$$l_2 = l(\text{Ri}_2) = 0.89\ l_0 = (8/9)\ l_0 \qquad (7)$$

$$l_0 = l(\text{Sa}) = l_0. \qquad (8)$$

A few more exercises with relations (1)–(8) using a calculator, will show some interesting results.

a) If any fret is taken as the reference instead of the first one as above and the calculations are pursued, the relations (1)–(8) are found to be similar everywhere, i.e. $l_{13} = l$ (Ṙi$_1$) = (1/2) l(Ri$_1$) = ½ l_1 = $(l_0/2^{(13/12)})$ and so on.
b) For various values of N, the approximations involved in relations (1)–(8) will be found to be closest for $N = 12$ and 24. For N values greater than 26, the subdivisions get so close to each other, that overlapping approximations result in confusing equalities.
c) Only the values of $N = 12$, 24 and 22 (values over 26 are ignored) satisfy the relations corresponding to (1)–(8) above, jointly. (It seems, Bharatha was not satisfied with $N = 12$ and has proceeded further to arrive at $N = 22$.)
d) $N = 17$ gives numbers that satisfy the relations (2) and (4) satisfactorily. (It seems ancient Arabian music[1] was centred around $N = 17$.)

What is the significance of these approximate relations? We refer to a textbook on physics[2], with a chapter on vibrations of stretched strings. If a stretched string is plucked, it produces a sound wave in the air around with a fundamental wavelength λ_1, that is proportional to the length of the string, l. It also produces a second harmonic sound with $\lambda_2 = \lambda_1/2$ that is proportional to 1/2 l as well as 3rd, 4th and 5th, etc. harmonics, with wave lengths proportional to the respective fractional lengths of the string. Consequently, it is obvious that plucking the veena wire for Sa also produces a Ṡa as second harmonic, a Ṗa as third harmonic, (for l(Ṗa) = l_{19} = (1/2) l (Pa) = (1/2) (2/3) l (Sa) = (1/3) l) and S̈a, G̈a$_3$, etc. as fourth, fifth, etc. harmonics. Similarly, plucking the wire for Ri$_1$, produces the harmonics, Ṙi$_1$ as the second, Dḣa$_1$ as the third, and so on.

For each fundamental note produced on the instrument within the musical scale, numerous higher harmonics, which are produced simultaneously,

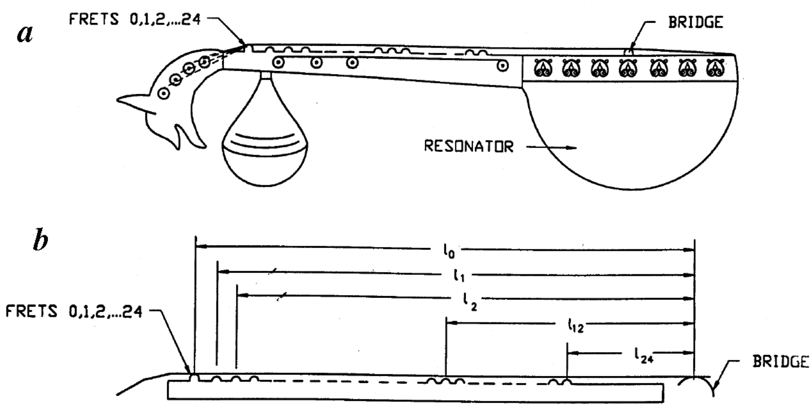

Figure 1. ***a***, Typical layout of a veena; ***b***, schematic of a veena wire.