Results & Discussion

Elemental composition of Lichen thalli in Parmelina (Parmelia) Leptogium and Usnea :

As it is known that the lichens are made up of phycobionts and mycobionts and it is also known that the lichen is one of the extremely slow growing plants and its requirements are minimum, the lichenologist prior to 1950's did not pay much attention to the importance of the mineral constituents in the growth and the development of lichen. At the end of 1950's when it was discovered that the lichens accumulate radionuclides, the importance of this aspect was appreciated. At the beginning of the 1960's several investigations of environmental radioactivity in the arctic region of Scandinavia and Alaska showed that, in animals and man there is high body burdens of strontium-90 and Cesium-137. This is due to the food chain and that leads from lichen through reindeer or caribou to Lapps and Eskimos. These observations resulted in several studies on lichens which are the first link of the food chain. Early investigations determined the radionuclide contents of lichens and compared these to the concentration found in other plants. Later studies were concerned with the radionuclides distribution in the lichen thalli and the retention and elimination rate of radionuclides from the thallus. These studies made it possible to predict future development of radionuclide levels in the biosphere and to evaluate the total radiation dose for man through food chains starting with lichens (Tuominen and Jaakkola, 1973).

Since the time that the lichens are known to accumulate the most hazardous chemicals, the radionuclides, it has been looked upon as a pollution indicator. One feature which makes lichens highly suitable organisms for pollution monitoring is the appearent absence of impermiable cuticular material. This feature coupled with the lack of well developed root system analogous to that of higher plants means that the atmosphere is the major, if not the exclusive source of cation for lichens (Brown, 1976).

One of the first investigations in this direction has been of J enkins and Davis (1966). Today there are number of publications which bring out the mineral composition of lichen thallus and its corelation with air quality or the environment around (Czehura, 1977; Doyle et al., 1973; Brown, 1976, Garty et al., 1977; Pilegaard, 1978 and Puckett and Finegan, 1980; Solberg, 1986; Van Haluwyn et al., 1986). The major emphasis of all following investigations is on the environment around the lichens.

1. Sodium and Potassium :

These monovalent cations although apparantly dealt together from the point of view of their position in the periodic table, their physiochemical as well as their electrolytic properties are quite different. Paradoxically Na^+ in plants is mostly a non-required element while K^+ is an indispensible element. And so far as plants are concerned large quantity of K^+ is absorbed against Na^+, perhaps even in plants of saline environment. Nevertheless the earth concentration of Na^+ is so high as to even salinise the water of the sea !

These elements that have been analysed from the thalli of Usnea ghatensis, Parmelina (Parmelia) wallichiana and Leptogium cyanescens are given in the Table 2 and also in Figure 2. It is clear from the Table that there is no variation in the Na^+ contents of Usnea and Parmelina (Parmelia) while Leptogium exhibits $1\frac{1}{2}$ times high amount of sodium in the thallus. As such , 159 and 216 mg 100 g^- dry tissue of Na^+ respectively in Usnea, Parmelina (Parmelia) and Leptogium itself appeared to be very high looking to the importance of this element. This reflects on the possible 'packing up' of this element from the atmosphere.

So far K^+ is concerned the three species appeared to be distinct in their thallus composition. As indicated in the Table 2 and Figure 2. Usnea has 129.6, Parmelina (Parmelia) has 388.8 and Leptogium has 325.2 mg 100 g^- dry tissue is extremely variable. In other words Parmelina (Parmelia) has highest K^+ content in the thallus followed by Leptogium, while Usnea has less than half that of the formers, and yet all the three species are growing more or less in the similar environmental conditions.

Table-2

Analysis of Inorganic constituents from three different lichens growing on the bark of tree plants of Sahyadri Ghat.

Elements	LICHENS		
	Usnea ghattensis	*Parmelina (Parmelia) wallichiana*	*Leptogium cyanescens*
Sodium (Na)	159.0	159.0	216.0
Potassium (K)	129.6 ± 0.03	388.8 ± 0.016	325.2 ± 0.016
Calcium (Ca)	4.31 ± 0.03	2.68 ± 0.016	1.81 ± 0.016
Manganese (Mn)	3.0 ± 0.0	10.5 ± 0.016	44.6 ± 0.016
Iron (Fe)	187.8 ± 0.016	352.8 ± 0.046	897.6 ± 0.039
Copper (Cu)	0.85 ± 0.016	1.45 ± 0.016	4.74 ± 0.016
Sp. Nikel (Ni)	2.81 ± 0.016	3.31 ± 0.016	4.60 ± 0.03
Cobalt (Co)	1.25 ± 0.016	1.91 ± 0.0	2.4 ± 0.016
Cadmium (Cd)	0.20 ± 0.016	0.23 ± 0.0	0.20 ± 0.0
Chromium (Cr)	3.93 ± 0.03	4.91 ± 0.03	3.84 ± 0.03
Zinc (Zn)	6.5 ± 0.016	8.8 ± 0.03	11.0 ± 0.03
Lead (Pb)	2.93 ± 0.03	3.28 ± 0.03	2.93 ± 0.016
Lithium (Li)	0.016 ± 0.0	0.049 ± 0.0	0.21 ± 0.12
Rubedium (Rb)	0.41 ± 0.03	1.04 ± 0.1	1.31 ± 0.083
Gold (Au)	0.88 ± 0.13	0.86 ± 0.1	0.91 ± 0.083

Values expressed are mg 100^{-1} g of dry tissue.

± S.E. of the [illegible]

Although it is difficult to attribute this quantitative difference in the accumulation between the species to the environment, all the same it can be referred to the inherent ability of these species for preferential absorption both from the atmosphere as well as from the bark through rhizoidal structure.

Correlative study of the mineral composition of lichen thalli and the substratum hitherto known is mainly to rocky substratum (Jaakkola et al., 1967; Jaakkola, 1969; Puckett and Finegan, 1980). Even the recent publication by Van Haluwyn et al. (1986) corelates the concentration of mineral such as Ca^{+}, K^{+} and Mg^{2+} in sexicolous and calcicolous lichens with of soil substratum. One of the recent studies carried out by Jagtap (1985) on the mineral composition of Parmelia simplicior, Leptogium azureum, he tried to correlate the mineral composition of the lichen with that of substratum i.e. the bark of the respective trees over which these lichens grow, and reported that there is no apparent correlation between the content of the two.

2. Calcium :

This divalent element has great significance in the metabolism of plants and animals; more so in plants as it makes an integral component of cell wall besides its requirement in number of cellular metabolic reactions. It is a non-toxic element belonging to major group of the biological system. Although Ca,

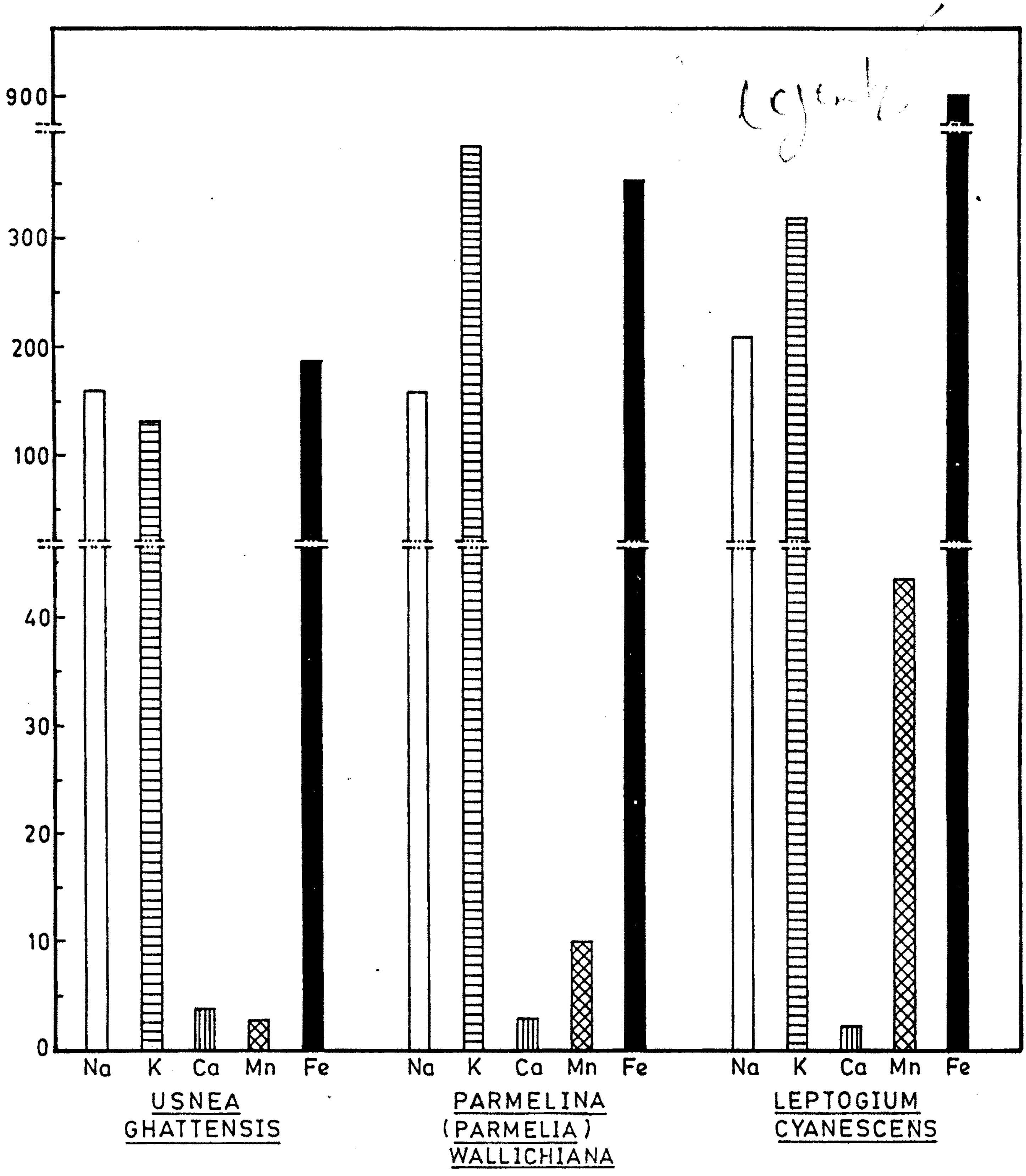

Fig. 2 – HISTOGRAM SHOWING Na, K, Ca, Mn, Fe CONTENTS IN THE THALLI OF *U. ghattensis* *P. wallichiana* AND *L. cyanescens* .

is similar to Mg in property it greatly differs and it is also larger than Mg.

The analytical data presented in the Table-2 as well as in Fig.-2.of Usnea ghatensis, Parmelina (Parmelia) wallichiana and Leptogium cyanescens indicate that there is no greater variation in the composition or content. The values are respectively 4.31, 2.68 and 1.81 mg/100 g dry tissue which is in the decreasing order of magnitude. Nevertheless, this order does not establish any seeming relation with either environment or interrelationship between these groups but for the metabolic requirement of the individual plant. In other words Usnea requires more Ca^{2+} than Parmelina (Parmelia) and Parmelina's (Parmelia) requirement is simply more than that of Leptogium for all these are growing in more or less, same environment and are collected from the same localities.

Higher calcium content in Parmelina (Parmelia) than that in Leptogium has been observed by Jagtap (1985). He attributed this phenomenon to the phycobiont associated with them that the Parmelina (Parmelia) has green algae which in the Leptogium, it is cyanobacteria i.e. blue green alga. And the basic structural difference between the cell wall of phycobiont might be making the difference. Although the present observation is in conformity with that of Jagatap (1985) the reason appears to be unfounded for Usnea has also green alga as phycobiont, and secondly, the quantitative difference between the values reported by Jagtap (1985) and that reported here is of the order of sky and earth and hence does not warrant any discussion. On the contrary the calcium content reported in present investigation casts doubt that whether the plants are suffering from deficiency.

Tuominen and Jaakkola (1973) while compiling the reports of mineral constituents of number of workers have shown that there are reports of calcium as low as 26 ppm and as high as 9640 ppm. These differences are extremely wide but at the same time are inexistent. The fact that large quantity of minerals, are passively taken in and accumilated it is difficult to distinguish which part is biologically active and which is not.

In an experiment to demonstrate passive mineral absorption by lichen thallus under laboratory condition. Brown (1926) showed that even trace elements and unessential toxic elements, such as Lead, Copper, Zinc, Nickel and Cobult are accumulated improportionately indicating that the process is rather passive than active.

It may be concluded that since the forest area is inhabitated by human activity obveously the analytical data shows the genuine requirement of the types rather than external passive absorption.

3. Manganese (Mn) :

This element belonging to trace element group, similar to that of iron, is a very important one in the plant metabolism. However, iron and manganese have antagonistic relation so far as their entry accross the membrane is concerned. Although it does not participate as a prosthatic group in many enzymatic reaction like that of iron, its participation is in the key metabolic events.

The analytical data of the thalli of Usnea ghatensis, Parmelina (Parmelia) wallichiana, Leptogium cyanescens are given in the Table-2 and Fig.-2. The values for these three species respectively are 3.0, 10.5 and 44.6 mg/100 g dry tissue. It is evident from the data that the values are in the increasing order of magnitude. Nonetheless they have no seeming relationship of each other. Moreover, these three species have been growing side by side perhaps on the same tree or on different trees. The Mn content in the Parmelina (Parmelia) is three times more than that of Usnea, while that in Leptogium is four times higher than that of Parmelina (Parmelia). Tuominen and Jaakkola (1973) compiling the results of various workers have shown that the Mn content as per dry weight basis ranged from 2.5 ppm to 10,000 ppm. In other words it is ranging from negligibly small quantity as expected of a trace element to highest value of 10,000 ppm which in normal case of plant is of highly a toxic level. Jagtap (1985) while studying seasonal variation in Mn content of Thalli of P.simplicior and L.azureum recorded the range of variation in the former from 5.97 to 9.32 to 11.06 mg/100 g dry tissue from rainy season to winter to summer, and in the latter 19.59 to 17.59 to 24.69 mg/100 gm dry tissue consecutively in three seasons. In other words overlooking the season the range of variation in the Mn content of these two species is 5.9 to 24.6 mg/100 g dry tissue which is quite expected of Mn requirement of a plant. Even the change of season did not inflict greater fluctuation in these species. Where as, the present investigation reflects on the fact that amongst the three species, Usnea accumulated lowest amount of 3 mg/100 gm dry tissue and highest of 44.6 mg/100 gm dry tissue is accumulated by Leptogium. These values do not warrant either deficiency or toxicity.

Puckett and Finegan (1980) have investigated the mineral constituents of Cladonia and Cetraria, the terricolous lichens, and reported that, the range of variation of Mn in the former is 13.2 to 22.2 ppm and in the latter it is 84.5 to 86.0 ppm. The reason about the moderately high content of Mn in the Thalli of these genera has been given as, these Lichens are absorbing from the substratum. Yet there are certain reports where the variation in the manganese level is as high as 2.5 to 27 ppm.

The fact that Usnea has low Mn content while other two have high content of Mn can only be attributed to the requirement of the species and then relationship with substratums and the environment. As it has already been indicated that the Lichens have the tendency to accumulate wanted and unwanted elements in their Thalli, it is difficult to identify whether high level of mineral in the organ is a result of passive absorption or it is the requirement of the plant.

4. Iron (Fe) :

As discussed earlier Fe is a very important member of trace element group from the point of view of cellular metabolism. Number of bio-chemical reactionsthat we examine have the participation of Fe as prosthatic group. If the Mn is required in photosynthesis and such other key reactions, the participation of Fe is found in almost every key reaction of cellular metabolism. The deficiency of Fe is readily expressed by the plants, while the deficiency of Mn often is undiscernible. The analytical data of the three genera Usnea, Parmelina (Parmelia) and Leptogium investigated here are given in the Table-2, Fig.-2 and the values respectively in three species are 187.8, 352.8 and 897.6 mg/100 gm dry tissue. One can see from these data that there is a range of variation in these three species similar to that of range of variation of Mn in these three species. However, the magnitudinal difference between Mn and Fe content in these three species, if compared is in the geometrical proportion. *Parmelina* (*Parmelia*) has almost double the content that of *Usnea* and the *Leptogium* has two fold as high Fe content as of *Parmelina* (*Parmelia*).

The compilation table of the results of various workers given by Tuominen and Jaakkola (1976) records as high as 78000 ppm and as low as 3.16 ppm (expressed as % oxides). year ?

Such a high range of variation of a trace element is almost unexplainable from the metabolic point of view. As a matter of fact, although Fe participates in number of biochemical reactions and its requirement is indispensible, it is always found in traces in the order of 10 to 100 ppm in plants. Beyond this concentration is only attributable to the passive accumulation, perhaps from the atmosphere.

Jagtap (1985) while studying the mineral content of *Leptogium azureum* and *Parmelina* (*Parmelia*) *simplicior* and the seasonal variation from rainy season to winter to summer recorded Fe content minimum of 346.28 mg/100 gm dry tissue in *P.simplicior* during rainy season and maximum 1090.14 mg/100 gm dry tissue in *L.axureum* during summer. These variations have sp ? no seeming relations with the season he concluded.

In the present investigation, therefore, the highest value 897.6 mg/100 gm dry tissue of Fe in the *Leptogium* and the lowest value 187.8 mg/100 g dry tissue of Fe in *Usnea*, has no seeming relation with the nutritional requirement of these Lichens; but it is due to simple passive accumulation either from the atmosphere or possibly absorbed from the bark. It can be concluded from the result that Leptogium, possibly has greater ability to accumulate the minerals, than the other two. In this ability if the three Lichen genera are to be arranged in the increasing order of magnitude it may be L.cyanescens > P.wallichiana > U.ghatensis the ability to accumulate minerals in the above order of magnitude is also applicable to other minerals. In other words if this phenomena is applied to the ability of pollution indicator Leptogium can be considered as the most sensitive indicator for it accumulates almost all minerals occurring in the atmosphere or in the substratum. In support of our observation are the findings of Jagtap (1985) where he showed that L.azureum accumulated as high as 1090.14 mg/100 g dry tissue, which is another species of Leptogium.

5. Copper (Cu) :

Copper also belongs to trace element group, however, its requirement to the plant is really in trace. The high copper content is likely to cause toxicity in plants and animal. Its essentiality is realised as an important cofactor in certain key, enzymes. It is also required during photosynthesis. The analytical data of copper in the three species investigated are given in the Table-2 and Fig.3. U.ghatensis as 0.85 mg, P.wallichiana has 1.45 mg/100 g dry tissue while

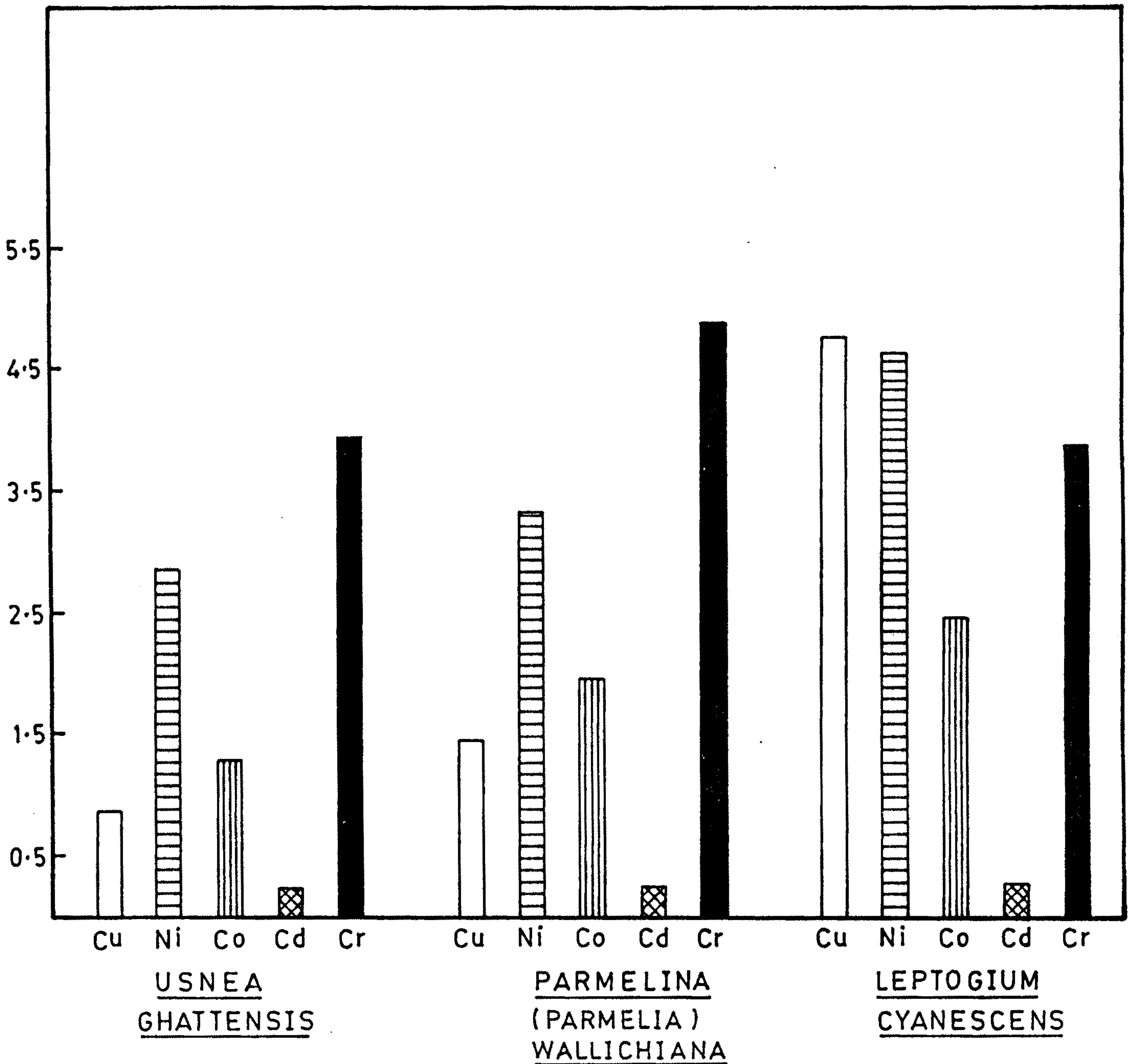

Fig. 3 – HISTOGRAM SHOWING Cu, Ni, Co, Cd, Cr CONTENTS IN THE THALLI OF *U. ghattensis* *P. wallichiana* AND *L. cyanescens*.

in *Leptogium cyanescens* it is 4.74 mg/100 g dry tissue. Even in the case of copper, *Leptogium* has the highest value followed by *Parmelina* (*Parmelia*) which in turn followed by *Usnea*. While listing the analytical data of biologically significant metals in *Lichens* reported by various workers Tuominen and Jaakkola have showed that there is as low value as 2.4 ppm and as high value as 3000 ppm. Jagtap (1985) has detected 1.4 mg/100 g dry tissue of copper in *P. simplicior* and 4.52 mg/100 g dry tissue in *L. azureum*. In these two species he did not find greater variation in copper content when he studied this aspect even seasonwise. The order of variation is about 1 to 1.5 mg/100 g dry tissue. Based on this, he concluded that the gelatinous Lichen *Leptogium* has greater copper level or in other words Copper accumulating ability than that of *Parmelina* (*Parmelia*) which contains *Trebouxia* as a phycobiont. He did not find any co-relation between copper content in the bark and that in the Thalli.

It is a general observation that the tissue level copper has always been low. Puckett and Finegan (1980) have analysed copper content from more than twenty representative genera of different sites in Canedian north west territories of Canada but did not find more than 8.5 ppm of copper. It is noteworthy to mention here that all these Lichens are terricose Lichens growing on rocks. In contrast to this the analytical data of copper in arctic Lichens reported by Tomassini *et al*. (1976)

as high as 480 ppm in the thallus. According to them this is an indication of wide departure in different species.

In an elegant experiment conducted by Brown (1976) to study the relative affinity of the Lichens for different cations he cultured Cladonia ranjiformis in the Copper solution of the concentration 1 mM and 0.1 M and the mixture of the different minerals such as lead, zinc, nickel, copper and cobalt; and concluded that firstly, with increasing concentration binding ability decreases, secondly, the relative ability of the Lichens for different cations, appears to be independent of concentration. He, while studying recovery of mixed Ion solution to the same species, concluded that the heavy metals are the individual preferences. A population growing in zinc rich area may exclude zinc and so on. But the heavy metals present have no competitive effect in uptake process. In other words it is totally the preferential process.

It is essential to mention here that in the process of passive absorption certain ion may not cause toxicity. However, the element such as copper has always been toxic. Puckett (1976) could clearly demonstrate that copper and mercury are toxic to Usnea and Ramelina as measured by depressed respiration. There are also reports on the metal toxicity in Lichen where photosynthetic membrane is affected, and overall growth has been reduced (Nash, 1975). Mathur and Sanderson (1980) have

year

shown that copper level of substratum is negatively correlated with Lichenase enzyme reflecting thereby copper toxicity affecting the enzymatic machinery of the organism.

In conclusion it may be said that may be because Copper is toxic, Usnea has low copper content which is 0.85 mg/100 g dry tissue while the gelatenous lichen Leptogium is able to accumulate relatively high proportion of Copper. Despite this variation the amount of copper content detected in the Thalli either of Leptogium or Parmelina (Parmelia) or Usnea does not appear to be toxic.

6. Cobalt (Co) :

Cobalt is another element belonging to trace element group whose requirement is essential in many metabolic reaction especially during nitrogen metabolism. As a matter of fact it is an integral component of enzyme of N metabolism just as Iron porphyrin in Haeme or Fe in cytochrome structural integrity. Therefore, generally its requirement to the plant is in the order of the one to few ppm. However, Tuominen and Jaakkola (1973) have listed the record where lichens accumulated Co from 3 to 100 ppm. Amazingly, reports on the accumination of Co by lichens are very few although we expect many for the reasons known to us. Our analytical data of elemental composition of the thalli of three lichens U.ghatensis, P.wallichiana and L.cyanescens given in the Table 2 and Fig.3 have recorded

Co respectively 1.25, 1.91 and 2.4 mg/100 g dry tissue which is quite well within the range of tissue expectation.

However, Jagtap (1985) after analysing the Thalli of P.simplicior, L.azureum one with green alga as phycobiont and other blue green alga as a phycobiont for cobalt reports that the former has 0.43 and the latter has 0.7 mg/100 g dry tissue. In other words both these algae have less than 1 mg/100 g dry tissue when he analysed the same element to study the seasonal variation in these Lichens even with the powerful tool such as atomic absorption spectrophotometer, Cobalt was not detectable. This indicates that apart from what the plant requires for its metabolism it is not even accumulated through atmospheric media. While on the other hand in the present investigation where another species of Leptogium is analysed we have been able to record 2.4 mg/100 g dry tissue of Co, it is already been indicated that cobalt is a part of complex structure of nitrogenase enzyme, and therefore, at least in the Lichens where cyanobacteria are there as phycobiont, one must be able to detect cobalt.

In an experiment to study the preferential uptake of ions from the substratum conducted by Brown (1976), he showed that Cledonea ranjiformas when cultured in 1 mM cobalt solution the recovery of ions from the plant tissue was 23.5 μ mol/g lichen. When the concentration was increased to 0.1 mole the recovery shot up to 54.1 μ mol/g lichen. In this experiment it was exclusively cultured in cobalt solution. But when the same was cultured in the mixture of Lead (Pb), Copper, Zinc, nickel and cobalt, both in the form of cobalt and nitrates the recovery drastically reduced. On the basis of this he concluded that the cobalt has least binding affinity or efficiency. And also he concluded that the selectivity is concentration dependant.

Now in the present investigation, it is difficult to know the source of cobalt for these Lichens are growing side by side in the same environmental condition. Instead of grading the relative affinity of Lichens for different cations we may arrange on the basis of ion concentration in the Thallus as follows <u>L.cyanescens</u> > <u>P.wallichiana</u> > <u>U.ghatensis</u>.

7. <u>Nickel (Ni)</u> :

Nickel is another member of micro-group whose requirement is in trace and less important than any of the earlier ones discussed. However, its prepondarance in the atmosphere is mainly due to automobiles. The three genera taken for the investigation, <u>U.ghatensis</u>, <u>P.wallichiana</u> and <u>L.cyanescens</u> for Ni content revealed that they have respectively 2.81, 3.31 and 4.60 mgs/100 g dry tissue of Ni which appears to be quite substantial from point of view of metabolism. Many lichen species investigated by various workers for elemental contents are comp iled by Tuominen and Jaakkola (1973). The range of variation among the population, so far as Ni is concerned 1.4 ppm to

3000 ppm. However, number of workers reporting Ni are relatively restricted.

A short term laboratory experiment to study the selectivity of ion uptake carried out by Brown included Ni also. When it was supplied singly in two concentration 1 mM and 0.1 M to Cladonia ranjiformis, as in the case of other metal ions so also here the uptake was proportionate with concentration. But when supplied in mixture with other heavy metal ions it was reduced. The degree of affinity absorption of the metal ions arranged in the order of magnitude showed that it preceded cobalt. In other words Ni is less bound by the Lichen.

Jagtap (1985) who investigated the elemental composition of P.simplicior and L.azureum showed that the former has 1.01 mg/100 g dry tissue Ni while the latter 2.26 mg/100 g dry tissue. However, by studying seasonal variation this metal could not be detected by him. Similarly Ni was also not traceable on the bark of the respective tree which sustained these Lichens. In contrast to his findings in the present investigation in all the three Lichens, it could be detected and if they are arranged in the order of magnitude Leptogium > Parmelina (Parmelia) > Usnea. In the absence of the study of the bark over which these Lichens grew it is not possible to know where from there Lichens are absorbing these ions.

missing Jacob (1987) carried out an experiment with transplantation of Ramalina duriaei to different high monitoring sites of pollutions for one year and analysed the Lichens for various metal ions including Ni. Although not all the metal ions could be detected in the Lichen Thallus a good correlation between proportionate increase in the amount of some metal with increase in the total number of motor vehicles passing by could be established in which Ni and Pb were there. On the basis of this he concluded that there metal ions are mainly emitted by the vehicle as pollutant.

In the present investigation it is difficult to establish such type of correlation between the automobiles, emission and Ni content of Lichens. One thing is true that Leptogium is an extremely sensitive Lichen for metal and therefore, besides other metal ions even Ni is absorbed in high quantity.

8. Chromium (Cr) :

Chromium is also a member of the micro element group quite dispensible with and required in a very small trace. This heavy metal however, is one of the metal pollutants found in the atmosphere, because it is an emission product of automobile; and is also toxic in high concentration. The analytical data compiled and presented by Tuominen and Jaakkola (1973) reveal that it ranged from 0.6 to 1000 ppm in various Lichens analysed. Our analytical date of Cr in three Lichens U.ghatensis, P.wallichiana and L.cyanescens revealed that they contained

3.93, 4.91, 3.84 mg/100 g dry tissue Cr respectively. Unlike other elements this element is accumulated in greater quantity by Parmelina (Parmelia) and relatively in less amount by Leptogium. However, Leptogium does not have greater affinity for this metal. Jagtap (1985) who carried out the analytical investigation of Cr.in P.simplicior and L.azureum could not detect the same while in both Parmelina (Parmelia) and Leptogium relatively high amount of this metal ion could be detected in the present investigation. This leads to state that change in the locality is the main difference rather than the efficiency of binding of these ions by the Lichen species.

Several Lichens analysed from various country such as Turkey, Greek, Colarado in 1962 by Leroy and Koksoy led them to show the increasing accumulation of there heavy metals in Thalli of there Lichen. They included Cu, Cr, Pb, Mo and Zn. These heavy metals are mainly emerging through automobile emission and the Lichens served as the best indicator (Cf. Tuominen and Jaakkola, 1973).

9. Zinc (Zn) :

Zinc is a very important member of the microelement group which is required for metabolism of essential hormones auxins and number of secondary metabolites. Similar to that of other trace elements such as Mn, Mo, this element is also required in small quantity of an order of a few ppm. Zn has

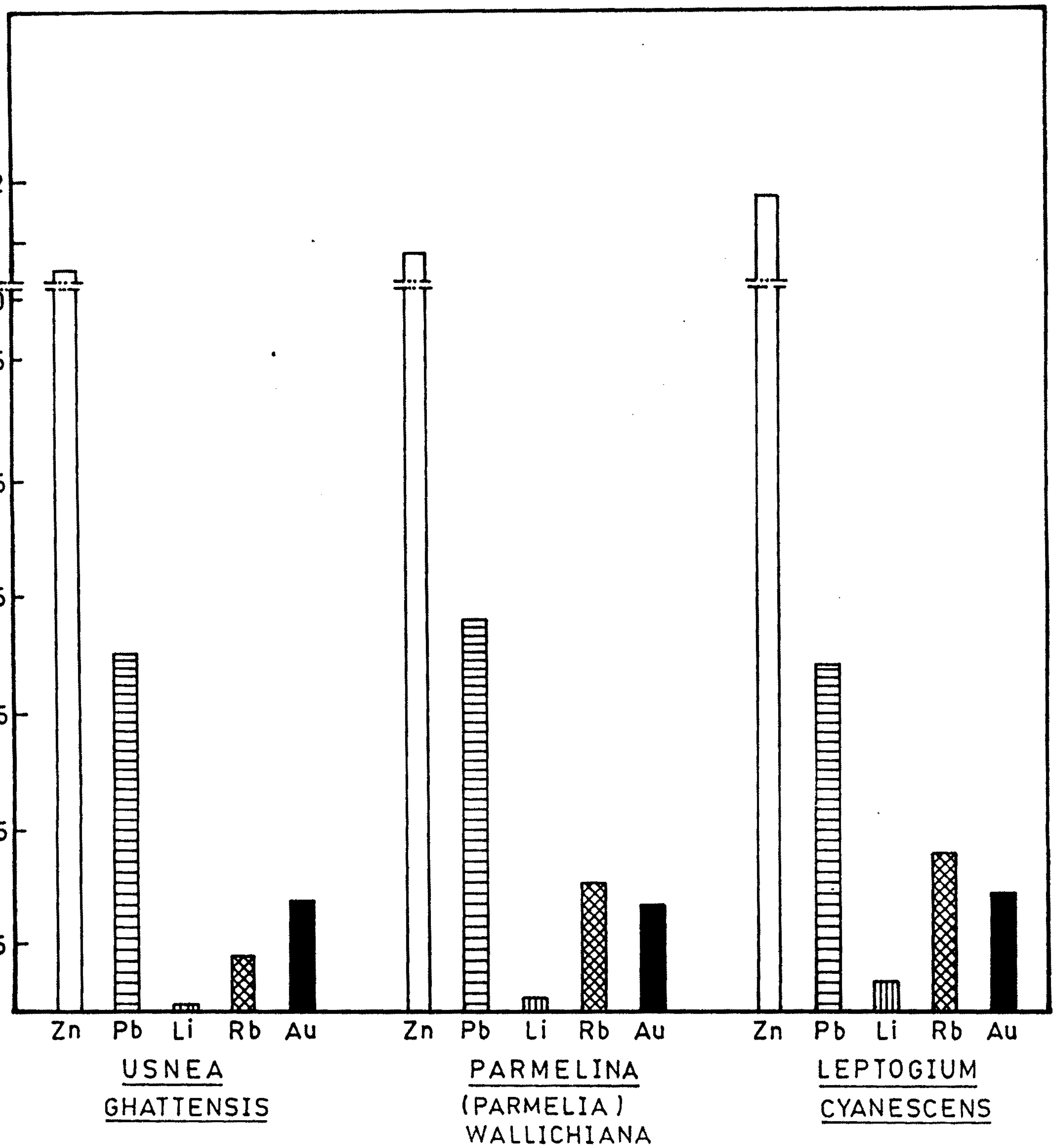

Fig. 4 – HISTOGRAM SHOWING Zn, Pb, Li, Rb, Au CONTENTS IN THE THALLI OF U. ghattensis P. wallichiana AND L. cyanescens.

also been analysed from the Thalli of three lichens genera and presented in the Table 2 and Fig.4. It is found that U.*ghatensis*, P.*wallichiana* and L.*cyanescens* have respectively 6.5, 8.8 and and 11.0 mg/100 g dry tissue. In other words *Leptogium* has highest detectable amount of Zn followed by P.*wallichiana* and relatively low amount is detected in U.*ghatensis*. Nonetheless, in comparison with other trace elements Zn accumulation is very high in all the three lichens.

Accumulation of Zn by Lichens has been widely reported. Tuominen and Jaakkola (1973) in their compilated report showed that the tissue load of Zn ranged from 20 ppm to 93400 ppm. This range of variation is enormously wide. According to them several species of lichens accumulate exceptionally high amounts of Zn. Lounamaa (1965) reported that saxicolous lichen *Umbilicarea pustulata* accumulated 1.67% of the ash. This indicates an efficient mechanism for selective uptake of Zn.

Again referring back to the elegant experiment of Brown (1976) where he studied selectivity of ion absorption by *Cladonia rangiformis* he showed that greater affinity is for Pb and is followed by Cu and is followed by Zn.

Jagtap (1985) reported 13.92 and 28.27 mg/100 g dry tissue of Zn in P.*simplicior* and L.*azureum* respectively. However, no greater variation in the Zn content with the variation in the seasons has been reported by him. Lawrey (1980) investigating the mineral cycling process in lichens and correlated the level of minerals with their environment and lichen herbivor has showed that there is considerable variation in the level of Zn relative to environment.

Exhaustive information is available on the toxic and deleterious effect of heavy metals on various metabolic events. Zn, therefore, is one of the heavy metal members which is known to cause purging off of important essential elements such as potassium (Puckett, 1974; Tomassini et al., 1976). In the present investigation the amount of Znn in any of the three genera does not appear to be very high so as to cause toxicity.

10. Lead (Pb) :

This element is an unessential element not belonging to any of the trace element or to the group of macroelement. Nonetheless Pb is one of the most toxic heavy metal elements reported to have been accumulated by the wide range of lichens. Pb mainly appears in the atmosphere as an industrial pollutant either through effluent or through automobile emission.

The analytical data of three lichens U.ghatensis, P.wallichiana and L.cyanescens are presented in the Table-2 and Fig.4. It reveals that Usnea has 2.93 mg/100 g dry tissue, the Parmelina (Parmelia) 3.28 mg/100 g dry tissue and Leptogium has 2.93 mg/100 g dry tissue. Although no many reports on the accumulation of Pb by various Lichens have been reported, based on available report Tuominen and Jaakkola (1973) have showed that the range of variation is 1.1 ppm to 3000 ppm. However, the Brown's experiment on selectivity of ion uptake in Cladonia rangiformis revealed that Pb is one of the most extensively absorbed elements. Among the 5 heavy metals studied singly in two concentrations of 1 mM and 100 mM and as a mixture with other metal elements in 1 mM concentrations revealed that the efficiency of Pb binding is highest. This indicates that whatever Pb that we detect in the lichens mainly arises from atmosphere.

Jacob (1987) studied the transplantation effect of a lichen Ramalina duriaci to different monitoring sites for 1 year and the amount of heavy metals such as Ni, Cr, Cu, Zn, Pb, Mn and Fe have been analysed and found that increase in Pb accumulation so as the other was in proportion with the increasing frequency of automobiles. This clearly indicates that Pb mainly occurs in the atmosphere through automobiles emission.

11. Lithium (Li) and Rubedium (Rb) :

These are the heavy metals and monovalent elements normally not required for the plant metabolism. However, Lithium always competes with Sodium and Rubedium with Potassium. These elements that have been analysed in the Thalli of three Lichen genera U.ghatensis, P.wallichiana and L.cyanescens are given in the Table 2 and Fig.4. In these three genera the Li value are respectively 0.016, 0.049 and 0.21 mgs/100 g dry tissue where as the Rb value are 0.41, 1.04 and 1.31 mg/100 g dry tissue respectively. Amongst the three genera the highest value of both Li and Rb could be seen in Leptogium, while the least value could be seen in Usnea. Similar to that in the case of other elements so also here selective absorption by Leptogium is more than the other two.

There are very few reports the listed by Tuomenin and Jaakkola (1973) about the accumulation of Rb and Li. However, so far as Li is concerned minimum value of 0.02 ppm and maximum of 0.29 ppm have been reported. And regarding the Rb it ranged from 2.4 to 24.6 ppm. In other words Rb value is much higher than the Li value. In the selective ion uptake by the Lichen our result is also in conformity with the one reported here. 89

Jagtap (1985) investigating the elemental composition of P.simplicior and L.azureum could detect Lithium only in trace, where as while studying the change of variation in the mineral composition of these Lichens with the changing season, he reported the Rb values in P.simplicior 2.28, 3.40, 3.2 mg/100 g dry tissue from rainy season to winter to summer, where as in L.azureum the same elemental value ranged from rainy season to winter to summer respectively 3.03, 6.03 and 4.78 mg/100 g dry tissue. In other words these values are relatively very high. Similarly Li values in these two lichens were less than 1 mg/

100 g dry tissue irrespective of the season with respective to Li. The situation similar to this is also same in present investigation. It is true that Li is dearer than Rb. However, amazingly these elements could be detected by him even in the bark, which sustained the Lichens and hence a correlation could be established.

These elements, as such, do not have greater biological significance, nor they are that abundant in the earth. Under the circumstances their occurrance in Lichens possibly is through atmospheric pollution which has been trapped by the Lichen. In the present investigation, therefore, it is difficult to understand that these Lichens are growing deep in the Kas forest but still exhibit relatively large quantity of it.

12. Gold (Au) :

Gold is a noble metal. This yellow metal does not have any biological significance in plants. In normal plants possibly the gold is not found even in trace but in the present investigation gold not only could be detected but detectediin very high quantity. The values are 0.88, 0.86, 0.91 mg/100 g dry tissue respectively in *U.ghatensis*, *P.wallichiana* and *L.cyananscens* (Table-2 and Fig.4). Even in the list compiled by Tuomenin and Jaakkola (1973) gold is not included. In other words it has not been possibly detected at all.

Jagtap (1985) while investigating the major metal ions in P.simplicior and L.azureum randomly sampled from various regions did not analyse gold nor it has been taken into consideration for seasonal variation study by him. However, while analysing the bark sustaining there Lichens he did analyse gold without detecting even in trace. Such a high proportion of gold, highest being in L.cyanascens, of the present investigation is difficult to explain in the absence of study with respective source as to whether it is coming from atmosphere or from the bark. The possibility of gold coming from bark is more probable simply because that there are no gold mines in nearby areas nor any automobile exhaust puts out in the atmosphere this yellow metal even in trace. It is an aspect worth contemplating as to where from such a large trace of Au is coming into the lichens.

13. Cadmium (Cd) :

Cadmium is another element unessential for the growth of the plant. Its occurrence in lichens, therefore, raises basic questions. In the present investigation Cd ions has been traced in all the three lichens. The results are presented in the Table-2 and Fig.4. The content in U.ghatensis is 0.20 mg/100 g dry tissue in P.wallichiana, it is 0.23 mg/100 g dry tissue and in L.cyanescens it is 0.20 mg/100 g dry tissue. Although the relative proportion of Cd in these lichens is not much higher so as to cause toxicity it certainly indicates that the atmosphere has this metal ion trace which is being accumulated by these Lichens deep inside the forest and possibly it comes in the atmosphere only through automobile exhaust. Jagtap (1985) in the earlier investigation could detect Cd, but in small quantity in P.simplicior while relatively more in L.azurium. The samples collected by him was mainly from Panhala and Mahabaleshwar where automobiles are more frequent. But the sample of present investigation is from Kas forest which is much deeper.