

Dry weight loss and changes in chemical composition of pine (*Pinus kesiya* Royle) needles and teak (*Tectona grandis* L.) leaves during processing in a freshwater lake

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Keywords: decomposition, *Pinus kesiya* Royle, *Tectona grandis* L., cellulose, hemicellulose, lignin, sugar, amino acid

Abstract

The dry weight loss and chemical changes during the process of decomposition of two types of litters viz., pine (*Pinus kesiya* Royle) needles and teak (*Tectona grandis* L.) leaves have been studied in a small freshwater lake using plastic net (1 mm pore size) bags. The results reveal that type of litter and depth of water were the most important factors regulating the rate of decomposition. The percentage composition of cellulose and hemicellulose showed little variation and only a minor fall was noted in their values towards the end of the study period. The lignin percentage increased steadily at all the stations except the deepest station. The sugar and amino acid concentration dropped appreciably during the initial phase and stabilised during later periods. The general trend of change in nitrogen percentage was initial fall - increase - fall - stabilisation at a near original value. The rate of decomposition was faster when compared with similar studies in Canada and Europe.

Introduction

The importance of terrestrial litters in nutrient deficient aquatic systems has been documented by various workers (Fisher & Likens 1973; Egglshaw 1964; Peterson & Cummins 1974; Thomas 1970). Most of the available studies deal with the woodland streams. The decomposition of terrestrial plant litters in lakes and ponds has received little attention (Hodkinson 1975; Gasith & Lawacz 1976; Gasith & Hasler 1976). The weight loss of litters has usually been found to be a good measure of the rate of decomposition (Olson 1963; Suberkropp *et al.* 1976), which is a function of the chemical nature of the material (Hodkinson 1975). Changes in the levels of soluble components (McConnell 1968; Lush & Hynes 1973), nitrogen (Kaushik & Hynes 1971; Howarth & Fisher 1976; Suberkropp *et al.* 1976), lignin (Triska *et al.* 1975; Meentemeyer 1978), cellulose and hemicellulose (Suberkropp *et al.* 1976) has been used as a measure of the degree of degradation

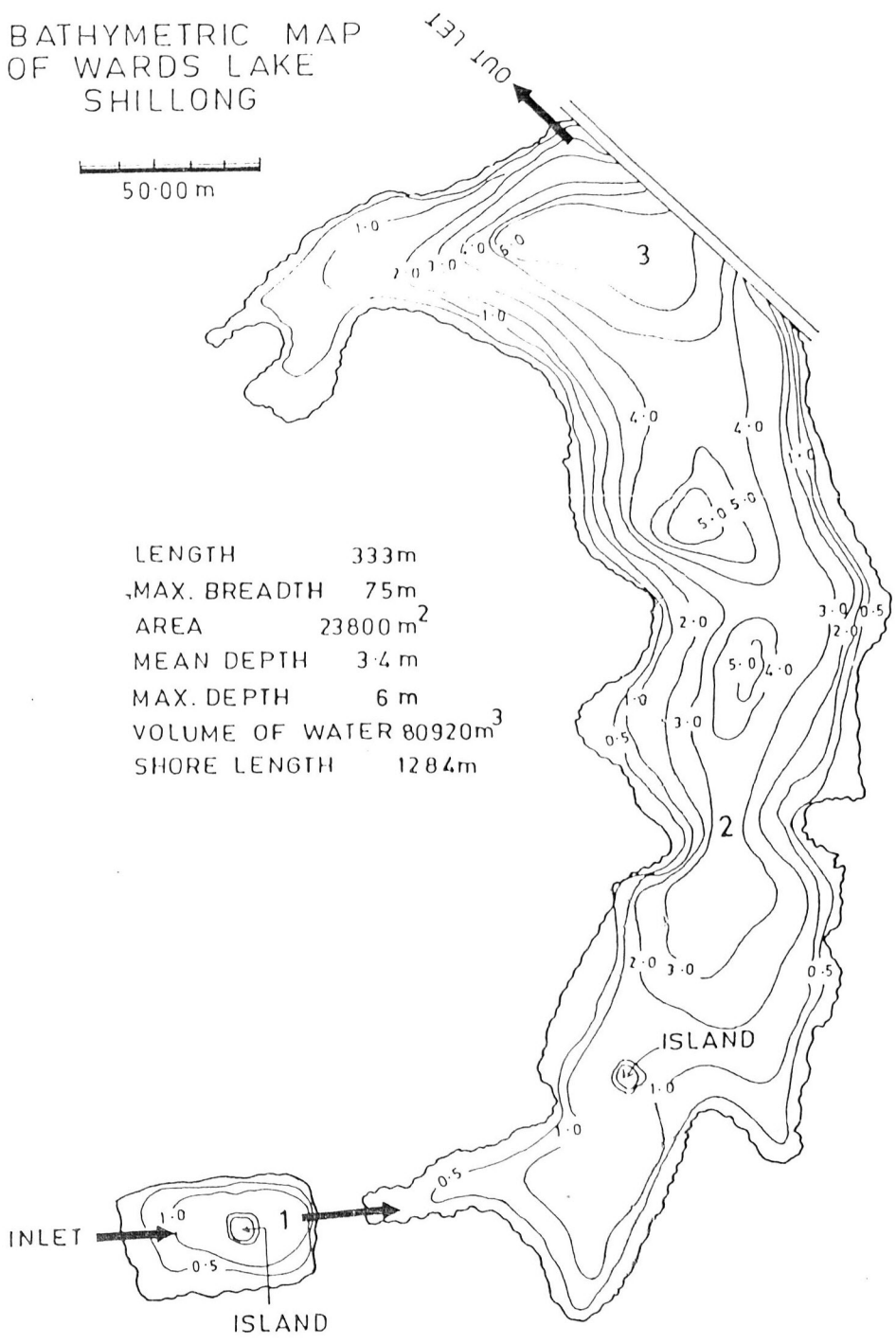
of plant materials.

This communication deals with dry weight loss and changes in the levels of cellulose, hemicellulose, lignin, sugar, amino acid and nitrogen of pine (*Pinus kesiya* Royle) needle and teak (*Tectona grandis* L.) leaf litters at three different depths in a shallow freshwater lake.

Study area

The study was conducted in Wards lake Shillong, India (Alt. 1460 m, Lat. 25°34'N, Long. 91°52'E). The slopes surrounding the lake are covered with dense managed grasses and scattered trees, predominantly pine (*P. kesiya*). The lake receives water inflow throughout the year and has a surface outlet which allows the excess water to flow out during rainy months. Throughout the year the water level does not change appreciably except during January - February when the level drops by ap-

BATHYMETRIC MAP OF WARDS LAKE SHILLONG



LENGTH 333m
MAX. BREADTH 75m
AREA 23800 m²
MEAN DEPTH 3.4 m
MAX. DEPTH 6 m
VOLUME OF WATER 80920 m³
SHORE LENGTH 1284m

Fig. 1. Bathymetric map and general morphometry of Wards lake, Shillong. Stations are shown by numbers 1 to 3.

prox. 30 cm. The bathymetric map and general morphometry of the lake is shown in Fig. 1. Stations are shown by bold numbers 1 to 3. Station 1 has a silty bottom, and profuse submerged growth of *Hydrilla verticillata* (Linn. P.) Royle. Station 2 is in the main body of the lake where the water depth is 3 meters and the bottom is rocky covered with gravel. Station 3 is 6 meters deep; the bottom is silt with a cover of semi-decomposed pine needles.

Materials and methods

Bulk samples of freshly fallen needles were collected from an area adjacent to the lake in March-April 1977. Senescent teak leaves were collected from a twenty-year-old forest plantation. All samples were air dried for three weeks and an oven dry (80 °C for 48 h) weight correction factor was determined. Five grams of air-dried litter was exposed in plastic bags (20 × 20 cm) of 1 mm mesh size which permitted entry of most of the invertebrate decomposers but reduced loss of small fragments of the litters.

Before introduction into the lake, weighed litter bags were placed in a moist atmosphere for two days to take up the moisture. This prevented the fragmentation observed when air-dried litter is put directly into water. The litter bags were placed in the lake on August 8, 1977 at three stations; hanged with 14 nylon cords each having 10 bags (5 pine needles and 5 teak leaves) and a stone of sufficient weight to keep the bags stationary on the lake bed. One cord from each station was randomly collected on each sampling date. The initial two collections of bags were made at 15 day intervals; thereafter four collections were made at monthly intervals and later collections were made at two to three month intervals. Samples were brought to the laboratory in polythene bags within an hour of collection. Bags were then gently agitated in distilled water to remove any visible covering of sediments or algal filaments and oven dried to determine the weight loss. Replicates were then mixed to form composite samples which were used for chemical analyses.

Cellulose and hemicellulose content of litter was estimated by Jermyn's (1955) method using a KOH extraction (cellulose) and an acetic acid ethanol neutralisation (hemicellulose) procedure. Lignin was estimated by the method described by Freu-

denberg (1955) using 72% sulphuric acid treatment procedure. Sugars were estimated colourimetrically using ninhydrin solution (Synge 1955). The nitrogen estimations were done by Kjeldahl Digestion method as outlined by Allen (1974). Three replicates were analysed for each sample and values in figures are means. Least significant difference (LSD) values are given in the figures.

Results and discussion

Weight loss

The two types of litter lost weight at different rates (Fig. 2). Decomposition of pine needles was very slow as compared with teak leaves. Initial decomposition of teak leaves was very fast and bags lost twenty to thirty percent of their weight within the first thirty days. In general, the rate of weight loss was fastest during the first sixty to hundred days but slowed over the next hundred to two hundred days. After three to four hundred days the rate was again quite fast. The rate of disappearance of pine and teak litters differed between stations. The highest rate was observed at station 2 (Table 1). This may be ascribed to the texture of the sediment. It appears that the deposition of silt particles slowed down the rate of decomposition at stations 1 and 3. Similar results were reported by Reice (1974, 1975). Data computed from the exponential decay

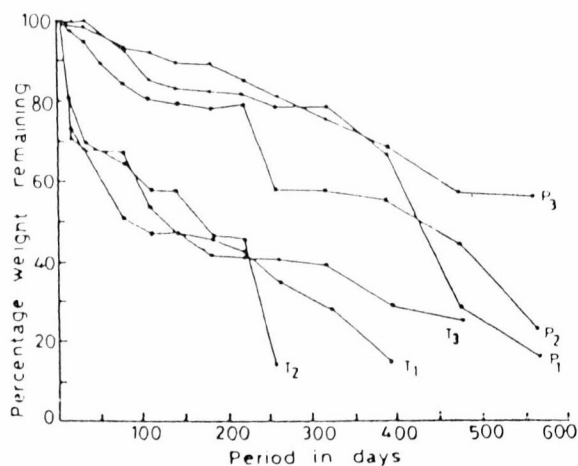


Fig. 2. Percentage weight remaining of pine (P) and teak (T) leaf litters at different stations (1-3) after various periods of processing in the lake.

model (Olson 1963) also suggest similar results. High values of correlation coefficient (r) between exposure time and percentage weight remaining clearly demonstrate that weight loss was a function of exposure time (Table 1). The rate of decomposition was found to be related to litter chemistry and depth of water (Table 1, Fig. 2) which was clearly manifested in the differential rate of weight loss of the two litter types and at the three stations. Hodgkinson (1975) reviewed results of several studies on decomposition of terrestrial litters in aquatic environments. He showed that litters of different chemical composition decayed at different rates. The lignin content (Fig. 3), wax deposition (Millar 1974) and less surface area (per unit weight) of pine needles were positive factors for its slow rate of decomposition. When compared with the similar studies conducted in Canada, the U.S. and Europe, the rate of decomposition was faster (Hodgkinson 1975). The steep loss in the weight during the initial phase of processing might be due to the loss of soluble components from the materials (Fig. 3). Gilbert & Bocoek (1960) estimated the water soluble fraction of freshly fallen oak and ash leaves and found that it amounted to 32% of the dry weight. Similar results were reported by Nykvist (1963), who found that angiosperm leaves contain up to 16.5% soluble components by dry weight compared with pine needles which contained only 0.9%. The higher amount of soluble fraction in the teak leaves appears to be the cause of its initial rapid weight loss (Figs. 2, 3). The initial period of rapid weight loss also coincides with a period of microbial colonization (Tiwari 1980). The two phenomena (dissolution of soluble components and microbial colonization) may be related and microbes might also be

responsible for the rapid loss in the weight during this period. However, the former cause (dissolution of soluble components) seems to be more important. The rate of weight loss slows down after two to four months, which was more clear in the case of pine needles. This period coincides with low microbial population (Tiwari 1980) and lower water temperature (November–January). It seems, therefore, that season may have an effect on the rate of decomposition, probably through the regulation of the microbial activity. The accumulation of refractory materials (eg. lignin fraction, Fig. 3) and subsequent slower breakdown of this material might be one of the most important reasons for the slow rate of the weight loss during later periods. The rapid loss in weight spring and summer (second year) coincides with the high population of bacteria and fungi (Tiwari 1980; Mishra & Tiwari 1982). The effect of bacterial and fungal population maximum was more pronounced on the weight loss of the teak leaves as compared with the pine needles. During this period, the teak leaves at stations 1 and 2 disappeared completely.

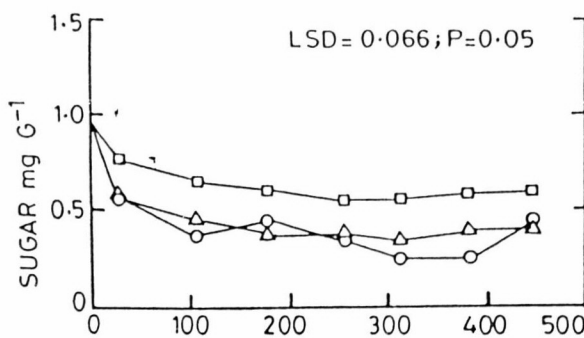
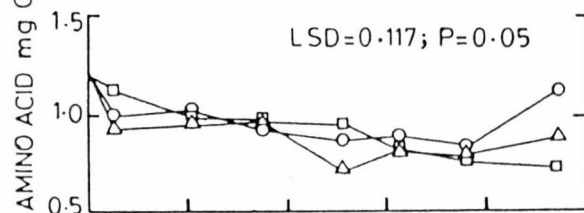
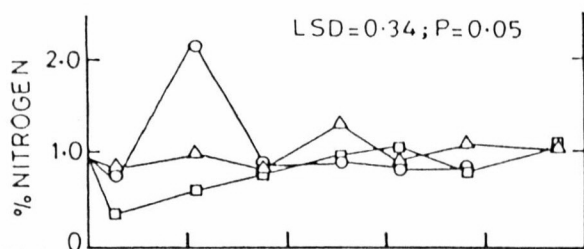
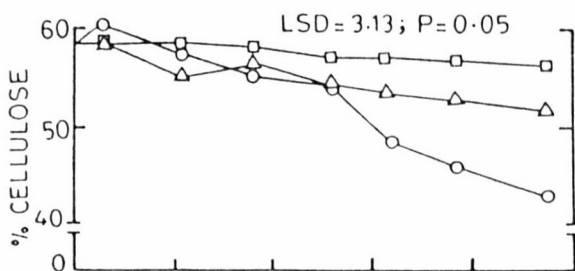
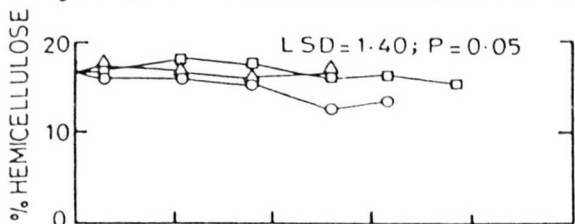
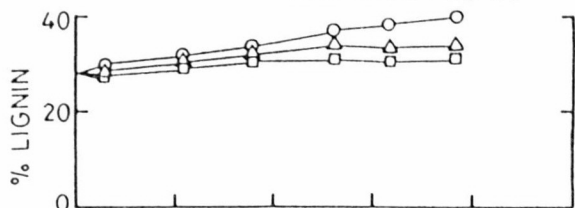
The data on decay parameters (Table 1) demonstrate that the weight loss for both the types of litter and/all the stations showed a close fit to Olson's (1963) negative exponential decay model. The comparison of k values with other similar studies poses problems due to the differences in the litter type, type of habitat, duration of experiment and litter bag mesh size. However, the range of k values for both the litter types in the lake are a comparable order of magnitude to those of Kaushik & Hynes (1971), Thomas (1970), Mathews & Kowalzeski (1969) and Hodgkinson (1975). The k values are lower when compared with the studies conducted in

Table 1. A, B and r values for regression analysis of pine needle (P) and teak leaf (T) decomposition weight loss data (percentage weight remaining vs. time in days).

Stations	Litter type	A	B ($\times 10^{-3}$)	r	k/day	Half life (days)	95% life (days)
1	P	4.951	2.999	0.929	0.0028	247.50	1071.43
	T	4.410	3.722	0.910	0.0041	167.02	731.70
2	P	4.647	2.138	0.977	0.0032	216.56	937.50
	T	4.493	5.574	0.927	0.0074	93.64	405.40
3	P	4.602	0.836	0.983	0.0009	770.00	3333.33
	T	4.334	2.451	0.881	0.0029	238.96	1034.48

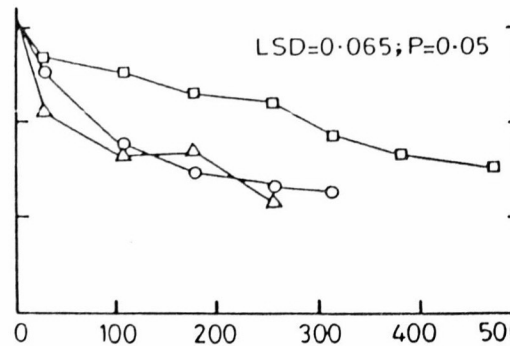
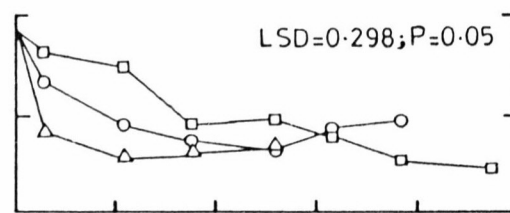
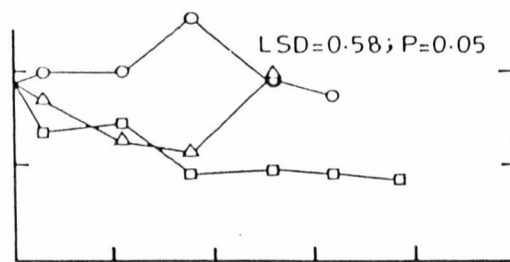
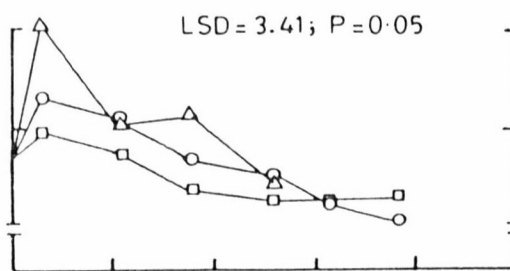
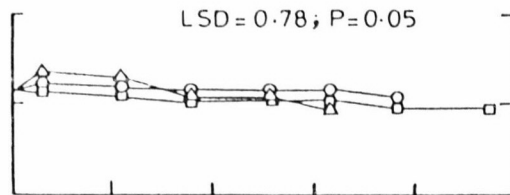
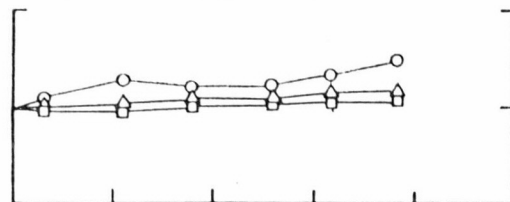
PINE NEEDLES

LSD=0.91; P=0.05



TEAK LEAVES

LSD=1.63; P=0.05



PERIOD IN DAYS

Fig. 3. Changes in chemical composition of pine needles and teak leaf litters after various periods of processing in the lake. O O: station 1; Δ Δ : station 2; \square \square : station 3.

streams and rivers (Kaushik & Hynes 1971; Thomas 1970) and higher when compared with the studies conducted in ponds (Hodkinson 1975). The higher rate of disappearance in streams has been attributed to current action. In general, the rate of decomposition of extraneous plant litter in the present system was high in comparison to similar systems in the temperate zone.

Chemistry change

The loss in cellulose and hemicellulose content of the litters was slow but steady throughout the study period. The data clearly demonstrate that the rate was slower at the greater depths. It appears that the decomposition of these components is continuous and it is only slightly higher than the other components (Fig. 3). The rate of disappearance of these components is slightly faster in the case of teak leaves than the pine needles, which may be attributed to the differences in the fine chemistry of the two litter types. These observations are comparable with the findings of Homdley (1954) and Suberkropp *et al.* (1976).

Like cellulose and hemicellulose, the initial content of lignin was also higher in pine needles than in teak leaves. The rate of disappearance of lignin was the slowest and an increase in the percentage lignin content was noted throughout the course of the study in both the types of litter, clearly indicating slow rate of decay of this material and/or preferential utilisation or other less refractile components. The accumulation and slow rate of lignin decomposition has been attributed to the complex chemistry of this component (Alexander 1961). Suberkropp *et al.* (1976) found a positive relation between the accumulation of lignin and nitrogen and they observed formation of a 'lignin nitrogen compound' which makes a high percentage of nitrogen unavailable to the microbes. Similar increase in the lignin fraction has been reported by other workers (Waksman & Tenney 1927; Kind & Heath 1967; Triska *et al.* 1975).

The disappearance of sugars and amino acids followed a similar trend, which was initially very rapid, then gradually slowed down in both the litter types. The initial rapid loss may be attributed to the soluble nature of these components which leached out after immersion of the litters into the lakewater. The findings are comparable to those of Krumholz (1972), who observed 55-80% loss of soluble car-

bohydrates in the initial two weeks. Suberkropp *et al.* (1976) found that 70-80% reducing sugars were lost during the first two weeks of processing of the litters. A low concentration of these components observed during the later periods of the processing may be due to the instantaneous loss of these materials (after release due to microbial activity) to the lakewater. No definite relationship between microbial population and disappearance of sugars and amino acids could be established in the present study, although initial rapid colonization of litters by microbes (Tiwari 1980) may be attributed to the higher values of these components.

The percentage nitrogen of litters varied differently at different stations. No clear cut pattern could be established except that at station 3 the teak leaves lost their nitrogen almost consistently with time. An increase in the nitrogen content of plant litters during the process of decomposition has been observed by a number of workers (Suberkropp *et al.* 1976) and this has been attributed to immobilization of N to the microbial biomass (Kaushik & Hynes 1968; Anderson 1973; Iversen 1973; Triska *et al.* 1975). The present study also, for the most part, confirms the findings of these workers, and the values are comparable with that of Hodkinson (1975). The decrease in the percentage nitrogen in the teak leaves at station 3 (anaerobic waters, Tiwari 1980) was quite interesting and may be attributed to low microbial colonization and less increment in the percentage lignin (less 'lignin nitrogen compound') concentration. It seems that the low oxygen content has clear bearing on this. Further experiments are required in order to elucidate the proper cause of this decrease.

Summary

The rate of decomposition and changes in chemical composition of two important terrestrial litters, viz. pine (*Pinus kesiya* Royle) needles and teak (*Tectona grandis* L.) leaves, have been studied in a small freshwater lake using plastic net (1 mm pore size) bags at three stations of 1, 3 and 6 m depth. The rate of decomposition of teak leaves was two to three times faster than the pine needles. Percentage content of cellulose and hemicellulose in the litter decreased towards the end of the study period, especially at the shallower stations. The lignin con-

centration, however, increased with time and quite interestingly the increase was more pronounced at the shallower stations. The sugar and amino acid concentration fell rapidly during initial period and remained near constant during later periods. Nitrogen content of the litters changed irregularly although a general trend of fall - increase - fall - stabilization could be observed at some stations. The rate of decomposition of litters in the present system was faster than in similar systems of Europe and Canada.

Acknowledgement

The authors are thankful to the University Grants Commission, New Delhi, India for financial assistance.

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Received 5 January 1982; in revised form 18 April 1982;
accepted 6 June 1982.