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50' + PLASTIC WATER STORAGE TANK

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A study on potability and mechanical behaviour of plastic water storage tanks

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Effect of carbon black concentration on the tensile properties of linear low density polyethylene has been studied in relation to its dispersion. The overall migration of leachable additives has been measured at different temperature and extraction duration. LLDPE tanks have been found to be suitable for storing potable water. No sign of surface deterioration has been observed after two years of natural weathering at Roorkee.

Plastic water storage tanks are relatively new materials which offer considerable potential to replace widely materials, such as brick, steel, RCC etc., conventionally used for this purpose. They are light weight, non-corrosive, possessing smooth inner surface, causing no incrustation and providing ease of installation and maintenance. Inspite these advantages, plastic tanks hardly share 3-4 per cent of total overhead tanks market. At present, total annual consumption of plastic tanks in India is about 1500 MT at a growth rate of 15-20 per cent per annum.

Linear low density polyethylene is a copolymer of ethylene which is the main monomer with one or two other higher olefins as co-monomer with density less than 0.935 gm/cc. It is being used to make water tanks in place of LDPE due to its better processibility low shear rates. In addition, it offers an excellent combination of rigidity, impact strength and environmental stress cracking resistance.

Virgin polymer is generally considered safe for storage of food, drinking water, etc. However, leaching of chemical additives added to plastic formulations has aroused great concern regarding health hazards[1-3].

Recognizing commercial significance of plastic tanks, much emphasis has been laid over the years on assessing their toxicological (potability) and mechanical behaviour in actual use conditions. Unstabilized polyolefins, such as LDPE, HDPE, and LLDPE are intrinsically unsuitable for outdoor applications. The use of carbon black for stabilization of polyolefins and other polymers against photo-oxidation is well known but particle size and good dispersion of carbon black in polyolefins are necessary requirements for optimum performance[4]. Availability of data on outdoor performance of plastic water storage tanks in Indian conditions is still very limited. Therefore, it is essential to assess their suitability with respect to environmental parameters.

A study was undertaken to examine dispersion of carbon black and its effect on mechanical behaviour of LLDPE and to assess potability characteristics of tanks under the influence of different temperature and storage time.

Experimental procedure

LLDPE tanks having capacity from 200-500 litres and wall thickness in the range of 4 mm - 5 mm were obtained from the Indian manufacturers.

In order to observe potability characteristics, overall migration of constituents from tank materials was determined using water as simulating solvent under different temperature and storage time. Tank materials were cut into small pieces of size 5 × 7 cm and washed with distilled water twice, then immersed into the water extractant in the ratio of 1 cm^2 tank material/2 ml extractant as per BIS recommendation[5]. Simultaneously water extractant was kept in glass bottles in an identical manner which served as control. Extracts were evaporated in a pre-weighed platinum crucible in an oven maintained at constant temperature ($100 \pm 5°C$). The difference between residue and corresponding control were taken as the measure of global migration in mg/L.

Additionally, these tanks were filled with tap water and other characteristics, such as *p*H, dissolved solid. Bacteriological test and maximum tolerance limit of mortality test[6] of water samples drawn periodically were carried out.

Dispersion of carbon black in LLDPE was studied by scanning electron microscope (Phillips 501, Holland). Specimens were coated with thin film of gold by vacuum coating unit to render them conductive.

Dumbell shaped samples were cut horizontally from tanks and tensile jproperties were determined in accordance with ASTMD 638-72 using Universal Testing Machine (Zwick 1475, Germany) at cross head speed of 5 mm/min. Other mechanical properties, such as resistance to impact, resistance to deformation, flexural modulus were determined as per IS-12701-89.

Results and discussion

Representative stress-strain curves, obtained under the conditions of constant displacement rate are presented in Fig. 1 for an unfilled and carbon black filled LLDPE polymer. The yield strength decreases with the addition of carbon black from 16.7 MN/m^2 to 11.8 MN/m^2. At lower concentration, say 1-1.5 per cent the decrease in yield stress and yield strain is small. However, it becomes more pronounced at higher carbon black concentration. The elastic modulus as determined by the initial slope of stress-strain curves does not alter appreciably. The reduction in tensile properties are mainly due to poor dispersion of carbon black. Examination of surface topography (Fig. 2 a,b,c) revealed two distinct features. With low concentration (1.5 per cent wt) the dispersed particles were clearly visible and uniformly dispersed but at higher concentration (2.5-3.0 per cent wt), dispersion of particles is observed in the form of large agglomerates in some portion.

The variation of overall migration of leachable additives from LLDPE with temperature at different storage time are plotted in Fig. 3. The points of the curves are the average of three replicates. It can be seen that initially the plots are linear but at about

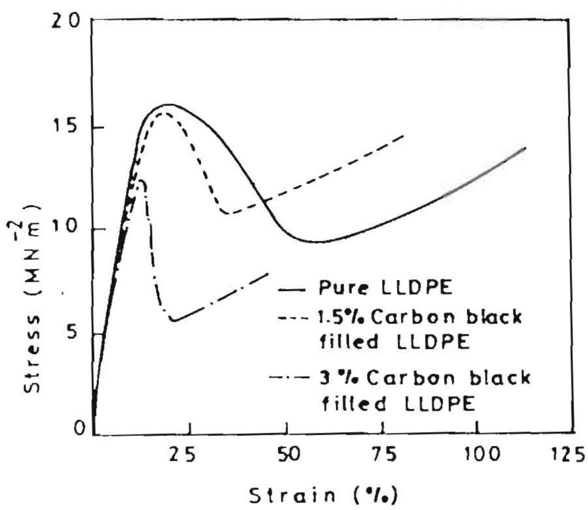

Fig. 1—Tensile stress-strain curve for carbon black filled LLDPE (Cross head speed 5 mm/min)

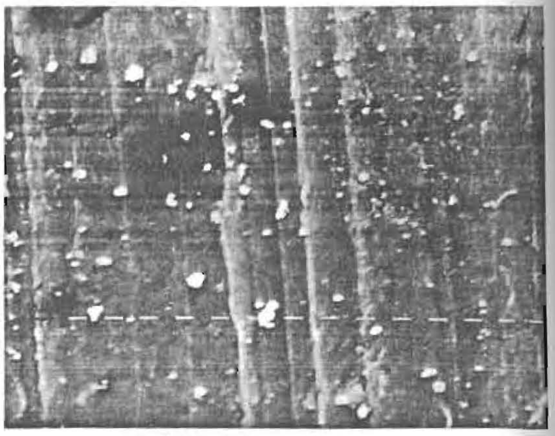

Fig. 2a—SEM micrograph shows uniform dispersion of carbon black (1.5% wt) in LLDPE 10 μm

Fig. 2b—SEM micrograph shows localized dispersion of carbon black (2.5% wt) in LLDPE 100 μm

Fig. 2c—SEM micrograph shows agglomerate of carbon black (3% wt) in some portion in LLDPE 100 μm

20-25 mg/L (especially in 5 days and 10 days) of overall migration, the lines start to deviate from linearity. The deviation from linearity indicates that there is probably a change in the mechanism of rate determining process (rate limiting or controlling process). The rate of migration for one day extraction duration is considerably lower than 5 days and 10 days extraction duration at all temperature, but a drastic change was observed at 60°C after 10 days extraction duration i.e. in the order of 55-60 per cent (in comparison to 1 day extraction period). It was also found that the value of overall migration at 60°C is roughly two times than that of room temperature for all extraction periods. However, the leachable additives were found to be under permissible limit (60 mg/L) for all temperature and extraction durations. This migration of additives from LLDPE may be possibly due to poor solubility of additives, its high rate of volatization which set up a concentration gradient near the surface and subsequently rate of diffusion from the bulk. The other main disadvantage is that they are not very compatible with non-polar LLDPE and will tend to form a crystalline aggregates in the polymer matrix, leaving large volume of unstabilized materials[7,8].

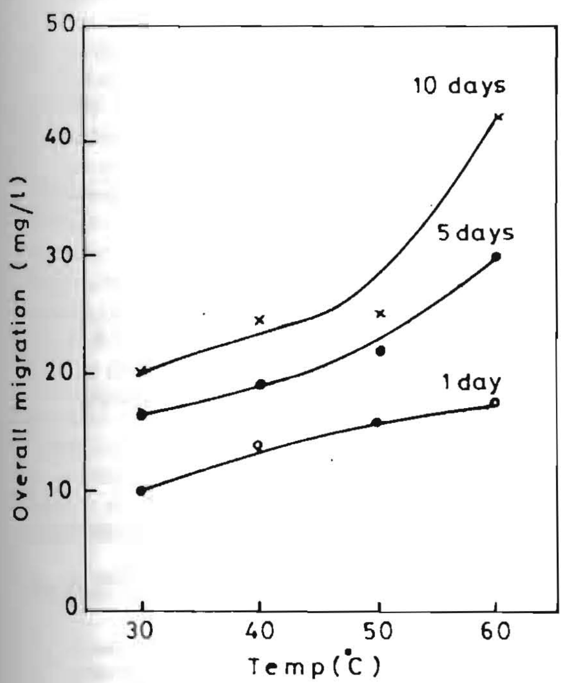

Fig. 3—Variation of overall migration of additives from LLDPE with temp. (°C) at different storage time

Some typical properties of tanks have been given in Table 1. pH and dissolved solid of water samples drawn from filled tanks after 1 day and 10 days storage time were almost similar and within permissible limits. No lethality was observed when Kanghi fishes (10 Nos.) were kept in filled tanks even after 10 days. In bacteriological study, it was found that there is no alteration in number of bacterial colony and MPN (most probable number of coliform groups) in fresh water and 10 days stored water in the tanks. Mechanical characteristics, such as tensile strength, flexural modulus, impact resistance and resistance to deformation were found to be under permissible limits (Table 2).

Natural weathering exposure of tank materials for a period of two years did not show any appreciable change in tensile strength and % elongation (Table 2).

Table 1—Potability characteristics of LLDPE water storage tanks

Sl. No.	Name of Tests	Permissible limit/ required value	Obtained value
1	pH	6.5-8.5	
	1 day		7.47
	5 days		7.67
	10 days		7.80
2	Total dissolved solids (mg/L) (IS: 10500-83)	500	
	1 day	—	302.00
	5days		307.50
	10 days		312.50
3	TLM test	—	No lethality was observed
4	Bacteriological tests:		
	(i) Total count on agar at 37°C for 24 hrs (count/ml)	—	< 1
	(ii) MPN of coliform bacteria (counts/100 ml)	—	< 2

Table 2—Mechanical characteristics of LLDPE water storage tanks

Sl. No.	Name of Tests	Obtained value	Permissible limit (IS:12701-89)
1	Tensile strength (N/mm^2) (IS:8543/Sec-(1983)		
	Fresh	15.80	> 12
	After two years exposure.	16.50	
2	Elongation (%) IS:8543/Part-4 Sec. 1.83		
	Fresh	110	
	After two years	90	
3	Flexural modulus (N/mm^2) IS:10661-1983	490.50	> 400
4	Resistance to impact (IS:12701-89)	—	No breakage
5	Resistance to deformation(%) (IS: 12701-89)	Negligible	< 2

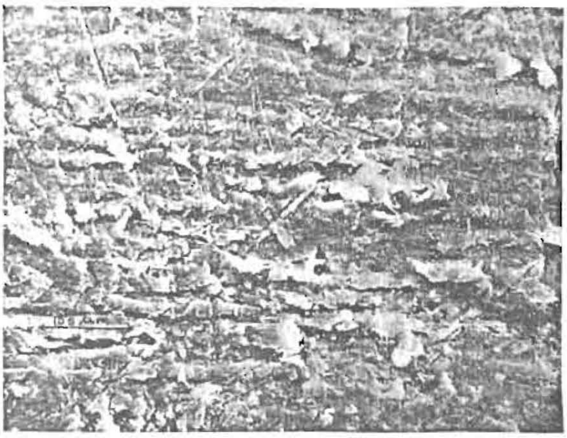

Fig. 4a—SEM micrograph of fresh LLDPE 100 μm

Fig. 4b—SEM micrograph of LLDPE after 2 years natural exposure 10 μm

Further work is in progress. It is also evident from Fig. 4 that fresh and exposed samples for two years show no crazing, cracking or pore formation. However, samples exposed for two years show some hazing and roughness on the surface (Fig. 4b).

Conclusion

It has been found that the addition of carbon black reduces the tensile properties of LLDPE which is mainly due to poor dispersion but the strength characteristics are still appreciably higher than LDPE and comparable to HDPE. The overall migration of leachable additives increased with the increase of temperature and extraction period probably due to high rate of volatization on prolonged storage and high temperature. Potability and mechanical characteristics of LLDPE tanks satisfy the requirement of BIS specification (IS 12701-89). SEM study revealed no appreciable changes, like cracking, crazing and pore formation on the surface after two years exposure in natural weathering at Roorkee.

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