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Monitoring the degradation of physical properties and fire hazards of high-impact polystyrene composite with different ageing time in natural environments

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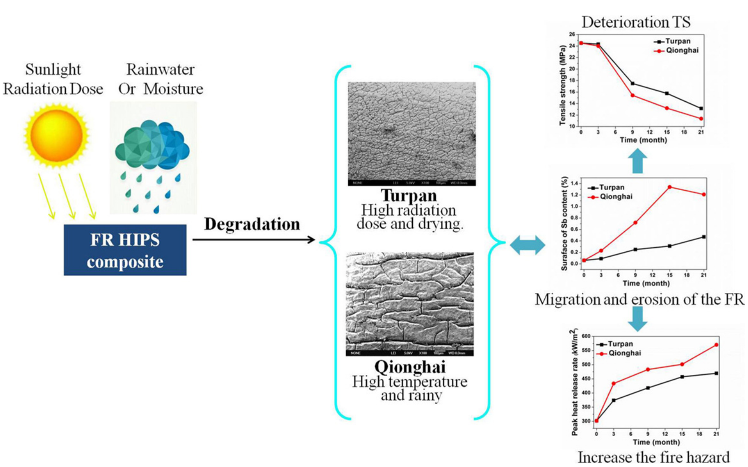
GRAPHICAL ABSTRACT



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ABSTRACT

The current study aims at monitoring the role of the different natural environments on the physical properties and fire hazards of HIPS composites ageing in Turpan and Qionghai. The results indicated that the chromatic aberration and degradation of surface appearance intensified with the increasing ageing time. More flame retardants migrated and were eroded for HIPS composites ageing in Qionghai than those ageing in Turpan, which was caused by the combination of sunlight, high temperature and rainwater in Qionghai. After degradation in the natural environments, the HIPS composites possessed the lower thermal stability and char residues, more toxic gases release, higher peak heat release rate and fire hazard. For example, the peak heat release rate in Qionghai increased by 88.9%, which is much higher than that of in Turpan (55.6%). Moreover, the tensile strength and elongation at break decreased by 46% and 59% for HIPS composites ageing in Turpan and reduced by 53% and 67% for HIPS composites aged in Qionghai, respectively. The results demonstrate that more serious

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degradation of physical properties and higher fire hazard for HIPS composites ageing in Qionghai than those in Turpan due to the different natural ageing environments.

1. Introduction

Polymers are essential materials in many industrial sectors and daily applications because of their excellent properties [1–3]. Most polymer materials reveal high flammability, heat release and smoke production during combustion, which greatly limits its application due to the severe fire hazard in their application. Different methods have been suggested to improve the fire safety of polymers, such as incorporating flame retardant into polymers via melt blending (physical methods), incorporating flame retardant into the chemical structure of polymers (chemical methods, e.g. via copolymerization or grafting) and coating the flame retardant layer on the surface of the material [4–11]. Different classes of flame retardant are used in polymers, such as mineral fillers [12,13] and boron- [14], phosphorus- [15–17], nitrogen- [18], halogen- [19] and nono-additives [20,21] based flame retardant.

The physical and chemical flame resistance method can achieve the perfect balance between the physical performance and flame retardancy for polymer materials. However, the flame retardant polymer materials need to meet different environmental requirements during their service life. These environmental requirements include light, heat, temperature, humidity or water vapor, irradiation, salt mist, etc [22–32]. To compare and evaluate the service life or performance of the polymer materials under different ageing conditions, accelerating ageing method and natural ageing test are employed for qualification testing in the defined sequences. A series of papers point out that flame retardant system can be much degraded in the presence of water or moisture [33–35]. In our previous research work, the mechanical, electrical property and flame retardancy of the ammonium polyphosphate flame retardant cable materials had greatly deteriorated with increasing the ageing time [36]. Jimenez et al investigated the influence of hydrothermal aging and salt water on the fire protective behavior for an epoxy-based intumescent coating which was used to protect a steel structure [37]. The fire safety of the coating was slightly deteriorated after ageing in distilled water and considerably decreased after ageing with salt water, which caused by the reason that ammonium polyphosphate can be easily dissolved and removed from the matrix. Inata et al. reported the migration of 16 halogenated compounds in polypropylene composited under thermal accelerating ageing test (at 110,130 and 145 °C) [38]. Mineral filler flame retardant is also reported about the migration of the flame retardant from inside to the surface during the photo-oxidation ageing test [39]. Li et al. studied polystyrene-block-polybutadiene-block-polystyrene block copolymer (SBS) natural aging tests in Wanning and Hailaer [40]. The results showed that the surface of SBS became yellow, and the elongation at break, the tensile strength as well as the tear strength decreased with increasing aging time. From the artificial and natural ageing test, it can be found that the surface color, mechanical, electrical and flame retardance properties of polymer materials deteriorated with increasing the ageing time. Particularly, it mainly contains deterioration of physical performance, reducing flame retardancy and improving the fire risk of polymer materials. Therefore, it is very necessary and important to monitor and evaluate the performance and fire hazard for flame retardant polymer materials during the period of service.

High-impact polystyrene (HIPS) is a multiphase copolymer system in which polybutadiene (PB) rubber particles are dispersed in the polystyrene (PS) rigid matrix. HIPS is employed in a wide range of applications, such as packaging, automotive components, building materials, electronic instruments and electrical appliances due to its low cost, good impact resistance and easy processing [41]. Like most other styrenic polymers, its high flammability and smoke production during combustion greatly limit its application in some areas especially in building construction, automotive and electrical and electronic equipment. Incorporating flame retardants has been proven to be an effective way to reduce the fire hazard of polymeric materials. There are a series of papers about HIPS ageing test in different artificial conditions [42–44]. During the degradation of HIPS, chain scissions and reduction of mechanical properties of HIPS was accompanied by yellowing the surface. However, very few reports has been made to monitor the mechanical properties, physical performance and fire hazard of flame retardant HIPS composites in their service environments.

Consequently, the current study first aims at investigating the role of the different natural environments on the physical properties and fire hazards of HIPS composites. HIPS composites containing chemical stable decabromodiphenyl ethane and antimony trioxide as flame retardant and then natural ageing test in Turpan and Qionghai since July 2012 for 21 months. Then the appearance, surface element, thermal, combustion, melt flow rate and mechanical properties of HIPS composites with different natural ageing test were analyzed in detail.

2. Experimental

2.1. Materials

The flame retardant high impact polystyrene (HIPS) was kindly provided by Kingfa Science and Technology Co., Ltd. It was filled with decabromodiphenyl ethane, antimony trioxide and barium sulfate.

2.2. Natural weathering tests

Natural weathering tests were carried out in Turpan and Qionghai, respectively. Turpan is located in the northwest desert of China and the climate is drying along with high sunlight radiation dose, which belongs to a typical continental warm temperate desert climate. Qionghai is located in Hainan Province and on the north side of the South China Sea. The climate in Qionghai is rainy with high temperature, which is a tropical humid zone oceanic climate. The conditions of the natural weathering tests are listed in Table 1. Samples were located on test racks made of inert materials and the ageing test began since July 2012 for 21 months. Sampling was performed on months 0, 3, 6, 9, 12, 15, 18, and 21.

2.3. Characterization

The change of color, ΔE, was studied with a spectrophotometer (CM-2300d, Konica Minolta, Japan) and calculated from the equation $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$. ΔL represents the brightness relationship

Table 1
Conditions of Natural ageing Tests in.2012–2014.

Location	Latitude	Longitude	Exposure angle south	Altitude(m)	RadiationDose(MJ·m-2)	Average ambient temperature (°C)	Average relative humidity (%)
Turpan	42°56' N.L.	89°12' E.L.	South 45°	61.5	6108.7	17.3	29.1
Qionghai	19°14'N.L.	110°28'E.L.	South 45°	10	4235.3	25.1	80.0