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Characterization and Feasible Applications of Waste Tyre Rubber Deposits from Airfield Runway

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ABSTRACT

The contribution of aviation industry in managing the time of travel around the world is overwhelming. Though its services are highly needed, the serious threat posed by the deposition of rubber during take-off and landing has to be addressed in the airfield runway to mitigate the ground-based accidents. As rubber is non-degradable in nature, the present work aims to study the use of aircraft tyre rubber waste in the removal of toxic metals like chromium from wastewaters and for partial replacement of sand in the production of rubberized concrete. The characterization of vehicular and aircraft tyre rubber waste shows that the siliceous material is equal and the presence of oxygen is observed in the aircraft tyre rubber waste compared to vehicular tyre rubber waste. The utilization of the aircraft tyre rubber waste for partial replacement of sand in the production of rubberized concrete showed that the slump values and compressive strength are decreased with an increase in the percentage of the tyre rubber waste and the acceptable limits are within 5% range. The removal efficiency of chromium from wastewaters using aircraft tyre rubber waste carbon (ATRWC) was obtained at 67.56% in a batch study for various parameters. From the results, it can be observed that ATRWC can be used as a low cost adsorbent for removal of chromium from wastewaters.

INTRODUCTION

The tremendous increase in frequency of landing and take-off of aircraft leading to deposition of rubber that reduces the skid-resistance and the frictional coefficient deciding the safe landing and take-off of any aircraft in the landing area (Dass 2010). The deposition of rubber on the runways is increasing day by day in international airports, which produce a huge amount of rubber waste on runways (Nicola et al. 2017). Removal of rubber from the runway is part of maintenance of the runway, which is considered as a worldwide environmental threat that requires immediate attention (Lakshmi et al. 2018a). It is understood that rubber materials are user-friendly but not eco-friendly because of their non-degradable nature (Davide 2013, Vinay Kumar et al. 2011).

The present work aims at optimum utilization of the aircraft tyre rubber waste in technical manner for partial replacement of sand in the production of concrete. Sand is commonly used as fine aggregate in concrete, but is an exhaustible material and becoming expensive due to the excessive cost of transportation from available sources. Based on the literature, the rubberized concrete is reasonable with the ability to withstand more pressure, impact and temperature when compared to conventional concrete (Mohammed et al. 2016, Raji et al. 1998). Rapid industrialization led to the release of toxic metals into the aquatic ecosystems, thereby posing a hazard to human health and the environment. The increased pollutants are found well above the tolerance limit many a time in the wastewaters (Mousavi et al. 2010). Chromium is a well-known legendary pollutant as it is widely used in many industries (Fatemeh et al. 2008 and Panda 2017). Chromium is released into the environment not only from natural sources but also from human activities. The major use of chromium is in leather-tanning (Ajmal et al. 2003, Ashraf et al. 2016).

Environmental pollution by chromium is a matter of increasing concern. Thus, treatment of the effluent to reduce/remove the pollutant before discharging into the environment becomes inevitable (Montanher et al. 2005). Adsorption is one of the most versatile and widely used techniques for the removal of toxic metals from the aqueous solutions. For more than three decades, activated carbon has been the water industry's standard adsorbent for the reclamation of municipal as well as industrial wastewater to make it possible for the potable usage (Chunlei Zhu et al. 2017). The present study also aims to assess the applicability of activated carbon derived from the aircraft tyre rubber waste for the adsorptive removal of chromium from aqueous solutions.

MATERIALS AND METHODS

Rubber sample collection: The vehicular tyre rubber waste was collected from Visakhapatnam, and the aircraft tyre rubber waste from the airport. The runway is being deposited by the rubber because of the impact load of aircraft and environmental changes (Fig. 1). As the part of runway maintenance work, the deposited rubber is removed using track jet. The cleaning performance of the track jet is up to 800 square meters per hour, the pressure is up to 2000 bar with the rotor speed of 863 revolutions per minute. The speed of the track jet engine is 1805 revolutions per minute and the speed of track jet is 379 meters per hour. The sample for the present study was collected from the yard of airport.

Chemical treatment of tyre rubber waste: The vehicular and aircraft tyre rubber waste was cleaned and washed thoroughly with distilled water (Fig. 2). It was dried in an oven at 100°C for 120 minutes. The obtained product was treated with 30% hydrogen peroxide (H_2O_2) for 15 to 20 minutes to oxidize adhering organic impurities. The sample was then placed in an oven for 24 hours at 60°C. The material was washed with deionized water several times to remove H_2O_2 and dried at 110°C for 120 minutes in the oven. The dried rubber sample was collected for further tests.

Rubberized concrete: Trial mixes were laid for the determination of the ratio of aggregate, cement and water to assess favourable properties. For the present study, three trail mixes were designed and casted based on literature for the partial replacement of sand with tyre rubber waste. The fine aggregate (sand) was replaced by 5%, 10% and 15% with aircraft tyre rubber waste for the concrete grades of M20, M25 and M30. The rubberized concrete compressive strength was compared with nominal concrete to confirm the applicability.

Workability (slump cone test): The required material of rubberized concrete mix was weighted as per the recommendation and mixed homogeneously for several times to produce uniform fresh concrete in large quantities in order to know the workability of fresh concrete using slump test as shown in Fig. 3.

Preparation of concrete moulds and curing: When the concrete mix showed the acceptable workability and uniform rubber particle distribution in the mix, it was placed in moulds and compacted. To test the compressive strength of rubberized concrete, standard cubical moulds of size 150mm × 150mm × 150mm were used to prepare concrete specimens (Fig. 4). Prior to de-moulding, the specimens were covered with plastic sheets and stored at room temperature for 24 hours. After de-moulding, the cubes were placed in water curing tank. On strength development and durability of concrete, curing plays an important role to maintain the desired moisture and temperature conditions for the extended periods of time.

Compressive strength: Compressive strength test on cubes was carried out using the Universal Testing Machine (UTM) (Figs. 5 & 6). Compressive test was carried out on cubes of dimensions 150 × 150 × 150 mm after cured for 7 days, 14 days and 28 days. The computation of compressive strength was done using the expression $F = \frac{P}{A}$ for cubes ...(1)

Where, F is the compressive stress in MPa, P is the maximum load applied in Newton. A is the cross-sectional area in mm^2.

After performing the compressive strength results, to check the uniformity of rubberized concrete, sample of the hardened cube was sent to Andhra University (AU) to perform the analysis by Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD).

Aircraft tyre rubber waste as a novel adsorbent: The biomass of aircraft tyre rubber waste has been identified as solid waste material and has a lot of scope to be used as a cost-effective adsorbent for the removal of heavy metals like lead, chromium, zinc etc. form wastewaters. Batch study was performed to determine the removal efficiency by testing the effect of various parameters such as contact time, dosage, initial concentration, pH of the solution and tem-

Table 1: Comparison of compressive strength of rubberized concrete.

Grade of Concrete	Nominal Concrete (Mpa)		Rubberized Concrete (Mpa)		
			5%	10%	15%
M20	7 days	11.52	11.03	8.52	8.47
	14 days	16.97	16.92	8.69	8.46
	28 days	19.18	18.24	14.43	13.87
M25	7 days	14.66	13.49	9.71	9.53
	14 days	21.92	21.85	11.06	9.99
	28 days	24.73	24.24	16.12	15.24
M30	7 days	20.49	17.92	13.97	13.27
	14 days	29.21	29.30	15.23	14.53
	28 days	32.83	29.92	18.34	18.20

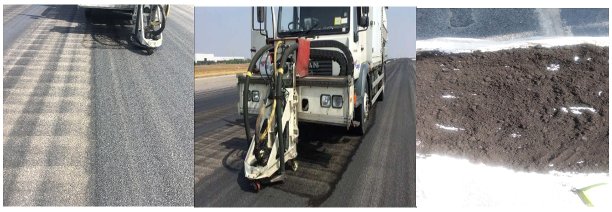

Fig. 1: Runway with deposited rubber and collecting sample using track jet.

Fig. 2: Process of cleaning tyre rubber waste.

Fig. 3: Process of concrete mixing slump test.

Fig. 4: Rubberized concrete cube, curing and drying for compressive strength test.

Fig. 5: Failure criteria for nominal concrete.

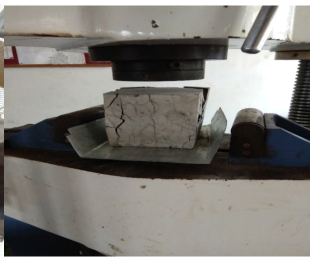

Fig. 6: Failure criteria for rubberized concrete.

perature. Much literature was found for the removal of chromium metal using vehicular tyre rubber waste but no work has been reported on the use of aircraft tyre rubber waste for the removal of chromium metal from wastewaters.

Preparation of the adsorbent: Activated carbon was prepared from aircraft tyre rubber waste via carbonization, chemical treatment and steam activation. The rubber waste powder was cleaned, thoroughly washed with deionized water, and then dried in an oven at 100°C for 4 h. For carbonization, the dried material was heated to approximately 120°C for 24 h. This was followed by treatment with 30 % hydrogen peroxide (H_2O_2) solution for 2h to oxidize adhering organic impurities. The material was washed with deionized water and dried in a vacuum oven at 60°C for 24h. The dried material was activated at 500°C for 2 h (N_2 flow 0.225 mL min^{-1}) in a muffle-furnace. Then, it was removed from the furnace and cooled in a desiccator. The material was then treated with 4 M nitric acid solution to remove the ash content and was then washed with deionized water. The product was finally dried in an oven at 120°C for 24h.

Batch adsorption experimental studies: Adsorption experiment of chromium from the wastewaters was carried out using adsorbent ATRWC. 250 mL conical flasks were madeup with 100 mL of chromium solution and deionized water. The stoppers were provided to avoid the change in concentration due to evaporation. The adsorption studies were conducted in exploratory conditions of various effective process parameters of pH 3-9, contact time 60-120 min, metal ion concentration ranges 50ppm-150ppm, dosage of the adsorbent 0.25g-0.75g and the temperature 25°C-35°C. The agitation speed of 350 rpm was kept constant in the orbital shaker with the suitable time interims. The mixed adsorbent solutions were taken out and filtered by Whatman filter paper and analysed for metal ion concentration in a UV-Visible Spectrophotometer (double beam). Batch experiments were conducted by changing the parameters.

RESULTS AND DISCUSSION

Characterization of Vehicular and Aircraft Tyre Rubber

The scanning electron microscopy (SEM) of the aircraft tyre rubber is shown in Figs. 7-9, energy dispersive X-ray spectrometry (EDS/EDX) in Figs. 10-12, and X-ray diffraction (XRD) in Figs. 13-15.

The analysis of the above parameters shows the minimum correlation between the samples of vehicular and aircraft. Purification of tyre rubber waste results in the removal of some chemical compositions. The characterization of vehicular and aircraft tyre rubber waste shows that the siliceous material is equal and the presence of oxygen is observed in the aircraft tyre rubber waste compared to vehicular tyre rubber waste.

Rubberized Concrete

By considering the mentioned results, it is clear that the slump values (Fig. 16) and compressive strength (Fig. 17) is

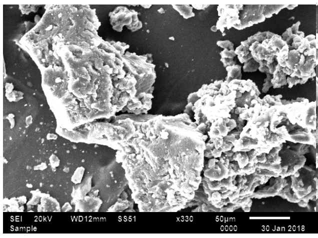

Fig. 7: 7.50µm and 330×Magnification.

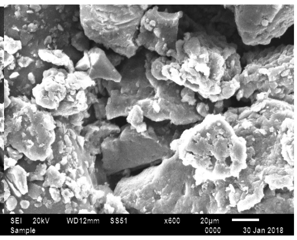

Fig. 8: 20µm and 600× magnification.

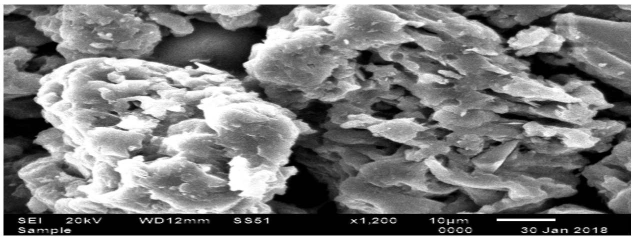

Fig. 9: 10µm and 1200× magnification.

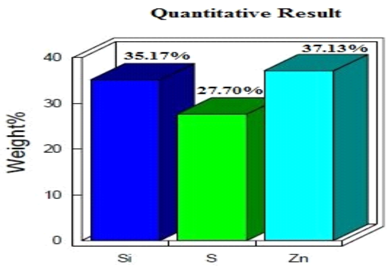

Fig. 10: EDS of vehicular tyre rubber.

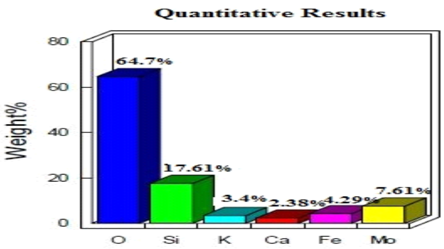

Fig. 11: EDS of aircraft tyre rubber.

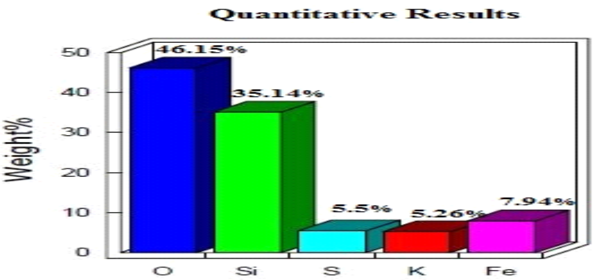

Fig. 12: EDS of purified aircraft tyre rubber.

decreased with an increase in the percentage of the tyre rubber waste. It is acceptable to utilize the aircraft tyre rubber waste up to 5% to produce rubberized concrete. Beyond which leads to heavier strength decrease (Table 1).

Aircraft Tyre Rubber as a Novel Adsorbent

Effect of pH: It is well known that the removal of heavy metals by adsorbent depends on the pH of the initial solution. Therefore, in order to establish the effect of pH on the adsorption of chromium ions, the batch equilibrium studies were carried out at different pH values. The pH range was chosen 3-9. The pH of the solution was adjusted by using 0.1N HCl and 0.1N NaOH and prepared tyre rubber adsorbent was added to 100 mL of solution in 250 mL flasks. The amount of chromium ions removed from solution decreases rapidly from pH 3 to pH 9. At pH 3, 90.30% of Cr ions were removed, while at pH 7, 8.16% of Cr ions were removed and at pH 9, the amount of chromium ions removed from the solution by the aircraft tyre rubber adsorbent steadily decreased to 5.93% (Fig. 18).

Effect of adsorbent dosage: To determine the capacity of an adsorbent for a given initial concentration of metal ion solution, dosage study is an important parameter which determines the capacity of an adsorbent. From the Fig. 19, it can be observed that increasing the adsorbent dosage increased the percent removal of chromium from 14.94 % up to 92.24 % with the required optimum dosage of 0.75g/100 mL of chromium solution. As expected, the removal efficiency increased with an increase in the adsorbent dosage for a given initial metal concentration. The reason is that for a fixed initial adsorbate concentration, increasing adsorbent dosage provides a greater surface area or more adsorption sites.

Effect of contact time: As indicated in Fig. 20, the Cr removal efficiency was decreased slowly up to 90 min and then reached to minimum after 60 min. The sharp decrease in the removal efficiency may be due to the existence of enormous vacant active sites on the adsorbent surface. However, by raising the contact time, the availability of Cr ions to the active sites on the adsorbent surface is limited, which results in low removal efficiency. It was reported in a study (Lakshmi et al. 2018b) that the adsorption of Cr on nano-carbonate hydroxyl apatite reached the equilibrium state at 90 min at different concentrations of Cr. Since 90 min is

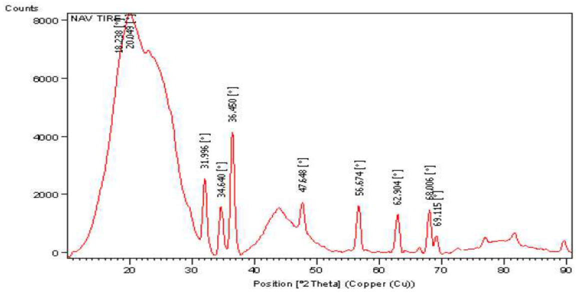

Fig. 13: XrD of vehicular tyre rubber.

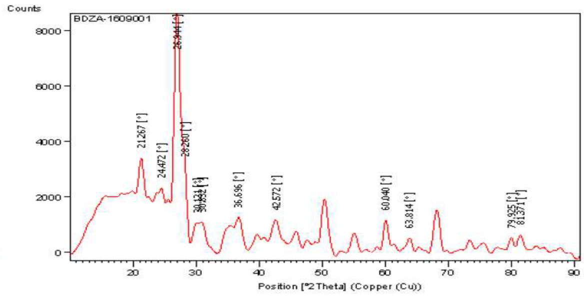

Fig. 14: XrD of aircraft tyre rubber.

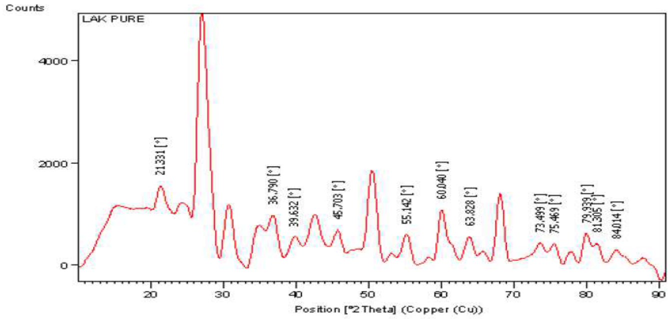

Fig. 15: XrD of purified aircraft tyre rubber.

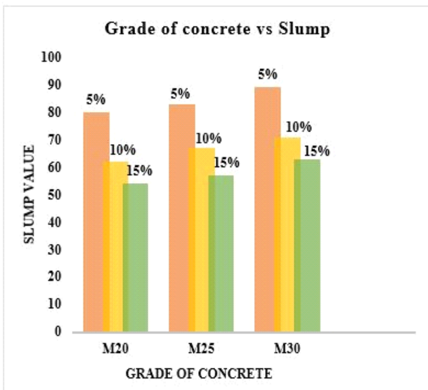

Fig. 16: Slump results.

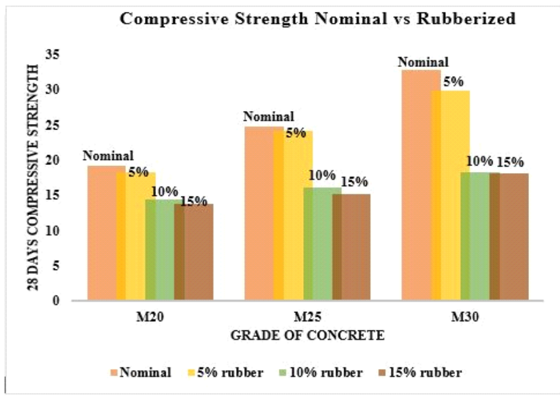

Fig. 17: Nominal vs rubberized concrete.

more than the optimal time obtained in the present study, it can be noted that the ATRWC has higher adsorption rate than nano-carbonate hydroxyl apatite.

Effect of concentration of metal ion: The concentration of the solution changes the percent removal of metal ions from aqueous solution. The effect of concentration was calculated by changing the concentration of the solution as 50 ppm, 100 ppm and 150ppm at 30°C with the contact time of 90 min, pH 3 and adsorbent dosage of 0.5g/100 mL of solution. Results mentioned in the Fig. 21, explained that the removal efficiency decreased with increasing the concentration of the metal ion solution.

Effect of temperature: It can be observed from Fig. 22, that the adsorption of chromium ions increased when the temperature was increased up to a certain temperature, i.e., at 25°C the amount of Cr ion removed was 9.34 %, whereas, at 30°C, 79.47% of Cr ion was removed by rubber carbon for an initial concentration of 100 ppm. It can be seen from the figure that, initially, the percentage removal increased sharply with the increase in temperature, but beyond a cer-

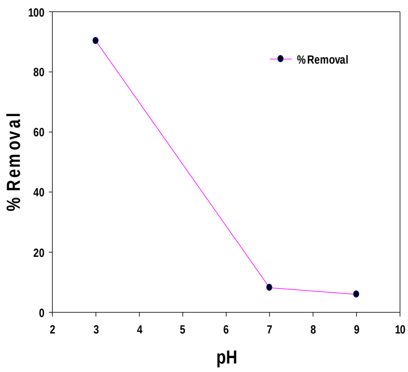

Fig. 18: Effect of pH on removal of Cr.

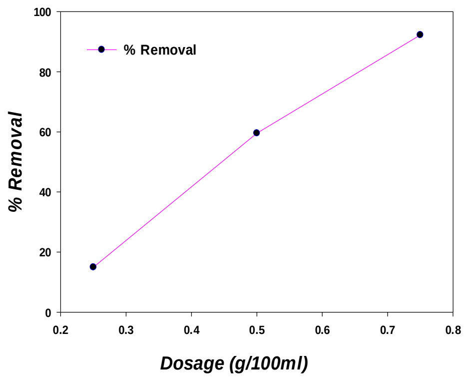

Fig. 19: Effect of dosage on removal of Cr.

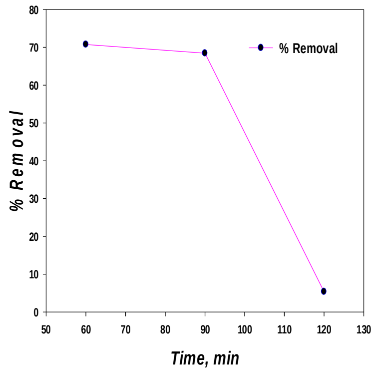

Fig. 20: Effect of time on removal of Cr.

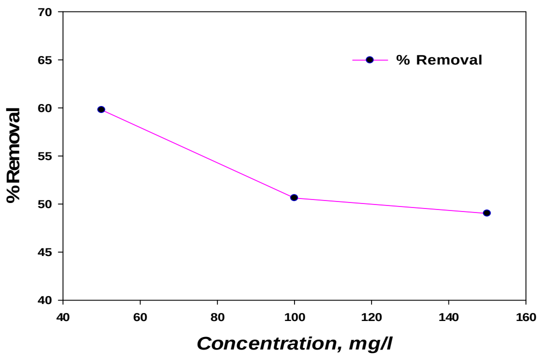

Fig. 21: Effect of concentration.

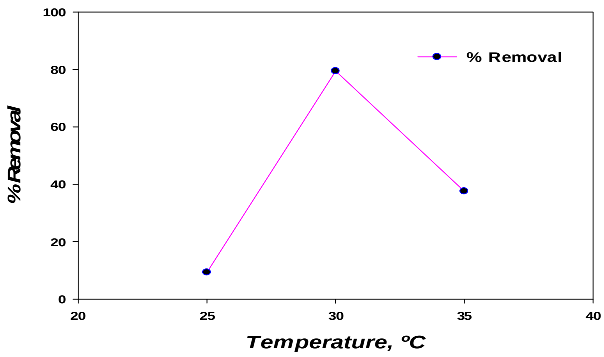

Fig. 22: Effect of temperature.

tain value of 30°C, the percentage removal decreased to a minimum value. These results showed that the sorption was endothermic in nature up to a certain point (Lakshmi et al. 2018c).

Functionalized activated carbon derived from aircraft tyre rubber was investigated for the adsorption of chromium from aqueous solutions. It was demonstrated in this study that aircraft tyre rubber carbon could be used as an effective adsorbent for chromium. The equilibrium time is 60 min for the adsorbent having concentration of 50ppm. The maximum adsorption takes place at the pH of 3.0 with an adsorbent dosage of 0.75 and temperature of 30°C.

CONCLUSIONS AND FUTURE SCOPE

The following conclusions were drawn from the present study:

- The results showed that the compressive strength is decreased with an increase in the percentage of the tyre rubber waste, and it is acceptable to utilize the aircraft tyre rubber waste up to 5% to produce rubberized concrete and beyond which it is strongly not recommended for replacing the fine aggregate.
- The removal efficiency of chromium from wastewaters using aircraft tyre rubber waste carbon (ATRWC) was obtained 67.56% in a batch study for process parameters like pH, adsorbent dosage, initial metal ion concentration, contact time and temperature.
- From the above results, it can be observed that ATRWC can be used as an eco-friendly and cost effective adsorbent for the removal of chromium from wastewaters and as a partial replacement of sand.

SCOPE AND SUGGESTIONS FOR FUTURE STUDIES

The aspects mentioned below may be considered for future investigation on the utilization of aircraft tyre rubber waste.

- The flexural and ductile tests need to be undertaken to confirm the utilization of aircraft tyre rubber in civil applications.
- The application of aircraft tyre rubber as a filler may be checked for vast utilization.
- Column studies are suggested for the effective removal of heavy metals from wastewaters.
- Studies on the optimization methods (RSM), logarith-

mic or exponential model and statistical designs can be done on full scale.

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