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Pollution Effect Of Painted End-Of-Life Tires On Water Resources: Case Study Of Landscape Applications

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Abstract— Reuse of End-of-Life Tires (ELT), especially in architectural applications or landscape areas, is highly preferred today. At the same time, waste tires are used to prevent collisions on the side surfaces of boats in recreational areas such as lakes. Being able to be painted in the desired color for open space design is also a great advantage for quality and cost-effective projects. However, some toxic pollutants can also be released by leaching from whole, wrinkled or granular ELT-based products. In this study research conducted on acrylic spray-painted whole size ELT to evaluate general leaching characteristics under two different water sources. The small variety found for pH in both experimental conditions (0.10 to 0.24 for lake water and 0.17 to 0.40 for ornamental pool water). The electrical conductivity (EC), Total Dissolved Solid (TDS) and Salinity were found to be constantly increases as soaking continue for both type of water. However, the highest EC value of 585 µs, TDS value of 430 ppm and Salinity value of 0.30 ppt were observed with ornamental pool water treatment conditions. A similar trend was also observed for turbidity, as leaching in progress which is continuously increased. It is reasonable to hypothesized that landscape applications (ornamental pool, landscape pool or parks) water is potentially more aging effects on acrylic painted ELT rather than lake water. As a result, the reuse of painted ELT's in open recreation areas, boats on the lake and parks will increase the risk of pollution of water resources.

Keywords—painted end of the life tire, landscape application, water pollution, turbidity, hardness of tire.

I. INTRODUCTION

The environmental effects of landfill areas can reach serious dimensions today. Landfills are today being overfilled with enormous amount and a wide variety of such substances as tires, metals, wood, ceramics, asbestos, glass, plastic, tiles [1]. In 2009, approximately 3.2 million tons of end-of-life tires (ELT) were discarded in Europe. However, much of them are disposed to landfill or burnt off without proper treatments, which cause serious environmental problems [2]. As tires worn, some toxic ingredients leach out, contaminated to soil, air and water sources [3]. The determination of all leachate chemicals from ELTs or fragments are a phenomenon, but toluene, various type aromatic compounds, carboxylic acids, aniline, benzene, phenolic compounds, hydrocarbons, copper, nickel, zinc, are reported by various of researchers [2-6]. Moreover, over time, these compounds could pose significant threats to natural balance, the leachates able to form complexes with ions affect the precipitation of the environment while these, complex formation changes the quality of habitat.

As a results of gradual increase in people's demands for quality of life, there is an increasing demand for landscaped green spaces in cities. In this regard, there is a growing need for using cost-effective materials on urban open space design applications. However, ELT is a man-made waste material which may be re-useable on design applications [7]. The whole ELT's recycling is simple and requiring no extensive processing, while other alternatives require that be split, punched, molded or shredded to make new products. Although there are some waste disposal problems, numerous studies have also indicated the use of ELT's have benefits on increasing sustainability of the construction industry while decreasing cost and the need for natural resources and giving solutions to environmental pollution [8-9].

Car tires are designed to be tough, rugged, durable, and as much as possible, indestructible throughout their service life while they have also continued to show those properties even after they have become a waste material [10-12]. It has already well presented by number of researchers that ELT-based products can effectively and affordably help bring some creative ideas to landscape design practices with many benefits [13-17]. It has well documented ELTs can be recycled into mulch, turned into edging, interlocking bricks, asphalt, paving, potting plants, crash barriers, at maritime ports, sound barriers, rubber bricks and patio stones [13, 14, 18, 19].

Leaching of materials is a natural process, typically rainwater and runoff via waterways occurs. Because water from rain, flooding, or other sources seeps into the ground, it can dissolve chemicals and carry them into the underground water supply. Thereby, leaching is concern when it contributes to groundwater contamination. A larger number of studies have reported the toxicity of tire particle leachates [15, 20]. It has already well proposed ELT could be release (leach) some compounds that effects aquatic, soil and atmospheric toxicity, scrap tires in landfills have direct effect on human health, contaminating soil and ground water [4, 6, 20, 21]. However, painted and colored whole, slitted and crumped waste tire-based materials are commonly utilized in urban open space design practices to create artistic objects, suitable to place environment [6, 13, 14, 17].

There are numerous literature findings on those complex phenomenon and reports on chemicals and variables. But almost all these studies are focused on chemical toxicity analysis rather than urban open space design evaluations [22 - 24]. At present, there has not information regarding a method to measure the paint leachates from whole ELT substrate in situ at urban open spaces. In this sense, it has considered a systematic research need to be carried out. Thus, a comprehensive understanding of the interaction between water and painted ELT are important and necessary. In this study, two different type of water source (water of Eğirdir Lake and landscape ornamental pool water) are utilized in terms of impact on leaching properties of acrylic spray-painted ELT under *in situ* conditions.

II. Material and Methods

An ELT was obtained from a local flat tire repair shop, in Isparta province, Turkiye. The general noted properties of ELT are;

- Type and size: M+S; 175/65/R14,
- Manufacturing year: 2013,
- Tread: Four plies; one polyester and polyamid cord, two steel cord,
- Sidewall: One ply polyester cord.
- Color of paint: Yellow color, a spray acrylic-based paint.

When whole size ELT bring to laboratory conditions, it was carefully washed with warm water (40-50 ºC) to remove dust, must and other contaminants then dried at room conditions.

Commercially available a spray acrylic-based paint (yellow color) was supplied in a 400ml can. Although each company has its own formulations, the acrylic paints are typically consisting of pigment suspended in acrylic polymer emulsion, plasticizers, solvent, and binder. Firstly, ELT was equally divided into three parts. Secondly, the spray paintings were conducted on each parts on vertically-mounted ELT at a constant rate of approximately 30 seconds while it was made from 30 cm distance. At the end of painting procedure, painted ELT was conditioned in room conditions at approximately 72 hours before further experimental tests.

The acrylic painted ELT was subjected to two different type water leaching test by soaking in water of Eğirdir Lake and ornamental pool water in 6.0 L. plastic container. The daily measurements (up to 14 days) were conducted in line (in situ) throughout experimental procedure at conditioned room for 14 days at 23 °C (± 2) and 50% (± 5) relative humidity conditions.

While very complex ingredients of acrylic dye and ELT, it is not intended to characterize and determine all leachate chemicals instead only basic pollution parameters were measured. In this sense, four water quality parameters, commonly accepted for determining water quality level, have been selected by following standard and recommended methods of analysis [6, 25, 26]. These were pH, total dissolved solids (TDS), electrical conductivity (EC), and salinity were examined. A multi-parameter instrument (Apera PC5, Wuppertal, Germany) was used to measure these values. The turbidity of water sample was determined by a turbidity meter (Hanna HI 93703, East Drive Woonsocket, RI, USA) according to the ISO 7027 International Standard.

A Shore Hardness (Scale D) instrument was utilized to measure the hardness properties of the ELT which were conducted according to the ASTM D2240 standard. Due to different sections on ELT, it was divided to three sections (sidewall, shoulder and tread) and each of those were measured separately. The ten measurements were conducted in each section and total of 60 measurements were made in each water treatment type (lake water and ornamental pool water) of ELT.

III. Results and Discussions

The whole doughnut shape of ELT can allow to use numerous places and purposes. But in simple way, as planter by filling with soil. In this utilization, control and maintenance of potting planting could be more manageable while rubber can also absorb sunlight to help root growth. However, painted uniform doughnut shape of ELTs can be very attractive for landscape practices, particularly when those are placed on parks or open spaces Fig 1 show some representative examples of painted ELT-based planters, placed on desired places.

Fig. 1. Painted ELT-based planters for landscape practices.

The leachate evaluation is very complex, and little research has been conducted to determine which of the constituents contribute to the toxicity of ELT leachate. However, most of the studies on the leachability of ELTs have been conducted for unpainted, shred and crumb samples. This approach could be unrealistic because whole ELT can seep into the flowing soil, may be spread to the field or absorbed by environment. In this study, leaching properties of acrylic spray-painted ELT soaked in lake water and ornamental pool water were measured under in-situ conditions. To interpret the experimental findings comparatively, the pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity, up to 14 days of measurements are given in Table 1.

TABLE I. THE EFFLUENT PROPERTIES OF PAINTED ELT TREATED IN LAKE WATER (X) AND ORNAMENTAL POOL WATER (Y)

Days	pH		EC (µs)		TDS (ppm)		Salinity (ppt)	
	X	***Y***	***X***	***Y***	***X***	***Y***	***X***	***Y***
0	8.16	7.65	426	362	304	258	0.22	0.18
1	8.19	7.80	427	503	315	358	0.22	0.25
2	8.27	7.82	440	511	312	361	0.22	0.25
3	8.19	7.95	447	520	319	369	0.23	0.26
4	8.16	7.79	451	512	323	363	0.23	0.26
5	8.20	7.97	473	532	337	377	0.24	0.27
6	8.21	7.86	488	546	346	388	0.24	0.27
7	8.23	7.81	496	554	351	392	0.25	0.28
8	8.17	7.82	503	556	357	394	0.25	0.28
9	8.34	7.83	517	568	369	404	0.25	0.28
10	8.40	7.82	517	574	369	406	0.26	0.29
11	8.16	7.83	527	580	375	407	0.26	0.29
12	8.37	8.03	546	582	385	400	0.27	0.29
13	8.26	8.04	564	584	394	420	0.28	0.29
14	8.17	8.05	566	585	403	430	0.29	0.30

*EC: Electrical Conductivity, TDS: Total Dissolved Solids

For pH, both show in small variate, only 0.10 to 0.24 different for lake water and 0.17 to 0.40 for ornamental pool water from controls, respectively. These clearly indicates only marginally changes in terms of acidity at given durations. However, other parameters (EC, TDS and Salinity) appear to constantly increases as soaking continue for both type of water treatments. The highest EC- (X: 566 µs, Y: 585 µs), TDS- (X: 403 ppm, Y: 430 ppm) and Salinity- (X: 0.29 ppt, Y: 0.30 ppt) values were found at 14 days of durations. Those values about 32.8% and 61.6% higher EC, 32.5% and 66.7% higher TDS and 31.8% and 66.7% higher Salinity properties than controls, respectively. The results presented in Table 1 clearly support hypothesis that pool water is potentially more aging effects on acrylic painted ELT rather than lake water.

Like other properties, more less similar trend was also observed for turbidity, as leaching in progress which is continuously increased throughout study. But it is important to note that the highest turbidity values of 8.22 NTU and 8.70 NTU were found to be after 14 days of soaking in both lake and ornamental pool water, respectively (X control: 3.20 NTU, Y control: 3.31 NTU). The turbidity difference values from controls were calculated and plotted in Fig 2 It appears turbidity values show very high correlation coefficient (R2: 0.0.879 for X and R2: 0.9538 for Y) which means dependent with measuring time (days). However, the pool water appears to more effective on aging/leaching on acrylic painted ELT than lake water, particularly after five days of treatment. It has well proposed the chemical conditions (e.g. chlorine) impact on the leaching of ELT. Although visual appearance of painted ELT is one of the important acceptance criteria for landscape design practices (gardens, park or ornamental pool) the measured mathematical results may be a consideration on ELT at public open spaces which aesthetic appearance is important.

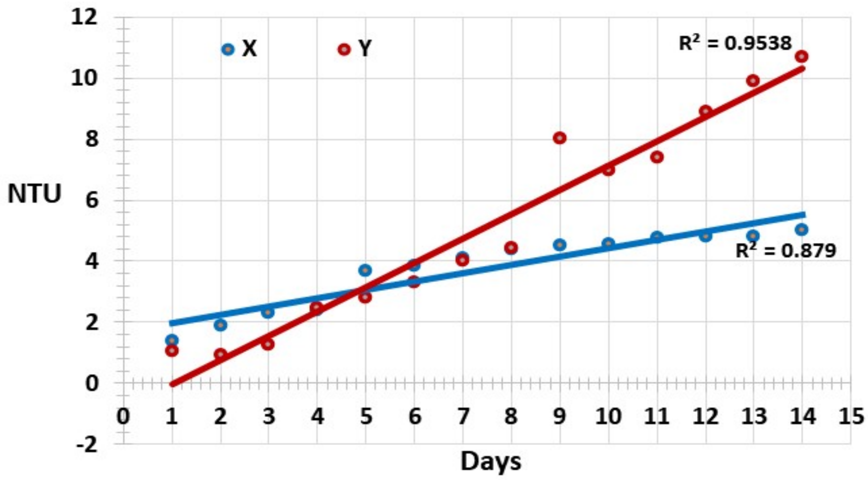

Fig. 2. Turbidity properties of sample

The EC values (differs from controls) of samples are plotted in Fig 3 It is clearly seen that the EC of ornamental pool water treated samples is rather high, means that it contains higher number of leachates than lake water leachates (X) at similar conditions.

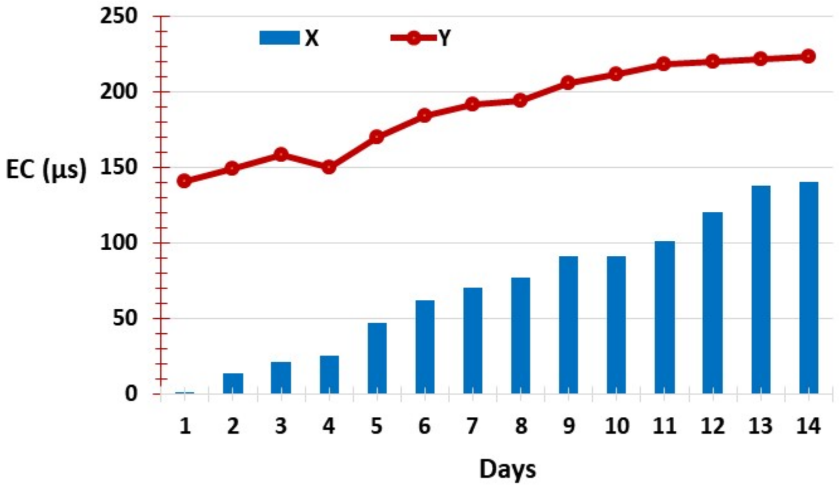

Fig. 3. The EC properties of samples

Total solid content, either dissolved or retained in solutions is one of the most often used tests in quality of waters. As mentioned above, several chemical constituents are reported by numerous scientists, in both acrylic paint and ELT which is a phenomenon to determine all those polymeric, organic and inorganic substances. However, TDS of the leachate waters was found to be 8 ppm to 99 ppm higher from lake water (X) and 100 to 172 ppm higher from ornamental pool water (Y) (Fig 4). As observed turbidity and EC properties, the similar results were also found for TDS which ornamental pool water impact on painted ELT higher rate than lake water at similar treatment conditions.

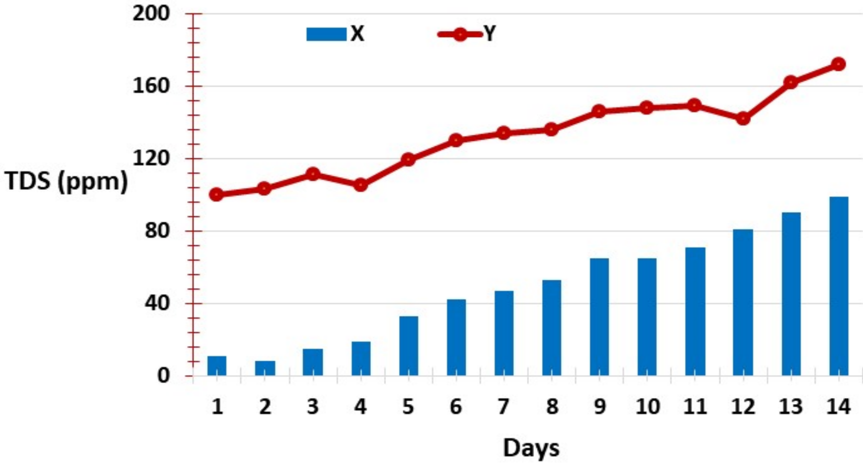

Fig. 4. TDS properties of samples

ELT contains several chemicals, including heavy metal components [21]. In case of contact with water, it increases the salinity, conductivity and dissolved solids amount of the water [6]. The findings obtained as a result of the study prove this effect and the use of dyed waste tires in parks and recreation areas may cause an undesirable physiological reaction.

Because of elasticity properties in cushioning need places, the hardness of ELT which treated with lake and ornamental pool water were determined. However, ELT typically bear different sections in terms of physicochemical properties. Thereby, the ELT divided to three parts (Fig 5), hardness measurements were made in these sections (sidewall, shoulder and tread), results are presented in Table 2.

Fig. 5. Different parts of ELT for Shore-D hardness measurements

In contrast to leachate findings, briefly presented above, the lake water treatment appears to more impact on hardness properties of ELT rather than ornamental pool water treatment. In all three sections, the lowest hardness properties were found with lake water treatment which Shore D hardness value of 17.0 was found with tread, followed by sidewall (18.0) and shoulder (25.91), in that order.

TABLE II. SHORE-D VALUES OF ELT'S DIFFERENT PARTS

Tire sections	Control	X	Y
Sidewall	21.79 (2.21)	18.61 (2.24)	24.64 (2.47)
Shoulder	28.41 (2.87)	25.91 (2.76)	28.59 (2.56)
Tread	28.18 (3.63)	17.0 (1.84)	28.64 (3.04)

Fig 6 show average hardness values of lake water and ornamental pool water treated ELT. Interestingly, ornamental pool water treatments increasing effects on hardness properties compare to control (26.13 vs. 27.29). However, lake water treatments effects lowering hardness properties which was found to be approximately 21.4% and 24.9% lower than control and ornamental pool water treatments, respectively.

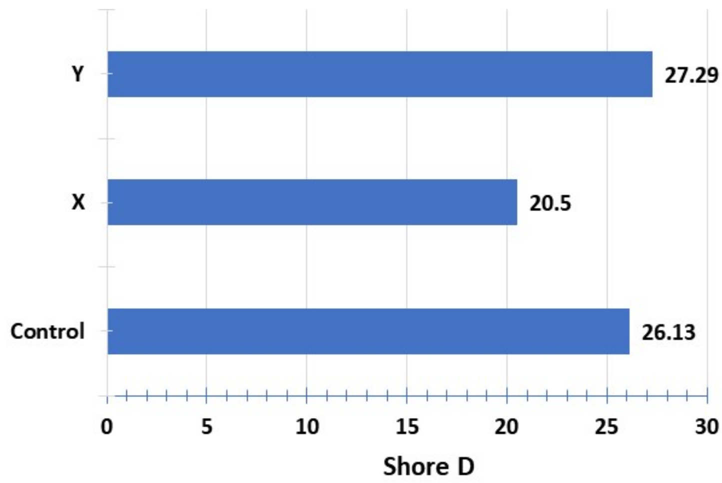

Fig. 6. Avarege shore D hardness of ELT

IV. CONCLUSIONS

Because ELT is potentially easy, cost-effective way to utilize in urban areas, and a creative a sustainability way to turn useless thing into something productive, there are vast literature reports and recommendations for ELT in landscaping. In our study, for determining acrylic painted ELT leaching characteristics which is typically faced at outdoor conditions, we were conducted an in-situ experimental procedures with two different water sources (lake and ornamental pool water). After the 14 days of continuously soakings, we were measured selected water physicochemical characteristics and hardness properties (Shore D hardness scale). We were assumed those measurements may be useful to determine leachability and most common material properties. It could be concluded that the doughnut shape of ELT may be an alternative and cost-effective design solutions in many landscape practices. But especially painted ELT's in water containing area should be used with caution.

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