



Comparison of Various Plastics Wastes Using X-ray Fluorescence

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Abstract: Plastics production is increased recently due to their various applications such as construction, electronic, packaging and others. The rising in plastics demand lead to developed of recycling and energy recovery method to control plastic wastes. Recycling process is needs to be arranged according to resins, colors and transparency of all plastics. Energy dispersive X-ray fluorescence (EDXRF) was developed for the determination of the chemical composition in different plastics materials (with resin identification code) of PETE (1) or PET (01), HDPE (2) or PE-HD (02), V (3) or PVC (03), LDPE (4) or PE-LD, PP (5) or PP (06), PS (6) or PS (06) and Others (7) or O (07). XRF was measured elements such as Si, S, Cl, Fr, Ca, Ti, V, Fe, Cu, Zn, As, Kr, Zr, Nb, Mo and Nb in both k_{α} and k_{β} lines, where PP with high percentage in both PET and PVC plastics, which is highly hazardous. In addition, chemical compositions in percentages were detected for various plastics materials.

Keywords: Plastics, XRF, Energy, Quantitative Analysis, Elements

1. Introduction

Plastics are as one of the greatest invention in the world [1], which can be produced from petroleum, natural gas, or renewable electricity [2]. They are responsible for changing quality of life through the developing of materials. These materials have variety applications due to their lightweight, high strength, design flexibility for any shape and their low cost [3]. Over the last 10 years, global production of plastics have been increased dramatically due to increasing demand in developing country as in Asia, Africa and South America [4], where China is the largest plastics producer in the world. The Europe plastics industry also expects expansion in global require [5]. Today, the person consumes a lot of plastic every year, mostly in the form of packaging materials and household parts. The growing waste is also become a big environmental issue in the world. In order to reduce plastic disposal to the landfill, recycling process is considered to reduce some amount of plastic waste. It is very important for plastics to be clean and then separated for recycling or energy demand including solar energy wind power, geothermal and

hydropower technology [6].

In this paper, we used plastics waste of wide range of materials including polyethylene terephthalate (PET) or (PETE) [7], high-density polyethylene (HDPE) [8] and low-density polyethylene (LDPE) [9], polystyrene (PS) [10], polyvinylchloride (PVC) or (V) [7], polypropylene (PP) [8], and others plastics including acrylic, acrylonitrile butadiene styrene, fiberglass, nylon, polycarbonate and polylactic acid (Other) or (O) [11]. LDPE, HDPE, and PP are the most type of thermoplastic used throughout the world for many applications such as bags, toys, containers, pipes (LDPE), housewares, industrial wrappings and film, gas pipes (HDPE), film, battery cases, automotive parts, electrical components (PP). In addition, polymers as polyethylene in contrast to condensation polymers as polyethylene terephthalate (PET) cannot be easily recycled using simple chemical methods [12], but the plastics can be recycled using either mechanical technique or chemical/feedstock recycling [13, 14]. Therefore, the more reliable method has been used

to reduce some amount of plastic waste.

Plastics contain different chemicals that are added to a polymer to improve manufacturing and materials performance such as durability, flexibility, longevity and aesthetics. Some of additives are highly hazardous as in PVC used on wire and cable, which contain lead and some end uses of polypropylene and polyethylene [15]. By comparing the plastics with other materials, the recycling of plastics can be used to identify and characterize of different collected plastics. There are various techniques used to determine the plastics type such as chemical analysis and infrared spectroscopy [16]. These techniques are less useful when looking for additives in the plastics. X-ray fluorescence (XRF) is evaluated as a method to determine the plastics types, where it used to determine chemical elements.

2. Material and Method

Plastics materials have been obtained from used personal plastics food, milk and water bottles and cosmetics containers. For the analysis, the plastic samples were cut into circular shape at diameter of around 3.5 cm. The elemental concentration and their emitted energies for seven various plastics were determined using energy dispersive X-ray fluorescence (EDXRF). All measurements were carried out under vacuum, using a Rigaku NEX CG with RX9, Mo, Cu and Al targets. Chemical elements of Si, S, Cl, Fr, Ca, Ti, V, Fe, Cu, Zn, As, Kr, Zr, Nb, and Mo were detected with plastics. The EDXRF K_{α} and K_{β} lines intensities were measured for almost all plastics elements, in which the applied voltage increased in general with the required lines energies. The X-ray measuring time was only 200 s for the Al target and 100 s for other targets.

In this study, X-rays from the X-ray tube pass through an optional filter on their way to the plastics sample. The sample placed in the chamber and measured by 20 mm diaphragm in vacuum. The X-rays then travel from the sample to the detector, which is cooled electrically. The signal is then processed by electronics and sent to a computer program, where the chemical compositions and intensity versus energy is measured, as shown in Figure 1.

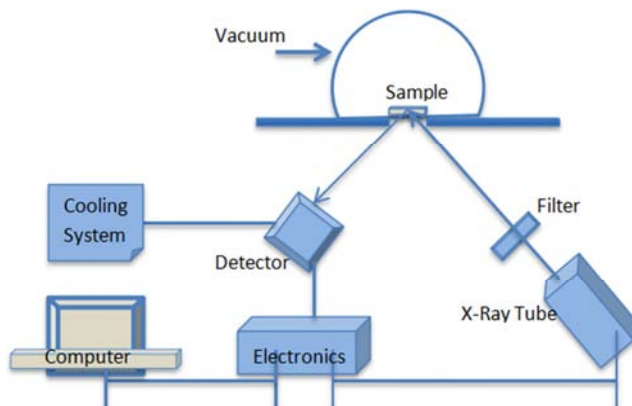


Figure 1. Schematic of a typical energy dispersive X-ray fluorescence EDXRF Spectrometer.

3. Results and Discussion

Rigaku NEX CG X-ray fluorescence (XRF) spectrometer analyses were used to determine elements using six plastics samples of PET, HDPE, PVC, LDPE, PP, PS and Others, numbered by 1, 2, 3, 4, 5, 6 and 7, respectively. When these samples are irradiated with X-rays, the intensity as a function of energy can be calculated over the energy range 1-20 keV at the same computing conditions. Figure 2 shows the peaks in the ranges of 1.74, 2.32, 2.63, 2.86, 3.69, 4.03, 4.52, 4.96, 6.4, 8.01, 8.81, 10.56, 12.63, 15.77, 16.83, 17.48, and 18.86 keV corresponding to Si- k_{α} , S- k_{α} , Cl- k_{α} , Fr- M_{β} , Ca- k_{α} , Ca k_{β} , Ti- k_{α} , V- k_{α} , Fe- k_{α} , Cu- k_{α} , Zn- k_{α} , As- k_{α} , Kr- k_{α} , Zr- k_{α} , Nb- k_{α} , Mo- k_{α} , Nb- k_{β} lines. It shows from figure that the intensity of Ti- k_{α} for HDPE sample has higher intensity than the other plastics samples, while the intensity of As- k_{α} , Kr- k_{α} and Zr- k_{α} have lower intensity or almost negligible intensity.

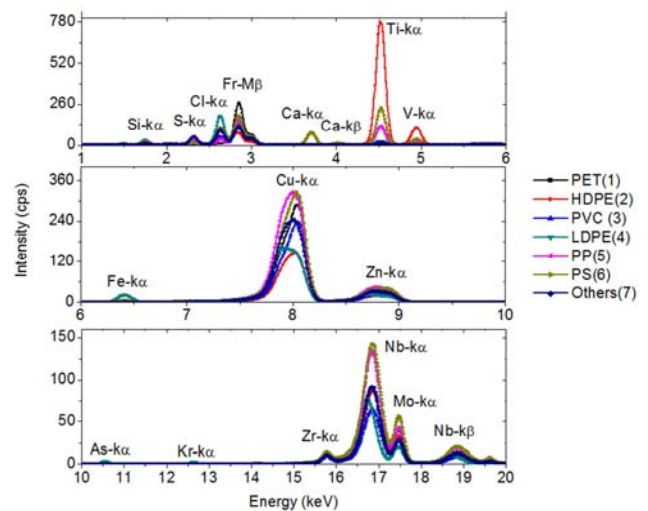


Figure 2. Intensity versus energy for various plastics of PET, HDPE, PVC, LDPE, PP, PS and Others calculated over the energy range from 1 to 20 KeV using XRF with RX9, Mo, Cu and Al targets.

Furthermore, the chemical compositions for plastics of PET (1), HDPE (2), PVC (3), LDPE (4), PP (5), PS (6) and Others (7) have detected by the XRF. As shown in Table 1, the results are given as a relative mass concentration % of the elements contained in seven types of plastic samples. PP was selected as a fixed value from computer program. The % concentration of propene PP appears to be high in almost all the samples. PP has a good chemical and heat resistance and applications include flowerpot, office folders, car bumpers, pails, carpets and storage boxes [17]. PP is about 100% in both PET and PVC plastics, which is highly hazardous if daily used. PET has great choice for various food products, mainly beverages such as mineral water, soft drink bottle and fruit juice containers [18], while applications of PVC has include wire and cable insulation, window frames, boots, food foil, medical devices, blood bags, automotive interiors, packaging, credit cards and synthetic leather [15].

The total percentages for the seven samples were less and more than 100% due to the statistical errors during

measurement. Element of Ti is appear with high percentage at about 1.67, 0.255 and 0.612 in HDPE, PP and PS, respectively, which is in good agreement with Figure 2, that Si is detected with high intensity. HDPE, PP and PS. Plastics coded 1, 2, 3, 4, 5, 6 and 7 have high concentration of Si at around 0.0075, 0.0182, 0.0068, 0.0567, 0.0335, 0.0363 and

0.0175, respectively. In addition, low concentrations at about 0.0001 were appeared in Mn, Cu, Hf and Zn for PET and PVC. Elements of (Br, Nb), (Hf, As, Rb), (Hf) and (Hf, Tb) appear also with very low concentration in HDPE, LDPE, PS and Others, respectively.

Table 1. XRF measurements for elements of Plastics (as percentages), where the totals are more than 100% due to the statistical errors.

No.	Elements	Concentration %						
		PET (1)	HDPE (2)	PVC (3)	LDPE (4)	PP (5)	PS (6)	Others (7)
1	PP	100	98.2	100	99.8	99.6	98.7	99.7
2	Si	0.0075	0.0182	0.0068	0.0567	0.0335	0.0363	0.0175
3	Sb	0.004	0.0009	0.0028	--	--	--	--
4	Ca	0.0022	--	0.0037	0.0081	0.0049	0.0391	0.0056
5	Al	0.0021	0.0274	0.0020	0.0429	0.0153	0.0341	0.0139
6	S	0.0014	0.0068	0.0013	0.0105	0.0136	0.0050	0.0201
7	Cl	0.0011	0.0117	0.0086	0.0363	0.0068	0.0222	0.0188
8	P	0.0009	0.0075	0.0010	0.0007	0.0027	--	--
9	Sn	0.0004	--	--	0.0005	0.0007	0.0008	0.0006
10	Fe	0.0003	0.0005	0.0005	0.0045	0.0006	0.0014	0.0003
11	Ti	0.0002	1.67	0.0004	0.0567	0.255	0.612	0.0221
12	Mn	0.0001	--	--	0.0002	--	--	--
13	Cu	0.0001	0.0001	0.0001	0.0005	0.0036	0.0002	0.0003
14	Hf	0.0001	--	0.0001	0.0001	--	0.0001	0.0001
15	Zn	0.0001	0.0007	0.0001	0.0005	0.0004	0.0056	0.0016
16	Mg	--	0.0167	--	--	0.0149	--	--
17	Br	--	0.0001	--	--	--	--	--
18	Nb	--	0.0001	--	--	--	--	--
19	K	--	--	--	0.0162	--	--	0.0007
20	Pb	--	--	--	0.0011	--	--	--
21	Cr	--	--	--	0.0011	--	--	--
22	Cu	--	--	--	0.0005	--	--	--
23	As	--	--	--	0.0001	--	--	--
24	Rb	--	--	--	0.0001	--	--	--
25	Na	--	--	--	--	--	0.201	0.136
26	No	--	--	--	--	--	0.0003	--
27	Sr	--	--	--	--	--	0.0001	--
28	Zr	--	--	--	--	--	0.0219	0.0159
29	Tb	--	--	--	--	--	--	0.0001
30	Co	--	--	0.0001	--	0.0001	--	--

4. Conclusions

In summary, we had compared a various plastics wastes of PET (1), HDPE (2), PVC (3), LDPE (4), PP (5), PS (6) and Others (7) using XRF. In almost all plastics samples, high concentrations of Si element were appeared, while with low percentage of Mn, Cu, Hf, Zn, Br, Nb, As, Rb, and Tb was detected in other plastics samples. Plastics present a 100% percentage of PP in both PET and PVC, which used daily life and it seems highly hazardous.

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