Employing Electronic Features Extraction to Improve The X-ray Detection Based on Aluminums Filter

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ABSTRACT

The X-ray detection improvement using many filters for soil samples are studied. The peak to background ratio is calculated for many filters and without filter mode. A non-destructive Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer was used for measuring and analysing samples. Five filters can be used to decrease the background noise. Aluminium filter gave the best performance of peak / background ratio when measure any sample comparing with other filters. This work also included a SpekCalc program to calculate the X-ray spectra from different filters for different thicknesses. For Al, Cu, Be and Ti filters, the value of peak / background ratio are calculated. The best result is achieved at a maximum value of peak / background ratio. The obtained results from EDXRF spectrometer and simulation showed that increases of Aluminum filter thickness improved the detection of material samples.

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1. INTRODUCTION

In early 1960s, X-ray fluorescence (XRF) is developed to process mineral in factories. XRF technique is used to identify and determine the concentrations of elements in shape of solid, powder and liquid samples. XRF is usually used in mining, geology research , Cement production and petroleum industry[1][2]. X-ray spectrometers contain a source, sample and detector .Electrons are emitted when applied high voltage through filament wire in X-ray tube. The electrons accelerating and move to anode. Bremsstrahlung radiation is produced when electron hits anode atoms. This radiation is consist of continuous band from energies. Another radiation is produced when electrons hit atoms and expel electrons from these atoms, this radiation is known as characteristic radiation[3][4]. Spectrum measurement systems are divided into wavelength dispersive systems (WDXRF) and energy dispersive systems (EDXRF). The elemental range of the elements that EDXRF spectrometer can detect is from Sodium to Uranium in the periodic table. The measurements are instantaneous for this device and it consumes a power of 5-1000 watts. Resolution is good for heavy elements and less optimal for light elements[5]. EDXRF uses selective excitation and broad-band detection. The detector of EDXRF spectrometer separates the radiation from the sample into the radiation of the elements in the sample. Silicon and Germaniumis the most material that used for semiconductor detectors. The properties of two materials are provide high energy resolution and a large size mono crystals with good electrical properties[6][7]. Because silicon is less exposure to charge carrier trapping and space charge accumulation, it considered the best detector for detecting low energy of X-ray. Silicon detectors are made by conventional technology: photolithography, oxidation, ion implantation and aluminum deposition[8]. In this study, EDXRF spectrometer provide by Si-PIN detector [9]. The important of PIN detector is reliability and accuracy in converting the measured currents into photon flux. In recently years, array of PIN detector is fabricated which is consist of 24 element. High absorption efficiency and high resolution energy is achieved by using array of PIN detector [10]. Accuracy of energy is affected by detector leakage current, operating temperature and interference between channel[6]. The filter of EDXRF spectrometer is placed between the X-ray tube and the sample and absorbs the X-ray by adjusting the spectrum coming from the X-ray tube. In other meaning, filter improve peak to background ratio by reducing background noise. In general, filters are typical pure metal sheets with a thickness of 10-500 µm. The voltage is first selected in kilovolts and then the filter is chosen. Filter properties are determined by selecting the material and determining its thickness[2]. Pure materials are used to evaluate peak to background ratios without filter and with filter: Al filter at 0.1mm thickness, Ag filter at 0.01mm and W filter at 0.01mm. different filters of portable system was compared with stationary X-ray system by Guiherme et al[7]. There are many methods to reduce background in the low energy region. Cesareo et al. used barium oxide powder for filtering output of Ag anode X-ray. Another method presented by Ferreti et al. this method use Cu filter with 0.3mm thickness to decrease bremsstrahlung from W anode X-ray tube. X-ray systems are developed to use two filters or more for getting required result. Aluminum filter is a simple absorption filter and it is popular use in EDXRF. Al filter have absorption edge at 1.5 K eV it absorbs L lines from X-ray tube to remove interference[11][12].

2. Instruments and Materials Used In Propsed Filters

Minipal 2 energy dispersive XRF Spectrometer from Philips company were used for analyzing elements. Instrument measure the concentrations from 100% down to ppm levels. Minipal2 based on flexible and fast software [13]. Filtering system and hardware configurations are controlled by software. Furthermore, XRF-Minipal2 is simple and no required any preparation for samples. EDXRF spectrometer used to measure the intensity of the different material in the research[14]. Minipal 2 provide with Si-PIN detector and rhodium as anode with Be window. Resolution of spectrometer is 160 eV at 5.9 K eV. The X-ray tube has a maximum voltage of 30 KV with a maximum current of 1mA[15]. The power of X-ray tube is about 9 watt, instrument spot area is $81.7\mathrm{mm}^2$. Minipal 2 can analyze different material in the form of liquids, powders, bulk solid and surface layer [16]. Twelve position of sample can be changed continuously in the EDXRF spectrometer as shown in Fig.1.

Figure.1: shows the XRF- Minipal2 instrument.

Five filters can be selected to improve the ratio of peak to background, while the background noise is decrease. Configuration of Minipal 2 system is shown in Fig.2 [12].

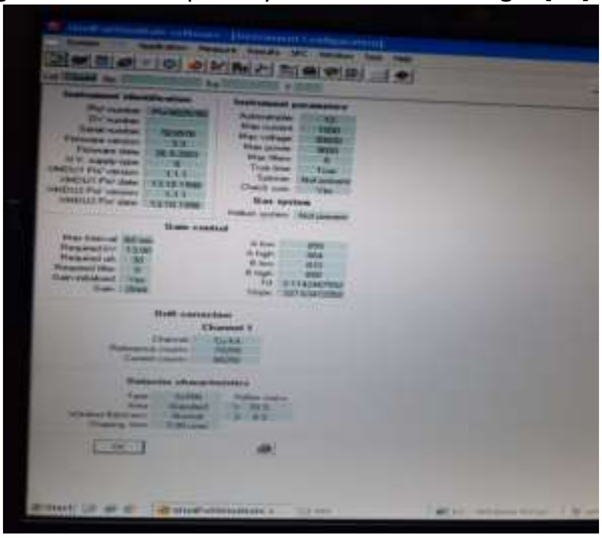


Figure.2: shows the instrument configuration.

The Instrument uses a Si-PIN detector with high efficiency and high resolution detector. The detector based on a peltier cooling system instead of liquid nitrogen cooling. The detector is operated with applied voltage equal to 5 and 60-70 voltage at the detector junction. Detector is operated at very low temperature at a value -70℃ [17][18].

3. Features of SpekCalc Program

SpekCalc is a computer program created by Cancer Research Institute in London[19]. This program is used to calculate X-ray spectra emitted from the tungsten anode for the X-ray tube. The program is a graphical user interface and based on Monte Carlo calculation. SpekCalc is used for research, education and medical physics. Half Value Layer (HVL) used to describe quality of x-ray[20]. HVL is the thickness of the material required to reduce the intensity of the X-ray to half initial value[11]**.** Wide range voltages from 40 to 300 KV are used to display and calculate energies for X-ray spectra. This program allows using a set of different filters with different thicknesses. Material is used for filtering spectra is determined in mm thickness: Al, Cu, W, Sn, Be, Water, Air, Ta, C, Ti. SpekCalc shows the mean energy of spectrum E_{mean}, and the effective energy E_{eff} measured by K eV[21]. Graphic User Interface of program is displayed in Fig.6.

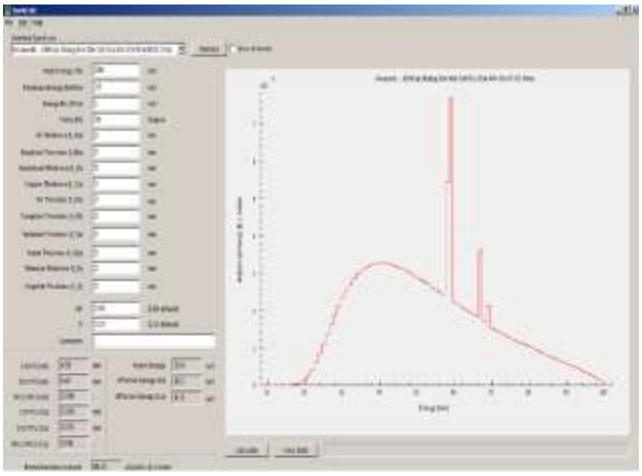


Figure.6: Graphic User Interface

4. Filters Simulation Process

By using SpekCalc, different filters are tested. The voltage is chosen at 120 kV for all Measurements. Theta is set at 30 which represents the anode inclination angle. This study includes an explanation of the effect of filters on peak/ background ratio by changing the thickness of filter. The program displays the spectrum of energy by reading the value of the intensity (count value per second) on the y-axis with the value of the energy on x-axis is in K eV[13]. The intensity and noise value is determined precisely from View Data in GUI.

For Al filter, the value of peak/ background ratio is calculated at each thickness. The thickness of Al filter is increased to improve the ratio of peak/ background. The maximum achieved value of peak/ background ratio is about 5.02 at 25mm thickness of Al filter. Peak to background ratio is calculated of Cu filter. The maximum obtained value of peak/ background ratio is about 5.02 at 0.7mm thickness of Cu filter. The peak/ background ratio of Be filter is calculated starting from 100mm thickness. The maximum peak to background ratio is determined at 300mm thickness. Finally, Ti filter is tested on X-ray spectra. The value of thickness is set from 1 to 3mm, the best ratio of peak/ background is determined at 3mm[22]. The filters thicknesses andratios of peak / background for Al, Cu, Be and Ti filters are shown in Table 7.

Table7: Display peak / background ratios and Thickness of filters in mm.

Al(mm)	P/B	Cu(mm)	P/B	Be(mm)	P/B	Ti(mm)	P/B
5	3.7	0.3	4.6	100	3	1	4.2
15	4.82	0.5	4.88	200	4.3	2	4.56
25	5.02	0.7	5.02	300	5.32	3	5

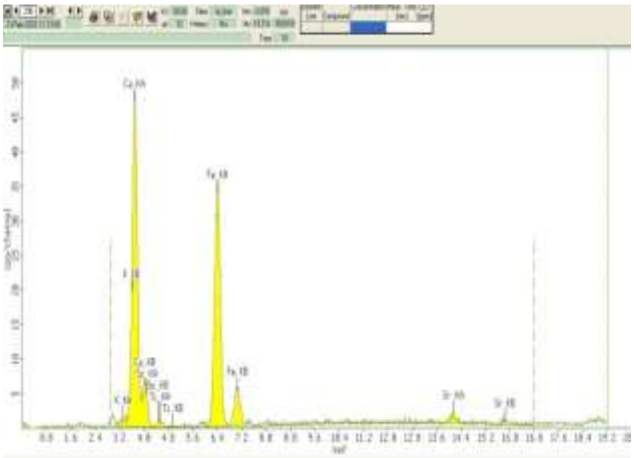
5. Results discussion

Three soil samples are analyzed using Minipal 2. In this experiment, peak to background ratio are calculated in order to choose the best filter that give the best performance of peak / background ratio. Five filters are used: Kapton, Al-thin, Al, Mo and Ag filter. Samples are measured at 30 KV and total measuring time 50 sec.

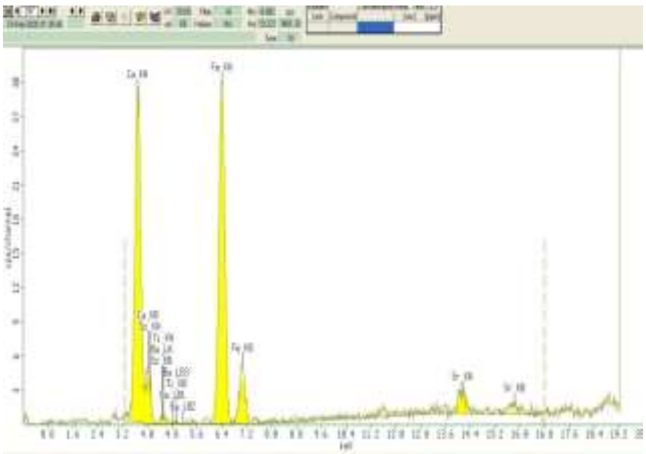
The first sample used in the research is a soil sample which composed of clay powder. Table1. Shows the peak/ background ratios for Ca ($k_{\propto}$), Fe ($k_{\propto}$). It is clear that Al filter gives the best results, the value of Ca ($k_{\propto}$) for Al filter is about 29.6, and the value of Fe ($k_{\propto}$) is about 29.9 while Al-thin filter gives the value of Ca ($k_{\propto}$) is about 23.5 and Fe ($k_{\propto}$) is about 17.25. It is observed from results that Mo filter gives a minimum value of peak / background ratio. The optimum results is obtained using Al filter compared to other filters. From these results conclude that Al filter with thickness equal 500µm can be used efficiently for detecting soil samples, which used for industry of many kinds of Cement. The effect of using Al-thin and Al filter on x-ray spectra is shown in Fig.3 (a, b). The percentage of concentration for Ca ($k_{\propto}$) and Fe ($k_{\propto}$) in sample1 using: Kapton, Al-thin, Al, Mo and Ag filter is shown in Table2.

Table 1: peak/ background ratios without filter and with filter of sample 1

Sample1	Without filter	Kapton filter	Al-thin filter	Al filter	Mo filter	Ag filter
Ca ($k_{\propto}$)	13	16.625	23.5	29.6	9	13
Fe ($k_{\propto}$)	6.2	8.15	17.25	29.9	9.5	17.75



(a)



(b)

Figure.3: Spectra of sample1 measured with: (a) Al-thin filter, (b) Al filter.

Table 2: percentage of concentration of elements in the soilsample1

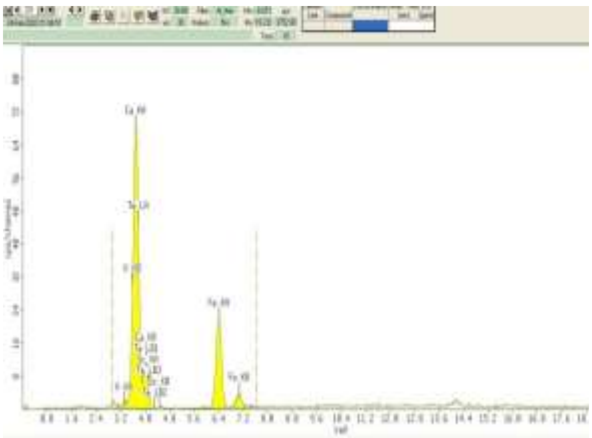
element	Kapton	Al-thin	Al	Mo	Ag

	filter	filter	filter	filter	filter
Ca ($k_\propto$)	76%	74%	73%	72%	67%
Fe ($k_\propto$)	20%	21%	23%	24%	24%

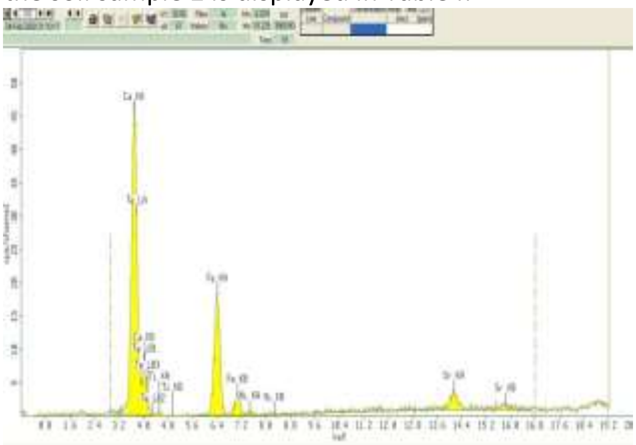
In this step, mixture sample is used for analyzing. Figure.4. shows the resulting X-ray spectrum for sample 2. The Al filter gives the value of peak/ background ratio for Ca ($k_\propto$) is about 45.5 and for Fe ($k_\propto$) is about 18.2. The value of Ca ($k_\propto$) is about 34.25 and the value of Fe ($k_\propto$) is about 10.7 by using Al-thin filter. The value of peak/ background ratio obtained for Ca ($k_\propto$) and Fe ($k_\propto$) shows the best improvement using Al filter. The comparison of peak / background ratio for filters are shown in Table3. The percentage of concentration for Ca ($k_\propto$) and Fe ($k_\propto$) in the soil sample 2 is displayed in Table4.

Table 3: Comparison of the peak / background ratio of sample2

Sample2	Without filter	Kapton filter	Al-thin filter	Al filter	Mo filter	Ag filter
Ca ($k_\propto$)	19.66	24.9	34.25	45.5	12.125	29.33
Fe ($k_\propto$)	3.44	4.94	10.7	18.2	5.25	15



(a)



(b)

Figure.4: Spectra of sample2 measured with: (a) Al-thin filter, (b) Al filter.

Table 4: the percentage of concentration of elements in the soil sample2

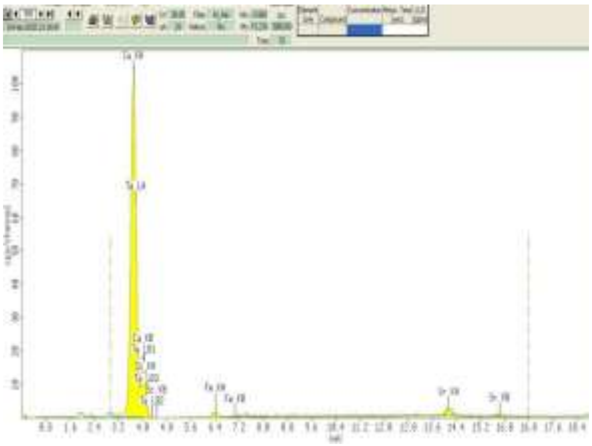
element	Kapton filter	Al-thin filter	Al filter	Mo filter	Ag filter
Ca ($k_\propto$)	87.2%	87%	85%	83%	81%
Fe ($k_\propto$)	9.8%	10%	11%	12%	12%

Stone sample is the third soil sample used for measuring and analyzing, Fig.5. Shows result of X-ray spectra for sample3. It is observed from the Table 5 of sample 3 that the maximum value of peak / background ratio was achieved at Al filter. The value of Ca ($k_\propto$) is about 58.15 for Al filter while the value of peak/ background ratio for Al-thin filter of Ca ($k_\propto$) is about 51.65. Mo filter gives the minimum value of peak/

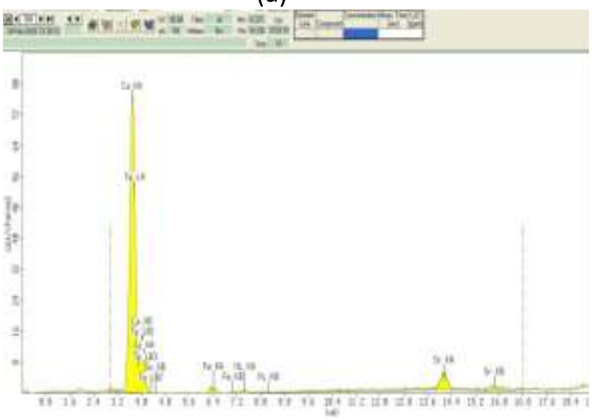
background ratio of Ca ($k_\propto$). Concentration of Ca ($k_\propto$) and Fe ($k_\propto$) for sample3 are shown in Table 6.

Table 5: Comparison of the peak / background ratio of sample3

Sample3	Without filter	Kapton filter	Al-thin filter	Al filter	Mo filter	Ag filter
Ca ($k_\propto$)	20.6	30.3	51.65	58.15	18.2	22.5
Fe ($k_\propto$)	—	0.325	0.65	0.92	0.5	0.625



(a)



(b)

Figure.5: Spectra of sample3 measured with: (a) Al-thin filter, (b) Al filter.

Table 6: shows the percentage of concentration of elements in sample3

element	kapton filter	Al-thin filter	Al filter	Mo filter	Ag filter
Ca ($k_\propto$)	98.7%	97.6 %	96.8 %	95%	92%
Fe ($k_\propto$)	0.41%	0.53 %	0.52 %	0.6 %	0.5 %

6. Conclusions

Al filter shows the best result to improve the peak/ background ratio for soil samples. Al-thick filter obtained the maximum value of peak to background ratio compared with Al-thin filter for all samples. Mo filter gave the lowest P/B ratio compared to other filters and no improvement can obtained using this filter. In SpekCalc program, the peak/background ratio is calculated for Al, Cu, Be and Ti filter. The Al filter gave the maximum ratio of P/B at 25mm thickness. The maximum value of peak/ background ratio is obtained at 0.7mm thickness of Cu filter. For Be filter, the maximum peak to background ratio is achieved at 300mm thickness. The best ratio of peak/ background for Ti filter is determined at 3mm.The thickness of Al, Cu, Be and Ti filter is increased to improve the ratio of peak/ background. The practical results are agreement with simulated results for Al filter, which concluded that increase Al filter will improve the detection of material samples.

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