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Identification of chemical elements in polluted soil using LIBS based on spectrum wavelengths range

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Abstract
Identification of chemical elements in polluted soil is very important because the soil can produce toxic substances or become a medium for the growth of microorganisms. This research used the LIBS (Laser Induced Breakdown Spectroscopy) method to detect chemical elements in polluted soil. The emission spectrum is taken from pure soil and polluted soil. Plasma emissions are then detected using a multichannel analyzer (OMA) to obtain an emission line spectrum that represents the chemical element content in the soil. The spectrum is compared with the standard reference spectrum of atoms, ions, and molecules (National Institute of Standards and Technology/NIST) so that the content of atoms and molecules in the sample can be known. The research results found that there were heavy metal elements in the form of Fe, Cu, and Mn in polluted soil.

Keywords: Polluted soil, LIBS, chemical elements

Introduction

Wastewater that contains suspended or dissolved solids, undergoes physical, chemical, and biological changes that will produce toxic substances or create a medium for germ growth. Waste will change color to blackish brown and foul-smelling. Several analytical techniques are used to identify the element content in the soil to determine the level of environmental pollution [1]. X-ray diffraction (XRD) techniques are used for pollution analysis in soil pollution [2]. The atomic absorption spectroscopy (AAS) technique is used for the analysis of heavy metal contamination in the soil around gold mining exploration in the city of Palu [3]. However, these conventional methods require complex and difficult sample preparation in the laboratory. In addition, the XRD and AAS methods require a very long time to analyze pollution on soils with a very large area so the method is not effective and efficient. Therefore, it is necessary to develop a new method that can be used for the analysis of soil pollution with fast time, does not require complicated sample preparation, can detect all elements contained in the target sample simultaneously, and has a high level of sensitivity for identification of impurities and elements Minor which is dangerous to the soil.

Soil samples are samples that have characteristics that are difficult to analyze using the LIBS method because of the matrix effect in the form of physical and chemical properties. However, we have succeeded in analyzing heavy metal pollution in soils using a new LIPS method [4]. As a result, toxic and heavy metal impurities in the soil can be identified with a high level of sensitivity (ppm order). These results promise the possibility of using the LIPS method for elemental analysis in polluted soils.

Dario Santos et.al. conducted an experiment on LIBS for the determination of cadmium in soil [5]. The soil sample was prepared in the form of a pellet before analysis. They concluded that the LIBS can be employed to screen cadmium pollution in soil. Pandhija et.al. demonstrated an experiment on LIBS for the determination of heavy metals Pb in soil [6]. Semi-quantitative analysis of Pb in soil can be realized with a detection limit of 45 ppm. Various studies on soil analysis by using LIBS have been made as reported elsewhere [7-12]. There is a lack of information dealing with the detection of oil pollution in soil by using LIBS.

Recently, laser-induced breakdown spectroscopy (LIBS) has become a tremendous method for qualitative and quantitative analyses of sample targets in various kinds of samples including liquid [13, 14], metals [15, 16], and solid [17, 18]. In this technique, a pulse neodymium yttrium aluminum garnet (Nd: YAG) laser is focused on/in a sample to induce a luminous plasma. In the plasma region, molecules and atoms ablated from the sample can be effectively dissociated and excited [19, 20]. Compared to other conventional analytical methods, standard LIBS is much superior because the rapid analysis can be performed without tedious sample preparation and it has low-cost experimental equipment [20]. Several studies have reported on the application of standard LIBS for the analysis of soil targets [21, 22]. Del`Agglio et al. have detected heavy metal elements such as Cr, Cu, Pb, and Zn in soil. A comparative study has been made by using ICP-OES. The satisfactory agreement confirmed the correlation between ICP-OES and LIBS [23]. However, in the standard LIBS method using pulse Nd: YAG laser, the soil sample should be prepared in the form of a pellet for an effective dissociation and excitation process [24, 25]. This research examines the LIBS method for identification of chemical elements, and analysis of the potential for toxic metal contents in soils polluted by the paper industry waste.

Methods

The arrangement of equipment used in the study is shown in the following Fig 1.

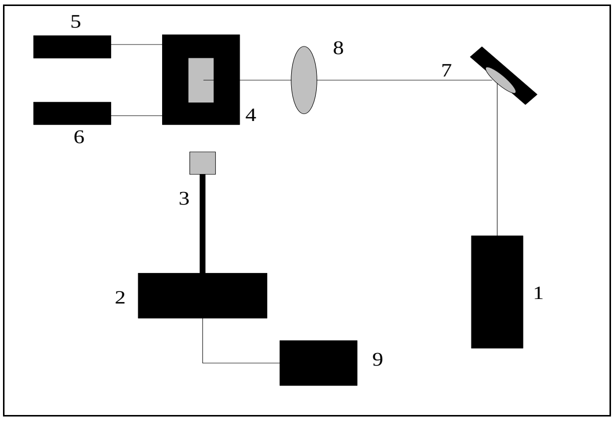

Fig 1: The arrangement of LIBS tools in research

The equipment used in this study is (1) Nd: YAG laser as an energy source (1064 NM, 150 mJ, 7ns), (2) Optical Multichannel Analyzer (OMA) connected to (3) optical fibers, (4) Chamber as a sample container connected to (5) vacuum pumps and (6) pressure measuring equipment, (7) mirrors, (8) lenses for laser beam focusing and (9) computers. Each sample is given the same experimental treatment, raised at a low pressure of 5 Torr, 83 mJ energy.
The samples used in this research were soil with contaminated waste and soil uncontaminated. The determination of an element in a sample can be known through spectrum graph data. The data for each detected wavelength intensity is matched with the Atomic Spectra Database Line Form reference data from the NIST (National Institute of Standards and Technology) Physical Measurement Laboratory.

Results and Discussions

In this research, the plasma spectrometer method identified the content of heavy metal elements in soil contaminated with waste around the disposal of paper mill liquid waste. The results obtained are compared with uncontaminated land that is far away from the waste disposal site. From the spectrum data obtained with OMA and the results compared with NIST, there are several chemical elements such as Fe I, Fe II, Mg, Al, Ca, and Si with different intensities in uncontaminated soils. Whereas in polluted soils, several chemical elements are detected such as Cr, Cu, Al, and S at certain wavelength ranges.
Fig 2 shows the spectrum difference between polluted soils and uncontaminated soils in the wavelength range of 250 nm -290 nm. In polluted soils, there are heavy metal elements in the form of Cr II at wavelengths of 267.71nm and 283.57nm. In the range of wavelength 370nm - 450nm (as shown in Fig 3), the contaminated soil detected elements of Mn I 370.61nm and Cr I 425.43nm. Fig 4 shows the heavy metal elements detected in polluted soils in the form of Ca I (558.88nm, 559.43nm, 559.87nm), S II (616.18nm), Al II (649.38nm) in the wavelength range of 450nm - 700nm.

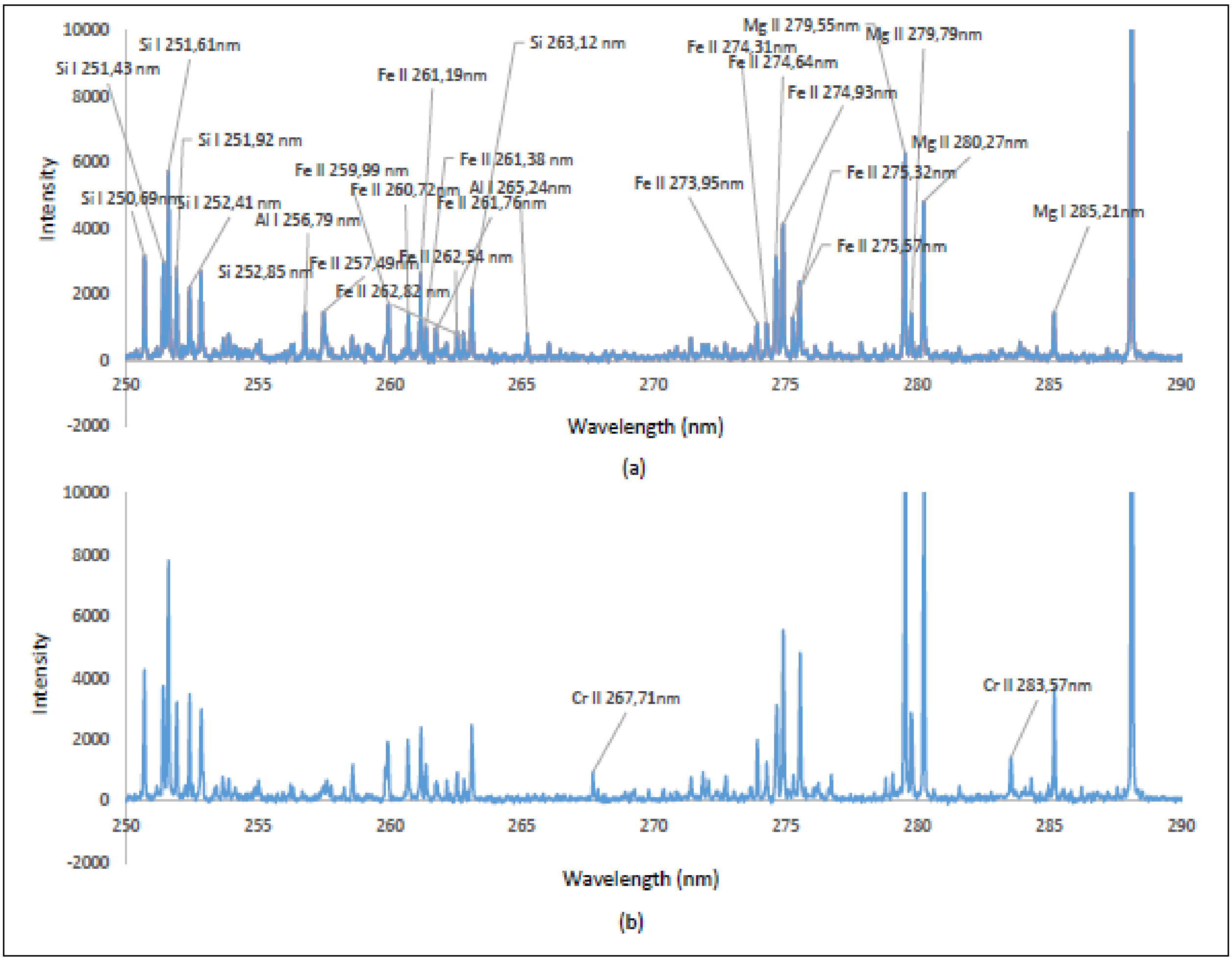

Fig 2: The spectrum difference between polluted soils (a) and uncontaminated soils (b) in the wavelength range of 250 nm -290 nm

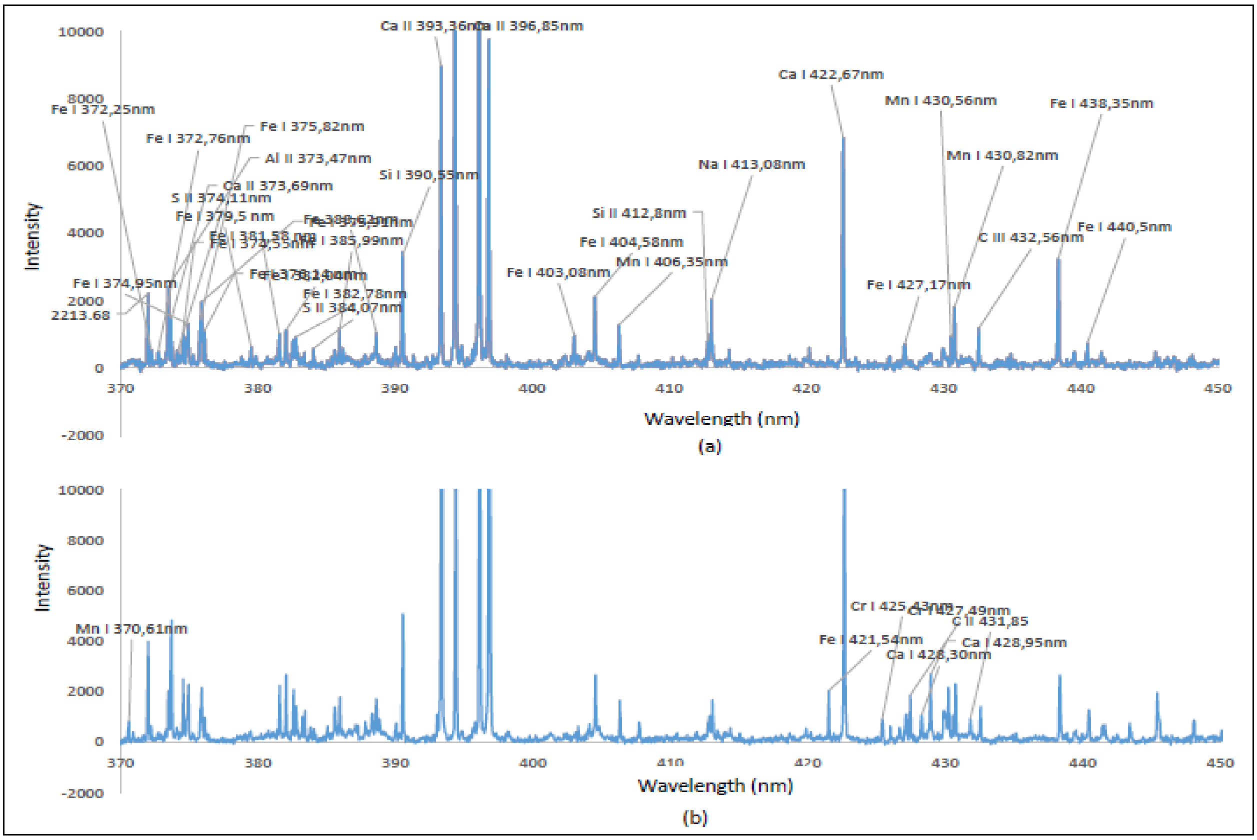

Fig 3: The spectrum difference between polluted soils and uncontaminated soils in the wavelength range of 370 nm -450 nm

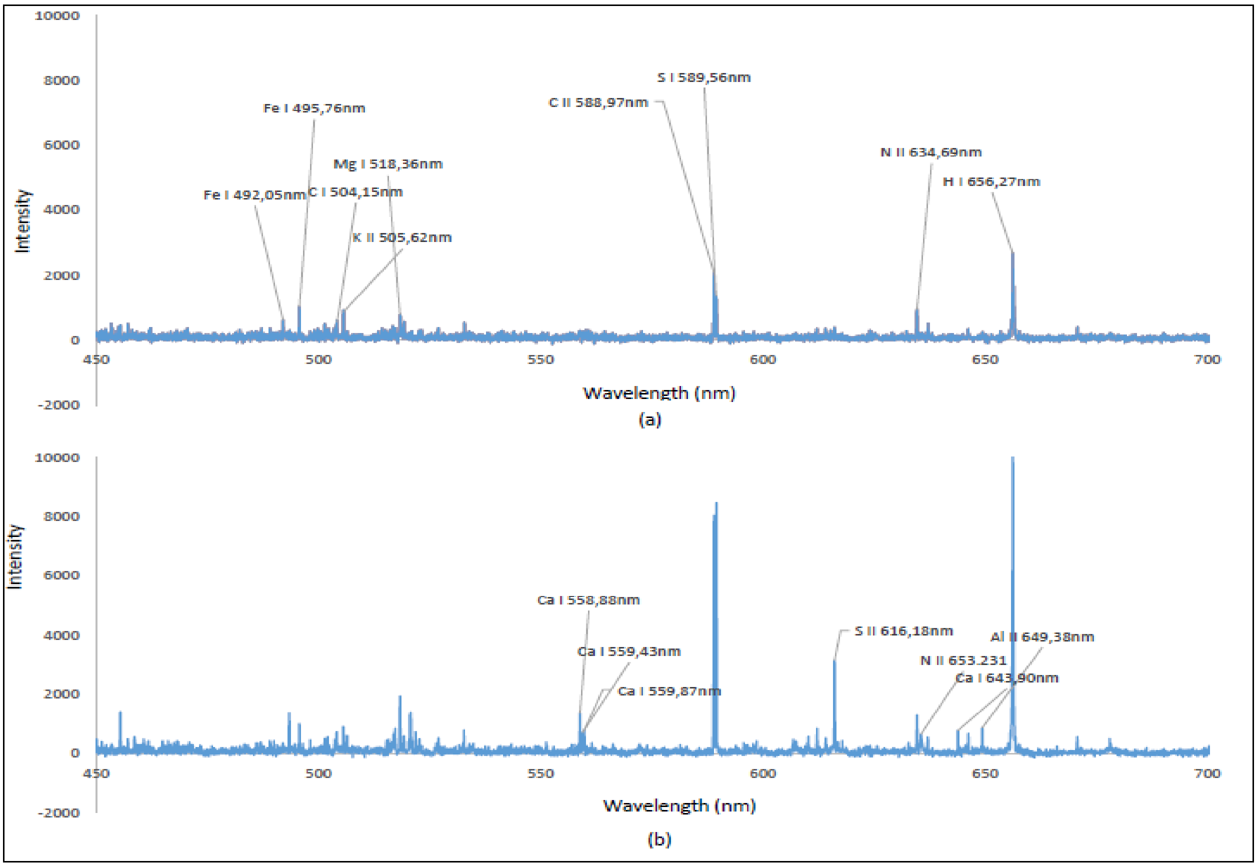

Fig 4: The spectrum difference between polluted soils and uncontaminated soils in the wavelength range of 450 nm -700 nm

Spectrum characteristics that represent elemental content have varying intensities. Each element has a different energy level from each other. The intensity of the spectrum resulting from the spectroscopic method is influenced by three factors, namely transition probability, population at each level, and sample concentration. The higher the intensity of the spectrum of an atom, it can be concluded the greater the concentration of atoms in the sample.

Conclusion

Based on the spectrum results obtained in the research, it confirms that the LIBS method can be used to identify chemical elements in polluted soil. In different spectrum wavelength ranges, the LIBS method can detect the presence of the elements Fe, Cu, Cr, Mn, Ca, and Al and other elements in polluted soil.

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