A PRELIMINARY EVALUATION OF ELEMENTAL CONSTUTUENTS OF THE DEGRADED MOTOR ENGINE OIL USING NEUTRON ACTIVATION ANALYSIS

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Abstract

The concentration of the elemental constituents of new and waste motor vehicle engine oil was determined using neutron activation analysis (NAA) technique. A neutron flux of 0.46E+10 $cm^{-2}s^{-1}$ at the Slowpoke-2 reactor of the Polytechnique Institute of Montreal for neutron irradiation, and a germanium detector for gamma-ray spectroscopy were employed. The waste oil was sampled from a public transport bus after operation over a cumulative distance of 13000 km. The concentration and degradation coefficient (α) were obtained for few elements detected in both samples indicating the degradation of the engine block itself. The study is aimed and enhancing the preventative maintenance of motor-vehicles and possibly the monitoring of the environmental impact of waste oil.

Keywords: Neutron activation analysis, motor engine oil, traces elements, degradation coefficient.

1. Introduction

The conventional motor oil as a lubricant protects the engine by minimizing friction between the moving components and removing any cumulative debris away. Much of this inevitable debris arises from the gradual wear and tear of the engine and moving internal components such as pistons. It is mostly deposited on the oil-filter and the bottom of the sump. However, it is likely that some minute amounts of this debris become dissolved or suspended in the oil. So any increase in the amounts of the debris in the oil and oil filter serve as an indication of the degree of the degradation of the engine and the integrity of its performance [1, 2]. It is also indicative of the degree to which the environment is affected by the releases due to the operation of the motor vehicle. In addition, the hydraulic characteristics of oil change with time of motor vehicle operation, thus having an impact on it performance. Therefore, waste oil and filters present a valuable source of information regarding the condition of the engine and its performance. This information may therefore guide the formulation and implementation of strategies for effective motor vehicle preventative maintenance as well as environmental protection.

In this study, the trace elemental concentrations of new and waste oil as the source of the strategic vehicle engine maintenance and possibly the assessment of the environmental impact of its operation were determined using the technique of Neutron Activation Analysis, NAA.

2. Sampling and experimental method

Several new and waste motor oil samples of type W40 were collected in vials. The waste oil was sampled from a public bus after its operation over a cumulative distance of 13

000 km. All samples were irradiated with neutrons under the same nuclear reactor conditions.

The reactor neutron flux used was about 0.46 x10^{10} $cm^{-2}.s^{-1}$. The samples were irradiated for 10 minutes and 4 hours in order to produce the short-lived and long-lived gamma - radioactivity among a possible range of elemental constituents in the new and waste oil. The irradiated samples were measured using a high purity germanium detector. The spectral data were analyzed using EPAA software program* developed by the Polytechnic Institute of Montreal.

Figure 1 shows the experimental set-up that was used at the SLOWPOKE-2 reactor facility.

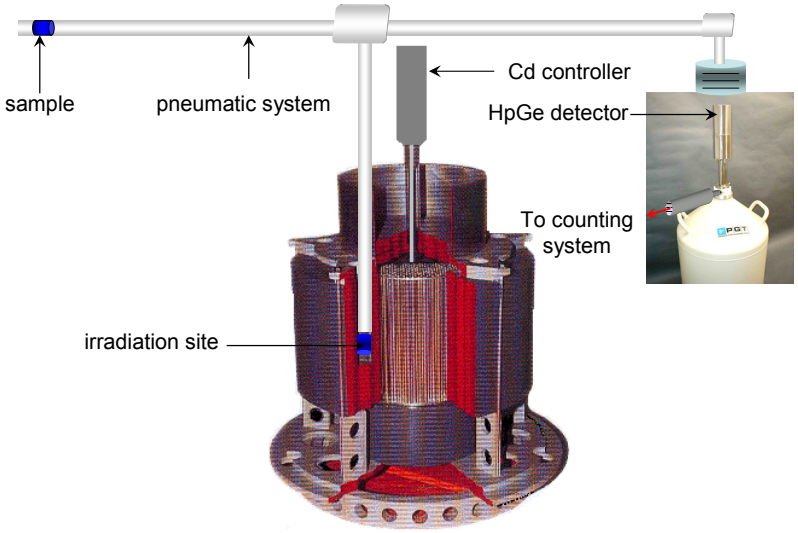

Figure1. NAA schematic experimental setup at Slowpoke-2 reactor
(Ecole Polytechnique website)

3. Results and Discussions

The gamma spectra of the activated samples and the results of the analysis re detailed in Figures 2 and 3 respectively.

* EPAA is the software developed at Ecole Polytechnique of Montreal for NAA

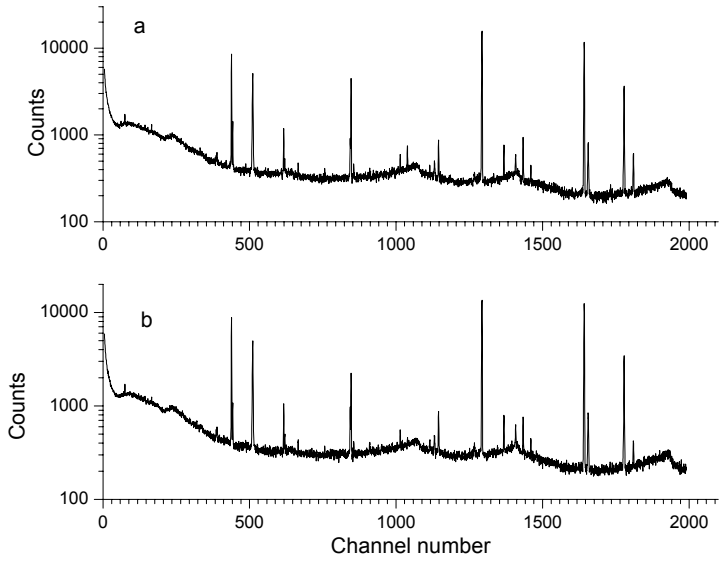

Figure2. Gamma spectra of the activated samples
a-waste oil, b-new oil

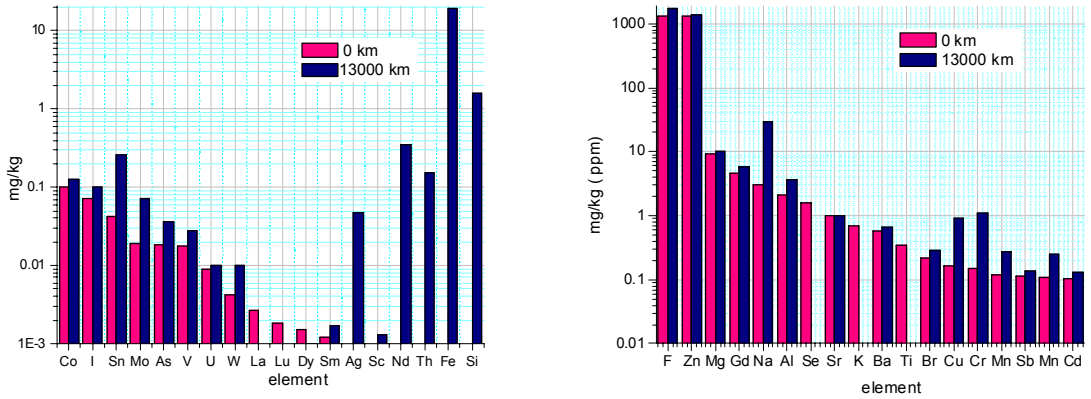

Figure3. Comparison of elemental concentrations of new and waste oil
(From Ecole Polytechnique website with modification)

The experimental results show that after the operation of vehicle over 13 000 km distance, *some elements have been removed or their concentrations in new oil have been decreased*, while *others that were absent or appeared in smaller concentrations in the new oil have been respectively introduced or their concentration increased*. The short-lived radioactive La, Lu and Dy and long-lived radioactive Se, K and Ti that were present in new oil, have been dissipated during the engine operation. The elements that have been significantly increased in their concentrations during the vehicular operation are mainly Sn, Mo Na, Cu and Cr. Whereas Fe and Si among others, were absent in the new oil, they have been introduced in significantly high concentration in the waste oil.

The elements that appear to have been generated or increased in concentration during the engine operation over 13 000 km mileage, may have originated mainly from the wear and tear of the engine block largely due to the friction between the moving metallic parts. These elements include Fe and Si, which are the major building of the engine block. The elements that have been have been removed from the oil, may have all been deposited in the filters and the engine surfaces, or eliminated through evaporation during the engine operation.

In a preliminary attempt to model the deterioration of the integrity of the engine oil and consequently that of the engine and its performance, a concept of degradation coefficient, α of a specific element is introduced and defined as follows:

$$\alpha = \frac{C_w}{C_0}$$

Where $C_0 > 0$ and is the elemental concentration of the new oil and C_w is that of the waste oil.

When $C_0 = 0$, α tends to infinity. This is a special case in which a new element was introduced to the engine oil during the vehicular operation.

This model may be used to quantify the changes that occur in the elemental concentrations in oil and thus evaluate its physical characteristics. Table 1 lists the values of α for a few trace elements, indicating an elemental increase when $\alpha > 1$ and decrease when $\alpha < 1$. The values of α that are presently reported are mainly for the purpose of illustrating the significance of the model in the quantification of the degradation of motor the engine oil.

Table 1: Degradation coefficient for few trace elements found in both oil samples

Element	α
Ag	3.140±0.010
Al	1.240±0.360
Ba	1.150±0.130
Cu	5.560±0.060
Dy	0.270±0.010
I	1.410±0.010
Mg	1.060±0.420
Cl	1.030±0.760

4. Conclusion

The elemental concentrations of new and waste oil have been determined using NAA. In this preliminary consideration, it was found that new elements had been introduced in the waste motor engine oil after its operation over a 13 000 km distance. Some elements that were present before the operation were either increased in their concentrations or appear to have been eliminated completely. The coefficient of degradation has been introduced in order to quantify the integrity of oil after the engine operation.

This study reveals a need to consider an extended scope of the investigations of the oil filters and engine inner surfaces in order to determine the fate of the elements that appear to have disappeared from the oil after vehicular operation. It is also envisaged that future studies will examine the behavior of the elemental degradation coefficient as a function of the distance of vehicular operation, and possibly refine the model. Furthermore, the model for the understanding of the oil degradation introduced in this consideration may find application in the assessment of the impact of motor vehicle waste oil and possibly the elemental constituent releases to the environment during the engine operation.

Finally, this study has highlighted the effectiveness of the NAA technique in preventative motor engine maintenance and possibly environmental protection [3, 4, 5].

References

[1] E. R. Booster, “Handbook of Lubrication”, Vol. 2, CRC Press, Inc., Boca Raton, Florida, 1983.
[2] L. G. I. Bennett, S. A. Swanson, J. S. Poland and R. T. Alexander,“ Instrumental Neutron Activation Analysis in support of implementation of quantitative filter debris analysis”, J. Radioanal. Nucl. Chem., 216 (1), 1997, pp. 81-85.
[3] D. Bodiz, S. and Seif El-Naser, “Trace element analysis of motor oil by reactor neutron activation analysis “J. Radioanal. Nucl. Chem., 136 (3), 1989, pp231-237.
[4] F. Ditrol, I. Mahunka, S. Takacs, and Seif El-Naser, “Trace element analysis of motor oil by CPAA method on external proton beam”, “J. Radioanal. Nucl. Chem. Letters, 130 (2), 1989, pp. 263-268.
[5] P. S. Adu, E. H. K. Akaho, B. J. B Nyarko, and Y. Serfo, “Determination of some wear elements in used car engine oil and oil filter paper using neutron activation analysis”, Journal of the Ghana Science Association, 2 (1), 2000, pp. 53-58.