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ANALYSIS OF DUST SAMPLE FROM VICTORIA LINE

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1. Introduction

1.1 A dust sample was submitted by Chris Woolf, Metronet Rail for analysis to determine its composition and the nature of hazardous components (if any).

1.2 The sample was received from the client on 1st June 2009. The dust was understood to have been collected from various sites along the Victoria Line. It had been found that the ventilation on the new 09TS tended to raise the settled dust to produce noticeable levels of airborne dust.

1.3 The sample was to be analysed via Scanning Electron Microscopy and for metals and standard contaminants that are typically found within the London Underground.

2. Physical analysis

An initial representative sample was evaluated via Scanning Electron Microscopy (SEM) with a built in EDX elemental analyser.

2.1 Qualitative analysis

The EDX spectrum obtained for a broad scan of the dust as a bulk sample is shown in Figure 1. Several individual particles were spot analysed and typical spectra are shown in Figures 2 and 3. The gold peaks shown on the spectra are due to the conductive film used to coat the filters and the chlorine peak is due to the filter itself. The elements detected are summarised below:

Scan type	Elements detected
Broad scan *(see Figure 1)*	Carbon, oxygen, silicon, sulphur, calcium, iron
Particle 1 - 10µm *(see Figure 2)*	Carbon, oxygen, silicon, chlorine, iron, gold
Particle 2 - 10µm	Carbon, oxygen, aluminium, silicon, chlorine, calcium, iron, gold
Particle 3 - 5µm	Carbon, oxygen, chlorine, iron, gold
Particle 4 - 3µm *(see Figure 3)*	Carbon, oxygen, silicon, chlorine, iron, gold
Particle 5 - 1µm	Carbon, oxygen, silicon, chlorine, calcium, iron, gold

The elements found are typically those found in dusts commonly analysed from within London Underground.

The presence of iron will be from wear of brakes, track and wheels.

The calcium, sulphur and aluminium are probably from the wear and tear of cementitious building products.

The quantitative analyses listed in Table 1, showed that the largest component of the dust was iron (at over 40% by weight) which was to be expected.

2.2 Particle Size analysis

A portion of the dust was then ultrasonically treated to remove any agglomerations and allow the particle size distribution of the dust to be estimated.

Measurements via the SEM indicated that 42.9% of the dust particles (by number) were less than 1 micron in size, with about 41.9% between 1-5 microns, about 11.5% between 5-10 microns and with the remainder (3.7%) being greater than 10 microns in size.

3. Chemical analysis : analytical methods

3.1 The chemical analysis of the samples was conducted using the following methods:

Chromium (Hexavalent)	-	Colorimetry
Chromium (Total)	-	Acid digestion & ICP
Nickel	-	Acid digestion & ICP
Copper	-	Acid digestion & ICP
Zinc	-	Acid digestion & ICP
Arsenic	-	Acid digestion & ICP
Selenium	-	Acid digestion & ICP
Mercury	-	Acid digestion & ICP
Lead	-	Acid digestion & ICP
Cadmium	-	Acid digestion & ICP
Iron	-	Acid digestion & ICP
Molybdenum	-	Acid digestion & ICP
Vanadium	-	Acid digestion & ICP
Antinmony	-	Acid digestion & ICP
Organic Carbon	-	Filtration and UV spectroscopy
Total Cyanide	-	Kjeldahl distillation followed by Colorimetry
Sulphide	-	Kjeldahl distillation followed by Colorimetry
Boron	-	Colorimetry
Sulphate	-	Gravimetry
Phenols	-	Kjeldahl distillation followed by Colorimetry
Elemental Sulphur	-	Solvent extraction & HPLC
pH	-	ISE (Glass Electrode)
Polyaromatic Hydrocarbons	-	Solvent extraction & HPLC
Total Petroleum Hydrocarbons	-	Gas chromatography FID

3.2 The samples were examined for asbestos content in accordance with the methods described in the *HSE Document HSG 248 Asbestos: The analysts' guide for sampling, analysis and clearance procedures, Appendix 2: Asbestos in bulk materials: Sampling and identification by polarised light microscopy (PLM)* and 4-RAIL Services Limited in-house test procedure 4R-E220. UKAS accredited laboratory No 1931.

4. Results of the chemical analysis

4.1 The results of chemical analysis (acid digestion) of the sample are listed in Table 1.

5. Discussion

5.1 Possible routes of exposure to the dust are dermal (skin contact), ingestion and inhalation. The dermal or ingestion routes can be controlled by good hygiene practices and should not be significant for occupants of the train. Dust monitoring carried out on the 09TS had indicated that inhalation could be a possible exposure route for occupants of the train when surface dust is disturbed by air currents from the train in the sidings.

5.2 The results in Table 1 show that approximately 40% of the dust by weight is iron. The presence of iron will be from wear of brakes, track and wheels. This is comparable to the iron level measured in the previous samples submitted from Victoria Station sidings (080672/1 & 080419/1). Iron is likely present in part as iron oxide hence the majority of the dust by weight may be iron oxide. The loss on ignition suggests up to 9.6% by weight could be organic materials part of which may be skin and hair from passengers. Again, this is comparable to the loss on ignition measured from samples 080672/1 & 080419/1.

The scanning electron microscopy elemental X ray analysis showed the other major components to be carbon, calcium, silicon and sulphur. The proportions of elements detected were similar to those found in the samples taken from Victoria Line sidings (080672/1 & 080419/1). All of these elements are likely derived from soil and cementitious building materials.

5.3 To allow an assessment of potential exposure to be undertaken the Workplace Exposure Limits given in HSE Document EH40/2005 were considered.

The following are compounds and substances in EH40 representative of cementitious building materials: aluminium oxide, calcium carbonate, Portland cement, magnesium oxide, plaster of Paris and gypsum. These have 8hour time weighted average exposure limits of 4 and 10mg/m^3 for respirable and total inhalable dust respectively. The limits of 4 and 10mg/m^3 are generally taken as those applicable to 'nuisance dusts' in a workplace setting.

The particle size analysis indicated that a large proportion of the dust would be classed as respirable, in that it is able to travel deep into the lungs. It was also noted that the smaller particles observed were mainly iron whereas the larger particles had greater amounts of silicon and calcium.

The Workplace Exposure Limits given in the table overleaf are for compounds and groups of compounds that were identified in the analysis. It should be noted that some materials do not have limits set in EH40.

Substance	**Workplace Exposure Limits**	
	Long term 8hr time weighted average (mg/m^3)	**Short term 15 minute (mg/m^3)**
Antimony and compounds except stibine (as Sb)	0.5	-
Arsenic and arsenic compounds except arsine (as As)	0.1	-
Cadmium & cadmium compounds except cadmium oxide fume, cadmium sulphide & cadmium sulphide pigments (as Cd)	0.025	-
Cadmium oxide fume (as Cd)	0.025	0.05
Cadmium sulphide & cadmium sulphide pigments (respirable dust as Cd)	0.03	-
Calcium hydroxide	5	-
Calcium oxide	2	-
Chromium	0.5	-
Chromium (III) compounds (as Cr)	0.5	-
Chromium (VI) compounds (as Cr)	0.05	-
Copper fume	0.2	-
Copper dusts and mists	1	2
Cyanides except HCN, cyanogens & cyanogens chloride	5	-
Iron oxide fume (as Fe)	5	10
Iron salts (as Fe)	1	2
Lead and lead compounds except organo lead compounds (as Pb)	0.15	-
Mercury and its divalent compounds*	0.025	-
Molybdenum compounds (as Mo) soluble compounds	5	10
Molybenum compounds (as Mo) insoluble compounds	10	20
Nickel and its inorganic compounds (except nickel tetracarbonyl): water soluble nickel (as Ni)	0.1	-
Nickel and water insoluble nickel compounds (asNi)	0.5	-
Oil Mist, mineral*	5	10
Parafin wax fume	2	6
Polyaromatic hydrocarbons	-	-
Selenium and compounds except hydrogen selenide (as Se)	0.1	-
Silica amorphous inhalable	6	-
Silica amorphous respirable	2.4	-
Silica crystalline	0.3	-
Zinc chloride fume	1	2
Vanadium pentoxide	0.05	-

*Taken from EH40/2002

Comparison of these limits with the results in Table 1 gives an indication of the amount of airborne dust that would need to be present as an average over 8hours for any one of the limits to be exceeded.

For example, to exceed the individual Workplace Exposure Limit for arsenic, present in the dust at 64mg/kg, the level of airborne dust would need to be greater than approximately 1500mg/m^3.

For iron, which is present in a higher proportion, an airborne dust level of approximately 12mg/m^3 or greater would likely exceed the relevant 8hour time weighted average Workplace Exposure Limit.

Evaluation of all the materials found suggests that the general Workplace Exposure Limits for ‘nuisance dust’ should apply. That is 4mg/m^3 for respirable dust and 10mg/m^3 for total inhalable dust. However, because the particle size analysis found the majority of particles to be less than 10µm the limit of 4mg/m^3 should be considered.

5.4 Waste classification and Hazards

The total petroleum hydrocarbon level measured in the sample 090115/010609/1 was lower than that measured in the previous sample from Victoria Station sidings (080672/1). In this case the level found was 1.6 %wt. The Approved Supply List (Eighth Edition), Information approved for the classification and labelling of substances and preparations dangerous for supply, Chemicals (Hazards Information and Packaging for Supply) Regulations 2002 (CHIP) provides information on chemical hazards. Degraded and used oils and greases are assigned a risk phrase R45 (May cause cancer) and are classified: Carcinogen Category 2.

Therefore the presence of total petroleum hydrocarbons in the sample at levels of greater than 0.1%wt warrants the classification of Hazardous Waste.

Personal protective equipment should be used when handling the dust, in particular impermeable gloves.

6. Conclusions and Recommendations

6.1 Most of the parameters measured in the sample from the Victoria line were found at comparable levels to those previously found in the sample taken from Victoria Station sidings.

6.2 The majority of the particles in the dust were found to be below 10µm in diameter and therefore respirable.

6.3 No asbestos fibres were detected in the dust.

6.4 Analysis of the dust indicated the major component by weight to be iron, likely derived from the brakes and wear of the wheel rail interface. The other major components were carbon, oxygen, calcium, silicon and sulphur. These are likely derived from soils and cementitious building materials.

6.5 As previously for the sample taken at Victoria Station sidings (080672/1), an evaluation of the components found (compared against the Workplace Exposure Limits in EH40/2005) suggested that the limits for ‘nuisance dust’ should apply. That is 4mg/m^3 for respirable dust and 10mg/m^3 for total inhalable dust. However, because the particle size analysis found the majority of particles to be less than 10µm the limit of 4mg/m^3 should be considered.

6.6 The presence of total petroleum hydrocarbons in the sample at levels of greater than 0.1%wt warrants the classification of Hazardous Waste should disposal of bulk quantities of the dust be required. This is because all petroleum oils carry the risk phrase of Category 2 Carcinogen unless proven or refined so as not to contain benzo(a)pyrene. Also, if the material from this location is to be land-filled, it is no longer acceptable to be mixed with other waste and must be analysed further as per the Waste Acceptance Criteria regulations to determine if and how it can be land-filled.

7. References

Department of the Environment, Industry Profile, Railway Land, 1995.

HSE EH40/2005 Workplace Exposure Limits and 2007 Supplement.

List of Wastes (England) Regulations 2005, Statutory Instrument 2005 No. 895 and Statutory Instrument 2005 No. 1673 (Amendment).

Landfill Regulations (England and Wales) 2002 Statutory Instrument 2002 1559 and Amendment 2004 Statutory Instrument 2004 1375.

The Approved Supply List (Seventh Edition), Information approved for the classification and labelling of substances and preparations dangerous for supply, Chemicals (Hazards Information and Packaging for Supply) Regulations 2002 (CHIP).

Table 1: Results of Analysis

4RS Sample Ref. No.	*090115/010609/1*	080672/1	Units
Parameter			
Arsenic (total)	*64*	19	mg/kg
Boron (soluble)	*38*	44	mg/kg
Cadmium (total)	*3.1*	15	mg/kg
Chromium (hexavalent)	*<0.1*	0.28	mg/kg
Chromium (total)	*420*	330	mg/kg
Copper (total)	*2400*	1,600	mg/kg
Lead (total)	*750*	840	mg/kg
Mercury (total)	*2.4*	0.85	mg/kg
Nickel (total)	*240*	220	mg/kg
Selenium (total)	*0.41*	0.30	mg/kg
Zinc (total)	*900*	1,000	mg/kg
Cyanide (total)	*<2.5*	9.2	mg/kg
Phenols (total)	*21*	17	mg/kg
Sulphate (total) as SO_3	*0.51*	0.41	%
Sulphide as S	*38*	44	mg/kg
pH	*9.6*	10.3	pH units
Total petroleum hydrocarbons	*16000*	20,000	mg/kg
Sulphur (elemental)	*<100*	<100	mg/kg
PAH (total)	*400*	340	mg/kg
Asbestos	*Not detected (<0.1%)*	Not detected (<0.1%)	%
Antimony	*230*	110	mg/kg
Iron	*410,000*	300,000	mg/kg
Molybdenum	*2300*	1,700	mg/kg
Vanadium	*55*	68	mg/kg
Loss on ignition	*9.6*	11	%
Total Organic Carbon	*10*	8.8	%

Figure 1: EDX Spectrum of dust sample – general area scan

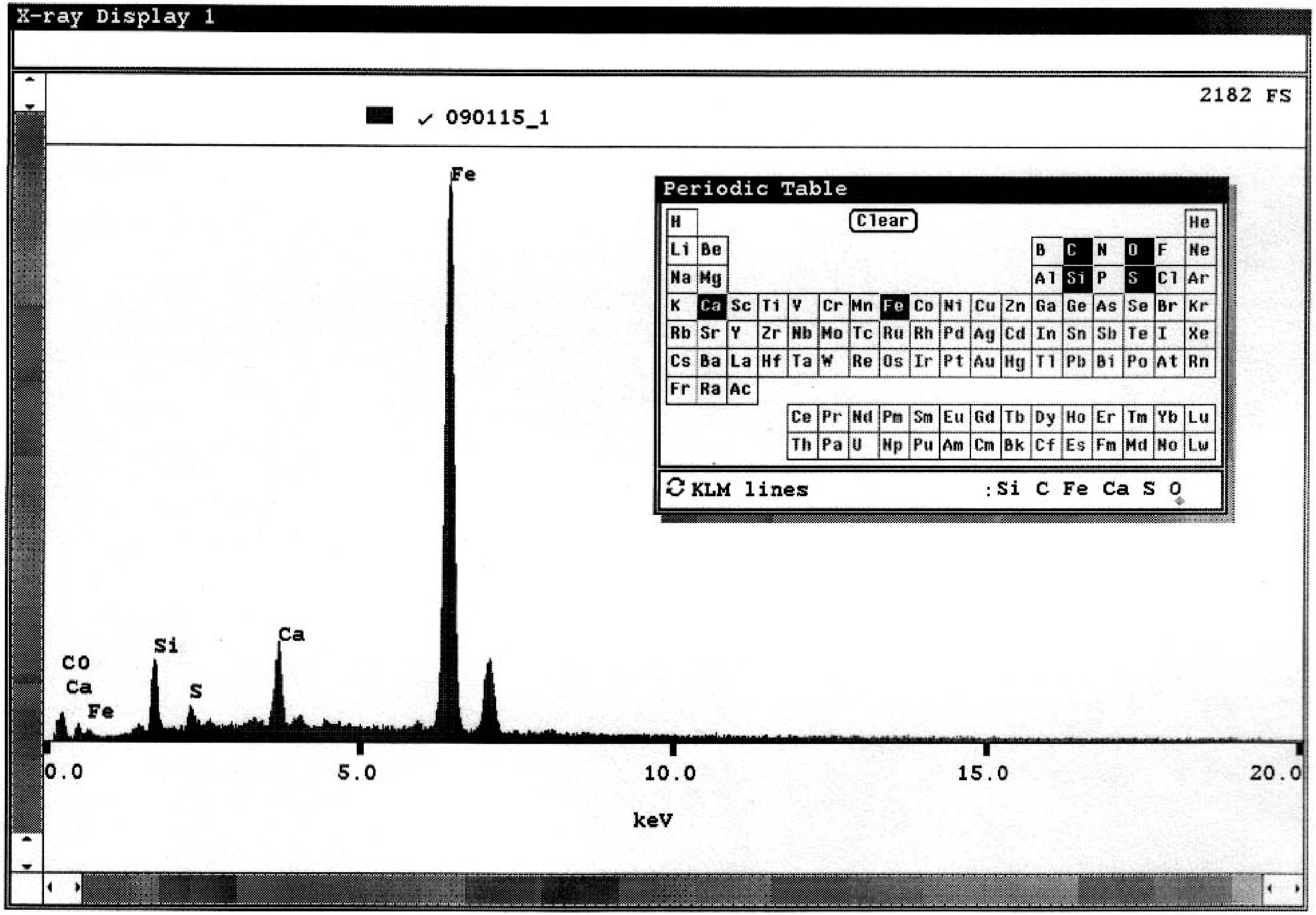

Figure 2: EDX Spectrum of dust particle – spot scan

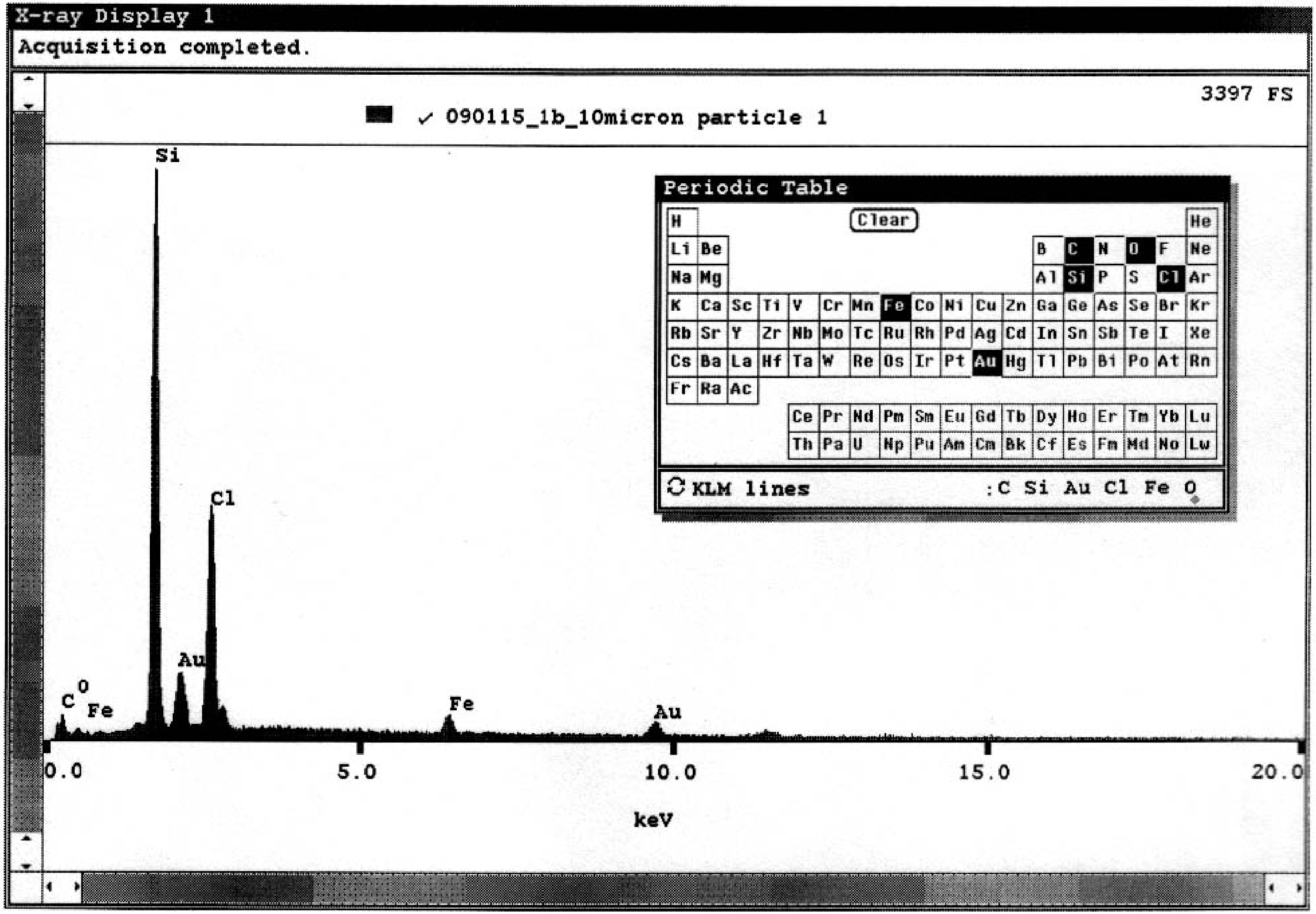

Figure 3: EDX Spectrum of particle – spot scan