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PROCEDURES FOR THE DETERMINATION OF TRACE ELEMENTS IN MILK BY ENERGY DISPERSIVE X-RAY FLUORESCENCE SPECTROPHOTOMETRY

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September 1, 1976

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PROCEDURES FOR THE DETERMINATION OF TRACE ELEMENTS IN MILK BY ENERGY DISPERSIVE X-RAY FLUORESCENCE SPECTROPHOTOMETRY

Abstract

A procedure for the simultaneous determination of K, Ca, Fe, Cu, Zn, Br, Rb, Sr, and Pb in milk by x-ray fluorescence spectrometry is described. Comparison of molybdenum-tube excitation and cadmium-109 isotopic excitation is discussed, and results of over 500 milk samples are summarized.

Introduction

A comparison of the results and operation of two x-ray spectrometer systems is made, and the possible application of this equipment to other problems in environmental monitoring is discussed. The interpretation of the results in terms of seasonal or geographical variations will be reported at a later time.

The analysis of trace elements in milk has been proposed as a means of monitoring the levels of toxic elements in an important constituent of the modern human diet.¹ Instrumental multielement analytical methods such as x-ray fluorescence analysis (XRFA) are attractive since they

offer the simultaneous determination of several elements. In our system a minicomputer controls the instrument, collects data, and checks the instrument calibration. A larger computer reduces data to give sample concentrations and prepares analysis reports.

This report describes the instrumentation and procedures that were used for determining the concentrations of K, Ca, Fe, Cu, Zn, Jr, Rb, Sr and Pb in over 500 samples of milk collected in Colorado in cooperation with Dr. Gerald Ward of the Animal Sciences Department at Colorado State University, Fort Collins.

Instrumentation and Procedures

The equipment and operation of the ¹⁰⁹Cd isotopic excitation x-ray spectrometer system were previously described by Bonner, Bazan, and Camp.² The procedures for analyzing milk samples with this equipment were reported by Ragaini et al.^{3,4}

Mo-TUBE SPECTROMETER

The tube-excited x-ray spectrometer was designed and assembled by Nuclear Semiconductor.* The spectrometer and auxiliary equipment are schematically shown in Fig. 1. The basic x-ray optics consists of a transmission target x-ray tube, a 20-position sample wheel, and a Si (Li) detector. Figure 2 is a photograph of the spectrometer with sample wheel and Mo tube. The tube-to-sample and sample-to-detector angles are both 45°, which minimizes the Compton scatter of the incident x rays. The x-ray beam from the tube is collimated to produce an elliptical irradiation pattern of about 1.6 cm by 1.2 cm for an approximately 1.5 cm² area on the sample. The detector is shielded and

collimated, but the angle of acceptance has not been measured.

The x-ray source is a molybdenum target transmission tube with maximum of 50-kV input, 40-W power. The high voltage power supply is adjustable from 0 to 50 kV in 0.1 kV increments and 0 to 1.00 ma in 0.01 ma increments. The 20-position sample wheel holds samples up to 3.18 cm (1.25 in) in diameter. Smaller diameter samples are mounted in adaptor rings. The sample wheel positioning is computer controlled so that any position can be centered in the x-ray optics.

A six-position filter wheel is located between the x-ray tube and the sample, and provides desired filtering of the primary x-ray beam. For analysis of milk, a 0.051-mm (2-mil) Mo filter was used to exclude x rays below the Mo-K α excitation energy of 17.44 kV.

The sample chamber can be evacuated so that the scattering and absorption of x-rays by air are eliminated. The vacuum path is routinely used for analysis of milk.

The electronics associated with detector signal processing are an analog-to-digital converter, a pulse-height analyzer, a live-time corrector, and an oscilloscope display. The

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Administration to the exclusion of others that may be suitable.

Fig. 1. Block diagram of Mo-tube x-ray optics and electronics, including computer and I/O hardware.

Fig. 2. Photograph of the Mo-tube-excited x-ray spectrophotometer, showing the sample wheel and Mo tube.

power supply for the detector also includes a safety circuit to turn off the high voltage to the detector should the liquid nitrogen coolant reservoir for the detector run dry or the main power be interrupted.

The computer hardware to which the x-ray spectrometer system is interfaced consists of a Digital Equipment PDP 8/e computer with 16K-memory core space, a TV-10 magnetic tape drive, a paper tape punch and reader, a Centronics Model B06 line printer capable of a minimum of 60 lines of 80 characters/min and a Diablo 33 disk drive containing one removable and one fixed disk, each

capable of 1.2 million 12-bit words of storage.

SOFTWARE

The programs are written in FORTRAN II, and the operating system is D.E.C. OS/8. Several programs have been written to control the spectrometer during routine operation or to assist in calibration of the spectrometer and to transfer data to desired output formats. The programs will only be outlined in this report.

The final data processing is done presently on the CDC 7600. Work is in progress to do all data processing in an on-line mode with the PDP-8/e to which the spectrometer is now interfaced.

- CALIB - Aids in selecting proper gain and zero potentiometer settings for desired energy range. Contains a centroid calculation for any two-element monitor standard.
- XRAY1 - Inputs the sample identification (ID), diameter, sample-wheel position, counting sequence, date, weight, and weight ratio. A maximum of 60 sample counts can be done in any order of the 20 sample positions. Automatically chains the program to next program.
- XRAY2 - Detects the end of counting time, copies the spectrum

from the pulse height analyser to a disk file, moves the sample wheel to the next sample position, starts the count, and chains to the next program. When the last sample has been counted, the program turns off the x-ray power source.

- XRAY3 - Reduces data. Writes a file on disk containing the integrated counts of selected windows for each element, and chains the program to XRAY2 to get the next spectrum or to the next program if the last sample is counted.
- XRAY4 - Creates a file in the format desired for output, listing the sample ID, description, count number, diameter, count time, weight, weight ratio, and a table of element symbols and integrated counts.
- XRAY5 - Copies spectra of samples or standards onto magnetic tape for permanent storage of data. This routine is used immediately after a series of samples has been counted.
- XRAY6 - Creates the punched paper tape required to prepare an IBM card deck for the data reduction programs done on the CDC 7600 computer. The sample ID, description, weight, count time, weight ratio, date, and

integrated peak counts for each element are placed on the punched tape.

- XRAY7 - Reads spectra from magnetic tape to disk files and will integrate over any windows desired. This makes possible the examination of old data for further information from samples already counted.

Other programs have been written to aid in various calibration and diagnostic procedures, such as linear regression programs, standard deviation calculations, sensitivity calculations, etc.

SAMPLE PREPARATION

Over 500 samples of milk were collected in Colorado and sent to LLL for processing. Samples were collected in acid-washed 500-ml polyethylene wide-mouth jars containing 2 ml of 37% formaldehyde as preservative. The formaldehyde was found to contribute no detectable impurities to the sample. Refrigeration was not required, and spoilage was less than 1% of all samples.

The liquid samples were warmed to 37°C and shaken. Aliquots of 200 g were taken for lyophilization in tared (acid-washed) 250-ml wide-mouth polyethylene bottles. The samples were shell-frozen on the container wall by rotating the

bottles while partially submersed in liquid nitrogen.

The frozen samples were placed in desiccators with special covers to facilitate connection to the vacuum manifold of the lyophilization apparatus. A maximum of 40 samples can be lyophilized at one time, and about 5 days are required to obtain completely dry samples. The dry samples were weighed, and the dry/wet ratios were recorded.

A 250-mg aliquot of the dried milk was pressed into a 2.54-cm-diameter disk with a pressure of 3000 kg on a laboratory press. The pressed samples were kept in desiccators to prevent warping resulting from absorption of atmospheric moisture.

X-RAY COUNTING PROCEDURE FOR THE TUBE-EXCITED SYSTEM

Up to 19 pressed milk samples can be placed in the sample wheel, using plastic adaptor rings. The first position is reserved for the vanadium + strontium (V-Sr) monitor. The sample chamber is evacuated to about 10^{-1} Torr. The routine CALIB is run to calibrate the spectrometer to 25 eV/channel, giving a total energy range of 0 to 25.6 keV.

Routine parameters are 35 kV, 0.3 ma power, and 1000 s (live time). The program XRAY1 is initiated, and the sample data are entered from the

teletype terminal. From this point on, sample counting is under the control of the computer programs XRAY2, XRAY3, XRAY4. A typical overnight run of 19 samples for 1000 s each and 3 counts of the V-Sr monitor (start, mid-run, end) at a live time of 60% is completed in 10.2 h. The high voltage to the x-ray tube is automatically turned off after the last sample is counted, but the sample chamber remains under vacuum until the samples can be weighed.

The samples are removed from the chamber and weighed immediately to obtain the weight of the counted sample in vacuo. This weight is representative of the sample after lyophilization, and no corrections are required for absorbed moisture.

The in vacuo weights are entered into the sample data file by teletype with the program DRYWT. Then a punched paper tape is produced with the program XRAY6. Also, the program XRAY5 is run to obtain a permanent record of the spectra on magnetic tape. A card file is created from the punched paper tape, and any editing is done on the cards. A monitor correction card is prepared containing the average count of the Sr peak of the three monitor counts during the run. This is analogous to the source decay correction used by Bonner, Bazan, and Camp,² and allows correction for

slight and uncontrollable long-time instrument drift.

COMPUTATIONS

Once the data have been obtained on a punched card file, all subsequent calculations required for quantitation of the data are done on a CDC 7600 computer. The computational procedures follow those reported in the analysis of air particulates by Bonner, Bazan, and Camp.² Figure 3 shows a flow-chart of the computations.

Background Subtractions

The background of the milk matrix is obtained by counting a typical milk sample for 8000 to 10,000 s and graphically measuring 11 channel integral values of a smoothed curve under each element peak. Figure 4 shows a spectrum of milk counted for 8000 s.

The background correction factor for an element is the ratio of the integral value to the sum of 21 channel integrals of the coherent and incoherent exciter peaks. Our experience indicates these background corrections are accurate to within 5% or better.

Interelement Interference

The interelement interference corrections are measured from the spectra of pure analyte elements. The

correction factors for an element A are the ratios of the net intensities in each of the other element windows to the intensity of A. Thus for 20 elements, a 20 by 20 matrix equation is necessary. In general, interelement interferences are small, but not trivial, except for classical cases such as the overlap of a K α peak with the K β peak of the adjacent lower atomic number (Z) element, or the K- and L-peak interferences.

Conversion of Net Counts to Micrograms

At this point, the data consists of net counts (or intensities) for each analyte element. To convert net counts into micrograms of analyte in the sample the sensitivity of the instrument for each element must be known in counts/s per $\mu\text{g}/\text{cm}^2$. The sensitivity for each element is determined by counting 29-mm-diameter filter papers onto which known aliquots of standard solutions have been freeze-dried to give uniform distribution of the element. Figure 5 shows a least-square quadratic fit of sensitivities for the K α fluorescence of elements Z = 19 through 38 (K through Sr). These values are in counts/s per $\mu\text{mol}/\text{cm}^2$ for 11 channel windows astride the element peak covering an energy range of 275 eV.

The uncorrected concentration C_u of an element in the sample aliquot

Flow chart for XRFA calculations

Fig. 3. Flow chart for XRFA calculations.

in $\mu\text{g}/\text{cm}^2$ is obtained by

$$C_u = \frac{I_n}{S}$$

where

I_n = net count rate, in counts/s, in the element window, corrected for background and interelement interference.

S = sensitivity of an element in counts $\cdot\text{cm}^2/\mu\text{g}\cdot\text{s}$.

Systems Blank Subtraction

The measurement of a systems blank for a tube-excited system is difficult, since we have found no matrix that gives the same scatter as milk samples and is known to be free of any impurities. The microcellulose Avicel has similar scatter properties, but contains some Fe, Cu, Zn, K, and Ca. The system therefore includes small Fe, Cu, and Zn blanks. The Zn blank is not subtracted in the analysis in milk because it is trivial relative to the range of Zn in milk. The Cu and Fe in milk are normally close to the detection limit; hence, the counting errors are so large that quantitation is not prudent.

Absorption Correction (Incoherent/Coherent Ratio Method)

The absorption of incident and fluorescent x rays in milk is determined by measuring the attenuation of a standard by a typical milk

Fig. 4. Spectrum of milk, using a Mo x-ray transmission tube (35 kV, 0.3 ma, counted for 1000 sec: in vacuo). Incoh = incoherent scatter peak.

Fig. 5. Sensitivity measurements of K- α lines on the Mo-tube XRF system with standard solutions freeze-dried onto Whatman No. 41 filter paper. (35 kV, 1.0 ma, 0.051-mm Mo filter).

sample. Figure 6 shows the absorption curves obtained for several milk samples with a standard mixture of the oxides of Cr, Ni, As, and Y in a matrix of Avicel. The mixture is pressed into a disk and mounted above a typical milk sample.

Absorption correction factors are obtained with a technique described by Bazan and Bonner.⁵ This correction is based on the relationship of the absorption coefficient of an element to the ratio of the

incoherent to coherent scattering of each milk sample.

The concentration of the analyte in the sample is calculated by multiplying the uncorrected concentration by the absorption correction factor, A, and the area of the sample, a, divided by the sample weight W

$$C = \frac{C_u a}{W}$$

The mean values for K and Ca for the first 112 samples using the ¹⁰⁹Cd system differ by as much as 37% and 11.3%, respectively, from the mean values of the remaining samples analyzed by the Mo-tube system. While it would not be reasonable to expect the same values from different sets of samples, it seems unlikely that the concentrations of K and Ca would vary in milk to this extent. Since the absorption correction for K and Ca are so large, small errors in the calculation of absorption coefficients would cause large errors in K and Ca concentrations. Also, the K and Ca absorption coefficients could not be measured directly, but were obtained by extrapolation of the absorption curves, which may have led to a systematic error in the results. Therefore, the reliability of these results is somewhat suspect, and should be confirmed by independent analytical methods.

Fig. 6. Absorption curves for several samples of milk using the Mo-tube XRF system. Individual samples are designated as o, Δ, □, ●, and ▲.

Results

The first 112 samples of this study were analyzed by the ^{109}Cd XRF system, and the remainder were analyzed by the tube-excited system. Table 1 is an example of the print-out obtained from the analysis of a typical milk sample. The errors given are counting errors, based on the square root of the total count. Appendices A and B show a summary of the data obtained. The results of Cu, Fe and Pb were not included in the summary because the concentrations of these elements were either close to or below the limits of detection for these elements, and also because systems backgrounds for Cu and Fe were not accounted for.

The sample data have been coded to enable correlation studies to be made with respect to geographical location, collection time, and sample type. The results of such studies will be reported at a later time.

The standard deviations given on pages A-3, B-2, B-6, and B-11 actually reflect the range of the concentrations in the samples and not the standard deviation of the analytical method.

PRECISION AND INSTRUMENT DRIFT

Several indications of the precision of the method are available

in the data. For each run of 19 samples, the Sr K α peak of a monitor standard is counted 3 times to monitor the drift within the run. The mean drift within each run for 9 runs was 0.5%, and the range of drift was 0.12% to 1.09%, indicating the overall stability of the system within runs.

The mean of the three monitor counts for each run is used to normalize all counting data to the data when the sensitivity of the instrument is first measured. This compensates for long term drift from run to run. The standard deviation of the mean monitor counts for 9 overnight runs over a period of 80 d was 2.8%, indicating a fairly good long term stability in the system.

Table 2 lists the results of a separate study to measure the precision of the entire method by preparing and counting six aliquots of the same sample. The results show that the precision of the overall procedure is quite acceptable, but that serious discrepancies exist for the analysis of K and Ca, probably resulting from the uncertainty in measuring absorption at low energies. We estimate the absolute error for the method to be $\pm 10\%$, except in the case of K and Ca, where the error

Table 1. Example of printout obtained from an analysis of a single sample.

DMB-342

DATA: MG/LY EXCITER: 35.0 BKG M DATA FILE: BAZ12

DAY: 05. YEAR: 76. COUNT TIME: 1000.

WEIGHT = 0.2801 WT RATIO = 0.1189 DIAMETER = 2.5400 THICKNESS = 0.0513 G/CM**2

DATE OF COMPUTATION = R 04/21/76 AT 08:14:21 XRAY10 DEC 31, 1975

ELEM	UG/SQ.CM.	ERROR	% ERROR	MICROG/G	MG/L	GROSS CTS	BKG	NET	ABS CORR	SYS BLK
K	887.883	3.543	0.41	17295.848	2124.576	65243.	1328.	63917.	8.891	0.
CA	483.380	1.983	0.41	9416.484	1158.807	79209.	1101.	78108.	6.710	0.
FE	0.092	0.016	16.80	1.800	0.221	870.	624.	246.	1.996	0.
ZN	1.413	0.015	1.08	27.527	3.387	10480.	828.	9852.	1.407	0.
BR	2.198	0.016	0.74	42.813	5.269	40087.	9709.	30378.	1.166	0.
RS	0.337	0.016	4.88	6.567	0.808	41417.	31139.	10278.	1.120	0.
SR	0.745	0.019	2.54	14.520	1.787	64163.	50819.	13344.	1.103	0.
INCOHERENT PEAK				1105560.						
COHERENT PEAK				594050.						
INCOHERENT/COHERENT RATIO				1.8611						

ELEMENTS BELOW MINIMUM DETECTABLE LIMIT(MDL). MDL SET AT 3. TIMES ERROR.

ELEM	UG/SQ.CM.	MDL(UG/SQ.CM.)	GROSS CTS	BKGD	NET	ABS CORR	SYS BLK
CU	0.010	0.015	739.	818.	121.	1.500	0.
PB	-0.005	0.022	1902.	1930.	-28.	1.141	0.

Table 2. Comparison of overall precision for XRFA of milk.

	^{109}Cd		MO TUBE	
	mg/l ^a	% σ	mg/l ^a	% σ
K	1710	0.9	2431	1.1
Ca	1134	1.2	1368	0.7
Zn	4.0	1.6	4.1	2.0
Br	1.7	1.2	1.8	3.4
Rb	1.5	2.1	1.5	3.3
Sr	1.2	1.4	1.2	4.4

^a Mean value of six aliquots carried through complete procedure.

may be as great as $\pm 30\%$ and $\pm 20\%$, respectively, because of the uncertainty in the large absorption corrections.

COMPARISON OF ^{109}Cd AND TUBE EXCITED XRF SYSTEMS

A study was made comparing the 3 σ minimum detection limits in milk for the two x-ray spectrometry systems. Figure 7 shows relationship of detection limit vs atomic number (Z). At Z = 19 or 20 the greater absorption of fluorescent x rays by the sample raises the detection limit in both systems. The tube system is 8 times

Fig. 7. Comparison of minimum detection limits of the ^{109}Cd and Mo-tube systems.

more sensitive than the ^{109}Cd system up to the point where the tail of the Mo-K α incoherent peak begins to contribute to the background correction at Z = 30. From this point on, the detection limit of the tube system increases and at Z = 37 (Rb) the two systems have the same detection limits. Table 3 compares the detection limits in milk of both systems.

The Mo-tube system can be used for analysis of K α x rays up to Z =

Table 3. Estimated limits of detection for x-ray fluorescence analysis of milk.

Minimum detection limits (MDL), mg/l ⁴			
	¹⁰⁹ Cd	Mo tube	Normal milk concentration, mg/l ¹
Cr	1.7	0.14	<0.015
Mn	1.4	0.1	0.03 to 0.21
Fe	1.0	0.06	0.2 to 1.5
Ni	0.5	0.03	0 to 0.025
Cu	0.5	0.03	0.02 to 0.04
As	0.4	—	<0.05
Se	0.2	0.04	0.012
Mo	0.2	—	0.023
Hg	0.5	0.1	0.005 to 0.015
Pb	0.6	0.2	0.025 to 0.079

39 (Y) while the ¹⁰⁹Cd system can range up to Z = 42 (Mo). Figure 8 shows a comparison of the spectra of a milk sample obtained with both systems. The vacuum path of the Mo-tube excited spectrometer removes the absorption resulting from air, giving better sensitivities for the lower energy x rays of elements with low Z.

The tube-excited system has some distinct advantages in that different target elements such as W, Cr, Ag, or Au can be used and the beam flux can be controlled by changing the current

and voltage. Also, the possibility of using secondary x-ray fluorescent optics is available, but this feature has not yet been evaluated. These alternatives can improve sensitivities for some specific elements or a desired range of the energy spectrum.

The isotopically excited system has the advantage of stability of the x-ray source. The x-ray flux can be controlled by sample position, within limits. Also, since the total area of a 2.54-cm-diameter sample is excited, the problems of sample inhomogeneity are avoided.

Fig. 8. A comparison of spectra of a milk sample. A) Cd isotopic excitation (counted for 3000 sec in air). B) Mo-tube excitation (0.051-mm Mo filter, 35 kV, 0.3 ma, counted for 1000 sec in vacuo). Numbers associated with elements are in units of mg/l.

Conclusion

The application of x-ray fluorescence analysis to the analysis of milk has demonstrated somewhat limited usefulness. Reliable data for Zn, Br, Rb, and Sr are obtained. The detection and quantitation of other elements of environmental interest, such as Cd, Pb, Hg, As, or Se would require more extensive treatment of the samples before analysis. At the outset of

this program, it was decided to limit the sample preparation to lyophilization and pressing and to avoid any treatments such as dissolution or ashing of the samples.

The use of preconcentration techniques such as ion exchange or precipitation would lower the detection limit of some elements of interest, but at a considerable cost of

time and effort. Those procedures that would provide multielement detection of the toxic elements

of environmental interest such as Hg, Pb, Cd, As, and Se would be most useful.

References

1. G.K. Murthy, "Trace Elements in Milk," ERC Crit. Rev. Environ. Contr. 4 (1), 1 (1974).
2. N.A. Bonner, F. Bazan, and D.C. Camp, Chem. Instrum. 6 (1) 1 (1975).
3. R.C. Ragaini, A.L. Langhorst, H.R. Ralston, and R. Heft, Instrumental Trace Element Analysis of California Market Milk, Lawrence Livermore Laboratory, Rept. UCRL-51859 (1975).
4. A.L. Langhorst, N.A. Bonner, and F. Bazan, "Determination of Trace Elements in Milk by Energy Dispersive X-Ray Fluorescence Analysis" presented at Pacific Conf. Chem. Spectrosc., North Hollywood, 1975.
5. F. Bazan and N.A. Bonner, "Absorption Corrections for X-ray Fluorescence Analysis of Environmental Samples" in Adv. X-ray Anal. Vol. 19, p. 381 (1975) (Kendall/Hunt Publishing Co.).

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Joseph B. Carlson wrote the final versions of the computer programs. Michael J. Allen wrote

the earlier programs and was responsible for the interfacing of the computer, spectrometer, and accessories.

Cynthia Shelton, Joan Beiriger, and Stacie Swingle assisted in lyophilization and preparing dried milk samples for analysis.

Appendix A. Data Summary for X-Ray Fluorescence Analysis of Milk Using ¹⁰⁹Cd Excitation

SAMPLE NO.	DRY/WET	K		CA		ZN		BR		RB		SR	
	RA/10	MICRO/G/G	MG/L	MICRO/G/G	MG/L	MICRO/G/G	MG/L	MICRO/G/G	MG/L	MICRO/G/G	MG/L	MICRO/G/G	MG/L
DMS001	0.437	9586.8	1428.8	7779.8	1157.1	28.6	4.3	25.1	3.7	2.7	0.4	6.2	0.9
DMS002	0.1082	12091.6	1354.1	9711.2	1057.5	25.6	2.9	32.9	3.7	3.9	0.4	8.7	1.0
DMS004	0.076	13116.2	1460.7	9498.4	1057.8	28.5	3.32	37.2	3.7	9.7	1.1	8.6	1.0
DMS005	0.127	16183.6	2892.7	1145.1	1992.1	33.0	3.9	38.9	5.1	6.9	0.9	11.8	1.7
DMS006	0.165	13063.8	2120.4	9832.3	1724.9	43.6	1.7	58.9	10.3	5.1	0.9	11.8	2.1
DMS007	0.110	3727.9	1577.1	9543.3	1096.4	30.1	3.5	47.5	5.5	4.7	0.5	6.8	0.8
DMS008	0.1187	2136.5	1454.7	8996.0	105.2	29.6	3.6	45.3	5.6	6.2	0.8	7.7	0.9
DMS009	0.1210	2932.9	1619.7	12352.5	1547.0	39.9	5.0	99.3	12.4	6.9	0.9	16.0	2.2
DMS010	0.097	17716.2	1993.2	12511.0	1407.6	43.0	4.6	93.7	10.5	11.0	0.9	16.3	1.2
DMS011	0.1248	1402.3	1470.5	9477.0	1170.6	29.7	3.8	36.0	4.6	5.1	0.7	8.8	0.9
DMS012	0.1303	1794.2	1455.7	8690.2	1172.0	28.1	3.6	40.2	5.4	3.8	0.5	6.5	0.7
DMS013	0.1024	15162.7	1607.0	10385.5	1100.7	34.0	3.6	39.3	4.2	6.3	0.7	7.0	0.7
DMS014	0.1234	9959.1	1333.8	7243.8	970.2	27.8	3.7	27.4	3.7	4.5	0.6	3.8	0.5
DMS016	0.1237	10924.2	1398.6	8108.7	1038.2	25.1	3.2	37.5	4.8	5.1	0.9	7.0	0.9
DMS017	0.1221	11843.1	1426.7	8071.4	1146.4	25.8	3.6	12.7	4.1	2.9	0.6	9.3	1.2
DMS018	0.1344	10635.0	1514.1	7015.0	975.8	23.0	3.2	71.1	9.9	4.1	0.6	7.1	1.0
DMS019	0.1227	11900.9	1511.3	8619.3	1094.6	25.7	3.3	58.2	7.4	6.0	0.8	8.5	1.1
DMS020	0.1236	11722.8	1500.9	8509.2	1088.5	27.6	3.5	57.8	7.4	5.2	0.7	6.3	0.8
DMS021	0.1210	11724.4	1468.9	8378.9	1049.3	29.4	3.7	55.3	6.9	7.3	0.9	7.2	0.9
DMS022	0.1240	10537.0	1358.7	8350.9	1073.0	25.4	3.3	38.4	4.9	6.2	1.0	6.2	0.8
DMS023	0.1264	10740.9	1405.2	8461.7	1107.0	25.7	3.4	34.4	4.5	7.8	1.0	6.7	0.9
DMS024	0.1180	13415.5	1630.4	8646.5	1056.0	27.1	3.3	74.3	9.1	7.9	1.0	11.0	1.3
DMS025	0.1243	12401.9	1596.5	8522.7	1096.5	27.4	3.7	67.5	8.7	3.6	0.8	11.3	1.5
DMS026	0.1325	12627.1	1689.4	8685.0	1191.0	28.7	3.9	74.4	10.7	4.1	0.7	10.7	1.4
DMS027	0.1222	11302.8	1430.4	8123.9	1028.2	26.2	3.5	45.4	6.0	6.3	0.8	10.6	1.4
DMS028	0.1217	1188.0	1497.3	8688.0	1093.7	26.4	3.3	37.9	4.8	4.8	0.6	11.6	1.3
DMS029	0.1234	12071.5	1542.1	8749.6	1117.5	29.6	3.8	52.2	6.7	6.0	0.8	8.8	1.1
DMS030	0.1264	12121.3	1585.3	8940.9	1169.7	27.6	3.6	49.9	6.1	6.1	0.8	9.3	1.2
DMS031	0.1197	12950.8	1592.9	9924.7	1105.6	42.0	3.6	42.0	4.3	5.8	0.7	8.0	1.0
DMS032	0.1214	11183.2	1518.2	9108.3	1135.2	29.0	3.6	34.3	4.3	5.8	0.8	8.0	1.0
DMS033	0.1417	11405.6	1672.7	9413.2	1380.5	37.7	5.5	34.9	5.1	5.7	0.8	5.9	0.9
DMS034	0.1243	11363.4	1526.2	8792.0	1131.1	24.7	3.2	47.0	6.0	7.0	0.8	8.9	1.3
DMS035	0.1306	11765.9	1590.4	9459.5	1278.6	32.6	4.4	45.9	6.6	6.9	0.8	9.5	1.3
DMS036	0.1275	15972.1	1764.6	8243.2	1087.8	21.9	3.7	21.7	10.9	5.9	0.7	10.7	1.1
DMS037	0.1242	11301.6	1452.8	8558.6	1074.6	26.8	3.4	34.8	4.5	6.8	0.8	7.9	1.0
DMS038	0.1263	11630.7	1520.4	9292.7	1214.7	31.3	4.1	54.8	7.2	7.5	1.0	10.0	1.3
DMS039	0.1209	12415.1	1550.3	8811.1	1102.5	32.4	4.1	84.6	10.6	6.8	0.8	9.0	1.1
DMS040	0.1248	11812.3	1575.6	8630.7	1130.9	27.4	3.6	42.9	6.9	6.9	0.9	11.6	1.5
DMS041	0.1233	11632.1	1476.9	8533.3	1119.8	28.2	3.6	40.4	6.3	6.8	0.9	10.7	1.4
DMS042	0.1257	1195.1	1367.3	8212.8	1088.5	26.9	3.5	37.9	4.9	8.2	1.1	8.9	1.2
DMS043	0.1239	11129.7	1434.9	8292.4	1063.4	26.3	3.4	69.5	8.9	4.6	0.6	11.3	1.4
DMS044	0.1272	12314.5	1621.2	7995.1	1052.6	24.5	3.2	77.4	10.2	4.2	0.5	10.6	1.4
DMS045	0.1302	10911.1	1474.4	7909.9	1065.9	20.1	2.7	47.1	6.4	4.4	0.7	13.9	1.9
DMS046	0.1257	11836.0	1539.3	8273.4	1076.4	27.2	3.5	29.2	3.8	5.4	0.4	9.3	1.2
DMS047	0.1265	11194.1	1465.6	8488.6	1112.3	29.6	3.9	47.6	4.1	5.5	0.5	13.5	1.8
DMS048	0.1286	11023.2	1444.4	8483.7	1109.0	27.3	3.6	68.3	9.9	6.0	0.8	8.6	1.1
DMS049	0.1216	11986.9	1508.6	9177.9	1155.1	30.4	3.8	43.5	5.5	7.8	1.0	8.8	1.1
DMS050	0.1210	11890.2	1489.1	8337.1	1044.1	27.7	3.5	49.5	6.2	7.3	0.9	7.1	0.9
DMS051	0.1232	10973.3	1399.3	8272.2	1054.8	30.1	3.8	56.1	7.7	10.1	1.3	6.9	0.9
DMS052	0.1250	12170.2	1574.5	8454.7	1093.8	26.9	3.3	3.9	0.9	9.5	1.2	7.4	1.0

SAMPLE NO.	DRY/VET RATIO	K MICROG/G	MG/L	CA MICROG/G	MG/L	ZN MICROG/G	MG/L	BR MICROG/G	MG/L	RB MICROG/G	MG/L	SR MICROG/G	MG/L
DME053	0.1269	11593.3	1510.7	6735.4	1136.3	25.6	3.3	22.9	3.0	5.1	0.7	7.0	0.9
DME054	0.1311	10873.9	1478.5	8924.0	1210.9	29.5	4.0	15.8	2.1	4.8	0.7	8.1	1.1
DME055	0.1377	11515.8	1641.2	8254.7	1176.5	29.1	4.1	32.2	4.6	4.5	0.6	6.2	0.9
DME056	0.1146	10777.7	1278.4	8420.4	998.8	28.4	3.4	40.1	4.8	5.7	0.7	6.9	0.8
DME057	0.1284	11823.8	1583.6	8625.2	1155.2	36.8	3.3	63.8	6.4	6.4	0.9	9.3	1.1
DME058	0.1356	10073.3	1358.9	8192.6	1107.5	26.8	3.6	45.6	6.3	5.5	0.7	7.9	1.2
DME059	0.0996	12374.6	1276.7	10183.4	1049.8	37.9	3.9	63.3	6.5	5.9	0.6	11.6	1.2
DME060	0.1194	11520.6	1423.7	9175.8	1133.9	33.3	4.1	52.5	6.5	6.0	0.7	9.7	1.2
DME061	0.1063	13795.7	1526.4	9933.6	1099.1	30.0	3.3	34.9	3.9	5.9	0.6	7.9	0.9
DME062	0.0852	2148.4	1071.3	6395.0	740.3	23.0	2.6	68.7	5.0	4.9	0.3	11.9	1.0
DME063	0.1218	9673.7	1219.4	8572.9	1079.3	26.7	3.4	55.5	6.7	6.6	0.7	7.9	1.0
DME064	0.1239	12484.3	1600.9	8137.3	1043.5	26.7	3.4	70.2	9.0	4.9	0.6	9.2	1.1
DME065	0.1165	11557.0	1393.5	8694.1	1048.3	27.9	3.4	56.3	6.8	4.9	0.6	6.7	0.9
DME066	0.1308	10367.2	1487.4	8440.8	1142.7	28.6	3.9	52.6	7.1	6.4	0.7	8.0	1.1
DME067	0.1312	10813.3	1468.4	8612.0	1169.4	34.5	4.7	29.4	4.0	5.4	0.7	9.0	1.2
DME068	0.1259	11572.7	1608.0	9150.4	1082.1	27.4	3.6	58.9	7.7	6.4	0.8	8.3	1.1
DME069	0.1254	11840.2	1538.7	8632.9	1120.5	31.8	4.1	50.6	6.6	6.2	0.8	9.3	1.1
DME070	0.1187	11375.1	1397.5	3540.7	1049.3	27.6	3.4	39.2	4.8	7.3	0.9	9.3	1.1
DME071	0.1156	12325.4	1474.7	8877.0	1062.1	28.2	3.4	21.1	2.5	7.2	0.8	5.1	0.6
DME072	0.1224	12451.9	1577.5	9571.6	1149.2	27.1	3.4	31.4	4.0	6.1	1.0	8.1	0.9
DME073	0.1287	11665.4	1556.0	8491.4	1119.5	25.4	3.7	21.2	2.8	20.1	2.6	6.7	0.9
DME074	0.1230	10579.0	1377.3	8579.0	1117.0	38.4	5.0	25.2	3.3	9.6	1.2	9.5	1.2
DME075	0.1056	13648.5	1505.9	9488.7	1046.9	37.3	4.1	27.6	3.0	9.4	1.0	9.9	1.1
DME076	0.1476	9734.9	1487.2	9256.9	1414.4	34.6	5.3	19.5	3.0	7.1	1.1	12.1	1.9
DME077	0.1285	10946.8	1467.2	7969.7	1070.9	25.4	3.4	49.8	6.8	6.4	0.8	8.8	1.2
DME078	0.1304	11420.7	1541.4	9333.3	1259.7	37.3	5.0	41.5	5.6	6.1	0.8	11.6	1.2
DME079	0.1346	11213.1	1562.1	8384.3	1168.0	30.4	4.2	35.3	4.9	6.1	0.9	8.9	1.2
DME080	0.115	11825.3	1445.5	8955.6	1094.7	28.6	3.5	56.8	6.9	8.3	1.0	8.5	1.0
DME081	0.1253	12563.8	1629.3	8271.1	1072.6	23.3	3.0	36.3	4.7	9.4	1.2	9.2	1.2
DME082	0.1289	11488.3	1532.7	9374.6	1277.4	32.8	4.4	33.2	4.4	5.9	0.8	8.6	1.1
DME083	0.1371	1176.7	1536.0	8474.8	1202.6	31.6	4.5	47.8	6.5	6.5	0.8	7.9	1.0
DME084	0.1242	11664.4	1469.4	9426.5	1211.7	29.8	3.7	36.9	4.9	6.0	0.7	7.9	1.0
DME086	0.1229	11500.5	1465.9	9579.6	1218.5	32.2	4.1	38.1	4.8	6.0	0.8	9.9	1.3
DME088	0.1242	11408.0	1568.5	8016.3	1030.5	26.2	3.4	18.0	2.3	4.6	0.6	5.2	0.8
DME089	0.1293	10755.7	1550.7	9447.0	1362.0	32.9	4.7	22.5	3.2	4.1	0.6	7.9	1.1
DME092	0.1281	12370.7	1640.2	8180.1	1034.5	21.7	2.9	78.1	10.4	8.2	1.1	10.6	1.4
DME093	0.1282	11415.2	1418.1	8213.1	1020.1	29.8	3.7	35.2	4.9	6.1	0.8	7.9	1.0
DME094	0.1136	10834.3	1329.9	8504.8	1044.0	29.8	3.7	25.8	3.2	12.8	1.6	7.3	0.9
DME095	0.1206	11397.1	1422.6	7962.4	996.4	26.7	3.3	63.2	7.9	5.7	0.7	10.0	1.3
DME096	0.1186	11215.3	1368.3	8057.4	997.4	27.5	3.4	52.0	6.4	5.5	0.7	9.0	1.1
DME097	0.1260	11500.0	1356.3	8035.0	1047.9	24.2	3.2	42.1	5.4	5.1	0.7	8.6	1.1
DME098	0.1242	11234.6	1444.2	9039.0	1033.3	25.8	4.4	45.0	6.6	5.0	0.8	8.1	1.1
DME099	0.1255	11023.5	1413.4	8110.5	1163.2	28.6	4.0	45.0	6.6	5.2	0.7	13.1	1.8
DME100	0.1245	1067.4	154.1	6643.0	1138.6	29.4	3.8	40.3	5.2	10.7	1.4	8.7	1.1
DME101	0.1194	10973.8	1349.7	7815.4	965.8	30.0	3.7	44.1	5.5	5.9	0.7	8.6	1.1
DME102	0.1215	10874.3	1366.3	7534.8	943.7	29.9	3.7	31.6	4.1	6.1	0.6	11.2	1.4
DME103	0.1287	11945.3	1467.7	7376.0	928.1	25.6	3.7	75.2	9.5	3.9	0.8	9.9	1.0
DME104	0.1226	11275.9	1333.1	7908.5	1009.0	27.0	3.6	75.0	9.5	6.0	0.8	8.9	1.2
DME105	0.1241	11356.9	1476.7	8079.0	1037.7	24.9	3.2	56.9	7.3	5.8	0.7	8.5	1.1
DME106	0.1240	11024.8	1424.1	8492.8	1037.0	27.4	3.9	47.1	6.1	5.6	0.7	8.8	0.8
DME107	0.1252	10882.5	1410.2	7911.3	1025.2	28.8	3.7	28.5	3.7	5.2	0.7	6.9	0.9

SAMPLE NO.	DRY/WET RATIO	K MICROG/G	MG/L	CA MICROG/G	MG/L	ZN MICROG/G	MG/L	BR MICROG/G	MG/L	RB MICROG/G	MG/L	SR MICROG/G	MG/L
DNB103	0.1202	11087.7	1350.4	8293.6	1031.8	22.4	2.8	28.9	3.6	4.2	0.5	8.5	1.1
DNB105	0.1174	11368.0	1442.2	8556.4	1039.7	20.4	3.4	37.0	4.5	4.4	0.5	8.3	1.0
DNB110	0.1183	11527.9	1414.8	8397.4	1089.4	31.2	3.8	35.9	4.4	5.5	0.7	8.3	1.0
DNB111	0.1190	11527.9	1431.8	8579.2	1089.0	28.8	3.8	36.1	4.4	5.5	0.7	9.0	1.1
DNB112	0.1185	11471.1	1408.1	8443.5	1036.4	28.4	3.5	44.6	4.8	7.6	0.7	9.3	1.1
DNB113	0.1255	11051.8	1447.4	8133.1	1055.0	28.0	3.7	36.4	4.8	7.6	0.7	9.3	1.1
DNB115	0.1276	11276.0	1485.2	8612.5	1058.2	27.1	3.6	55.2	7.3	5.6	0.7	8.0	1.0
DNB116	0.1300	10594.9	1305.9	9235.5	1242.6	31.4	4.2	38.6	5.2	5.2	0.7	9.4	1.3
DNB117	0.1145	11015.4	1308.6	8486.1	1008.3	25.8	3.1	43.7	5.2	4.9	0.6	7.7	0.8
DNB119	0.1287	10333.0	1301.2	8155.5	1094.9	32.8	4.4	52.5	7.0	4.6	0.6	8.1	1.1
DNB112	0.1245	10443.2	1318.1	8558.2	1058.4	29.0	3.7	33.9	5.0	5.1	0.7	7.9	1.0
NO. OF SAMPLES 112													
MEAN		11923.8	1490.5	8655.0	1119.3	29.1	3.7	45.4	5.8	6.3	0.8	8.7	1.1
STD DEV		1146.4	184.5	810.2	143.8	4.1	0.7	16.8	2.2	2.2	0.3	1.9	0.3

COMMENTS

1. RESULTS ARE GIVEN IN MICROGRAMS PER GRAM (PPM) OF DRIED SAMPLE, AND MILLIGRAMS PER LITRE OF MILK
2. ESTIMATED ACCURACY IS 10 PERCENT OF BETTER FOR ALL ELEMENTS EXCEPT POTASSIUM WHICH IS 20 PERCENT DUE TO LARGE ABSORPTION CORRECTION REQUIRED
3. OTHER ELEMENTS SOUGHT AND APPROXIMATE MINIMUM DETECTION LIMITS ARE AS FOLLOWS:

ELEMENT	MIN. DETECTION LIMIT (EST)
	PPM
TI	30.0
CR	14.0
MN	11.0
FE	7.7
NI	4.5
CU	4.0
AS	3.2
SE	2.0
ZR	1.2
MO	1.8
AU	4.8
HG	4.4
PB	4.6
	MG/L
	0.3
	1.7
	1.4
	1.0
	0.5
	0.5
	0.4
	0.2
	0.15
	0.2
	0.8
	0.6
	0.6

Appendix B. Data Summary for X-Ray Fluorescence Analysis of Milk Using the Tube-Excited System

SAMPLE	DRY/WEI	K		CA		ZN		BR		RB		SR	
NO	RA TIO	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L
DNC-411	0.1266	15715.2	2059.2	9321.8	1221.4	31.0	4.1	46.9	6.2	10.0	1.3	5.9	0.8
DNC-412	0.1250	15827.2	2047.6	9482.0	1226.9	29.5	3.8	33.7	4.4	3.9	0.5	5.5	0.7
DNC-413	0.1343	13546.4	1893.0	9406.3	1307.6	32.6	4.6	32.9	4.6	3.8	0.5	7.8	1.1
DNC-414	0.1276	15763.8	2032.1	9513.6	1269.6	28.6	3.8	48.4	6.4	6.3	0.9	7.7	1.0
DNC-415	0.1145	17707.3	2098.5	10751.9	1272.2	32.5	3.8	40.5	4.1	4.8	0.6	7.5	0.9
DNC-416	0.1092	13184.6	2055.3	11400.2	1288.5	35.8	4.0	53.1	6.0	4.7	0.5	9.8	1.1
DNC-417	0.1216	16352.9	2058.1	10339.1	1301.2	31.9	4.0	40.0	5.0	5.5	0.7	8.5	1.1
DNC-418	0.0931	23177.4	2281.3	14398.0	1417.2	39.8	3.9	56.2	6.3	0.6	11.0	1.1	1.1
DNC-419	0.1072	20505.6	2225.9	12458.0	1382.3	36.8	4.1	57.8	6.4	0.7	9.0	1.0	1.0
DNC-421	0.1154	16149.5	1928.9	9744.1	1163.8	34.0	4.1	64.8	0.6	11.7	1.4	6.6	0.8
DNC-422	0.1178	17746.0	2153.2	10742.8	1309.8	32.6	4.1	40.5	4.1	4.8	0.6	6.6	0.8
DNC-423	0.0939	16401.8	2103.3	9901.3	1269.7	27.7	3.6	3.9	0.5	9.3	1.2	6.1	0.8
DNC-424	0.0936	23431.5	2274.0	14189.5	1374.6	42.2	4.1	32.0	3.5	9.5	0.9	7.5	0.7
DNC-425	0.1225	16182.4	1922.4	9738.0	1234.7	33.3	4.2	27.5	3.5	5.6	0.7	6.8	0.9
DNC-426	0.1388	14128.0	2029.6	9649.7	1414.9	32.7	4.7	40.0	5.8	6.4	0.8	7.9	1.1
DNC-427	0.1289	16643.5	2220.4	10428.4	1391.3	26.1	3.5	30.5	4.1	6.5	0.9	6.8	0.9
DNC-428	0.1189	17611.9	2167.3	11431.1	1406.7	30.7	3.8	126.6	15.6	5.3	0.6	6.3	0.8
DNC-429	0.1254	17760.0	2305.1	10570.5	1371.9	29.1	3.8	138.1	17.9	5.0	0.7	6.1	0.8
DNC-430	0.1317	14407.1	1963.8	9052.5	1233.9	29.7	3.4	111.3	15.2	2.2	0.3	8.7	1.2
DNC-431CF	0.1236	15935.9	2044.8	9474.2	1212.0	29.6	3.8	36.2	4.8	9.0	1.1	7.5	1.0
DNC-432CF	0.1122	16014.4	1959.7	9087.3	1149.0	26.3	3.1	55.5	6.4	4.4	0.3	9.8	1.1
DNC-433	0.0902	22781.0	2126.8	1380.0	1288.3	29.4	3.8	85.4	8.0	4.4	0.4	14.5	1.4
DNC-434	0.1365	14760.6	2036.9	9131.4	1295.6	26.8	3.8	52.0	7.3	2.7	0.4	10.0	1.4
DNC-435	0.1210	15749.6	1972.4	9706.5	1215.6	27.4	3.4	40.7	5.1	7.8	1.0	6.9	0.9
DNC-436	0.1102	18574.0	2118.5	11494.6	1311.0	33.4	3.8	58.3	6.7	5.0	0.6	11.6	1.5
DNC-437	0.1211	16300.3	2105.9	9432.6	1232.4	32.6	3.8	58.3	6.7	5.0	0.6	11.6	1.5
DNC-441	0.1304	13766.8	1838.0	9233.7	1253.0	33.2	4.5	54.2	7.3	4.0	0.5	7.5	1.0
DNC-444	0.1291	15509.3	2072.4	10138.4	1409.8	35.1	4.7	50.4	6.7	4.4	0.6	8.0	1.1
DNC-447	0.1254	16342.3	2185.6	10703.3	1388.9	33.2	4.3	27.7	3.6	5.0	0.6	9.6	1.2
DNC-448	0.1438	15398.2	2251.7	9531.0	1103.3	29.3	3.3	17.0	1.7	1.4	0.4	4.9	0.6
DNC-455	0.1225	15535.1	1952.8	9811.2	1244.7	26.7	3.3	42.1	4.8	2.4	0.7	6.6	0.8
DNC-456	0.1307	14721.9	1931.3	10454.5	1411.5	34.5	4.7	53.1	7.9	2.9	0.5	9.3	1.3
DNC-457	0.1385	14139.2	2022.5	9252.2	1326.3	28.0	4.0	40.2	5.8	4.7	0.7	5.8	0.8
DNC-459	0.1268	17033.2	2236.1	10574.2	1385.3	34.2	4.5	59.1	7.8	4.2	0.9	7.7	1.0
DNC-460	0.1193	17033.2	2236.1	10574.2	1385.3	34.2	4.5	59.1	7.8	4.2	0.9	7.7	1.0
DNC-461	0.1247	16524.3	2132.7	10421.0	1345.0	30.0	3.9	67.5	8.7	4.6	0.6	7.7	1.0
DNC-462	0.1100	16234.0	2180.7	9650.2	1315.1	31.6	4.2	38.1	5.1	12.3	1.6	6.2	0.8
DNC-463	0.1210	17197.4	2148.7	10339.1	1299.6	32.9	4.1	48.0	6.0	5.6	0.7	6.1	0.8
DNC-465	0.1139	15753.4	2067.1	9917.6	1300.3	32.6	4.3	52.4	6.8	7.3	1.0	9.1	1.2
DNC-465S	0.1136	16270.4	2084.0	9739.1	1251.7	32.9	4.3	29.3	25.1	7.7	0.9	4.3	0.6
DNC-465E	0.1203	15763.8	2032.1	10023.3	1457.5	35.8	5.8	42.7	6.8	3.3	0.5	6.3	0.9
DNC-465EA	0.1134	17225.5	1845.6	10507.1	1293.2	33.0	3.9	77.4	9.1	4.2	0.5	7.9	0.9
DNC-469CT	0.1293	15707.7	2115.4	9532.9	1317.2	31.1	4.2	67.6	9.1	7.7	1.0	10.4	1.4
DNC-4709F	0.1237	15711.4	2018.0	9328.7	1213.7	28.4	3.7	82.1	10.7	2.0	0.3	13.1	1.7
DNC-4710F	0.1452	16109.1	2094.1	10445.3	1365.1	32.5	4.5	56.8	7.0	2.0	0.3	13.1	1.7
DNC-4720L	0.1325	14731.2	2022.9	9238.7	1257.0	32.7	3.9	41.3	5.7	7.5	0.9	9.6	1.2
DNC-4730Z	0.1193	16481.6	2011.4	10669.7	1248.6	30.7	3.8	56.2	7.7	6.0	0.7	9.6	1.2
DNC-4740J	0.1253	15822.8	2052.0	9833.5	1249.6	29.3	3.8	44.4	5.8	5.2	0.7	10.7	1.4
DNC-4750H	0.1334	15133.6	1975.0	9670.4	1335.1	31.8	4.1	66.7	8.5	5.2	0.8	8.8	1.1
DNC-477FL	0.1183	17099.9	2092.5	10170.4	1453.3	32.6	4.0	30.8	3.8	4.7	0.6	7.4	0.9

SAMPLE NO.	DRY/WET RATIO	CA MICROG/K MG/L	CA MICROG/G MG/L	ZN MICROG/G MG/L	BR MICROG/G MG/L	RB MICROG/G MG/L	SR MICROG/G MG/L
DMC-479ER	0.1331	14416.7	1936.0	9850.3	1357.0	30.1	4.1
DMC-480EO	0.1205	15248.4	1914.2	9832.8	1101.6	31.0	3.9
DMC-481EO	0.1205	16283.7	2030.9	10632.0	1326.0	33.1	4.1
DMC-482ED	0.1271	14554.5	1955.4	9357.9	1232.3	33.1	4.4
DMC-483EU	0.1200	16744.7	2079.7	9964.2	1237.6	33.2	4.1
DMC-484ED	0.1211	17003.2	2131.2	9659.9	1210.8	28.2	3.5
DMC-485AS	0.1233	17915.2	2276.3	10078.2	1388.2	33.2	4.2
DMC-486AC	0.1147	16438.8	1951.1	10169.5	1200.1	31.5	3.7
DMC-487AZ	0.0763	22459.5	1823.4	13797.0	1118.1	41.8	3.4
DMC-488AB	0.0350	13820.4	1655.7	11581.0	1013.6	38.3	3.4
DMC-489AF	0.1205	14338.4	1973.5	9708.4	1291.2	28.1	3.5
DMC-490AF	0.1226	12670.8	1607.9	8315.6	1055.2	33.7	4.3
DMC-491AO	0.1294	14324.5	1918.5	9757.5	1306.8	31.8	4.3
DMC-492BO	0.1257	14688.8	1911.0	9330.3	1214.9	28.8	3.7
DMC-493EC	0.1077	19355.6	2224.4	11040.5	1230.7	27.9	3.1
DMC-494DG	0.1015	22240.3	2336.4	12066.3	1269.7	36.8	3.9
DMC-495EF	0.1022	21751.6	2300.8	14394.5	1522.6	43.0	4.5
DMC-496EF	0.1254	21177.1	2748.5	12450.0	1915.9	35.7	4.6
DMC-497BD	0.1212	16759.1	2107.3	10789.3	1353.4	33.0	4.1
DMC-498DE	0.1227	17921.9	2161.7	10378.9	1318.1	28.1	3.6
DMC-499DE	0.1268	15521.2	2082.1	10234.8	1343.2	29.1	3.8
DMC-500BK	0.1091	19306.9	2193.7	12714.3	1422.5	39.6	4.4
DMC-501BK	0.1159	19162.0	2137.5	12043.1	1457.1	36.6	4.4
DMC-502BL	0.1215	17680.9	2233.4	10803.4	1350.6	29.1	3.7
DMC-503BL	0.1261	16483.2	2151.3	12568.7	1642.7	27.3	3.6
DMC-504EO	0.1108	16812.8	1928.1	14330.3	1643.4	35.4	4.1

NO. OF SAMPLES 76

MEAN	16315.6	2076.8	10549.8	1305.2	32.1	4.0	54.3	6.8	6.7	0.8	8.1	1.0
STD DEV	2333.1	162.8	1382.7	112.7	4.0	0.4	34.3	4.3	2.8	0.4	2.4	0.3

COMMENTS

1. RESULTS ARE GIVEN IN MICROGRAMS PER GRAM (PPM) OF DRIED SAMPLE, AND MILLIGRAMS PER LITRE OF MILK
2. ESTIMATED ACCURACY IS 10 PERCENT IF BETTER FOR ALL ELEMENTS EXCEPT POTASSIUM WHICH IS 20 PERCENT OR BETTER DUE TO LARGE ABSORPTION CORRECTION REQUIRED
3. OTHER ELEMENTS SOUGHT AND APPROXIMATE MINIMUM DETECTION LIMITS ARE AS FOLLOWS:

ELEMENT	MIN. DETECTION LIMIT (EST)
	PPM
TI	30.0
CR	14.0
MN	11.0
FE	1.7
NI	4.5
CU	4.0
AS	3.2
SE	2.0
SR	1.2
MO	1.8
AU	4.8
HG	4.4
PB	4.6

Data Summary for Xray Fluorescence Analysis of Milk

SAMPLE NO.	DRY/WET RATIO	K MICROG/G	MO/L	CA MICROG/G	MO/L	ZN MICROG/G	MO/L	BR MICROG/G	MO/L	RB MICROG/G	MO/L	SR MICROG/G	MO/L
DMB-312	0.132	18092.1	2232.1	9145.1	1128.2	29.8	3.7	35.5	4.4	4.8	0.6	8.8	1.1
DMB-313	0.1523	11381.4	1784.1	7181.1	1132.0	22.9	3.6	37.5	4.9	2.8	0.4	8.0	1.3
DMB-314	0.1210	16205.7	2029.5	9691.8	1213.8	25.5	3.2	21.9	2.0	9.9	0.2	9.5	0.6
DMB-315	0.1226	15791.2	2003.8	9588.4	1216.7	27.3	3.3	16.0	0.0	1.7	0.4	7.4	0.6
DMB-316	0.1150	17015.4	2025.8	9344.4	1112.0	27.3	3.3	5.7	0.0	1.1	0.9	6.6	0.9
DMB-317	0.1163	77716.2	2132.5	9809.2	1180.7	29.7	3.6	25.8	2.2	2.0	0.6	5.6	0.6
DMB-318	0.1163	8029.9	2207.6	9876.7	1209.3	30.8	3.8	25.8	3.0	3.0	0.6	5.6	1.1
DMB-319	0.1213	16442.6	2064.3	9519.2	1195.1	31.0	3.9	23.3	3.3	3.3	0.7	5.6	0.7
DMB-320	0.1339	14542.3	2015.4	8720.1	1205.5	29.3	3.2	19.3	3.3	3.3	0.8	5.6	1.1
DMB-321	0.1150	16950.3	1960.3	9383.3	1205.5	29.3	3.2	19.3	3.3	3.3	0.8	5.6	1.1
DMB-322	0.1225	16782.3	2146.7	9824.1	1245.6	26.6	3.6	19.1	4.4	3.8	0.7	6.6	0.7
DMB-323	0.1205	17212.3	2146.7	10109.4	1245.6	26.6	3.6	56.6	6.6	6.6	0.9	6.0	1.0
DMB-324	0.1216	15627.5	1966.8	10259.7	1291.2	25.2	3.2	101.0	7.7	5.4	0.7	7.6	1.0
DMB-325	0.1197	17230.8	2142.2	9893.1	1225.9	26.6	3.3	53.2	4.4	4.4	0.6	5.3	0.7
DMB-326	0.1232	17207.4	2229.5	10775.5	1385.9	26.6	3.3	42.4	4.4	4.4	0.6	4.6	0.6
DMB-327	0.1247	16346.3	2103.7	9782.1	1262.6	26.7	3.3	27.1	4.4	4.4	0.6	6.6	0.6
DMB-328	0.1220	16633.4	2100.3	9674.2	1321.6	27.6	3.5	35.3	4.8	5.5	0.7	5.5	0.7
DMB-329	0.1225	17685.9	2242.3	10140.9	1335.7	29.1	3.6	23.4	4.0	2.9	0.4	5.4	0.7
DMB-330	0.1194	17405.2	2150.9	10209.0	1261.5	29.1	3.6	76.9	4.0	2.9	0.7	5.4	0.7
DMB-331	0.1037	16834.1	1812.2	9577.7	1029.0	23.5	2.7	72.2	2.2	2.2	1.0	3.9	0.6
DMB-332	0.1199	16441.8	2003.3	9628.8	1181.9	25.4	3.0	41.4	4.4	4.4	0.6	3.9	0.3
DMB-333	0.1206	17156.4	2141.6	9938.1	1240.5	23.9	3.0	162.0	2.0	2.0	0.4	3.7	1.1
DMB-334	0.1217	17096.5	2153.5	9661.0	1216.9	28.4	3.6	23.1	4.6	1.8	0.9	7.3	0.9
DMB-335	0.1212	15875.9	1991.1	9194.2	1153.3	25.9	3.7	76.8	4.4	4.4	0.7	7.7	1.1
DMB-336	0.1151	17097.8	2035.6	9414.0	1121.5	24.8	3.5	55.1	4.4	4.4	0.6	7.7	1.1
DMB-337	0.1249	15815.0	2044.9	9539.0	1232.7	24.9	3.0	30.5	4.4	4.4	0.6	7.7	1.1
DMB-338	0.1232	16620.7	2119.3	9241.6	1176.4	24.9	3.0	17.6	4.4	4.4	0.4	7.3	1.0
DMB-339	0.1221	17430.5	2202.9	9452.3	1194.5	25.8	3.4	60.4	4.4	4.4	0.9	12.5	1.1
DMB-340	0.1225	16312.6	2058.8	9323.3	1122.1	26.6	3.4	39.1	4.4	4.4	0.7	12.5	1.1
DMB-341	0.1160	17112.3	2088.9	9758.8	1193.0	27.7	3.4	39.5	4.4	4.4	0.7	12.5	1.1
DMB-342	0.1169	17238.3	2088.9	9758.8	1193.0	27.7	3.4	39.5	4.4	4.4	0.7	12.5	1.1
DMB-343	0.1176	17068.1	2080.0	9752.4	1187.0	26.8	3.4	42.3	4.4	4.4	0.9	12.5	1.1
DMB-344	0.1101	16339.4	2058.3	9759.2	1192.9	27.9	3.4	47.1	4.4	4.4	0.6	10.0	1.0
DMB-345	0.1241	15178.8	1949.0	9578.8	1230.3	29.7	3.8	41.3	4.4	4.4	0.7	7.7	1.1
DMB-346	0.1038	16363.3	1732.2	10859.3	1055.3	26.6	3.0	35.0	4.4	4.4	0.6	7.7	1.1
DMB-347	0.1410	13945.3	2042.0	9395.1	1399.8	33.9	4.0	45.0	4.4	4.4	0.9	6.6	0.9
DMB-348	0.1258	13415.5	2007.1	9902.2	1286.3	34.5	4.5	47.5	4.4	4.4	0.8	6.6	1.0
DMB-349	0.1172	16306.0	1976.0	9601.0	1164.6	23.6	2.9	32.0	4.4	4.4	0.6	5.5	0.6
DMB-350	0.1193	16951.0	2093.0	10084.5	1245.2	30.0	3.7	46.8	4.4	4.4	0.6	5.5	0.7
DMB-351	0.1146	14497.3	2013.5	9717.1	1358.0	30.7	4.3	40.2	4.4	4.4	0.6	6.4	0.6
DMB-352	0.1055	18205.5	1997.9	10537.7	1180.6	33.4	3.9	41.0	4.4	4.4	0.6	6.4	0.6
DMB-353	0.1162	18450.4	2219.9	11084.6	1333.1	32.6	3.9	61.9	4.4	4.4	0.7	7.3	0.6
DMB-354	0.0931	26630.6	2371.9	16968.2	1635.0	42.1	4.1	61.2	4.4	4.4	0.9	10.4	1.1
DMB-355	0.1207	17237.7	2133.4	9581.1	1196.9	28.7	3.6	37.1	4.4	4.4	0.6	10.4	1.1
DMB-356	0.1265	15767.8	2133.4	9581.1	1196.9	28.7	3.6	37.1	4.4	4.4	0.6	10.4	1.1
DMB-357	0.1233	18027.7	2300.6	9538.8	1217.2	30.3	3.9	45.0	4.4	4.4	0.7	8.0	0.9
DMB-358	0.1246	16604.2	2144.7	9192.0	1187.3	29.0	3.7	43.4	4.4	4.4	0.6	7.0	0.9
DMB-359	0.1145	16501.7	1955.6	9080.9	1076.2	23.7	2.8	43.6	4.4	4.4	0.6	6.6	0.6
DMB-360	0.1273	15056.4	1984.0	9243.3	1217.9	25.6	3.9	45.0	4.4	4.4	0.6	6.6	0.6
DMB-361	0.1541	12416.6	1980.4	7191.0	1147.0	21.6	3.4	33.0	4.4	4.4	1.1	9.4	0.6

SAMPLE NO	DRY/WET RATIO	MICROG K MG/L	MICROG CA MG/L	MICROG ZN MG/L	MICROG BR MG/L	MICROG RB MG/L	MICROG SR MG/L
DMB-365	0.1303	14837.6	2001.0	8798.9	1186.6	27.6	4.8
DMB-366	0.1115	1593.6	1901.5	10336.6	1236.8	36.5	0.7
DMB-367	0.1230	9569.0	2020.2	9769.7	1116.3	28.1	0.9
DMB-368	0.1329	4564.1	2003.3	9601.4	1020.7	30.2	0.3
DMB-370	0.1133	16939.5	1986.4	9525.1	1111.0	28.7	0.6
DMB-371	0.1484	3548.7	2081.0	8064.0	1235.6	24.4	0.8
DMB-372	0.1650	11505.3	1930.8	7981.2	1373.8	31.4	0.9
DMB-373	0.1304	6130.6	2177.1	8753.0	1181.3	22.2	0.7
DMB-374	0.1394	5924.0	2197.5	9320.0	1344.7	30.0	0.9
DMB-375	0.1340	4795.4	2052.0	9946.5	1379.5	30.8	0.8
DMB-376	0.1380	5181.3	2225.9	8215.6	1181.9	20.5	0.7
DMB-377	0.1260	15598.8	2042.3	9694.3	1264.2	26.8	0.6
DMB-378	0.1316	3695.7	1865.4	9877.4	1345.4	33.5	0.9
DMB-379	0.1235	4509.0	1854.6	8351.8	1068.8	19.6	0.8
DMB-380	0.1290	5252.7	2040.5	9280.0	1239.0	25.8	0.7
DMB-382	0.1268	13331.0	2070.9	9487.3	1245.1	27.4	0.6
DMB-384	0.1341	3484.0	1867.3	8807.0	1222.4	28.2	0.9
DMB-385	0.1275	4098.8	1862.6	9698.2	1282.8	26.2	0.8
DMB-386	0.1134	2879.4	1511.6	7878.4	924.7	21.1	0.7
DMB-387	0.1334	13503.3	1864.4	8861.5	1223.5	28.8	0.8
DMB-388	0.1290	13331.0	1779.9	9760.1	1169.3	26.7	0.9
DMB-389	0.1299	6126.0	2168.1	11129.5	1496.3	35.3	0.6
DMC-390	0.1296	4183.1	1902.5	9096.2	1220.1	28.5	0.8
DMC-391	0.1255	5069.6	1937.4	9466.3	1229.6	29.8	0.9
DMC-392	0.1308	14108.6	1910.0	9230.6	1242.6	28.4	0.7
DMC-393	0.0978	21740.2	2145.6	13415.1	1345.3	38.2	0.8
DMC-394	0.1050	18534.0	2063.3	9200.3	1300.3	34.3	0.9
DMC-395	0.1444	13404.2	2003.3	10141.1	1515.6	39.5	0.6
DMC-396	0.1264	15911.1	2081.6	10186.6	1332.6	29.9	0.8
DMC-397	0.1235	16832.1	2131.5	10524.2	1345.2	33.3	0.7
DMC-398	0.1320	15058.0	2056.8	9351.2	1359.6	33.0	0.9
DMC-399	0.1247	15180.0	2061.9	9347.8	1283.9	30.4	0.6
DMC-400	0.1221	15312.1	1935.0	9916.0	1253.1	36.7	0.8
DMC-401	0.1226	14730.5	1869.2	10362.2	1314.9	23.9	0.9
DMC-402	0.1253	14681.2	1901.3	9573.9	1241.6	28.0	0.7
DMC-403	0.1292	14148.4	1891.3	9044.6	1209.5	30.9	0.8
DMC-404	0.1205	18310.6	1914.3	9454.1	1182.1	34.0	0.6
DMC-405	0.1217	16028.8	2018.9	9380.2	1181.5	27.9	0.9
DMC-406	0.1287	16578.9	2208.4	9712.1	1293.7	31.6	0.7
DMC-407	0.1247	14590.3	1883.1	9360.4	1208.1	28.8	0.8
DMC-408	0.1265	14740.1	1922.3	9287.4	1211.2	26.4	0.9
DMC-409	0.1270	15837.8	2081.8	9127.3	1198.7	28.0	0.6
DMC-410	0.1262	15398.2	2011.3	9633.0	1258.2	33.9	0.8
DMC-448	0.1273	16273.0	2144.1	9733.9	1282.5	29.7	0.9
DMC-449	0.1317	15051.1	2053.1	8419.5	1147.7	31.1	0.7
DMC-450	0.1389	16454.2	2330.2	9033.4	1290.2	30.8	0.8
DMC-451	0.1670	11937.7	2065.7	9036.6	1647.6	41.3	0.9
DMC-452	0.1385	14842.2	2127.6	11117.7	1593.7	23.6	0.6
DMC-453	0.1265	15294.0	2002.4	9053.4	1185.3	23.3	0.8
DMC-458	0.1254	17852.8	2318.5	10923.7	1417.8	33.7	0.7

SAMPLE NO.	DRY/WET RATIO	K		CA		ZN		BR		RB		SR	
		MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L
DMC-464	0.1314	15288.3	2078.9	10139.7	1379.0	33.1	4.5	40.8	5.6	5.0	0.7	7.4	1.0
DMC-476	0.1202	16095.6	2002.4	11410.0	1419.5	29.1	3.6	39.0	4.8	3.4	0.4	7.4	0.9
DMC-478	0.1235	15552.8	1996.0	10173.3	1300.4	33.0	4.2	49.3	6.3	2.4	0.3	7.7	1.0
NO. OF SAMPLES 103		15913.9	2042.7	9680.9	1245.9	29.1	3.8	47.3	6.1	5.8	0.7	7.2	0.9
MEAN		1930.4	138.5	1124.4	112.8	4.2	0.7	22.1	2.8	2.0	0.2	2.1	0.3
STD DEV													

COMMENTS

1. RESULTS ARE GIVEN IN MICROGRAMS PER GRAM (PPM) OF DRIED SAMPLE, AND MILLIGRAMS PER LITRE OF MILK
2. ESTIMATED ACCURACY IS 10 PERCENT OR BETTER FOR ALL ELEMENTS EXCEPT POTASSIUM WHICH IS 20 PERCENT OR BETTER DUE TO LARGE ABSORPTION CORRECTION REQUIRED
3. OTHER ELEMENTS SOUGHT AND APPROXIMATE MINIMUM DETECTION LIMITS ARE AS FOLLOWS:

ELEMENT	MIN. DETECTION LIMIT (EST)	
	PPM	MG/L
TI	30.0	3.7
CR	14.0	1.7
MN	11.0	1.4
FE	7.7	1.0
NI	4.5	0.5
CU	4.0	0.5
AS	3.2	0.4
SE	2.0	0.2
ZR	1.2	0.15
MO	1.8	0.2
AU	4.8	0.6
HG	4.4	0.5
PB	4.6	0.6

Data Summary for Xray Fluorescence Analysis of Milk

SAMPLE NO.	DRY/WET RATIO	MICROG/K	MG/L	MICROG/CA	MG/L	MICROG/ZN	MG/L	MICROG/BR	MG/L	MICROG/RS	MG/L	MICROG/SR	MG/L
DM3-121 COL	0.1249	15424.0	1993.9	9627.2	1244.5	29.1	3.8	51.7	6.7	6.1	0.8	11.2	1.5
DM3-122 COL	0.1234	15063.1	1923.9	9021.7	1152.2	27.3	3.6	52.0	6.6	8.1	0.8	6.22	0.8
DM3-123 COL	0.1234	15977.8	2040.7	9622.0	1264.5	32.8	4.1	49.2	6.3	8.1	0.8	9.6	1.2
DM3-124 COL	0.1234	20112.8	2252.3	10522.2	1178.4	28.3	3.2	49.5	6.3	6.9	0.8	13.6	1.4
DM3-125 COL	0.1254	15492.4	2026.8	9123.8	1193.6	25.9	3.4	43.2	5.7	6.0	0.8	10.8	1.4
DM3-127 COL	0.1211	16026.7	2008.8	9530.2	1194.5	19.3	2.4	60.8	7.6	8.2	1.0	11.1	1.4
DM3-128 COL	0.1259	16627.3	2166.7	9890.2	1288.8	27.7	3.6	70.5	3.6	3.3	0.4	6.8	1.1
DM3-129 COL	0.1243	17090.3	2098.7	9438.8	1244.3	25.7	3.3	41.7	3.5	4.1	0.5	8.5	1.1
DM3-130 COL	0.1270	15938.3	2035.1	9167.0	1205.0	25.9	3.4	41.7	3.5	3.8	0.5	3.6	0.7
DM3-131 COL	0.1192	16771.5	2069.1	9551.7	1190.8	28.3	3.5	42.6	5.3	6.9	0.8	5.8	0.7
DM3-132 COL	0.1180	17143.4	2093.7	9789.7	1195.6	27.4	3.3	69.0	8.4	14.2	1.7	6.6	0.8
DM3-133 COL	0.1351	14671.4	2051.5	8754.8	1224.2	21.5	3.3	28.5	12.5	3.6	0.6	6.6	1.2
DM3-134 COL	0.1214	17041.4	2141.1	9804.2	1231.9	27.6	3.9	40.0	5.0	8.0	1.0	9.1	1.1
DM3-135 COL	0.1218	16284.6	2052.9	10059.2	1269.3	29.4	3.7	89.1	11.2	4.9	0.6	10.9	1.4
DM3-136 COL	0.1187	17217.3	2115.5	10335.5	1273.4	29.0	3.6	54.4	6.7	6.3	0.6	12.2	1.3
DM3-137	0.1254	15768.2	2046.5	9032.3	1172.3	26.7	3.5	33.7	4.4	5.4	0.7	11.9	1.5
DM3-138	0.1200	16163.1	2007.5	9657.4	1199.4	28.7	3.6	28.5	3.5	7.6	0.9	8.8	1.1
DM3-139	0.1213	16211.7	2035.3	9357.1	1174.7	31.3	3.9	64.6	8.1	7.3	0.9	9.1	1.1
DM3-140	0.1237	15115.2	1935.2	9295.4	1190.1	26.1	3.3	69.3	8.9	4.5	0.6	12.1	1.5
DM3-141	0.1215	15948.8	2005.4	9193.8	1156.1	26.6	3.3	16.0	2.0	7.8	1.1	3.8	0.5
DM3-142	0.1269	14748.2	1937.1	9362.2	1229.6	26.4	3.5	28.4	3.7	6.8	0.9	12.8	1.7
DM3-143	0.1287	15612.8	2079.7	9634.1	1233.3	32.1	4.3	26.5	3.5	7.5	1.0	7.6	1.0
DM3-144	0.1235	15835.9	2024.2	9811.8	1254.2	29.8	3.8	27.5	3.5	4.0	0.5	5.9	0.8
DM3-145	0.1271	16381.1	2154.9	9305.5	1289.9	30.7	4.0	22.9	3.7	7.4	1.1	7.4	1.0
DM3-146	0.1280	16344.6	2131.5	9484.0	1236.8	27.1	3.5	29.1	2.8	5.8	0.6	9.3	1.2
DM3-147	0.1207	16468.6	2057.3	10237.5	1278.9	31.8	4.0	27.7	3.5	5.2	0.6	6.6	0.5
DM3-148	0.1229	16543.2	2104.3	9519.7	1210.9	28.7	3.7	6.8	0.9	10.7	1.4	5.4	0.7
DM3-149	0.1133	18293.1	2239.8	10346.5	1266.8	27.8	3.4	2.6	0.3	9.2	1.1	6.2	0.8
DM3-150	0.1170	18416.0	2230.1	10884.3	1318.0	33.3	4.0	2.2	0.7	9.8	1.2	6.0	0.7
DM3-151	0.1226	16290.8	2071.5	9586.1	1259.2	33.3	4.7	2.2	2.3	9.9	1.2	6.0	0.8
DM3-152	0.1268	15658.8	1925.6	9455.8	1184.0	36.0	3.2	13.3	2.9	13.3	1.4	6.1	0.8
DM3-154	0.1183	18037.9	2208.6	11117.7	1361.3	30.8	3.8	60.5	7.4	6.6	0.9	8.5	1.0
DM3-155	0.1245	17124.4	2206.6	11239.2	1448.3	37.0	4.8	48.4	6.2	6.5	0.8	10.2	1.3
DM3-157	0.1124	16877.7	1963.4	10180.4	1184.3	29.3	3.4	33.6	7.4	6.8	0.7	8.7	1.0
DM3-158	0.1375	15591.8	2218.8	9572.9	1362.3	33.1	4.7	45.4	9.6	6.5	0.9	9.2	1.1
DM3-159	0.1145	17266.1	2046.1	10981.9	1301.4	32.8	3.8	45.4	9.6	6.5	0.9	9.2	1.1
DM3-161	0.1218	15953.9	2011.2	9906.6	1256.4	29.5	3.7	47.7	6.0	6.6	0.8	10.5	1.3
DM3-162	0.1201	16545.7	2056.7	9409.2	1169.6	29.2	3.6	56.0	7.0	6.9	0.9	7.9	1.0
DM3-163	0.1216	15786.3	1986.8	9823.6	1236.4	28.8	3.6	58.6	7.4	6.8	0.9	11.5	1.4
DM3-164	0.1198	17320.9	2147.6	9931.8	1231.5	28.6	3.5	58.4	7.2	9.1	1.1	13.0	1.6
DM3-165	0.1201	16205.7	2263.0	9639.5	1198.2	28.3	3.2	85.2	10.8	7.9	0.6	7.9	1.0
DM3-166	0.1137	17240.4	2135.9	10927.1	1279.4	30.2	3.7	67.8	8.4	4.7	0.8	8.5	1.1
DM3-167	0.1296	17087.6	2292.1	9778.4	1311.6	26.3	3.5	33.2	4.4	6.4	0.9	6.1	0.8
DM3-168	0.1250	13227.0	417.5	2043.0	264.3	6.4	0.8	9.2	1.2	1.1	0.1	8.1	0.1
DM3-169	0.1283	16000.4	2124.7	10196.2	1354.0	35.1	4.7	36.5	4.9	5.2	0.7	8.1	1.2
DM3-170	0.1193	16065.8	2230.7	10987.6	1354.2	32.4	4.0	41.0	5.1	5.1	0.9	10.1	1.2
DM3-171	0.1248	16593.5	2138.2	9879.4	1276.1	31.7	4.1	19.7	2.5	4.5	0.6	6.8	0.9
DM3-172	0.1167	19255.3	2325.7	10988.4	1327.2	30.7	3.7	42.0	5.1	4.3	0.5	10.3	1.2
DM3-173	0.1188	17169.4	2111.1	10262.9	1261.9	30.0	3.7	37.1	4.6	4.3	0.5	7.4	0.9
DM3-174	0.1219	16897.7	2131.9	10001.4	1261.8	32.9	4.2	38.2	4.8	4.9	0.5	6.9	0.9

SAMPLE NO.	DRY/WET RATIO	K MICROG/G	MG/L	CA MICROG/G	MG/L	ZN MICROG/G	MG/L	BR MICROG/G	MG/L	RS MICROG/G	MG/L	SR MICROG/G	MG/L
DMB-175	0.1233	15337.7	1957.3	9349.3	1193.1	27.1	3.5	29.0	3.7	4.1	0.5	7.5	1.0
DMB-176	0.1340	14904.5	2067.1	10342.8	1434.4	38.1	5.3	25.8	3.6	3.9	0.55	6.9	1.0
DMB-177	0.1252	15517.1	2010.7	10056.5	1303.1	31.1	4.0	30.9	4.0	9.4	1.22	6.8	0.9
DMB-178	0.1240	14825.2	2002.7	9035.0	1162.1	28.1	3.0	80.3	10.3	7.1	0.9	6.8	0.7
DMB-179	0.1014	18132.1	1902.9	11332.5	1188.3	32.1	4.0	86.1	10.3	0.0	0.7	13.55	1.4
DMB-181	0.1246	15753.7	2031.8	9417.0	1214.4	27.9	3.6	60.1	10.3	6.3	0.8	8.8	1.1
DMB-182	0.1161	15597.6	1874.3	10603.3	1274.1	23.2	2.8	31.9	3.8	4.7	0.6	9.7	1.2
DMB-183	0.1191	17533.7	2161.3	9615.6	1195.3	27.7	3.4	72.9	9.0	6.1	0.7	9.8	1.0
DMB-184	0.1133	16730.2	2060.8	9806.2	1210.1	31.1	3.3	27.9	12.1	9.7	0.6	7.2	0.9
DMB-185	0.1199	15708.6	2033.3	9870.8	1237.9	27.9	3.6	126.1	10.3	6.6	0.7	9.2	1.2
DMB-186	0.1257	16681.1	2170.2	9754.6	1269.1	28.6	3.5	25.3	3.7	5.1	0.7	9.4	1.2
DMB-187	0.1172	17950.3	2177.4	10282.8	1247.4	29.3	3.6	27.7	3.0	9.9	1.0	6.2	0.8
DMB-188	0.1231	16949.6	2159.5	10050.2	1200.5	34.9	4.5	2.0	3.7	7.7	1.0	6.4	0.8
DMB-189	0.1244	15939.8	2039.4	10056.8	1294.8	30.3	3.9	29.8	3.8	4.4	1.0	8.9	1.7
DMB-190	0.1252	17281.6	2239.8	9959.8	1235.8	27.9	3.6	42.3	4.4	6.6	0.6	2.8	1.6
DMB-191	0.1309	15900.4	2144.3	9670.6	1304.2	27.6	3.7	36.4	5.9	6.6	0.9	11.6	1.6
DMB-192	0.1262	16205.7	2116.7	9393.7	1227.0	27.2	3.6	44.8	5.4	6.6	0.6	12.8	1.7
DMB-193	0.1259	17248.2	2247.7	10472.8	1364.7	32.6	4.3	60.7	10.3	1.1	0.7	11.7	1.5
DMB-194	0.1188	15720.5	1933.0	10483.9	1289.1	27.1	3.3	36.6	4.4	5.1	0.7	11.2	1.4
DMB-195	0.1227	14852.9	1891.3	11280.3	1432.5	32.1	4.1	33.0	11.1	0.0	1.4	9.2	1.0
DMB-196	0.1177	16645.2	2027.7	9465.6	1153.1	30.9	3.8	48.7	5.7	5.9	0.7	6.1	1.0
DMB-197	0.1126	16887.1	1968.0	10527.3	1226.9	29.5	3.4	64.5	7.5	5.3	0.6	7.2	0.8
DMB-199	0.1187	15369.4	1961.9	11246.9	1381.7	34.2	4.2	43.5	5.3	4.9	0.5	9.7	1.2
DMB-200	0.0847	18498.9	1621.7	10771.9	944.3	26.5	2.3	42.3	4.3	9.9	0.5	6.3	0.6
DMB-202	0.1204	17243.4	2148.8	11582.6	1449.3	39.3	4.9	47.8	6.0	4.2	0.9	8.5	1.1
DMB-203	0.1226	17289.3	2193.5	9715.6	1233.2	28.2	3.6	79.6	10.3	0.0	0.5	11.9	1.5
DMB-204	0.1212	16531.9	2073.8	10251.6	1286.0	30.5	3.8	50.0	6.3	7.8	1.0	6.8	0.8
DMB-205	0.1216	16070.6	2123.3	10625.9	1337.3	31.0	3.9	42.8	5.4	5.6	0.7	8.9	1.1
DMB-206	0.1240	16373.6	2165.6	9939.3	1278.2	28.9	3.7	48.1	6.2	5.8	0.7	9.1	1.2
DMB-207	0.1232	16255.3	2327.8	10201.4	1300.8	33.1	4.2	48.2	5.1	9.3	1.1	6.3	0.8
DMB-208	0.1236	16060.8	2054.6	10055.7	1286.6	30.5	3.6	48.2	6.2	5.2	0.9	11.2	1.4
DMB-209	0.1161	18041.8	2168.0	11333.6	1361.9	30.0	3.6	59.3	7.1	6.9	0.7	10.5	1.3
DMB-210	0.1255	15843.2	2057.9	10315.2	1339.9	30.6	4.0	53.4	6.9	5.9	0.6	9.6	1.2
DMB-211	0.1251	12127.7	1695.8	8459.0	1184.2	26.0	3.6	43.9	4.9	6.1	0.7	7.7	1.1
DMB-212	0.1372	13933.4	1964.8	9054.8	1285.8	28.3	4.0	47.4	4.7	7.7	0.7	9.2	1.3
DMB-213	0.1171	17436.3	2113.3	11010.9	1334.5	34.4	4.3	44.4	5.1	5.5	0.6	11.0	1.4
DMB-214	0.1191	17043.3	2100.9	11058.0	1363.1	35.0	4.3	46.2	5.5	6.2	0.6	11.0	1.3
DMB-215	0.1187	16370.8	2011.2	9574.2	1176.2	27.1	3.6	35.3	4.3	9.8	1.2	11.5	1.4
DMB-216	0.1266	13745.3	1801.1	8594.0	1126.1	29.4	3.6	13.9	1.8	3.1	0.4	5.9	0.8
DMB-217	0.1206	16635.9	2076.5	10018.8	1250.6	30.9	3.9	35.9	4.3	6.5	0.6	11.1	1.4
DMB-218	0.1214	16551.9	2079.7	9409.8	1182.3	27.1	3.1	41.5	4.4	6.4	0.6	13.1	1.7
DMB-219	0.1253	14725.6	1909.7	9808.7	1263.7	32.0	4.1	44.8	5.1	7.7	0.7	10.9	1.3
DMB-220	0.1182	16745.3	2043.6	9466.1	1160.5	35.6	4.3	43.2	5.3	7.7	1.1	10.9	1.3
DMB-221	0.1310	17218.6	2334.6	9442.9	1260.3	28.1	3.8	50.5	6.0	6.6	0.8	16.0	2.2
DMB-222	0.1240	17274.1	2217.0	9433.4	1210.7	27.5	3.5	49.1	5.3	5.3	0.7	15.4	2.0
DMB-223	0.1158	16739.7	2058.3	10140.9	1246.9	28.9	3.3	47.1	5.2	5.8	0.7	13.2	1.6
DMB-224	0.1214	16856.7	2017.5	9426.6	1184.4	25.6	3.3	46.8	5.1	5.9	0.6	13.0	1.6
DMB-225	0.1175	16148.1	1963.9	9858.1	1193.9	25.6	3.2	46.8	5.1	5.9	0.6	6.7	0.8
DMB-226	0.1368	14253.3	2018.1	8490.7	1202.2	24.5	3.5	14.7	1.7	8.2	1.1	4.3	0.6
DMB-228	0.1197	17126.4	2121.8	9889.7	1225.2	30.2	3.7	5.4	0.7	10.5	1.3	9.0	1.1

COL

SAMPLE NO.	DRY/WET RATIO	MICROG/K	MG/L	MICROG/CA	MG/L	MICROG/ZN	MG/L	MICROG/BR	MG/L	MICROG/RS	MG/L	MICROG/SR	MG/L
DMB-229	0.1170	18100.4	2191.9	10248.7	1241.1	31.5	33.8	7.2	0.8	8.2	1.0	6.1	0.7
DMB-230	0.1205	15951.2	1989.4	9508.1	1185.8	30.3	33.8	23.7	0.8	9.1	1.2	6.7	0.8
DMB-231	0.1216	17855.7	2209.5	9753.8	1227.8	28.1	33.8	23.7	0.8	9.1	1.2	6.7	0.8
DMB-232	0.1207	16544.0	2056.7	9925.2	1239.8	30.8	33.8	22.8	0.8	8.8	0.8	6.3	0.8
DMB-233	0.1282	16013.7	2124.6	9533.3	1284.9	31.7	4.2	26.7	3.5	7.3	1.0	6.6	0.9
DMB-234	0.1282	15615.7	2072.0	9901.9	1234.2	29.3	33.8	25.7	3.3	5.1	0.7	6.1	1.1
DMB-235	0.1281	16767.2	2223.1	10461.9	1367.1	30.7	33.8	40.3	3.3	6.3	0.8	6.7	1.1
DMB-236	0.1198	16932.8	2095.5	9831.1	1219.0	32.0	33.8	23.1	3.1	8.0	1.2	6.2	0.8
DMB-237	0.1184	17345.1	2125.5	9815.0	1202.8	26.4	33.8	74.1	7.1	7.5	1.0	6.1	0.8
DMB-238	0.1327	17435.4	2394.7	10429.0	1432.4	25.9	33.8	60.8	6.3	6.0	0.8	4.7	0.6
DMB-239	0.1116	16461.2	2034.1	10158.7	1173.4	24.1	33.8	35.3	4.1	6.0	0.7	9.3	1.1
DMB-240	0.1196	17951.1	2222.1	10329.2	1267.3	23.0	33.8	31.4	3.9	5.1	0.6	11.9	1.4
DMB-241	0.1190	17871.7	2201.2	10347.8	1274.3	28.4	33.8	19.8	1.6	7.1	10.7	1.3	0.7
DMB-243	0.1166	20337.3	2484.4	12342.9	1477.5	32.3	33.8	27.3	3.3	7.7	0.9	6.2	0.7
DMB-244	0.1015	21708.4	2280.3	13435.1	1413.5	33.1	33.7	79.8	6.4	0.0	1.1	7.6	0.8
DMB-245	0.1206	18708.1	2334.1	10889.8	1399.3	31.2	33.9	21.8	2.7	2.3	0.7	6.8	0.8
DMB-246	0.1192	18023.3	2223.6	9877.3	1218.8	20.8	33.8	22.3	2.2	7.8	1.0	6.9	0.8
DMB-247	0.1208	18024.1	2261.0	10401.8	1305.3	30.7	33.8	74.7	8.3	5.1	0.8	4.0	0.3
DMB-248	0.1266	16621.4	2212.3	10317.9	1379.3	27.1	33.8	23.8	3.2	7.7	1.0	7.0	0.9
DMB-249	0.1307	16072.8	2174.2	10245.8	1366.0	29.6	4.0	23.0	3.4	4.6	0.8	4.8	0.6
DMB-250	0.1218	16213.0	2043.9	10390.6	1290.5	23.9	33.3	38.0	4.8	8.3	0.7	10.1	1.3
DMB-251	0.1224	17142.9	2171.7	9967.6	1250.1	27.4	33.3	43.6	5.3	4.0	0.5	9.3	1.2
DMB-252	0.1274	16652.6	2201.1	9149.1	1206.4	23.0	33.4	33.2	4.4	6.0	0.8	9.5	1.1
DMB-253	0.1174	16131.0	1966.1	9595.8	1166.0	28.7	33.1	38.7	4.7	8.2	0.6	11.5	1.4
DMB-254	0.1188	16409.9	2017.7	9703.8	1193.2	27.7	33.4	27.8	3.4	5.1	0.8	9.3	0.7
DMB-255	0.1176	15806.9	1924.0	9231.9	1123.7	26.9	33.3	88.3	6.1	7.6	0.9	6.3	0.8
DMB-256	0.1240	15899.8	2040.6	9657.7	1239.4	23.3	33.0	88.7	11.4	4.2	0.5	9.2	1.0
DMB-257	0.1187	17739.8	2179.4	10446.1	1283.3	23.4	33.4	38.2	14.4	17.3	2.1	8.1	1.0
DMB-258	0.1188	17739.8	2179.4	10446.1	1283.3	23.4	33.4	38.2	14.4	17.3	2.1	8.1	1.0
DMB-259	0.1290	15213.3	2043.8	9779.1	1313.0	25.6	33.6	168.5	9.3	8.1	0.9	12.1	1.6
DMB-260	0.1194	18197.3	2240.8	9974.0	1232.6	27.6	33.4	119.8	14.8	4.1	0.7	9.0	1.1
DMB-261	0.1209	16638.1	2088.2	9788.2	1224.6	26.7	33.3	55.8	6.7	7.9	1.0	7.7	1.0
DMB-262	0.1211	17314.1	2170.1	9733.5	1220.0	29.0	33.6	35.2	4.4	4.9	0.8	7.7	0.7
DMB-263	0.1190	16243.0	2068.1	10454.3	1250.2	26.4	33.3	33.1	3.3	1.1	0.8	7.7	0.7
DMB-264	0.1304	16254.4	2193.8	10388.1	1243.4	33.1	33.3	33.1	3.3	3.3	0.8	7.7	0.7
DMB-265	0.1274	15777.7	2080.4	9431.1	1243.6	33.1	4.4	34.4	4.3	4.3	0.8	7.7	1.0
DMB-266	0.1221	17066.2	2157.0	10761.9	1360.0	32.7	4.1	33.9	4.3	4.3	0.8	7.7	1.0
DMB-267	0.1140	17710.8	2089.7	9659.7	1139.8	26.0	33.1	83.1	7.4	4.8	0.8	7.7	1.0
DMB-268	0.1241	16935.1	2045.7	9580.7	1230.6	25.1	33.3	100.3	12.9	12.9	0.8	7.7	1.0
DMB-269	0.1234	16207.7	2070.0	10193.8	1301.5	23.9	33.3	78.0	10.1	10.1	0.8	7.7	1.0
DMB-270	0.1211	16143.5	2023.4	9655.3	1173.8	23.9	33.0	78.8	9.8	6.3	0.6	10.2	1.3
DMB-271	0.1223	15895.5	1992.8	9694.5	1125.9	23.9	33.3	25.9	3.3	10.3	1.0	6.4	0.8
DMB-272	0.1239	15440.0	1980.0	9219.3	1143.8	23.9	33.1	39.1	3.0	7.8	1.0	7.8	1.0
DMB-273	0.1200	17315.6	2150.6	10261.0	1274.4	31.8	33.8	188.9	8.8	1.1	0.8	6.0	1.0
DMB-274	0.1225	16930.9	1893.0	9385.2	1188.8	23.9	33.8	188.9	8.8	1.1	0.8	6.0	1.0
DMB-275	0.1232	16030.8	2044.1	9437.7	1203.4	28.1	33.6	15.5	3.0	8.8	1.1	9.7	1.2
DMB-276	0.1312	14267.3	1937.4	9136.2	1240.6	28.0	33.8	4.9	1.2	8.4	0.7	10.0	1.4
DMB-277	0.1250	15635.8	2022.9	9726.3	1123.0	26.1	33.4	41.2	5.3	8.2	0.8	7.0	0.9
DMB-278	0.1254	14692.1	1906.9	9604.8	1246.6	26.0	33.6	27.9	5.3	8.2	0.8	7.0	0.9
DMB-279	0.1195	17068.6	2111.1	9947.9	1280.4	31.0	33.8	82.8	8.2	7.8	1.0	8.8	1.0

SAMPLE NO.	DRY/WET	K	CA	ZN	BR	RS	SR
	RATIO	MICROG/G	MG/L	MICROG/G	MG/L	MICROG/G	MG/L
DMB-280	0.1284	15292.0	2032.2	8511.2	1131.1	26.5	3.5
DMB-281	0.1275	14713.2	1941.6	8983.7	1185.5	27.2	3.6
DMB-282	0.1232	17007.8	2168.7	9797.4	1249.3	25.1	3.2
DMB-283	0.1242	15462.9	1987.7	9643.2	1239.6	29.0	3.7
DMB-284	0.1322	15083.8	2063.9	8954.0	1225.1	28.5	3.8
DMB-285	0.1220	16777.8	2118.5	9387.2	1182.8	27.8	3.5
DMB-287	0.1310	14225.7	1928.8	9553.4	1296.7	27.8	3.7
DMB-289	0.1088	16558.2	1864.6	10134.7	1141.2	27.0	3.0
DMB-292	0.1442	12484.9	1863.3	7879.5	1176.0	21.2	3.2
DMB-293	0.1373	14031.7	1994.0	8577.3	1080.6	34.3	4.4
DMB-294	0.1218	16121.2	2032.3	9400.7	1185.1	28.2	3.6
DMB-295	0.1083	20349.6	2281.0	11793.3	1321.9	60.1	6.7
DMB-296	0.1324	14467.8	1982.6	8787.6	1204.2	22.6	3.1
DMB-297	0.1185	16128.9	1978.2	9297.0	1140.2	31.7	3.9
DMB-298	0.1218	16693.8	2104.5	9536.5	1202.2	29.2	3.7
DMB-299	0.1212	15765.5	1977.8	9551.5	1198.2	26.0	3.3
DMB-300	0.1261	16038.9	2093.3	9630.4	1284.5	20.6	3.2
DMB-301	0.1174	17839.6	2167.7	9988.7	1261.6	27.0	3.3
DMB-302	0.1015	21518.4	2260.6	12183.5	1279.9	32.1	3.4
DMB-303	0.1155	18358.9	2194.7	10595.1	1278.6	32.5	3.9
DMB-304	0.1698	16473.3	2895.1	10784.3	1395.3	31.4	3.5
DMB-305	0.1234	16545.8	2113.2	9619.8	1228.6	33.2	4.2
DMB-306	0.1303	16021.2	2160.6	9398.1	1267.4	34.6	4.7
DMB-307	0.1210	18189.8	2278.0	10814.6	1254.4	31.1	3.9
DMB-308	0.1183	19194.3	2350.2	10982.1	1234.5	29.4	3.6
DMB-309	0.1225	16922.4	2145.5	10054.1	1274.7	30.3	3.8
DMB-310	0.1008	24231.0	2528.6	13245.8	1381.9	30.2	3.1
DMB-311	0.1233	16710.8	2132.9	10167.1	1297.5	30.9	3.9

NO. OF SAMPLES 178
MEAN
STD DEV

16547.9	2087.4	9897.8	1249.9	29.1	3.7	45.0	5.7	6.5	0.8	8.8	1.1
1786.3	190.5	973.1	117.0	4.4	0.6	23.7	2.9	2.5	0.3	2.8	0.3