Geological Survey of Israel
Ministry of National infrastructures
Energy and Water Resources

Israeli Fly Ash Data Implementation into LeachXS

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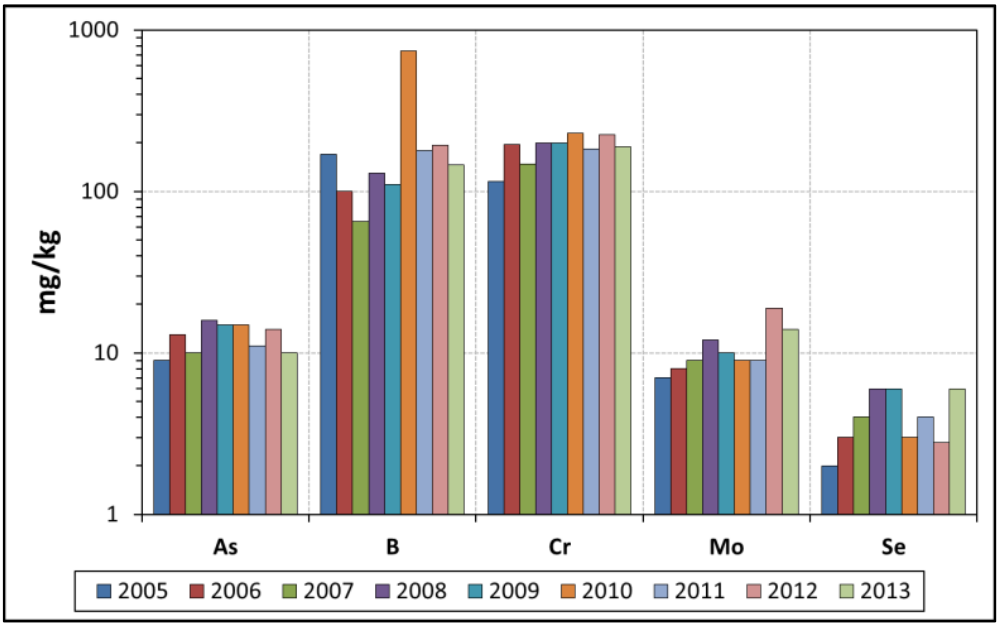

GSI/19/2016

Jerusalem, June 2017

30 Malkhe Israel St. Jerusalem 9550161, Israel

Front Cover: Total content of five constitutes of interest (As, B, Cr, Mo, Se) of the South African 'BB Prime' fly ash, measured annually from 2005 through 2013.

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[1]**Geological Survey of Israel**
Jerusalem, Israel

[2]**Vanderbilt University**
Nashville, Tennessee, United States

[3]**Energy Research Centre of The Netherlands**
Petten, The Netherlands

[4]**Hans van der Sloot Consultancy**
Langedijk, The Netherlands NL

GSI/19/2016

Jerusalem, June 2017

Abstract

Fly ash (FA), a by-product of coal based electricity generation, is fully utilized in Israel almost exclusively as an additive in production of cement and concrete. Characterization of the FA and its application products is an important tool for evaluating the environmental aspects of FA usage. The National Coal Ash Board (NCAB) chemical characterization of coal fly ash conducted in the Geological survey of Israel (GSI) routinely includes total content along with the two leaching tests: Toxicity Characteristic Leaching Procedure (TCLP, EPA Method 1311) and Leaching of Granular Waste Materials and Sludges (EN 12457-2). Until now, characterization results have been accumulated in Microsoft Excel workbooks, which make data analysis and comparisons cumbersome. Development and validation of the Leaching Environmental Assessment Framework (LEAF) in the United States and Europe have resulted in the standardization of a suite of United States Environmental Protection Agency (USEPA) leaching tests and implementation of LeachXS software as a common data management, analysis and scenario simulation platform. Several NCAB coal fly ash samples also have been characterized using the LEAF pH dependence leaching test (USEPA or European equivalents). The objectives of this research were to: (i) increase familiarity and efficiency in use of LEAF test methods along with use of LeachXS as a data management and evaluation tool, and (ii) develop a LeachXS database of all results from testing of Israeli coal ash samples and ash derived products since 2004, along with comparative information from other sources. The current report focuses on the production of an Israeli LeachXS database for all fly ash data from the years 2004-2013. Typical forms of data analysis and presentation that are now available using LeachXS are also illustrated in this report.

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1. Introduction and Objectives

The use of coal ash in Israel in general and fly ash (FA) in particular spans various application fields including infrastructure, construction and agriculture. The extent to which FA can be used depends on the criteria for "usable ash" from the perspective of environmental safety, which is a function of intrinsic properties of the ash, the scenario in which the ash is to be used, and the regulatory decision basis for determining an “acceptable use”. In the various applications in which FAs are utilized, the FA is exposed to other substances that could influence its characteristics, such as cement in concrete mix or soils and other materials in agricultural and infrastructure applications. Therefore, FA characterization is an important tool in evaluating the environmental aspects of FA usage. Over the years, the Geological Survey of Israel (GSI) has characterized coal and FA supplied by the National Coal Ash Board (NCAB) representing the main sources utilized for electricity production in Israel. The GSI characterization focuses on chemical characteristics including major and trace elements composition of the coal and FA and leaching properties of the FA. These include the USEPA TCLP procedure (Toxicity Characteristic Leaching Procedure; USEPA SW-846 Method 1311), which is the regulating procedure required by the Ministry of Environmental Protection and the European EN protocol (Compliance test for leaching of granular waste materials and sludge; EN 12457-2) requested by the NCAB. In addition, the GSI has recently carried out a research on cement mixtures containing FA. Data of all analysis have been stored in Microsoft Excel® (hereafter Excel) in which data comparisons for answering specific questions is cumbersome.

Over 20 years of collaboration between United States and European research teams in the field of leaching, environmental assessment, and test standardization resulted in the joint scheme “Leaching Environmental Assessment Framework” (LEAF). The framework includes a collection of four leaching tests (Garrabrants et al., 2012a; 2012b) with the dedicated software LeachXS as a data management and evaluation tool. The program LeachXS Lite™ is used for database management, enabling comparisons of leaching data for different tests or materials, including outputting data to Excel. LeachXS Lite is available for free licensing and is based on the LeachXS™ platform. The full-featured software in LeachXS Pro allows for advanced modeling and data management capabilities beyond the features included in LeachXS Lite and is licensed for an annual fee.

As a first step for incorporating the LEAF framework into Israeli FA research and customary characterization, previous data should be implemented into LeachXS database. This stage is an initial step of an overall research goal to provide a risk-informed environmental safety assessment framework based on LEAF for evaluation of beneficial use of coal FA that is tailored to Israeli needs. The resulting data and methodologies can then be used by regulators to establish specific FA use criteria.

The specific research objectives are:

(i) Increase familiarity and efficiency in use of EPA Leaching Environmental Assessment Framework (LEAF) test methods along with use of LeachXS as a data management and evaluation tool.

(ii) Develop a LeachXS database of all results from testing of Israeli coal ash samples and ash derived products, along with comparative information from other sources.

The current report focuses on the construction of an Israeli LeachXS dataset for all FA data from the years 2004-2013 (NCAB 2016a, 2016b; Teutsch and Berlin 2013, 2015a, 2015b, van der Sloot, 2009 and NCAB unpublished FA total content data).

2. Methodology

Data implemented in LeachXS included:

- Total content of major and trace elements from 2004-2013
- pH dependence (pH 2-13) of four current FAs (GSI) and two previous FAs (Energy research Centre of the Netherlands, ECN)
- TCLP (2004-2013) – acidic leaching (low pH); trace element concentrations
- EN 12457-2 (2008-2013) natural leaching (high pH); trace element concentrations
- Monolith leaching of cementitiuos mixtures containing FA - CLSM and grout; trace element concentrations

The Israeli FA data stored in Excel worksheets had to be converted into specific Excel templates (Fig. 2.1) in order to be converted to an XML file that can be used by LeachXS to enter a database. As most Israeli FA data could not fit in the regular LeachXS templates, specific templates had to be used, some of them specially adapted by the LeachXS development team for the Israeli data. The template files were uploaded to LeachXS to produce and XML file, which is then entered into a database. This conversion procedure from Template to XML demanded exactness in the template data files, which were of different form for each of the data types. After much trial and error, the templates were successfully converted into XML files. A library of XML files was also developed to allow selective use of data in future databases for specific purposes (e.g., FA used in concrete and resulting concrete leaching properties). The data input templates are also saved for archival purposes.

In each template (example in Fig. 2.1), details of the FA (name, type, date of analysis etc.) are followed by the concentrations (mg/kg) of the analytes in the solid phase for total content analyses, and the concentrations (mg/L) in the laboratory extracts for leaching test results. For each analyte the mode of analysis (ICP-OES/ ICPMS/other), analytical detection limit and quantification limit are inserted above the results. These limits are necessary for the presentation of data in LeachXS and can not be presented in the form of < value. Hence, all < values which were the form used in previous years, had to be converted into numeric low values.

The implementation procedure was in the general form:

Excel data → Excel Template → XML file → LeachXS Database

Datasets produced during the implementation contain all the above-mentioned Israeli FA data.

The LeachXS enables various ways of presentation and comparisons between different materials, years and methods. These will be presented in the following data presentation sections.

TOTAL CONTENT INPUT (Historic Data)

Template Version 1.0

↓indicates a drop down menu with data validation.

Detection and Quantification Limits

	Al	Sb	As	Ba	Be	B	Cd
/kg)	950	0.7	0.3	1	0.05	5	0.1
ML (mg/kg)	2800	2.0	1.0	3	0.15	15	0.3
Analytical Method ↓	P-AES/ICP-O	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS

Analytical Lab Name

Material Name	Total Content Method	Test Replicat	Test Date	Material Class ↓	Material Subclass ↓	Composition Aluminum Al mg/kg	Antimony Sb mg/kg	Arsenic As mg/kg	Barium Ba mg/kg	Beryllium Be mg/kg	Boron B mg/kg	Cadmium Cd mg/kg
Billiton- BB Prime - 2012	other	A	09/09/2012	Coal Combustion	Fly Ash	159558	3	14	1533	13.0	194	0.8
Drummond- La Loma LS - 2012	other	A	09/09/2012	Coal Combustion	Fly Ash	113787	20	36	2277	8.0	318	1.3
CMC- CerD - 2012	other	A	09/09/2012	Coal Combustion	Fly Ash	105848	9	38	1193	6.0	188	1.9
Billiton- DMO - 2012	other	A	09/09/2012	Coal Combustion	Fly Ash	152421	2	15	1741	14.0	193	0.7
Glencore- Cal - 2012	other	A	09/09/2012	Coal Combustion	Fly Ash	106907	12	36	1381	7.0	114	2.1
Drummond- La Loma MS - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	103731	12	67	2209	5.5	155	2.7
Suek- SKH - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	119608	4	28	1748	6.2	274	0.7
Drummond- La Loma - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	112728	11	79	2174	6.2	163	2.6
MIM- Newlands - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	157714	2	6	511	4.4	40	0.3
Kpc- Melawan - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	95793	11	66	1754	5.4	471	2.5
Xstrata- GGV - 2012	other	A	06/03/2013	Coal Combustion	Fly Ash	137073	6	30	2037	11	184	1.2

Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	P	K	Se	Si	Ag	Na	S	Tl	Th	Ti	U	V	Zn	ash content	LOI	TOC
1400	2	1	1	300	0	800	70	0.05	1	1	2300	600	2	2000	1	700	2500	0.03	1	200	0.03	1	1	300	100	0.05
4000	6	3	3	1000	1	2500	200	0.15	3	3	7000	2000	6	6000	3	2000	7500	0.10	3	600	0.10	3	3	1000	300	0.15
P-AES/ICP-O	ICP-MS	ICP-MS	ICP-MS	P-AES/ICP-O	ICP-MS	P-AES/ICP-O	ICP-MS	other	ICP-MS	ICP-MS	P-AES/ICP-O	P-AES/ICP-O	ICP-MS	P-AES/ICP-O	P-AES/ICP-O	P-AES/ICP-O	P-AES/ICP-O	ICP-MS	ICP-MS	P-AES/ICP-O	ICP-MS	ICP-MS	P-AES/ICP-O	other	other	other

Calcium Ca mg/kg	Chromium Cr mg/kg	Cobalt Co mg/kg	Copper Cu mg/kg	Iron Fe mg/kg	Lead Pb mg/kg	Magnesium Mg mg/kg	Manganese Mn mg/kg	Mercury Hg mg/kg	Molybdenum Mo mg/kg	Nickel Ni mg/kg	Phophorus P mg/kg	Potassium K mg/kg	Selenium Se mg/kg	Silicon Si mg/kg	Silver Ag mg/kg	Sodium Na mg/kg	Sulfur S mg/kg	Thallium Tl mg/kg	Thorium Th mg/kg	Titanium Ti mg/kg	Uranium U mg/kg	Vanadium V mg/kg	Zinc Zn mg/kg	ash content ash content mg/kg	LOI LOI mg/kg	Total C TOC mg/kg
57286	226	47	88	18537	102	8489	486	0.13	19	105	6594	3983	2.8	218854	2.3	809	3297		189	9963	20	225	139	140000	53000	46000
22156	121	76	86	37770	38	9046	364	0.11	24	183	873	12452	21	275804	3.8	14095	2803		52	6175	8	302	165	78700	26000	16000
16438	144	30	72	48262	37	9046	476	0.14	24	90	1746	14943	20	280479	0.5	5935	1602		74	5935	9	290	181	102700	30000	25000
41452	240	72	87	22382	80	9649	436	0.08	12	113	4364	4151	3.9	234667	2.7	742	2002		169	9352	17	266	128	153200	43000	36000
20011	116	35	74	42666	34	7237	336	0.14	24	79	1746	13282	26	286556	0.9	5193	2002		69	6115	7	246	142	95100	32000	26000
22156	100	24	68	54557	29	9046	356	0.11	33	72	1746	13282	36	286088	2.1	10386	2803		17	5995	6	233	175	55800	18000	8000
39308	126	34	63	32175	47	11458	425	0.06	15	78	3491	14113	5	255703	5.5	5935	2803		34	6594	9	162	163	131200	52000	38000
22156	124	40	81	53857	35	7840	405	0.12	36	100	1746	12452	35	272532	6.3	6677	2002		24	6594	7	287	196	51500	25000	17000
28588	99	33	121	26579	49	4221	261	0.05	7	74	5237	6641	5	239342	1	3709	1201		24	8393	7	203	104	144600	20000	46000
27873	104	34	65	79737	30	15077	611	0.07	28	86	873	14113	31	270194	5.6	6677	801		17	4796	5	256	196	47000	54000	7000
58605	206	42	74	25180	53	9649	451	0.1	16	97	7855	7471	15	231862	1	2967	2803		58	9592	15	294	142	154500	43000	37000

Figure 2.1. An example of a total content (2012) template developed especially for Israeli data. The template includes details of the FA analyzed followed by the major and trace element concentrations (mg/kg) in alphabetical order (the lower part is presented in a smaller scale). Ash content, LOI and TOC have been also implemented (last data entries).

3. Data Presentation

3.1. Total Content

As for other entries in LeachXS, total content of a FA can be presented with all the measured constituents of a specific FA such that the entire composition of the FA, including major and trace elements, can be viewed in one figure. All total content data are presented in mg/kg units. Figure 3.1 is a bar chart representing the total content of all constituents (n=34) of the FA Drummond - La Loma analyzed in 2013.

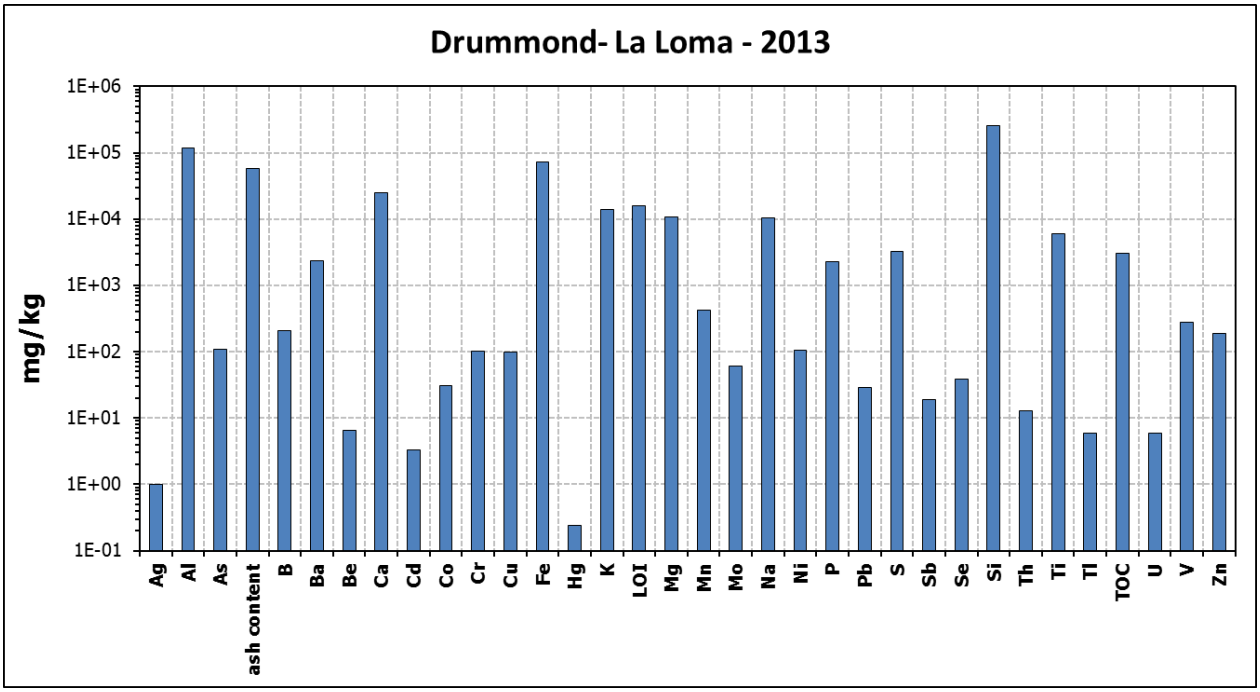


Figure 3.1. An example of a bar chart representing the total content of all constituents (mg/kg) of the FA Drummond- La Loma analyzed in 2013. Note that the concentrations are presented in logarithmic scale. Ash content refers to the content of FA in the coal and TOC is total organic carbon.

Another way of presenting data is by comparison of selected constitutes for several FAs or for a specific FA analyzed several times. Figure 3.2 is an overall bar chart presenting five trace elements of interest (As, B, Cr, Mo, Se) of the FA BB Prime measured annually from 2005 through 2013.

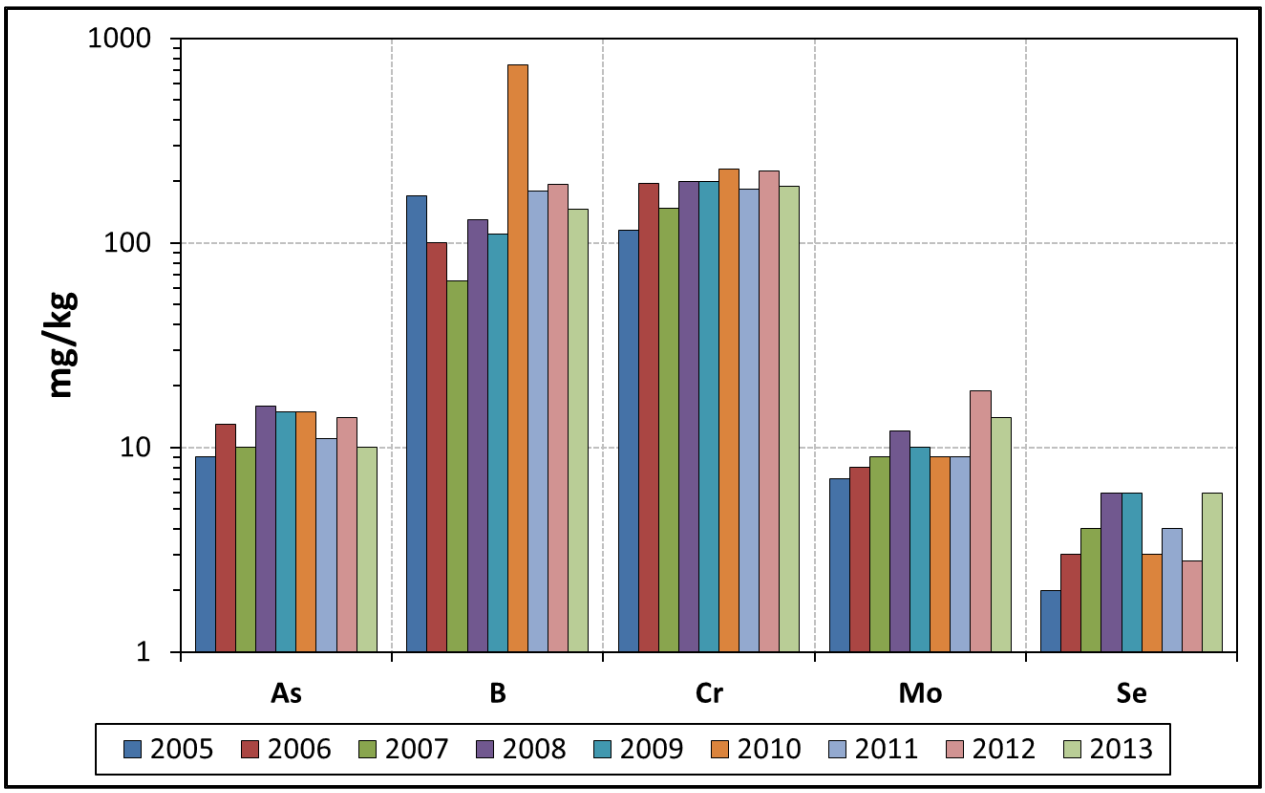


Figure 3.2. Constitutes of interest of BB Prime (2005-2013) total content in an overall bar chart.

LeachXS enables also comparison of a wide number of data values such that the entire range of certain constitutes could be observed. Figure 3.3 presents four FA characteristics in the percentage range, Ash content, Ca and S concentrations, and total organic carbon (TOC) content of all 86 FA that have been examined during 2004-2013.

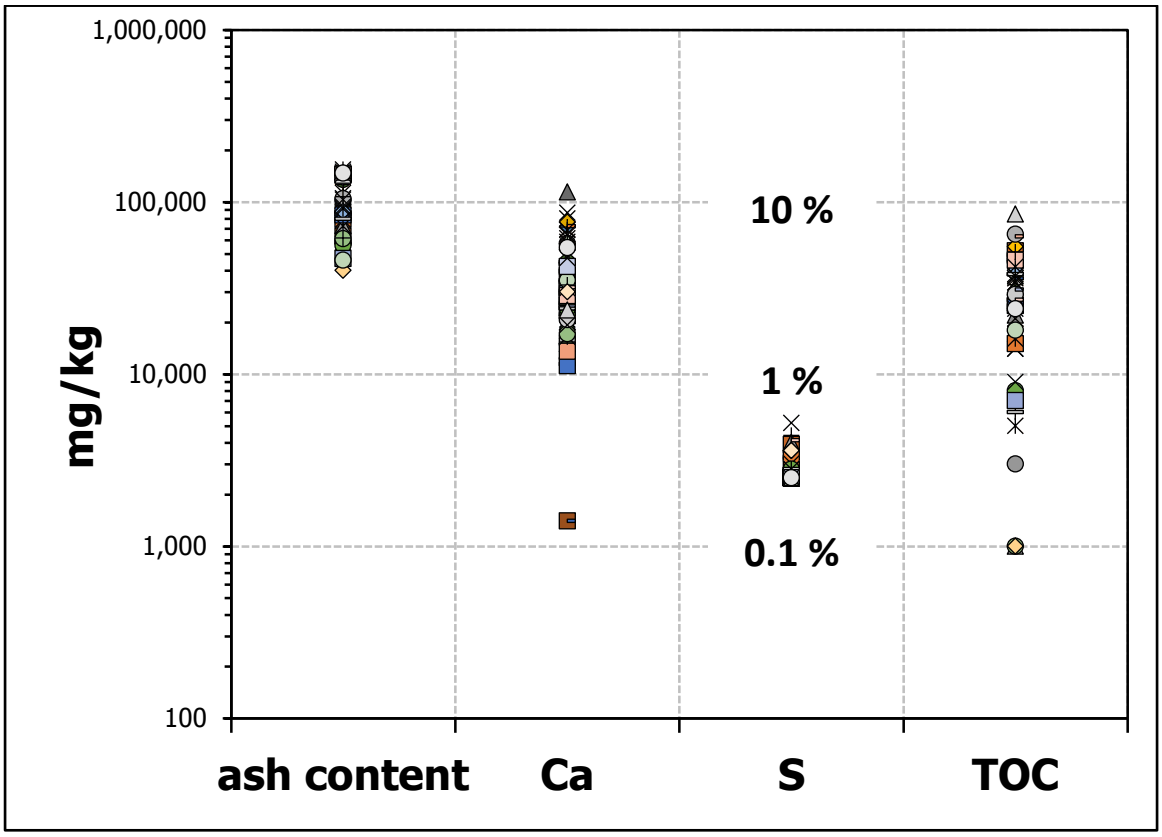


Figure 3.3. Ash content, Ca and S concentrations, and total organic carbon (TOC) content of all 86 FA examined for their total content during 2004-2013. For convenience, the relevant mg/kg values are also shown as percentage values.

3.2. TCLP and EN Leaching Procedures

As TCLP is enforced for FA regulation by the Ministry of Environmental Protection, it is useful to examine the data in light of regulation criteria. In the case of TCLP, two regulation levels (mg/L) are available: the EPA toxicity level (EPA, 2004) and useable FA (NCAB, 2016a). Figure 3.4 presents all Cr TCLP values for the years 2008-2013 (n=85). Similar data presentation can be readily developed for other constituents using LeachXS. The TCLP data of another eight microelements that have high significant meaning in health, environmental and agricultural aspects are presented in Appendix A. These include As, B, Cd, Mo, Sb, Se, Pb, and U.

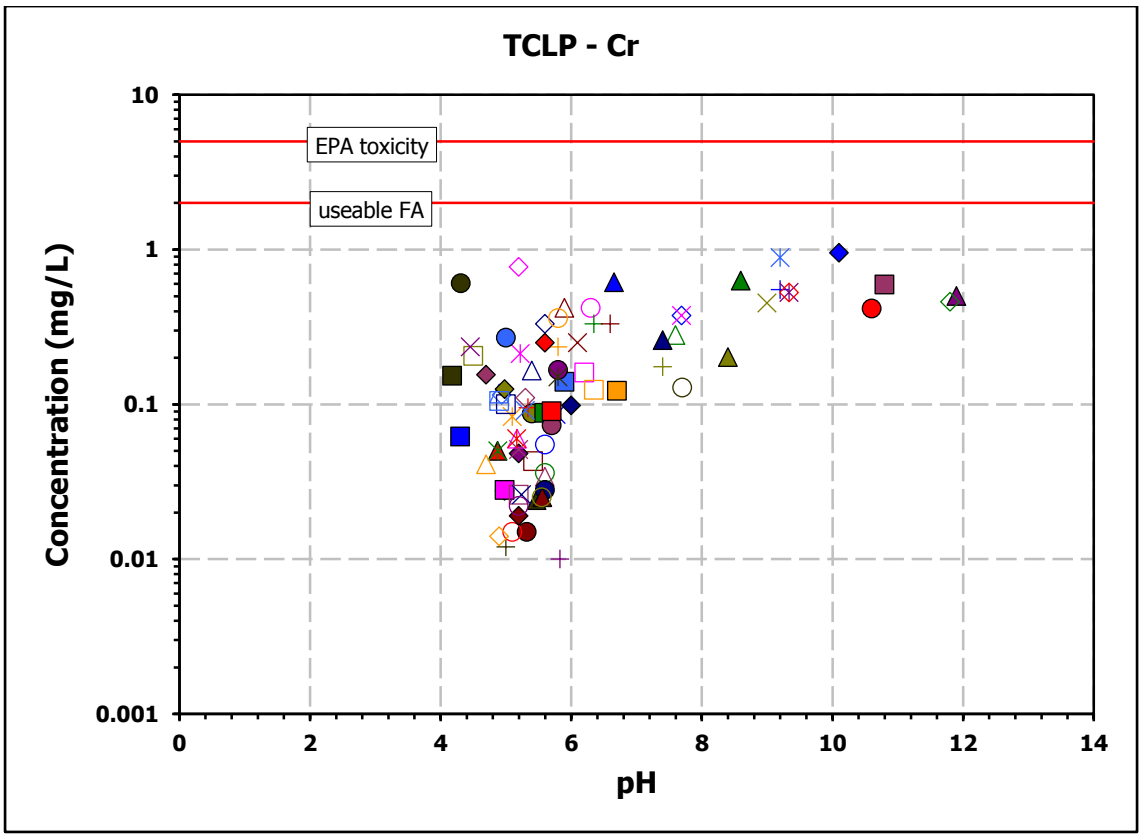


Figure 3.4. Chromium TCLP leach concentrations (mg/L) of FA examined during 2004-2013 (n=85). The two types of criteria levels EPA toxicity level and useable FA applicable for TCLP analysis are plotted. In this example, all Cr values are below both criteria levels. Legend in Appendix A.

The EN data can be presented in a similar way to TCLP. However, the criteria for EN is the amount released (mg/kg) during the leaching process (in solid to liquid ratio of 1:10) rather than the solution concentrations (mg/L). The relevant criteria values are EN-inert and EN-non hazardous (European Council, 2003; NCAB 2016b). Figure 3.5 presents all Mo EN values for the years 2008-2013 (n=85). Similar data presentation can be readily developed for other constituents using LeachXS. The EN data of another eight microelements that have high significant meaning in health, environmental and agricultural aspects are presented in Appendix B. These include As, B, Cd, Cr, Sb, Se, Pb, and U.

For interpretation of leaching data with respect to specific use scenarios, it is important to recognize that the applicable pH range depends on the use scenario being evaluated.

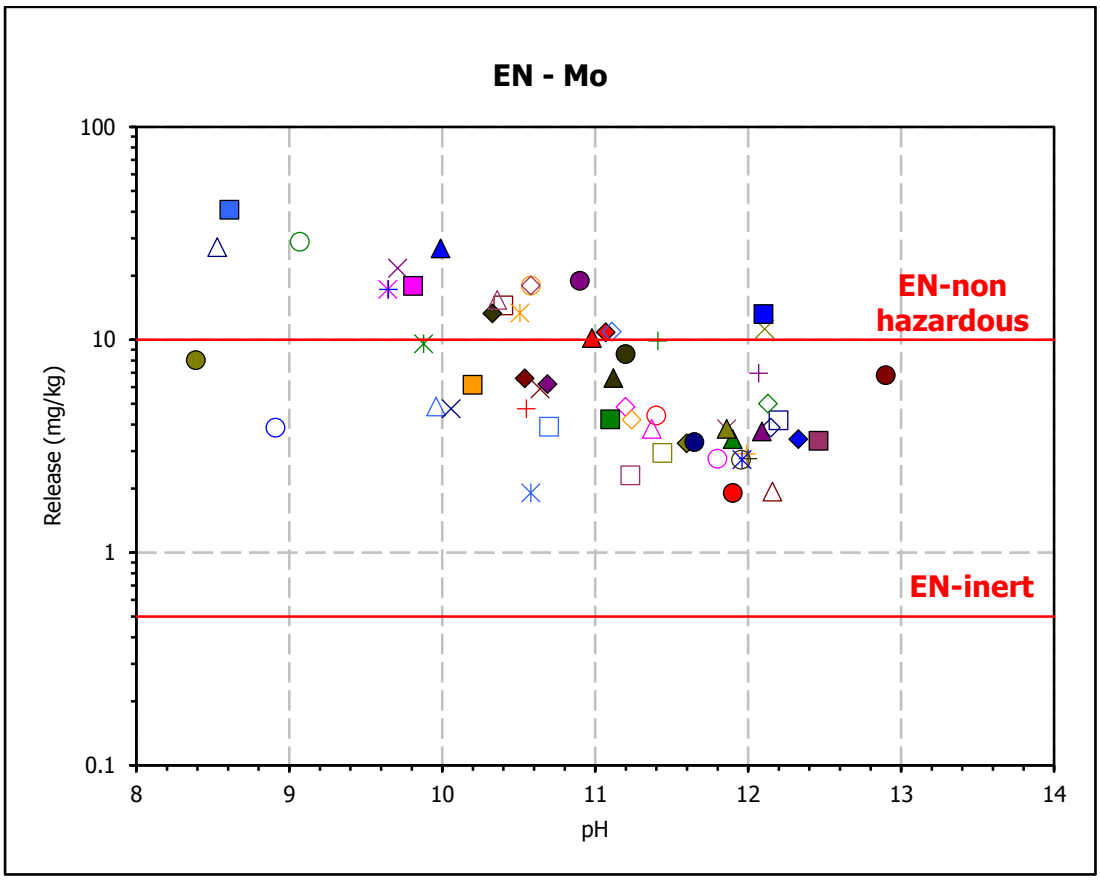


Figure 3.5. Molybdenum concentrations (mg/kg) released during EN procedure of FA examined during 2008-2013 (n=63). The two EN criteria levels, non hazardous and inert are plotted. In this example, all Mo values are above the EN inert criteria and a substantial number of FA are above the non hazardous criteria level.

3.3. CLSM and Grout

The results of the monolithic tank test (EA NEN 7375:2004) of both cementitiuos mixtures of CLSM and Grout containing FA (Teutsch and Berlin, 2013; 2015a) were also implemented into LeachXS. These tests were performed on mixtures with high ash contents of the Columbian FA CMC-CerD. This FA is characterized by a high concentration of constituents of potential concern (COPCs) and with a low pozzolanic activity (expected to release the highest COPCs concentration). An example of the various types of charts produced by the LeachXS software are presented in figure 3.6 for Se leaching out of CLSM composition of monolith for cubes of compositions with and without FA cured for various length of times (7, 28, and 90 days).

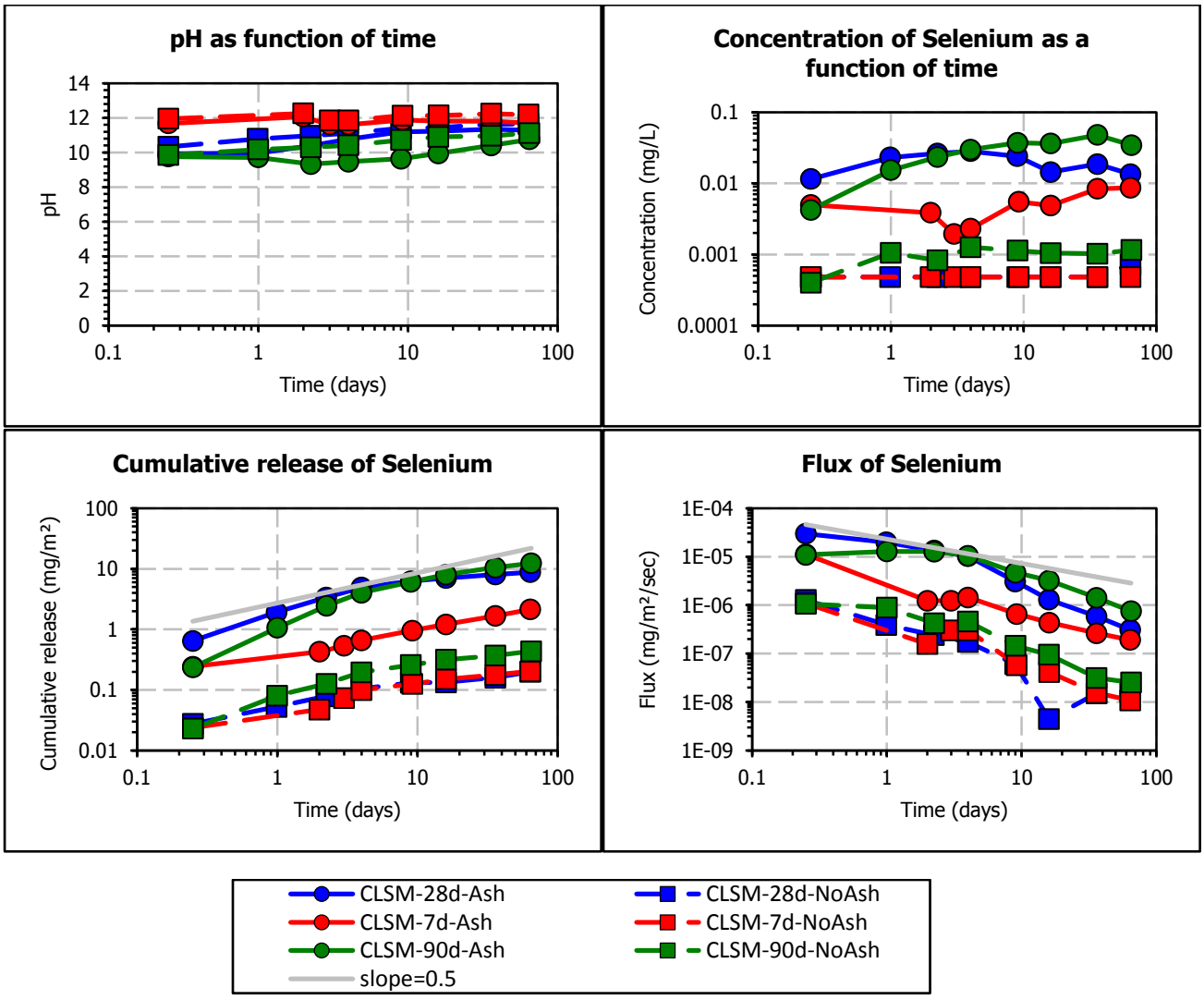


Figure 3.6. Comparison of Se released during the monolithic leaching test for three periods of curing times (7, 28 and 90 days) for the cementitiuos material CLSM of compositions with and without FA. These are presented in the four different types of charts produced by the LeachXS software for monolithic tests.

3.4. Data Comparisons

As all data is incorporated in the LeachXS dataset, various data comparisons are available. Alongside data implementation into LeachXS, pH dependent data has been collected and evaluated using the LEAF approach (Teutsch and Berlin, 2015b). Figure 3.7 presents a comparison of TCLP and EN data (both in mg/L) compared to pH dependent concentrations of two FAs, BB-prime and Newlands. It can be seen that the values of the one point leachates (TCLP and EN) fit to the overall trend of the pH dependent results.

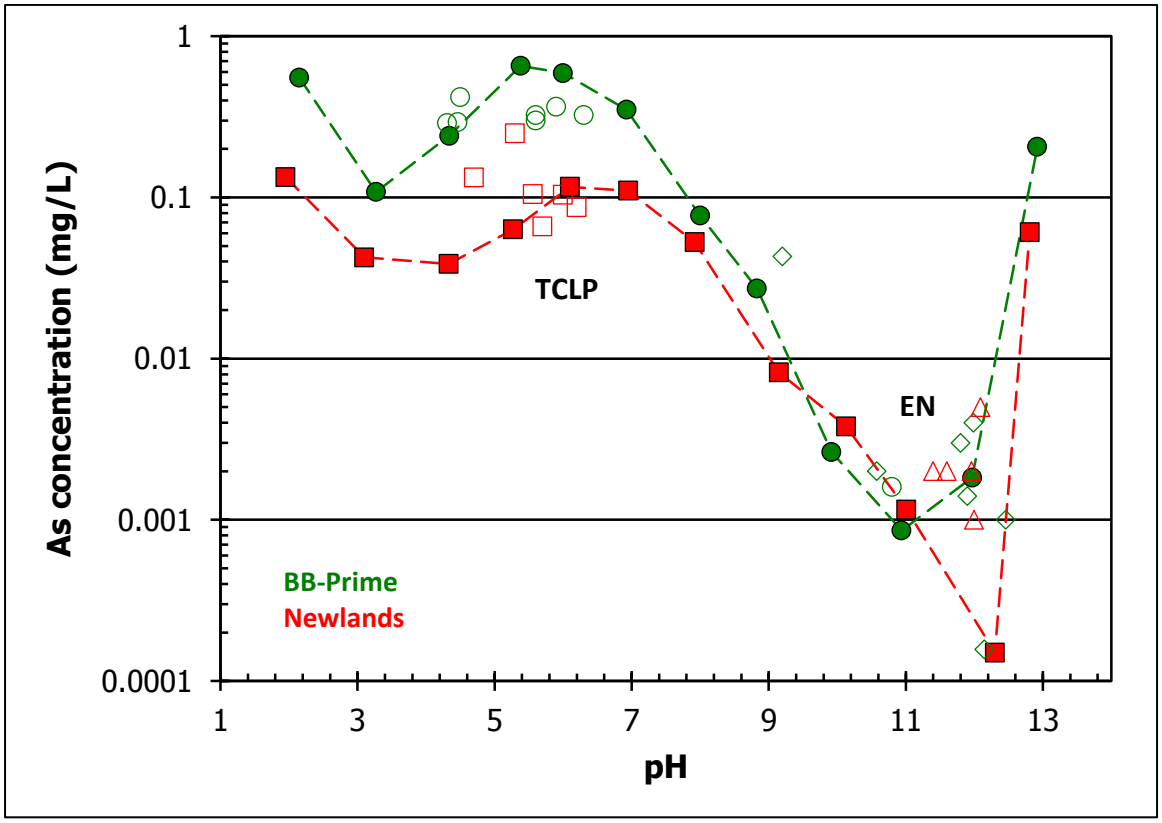


Figure 3.7. Arsenic pH dependent concentrations (mg/L) of BB Prime (full green circles) and Newlands (full red squares) with EN (green diamonds and red triangles) and TCLP (empty green circles and empty red squares).

4. Summary and Recommendations

All fly ash data from 2004 to 2013, including total content, TCLP and EN leachate concentrations, and CLSM and grout monolithic leaching concentrations, were implemented into LeachXS databases. The resulting database in conjunction with the LeachXS Pro software allows for evaluating and displaying the Israeli coal fly ash composition and leaching data in multiple ways. Thus, readily facilitating comparisons to regulatory criteria, addressing specific questions (e.g., what is the impact of the coal source on the fly ash leaching?), as well as discerning temporal trends. It is recommended that the LeachXS database be maintained up-to-date with coal fly ash content and leaching data as part of routine characterization. Furthermore, periodic reports should be produced that present the trends in coal fly ash data important to decision making.

5. References

EPA (2004). Local Limits Development Guidance Appendices. *EPA 833-R-04-002B* U.S. EPA, Office of Wastewater Management: Washington, DC.

European Council (2003). Establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31. *Official Journal of the European Communities 2003/33/EC*.

Garrabrants, A.C., Kosson, D.S., Stefanski, L., DeLapp, R., Seignette, P.F.A.B., Van der Sloot, H.A., Kariher, P., and Baldwin, M. (2012a). Interlaboratory validation of the leaching environmental assessment framework (LEAF) method 1313 and method 1316. *EPA-600/R-12/623*, September 2012.

Garrabrants, A.C., Kosson, D.S., DeLapp, R., Kariher, P., Seignette, P.F.A.B., Van der Sloot, H.A., Stefanski, L., and Baldwin, M. (2012b). Interlaboratory validation of the leaching environmental assessment framework (LEAF) method 1314 and method 1315. *EPA-600/R-12/624*, September 2012.

NCAB (2016a). Trace elements concentrations in fly ash TCLP leachates and Israeli useable and US-EPA toxicity criteria http://www.coal-ash.co.il/wordpress/?page_id=2624.

NCAB (2016b). Trace elements concentrations in fly ash EN 12457-2 leachates and EN waste criteria http://www.coal-ash.co.il/wordpress/?page_id=2483.

Teutsch and Berlin (2013). Examination of the potential release of trace metals from cement Mixtures containing fly ash – CLSM. *Israel Geological Survey Report TR-GSI/01/2013* (in Hebrew).

Teutsch and Berlin (2015a). Examination of the potential release of trace metals from cement Mixtures containing fly ash – grout. *Israel Geological Survey Report TR-GSI/02/2015* (in Hebrew).

Teutsch and Berlin (2015b). The effect of pH on leaching of trace elements from fly ash. *Israel Geological Survey Report TR-GSI/05/2015* (in Hebrew).

Van der Sloot, H.A. (2009). Impact evaluation of coal fly ash in beneficial uses. *NCAB report*.

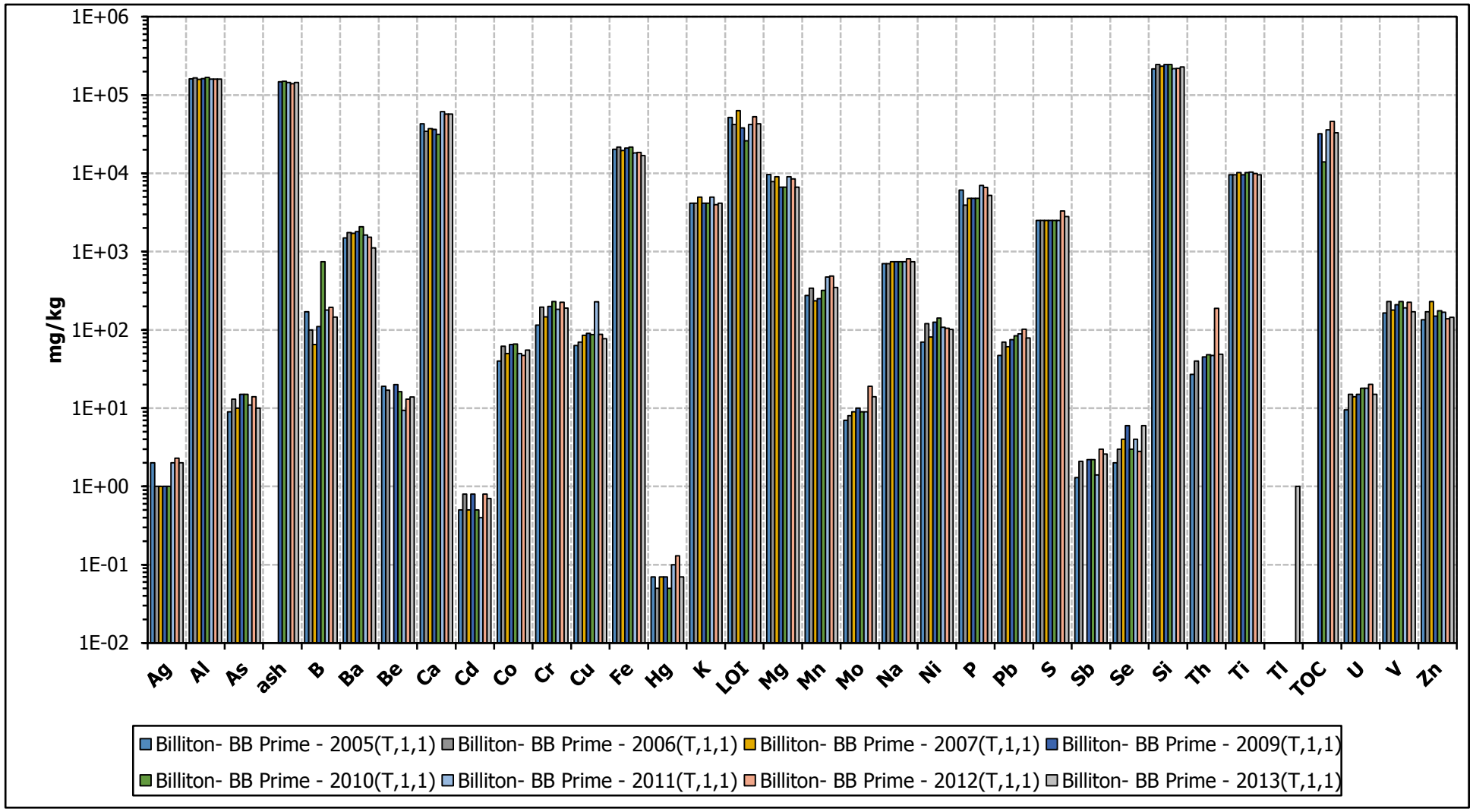
6. CD with files

a. LXS databases ('GSI EN&TCLP&TC 2004-2014' and 'GSI CLSM&GROUT 2012_1315') including all data entries.
b. Excel output spreadsheets – files produced to create all figures (including appendices).
c. Folders with Input Templates (excel files) and XMLs of all data (TC, TCLP, EN, grout & CLSM).

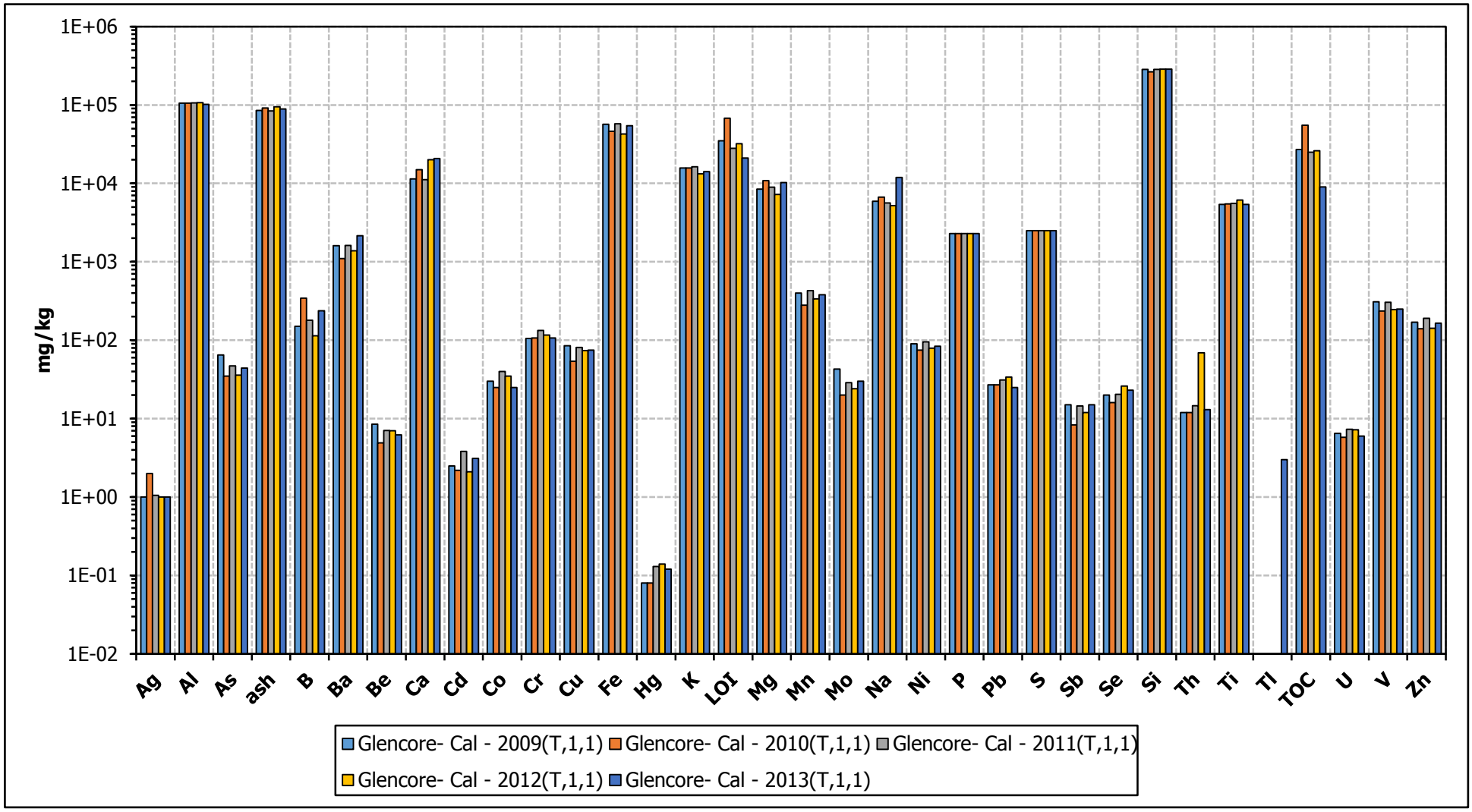
7. Appendices

A. Total Content figures of all constituents of five main FA sources:
    i. Billiton BB Prime
    ii. Glencore Cal
    iii. Drummond La Loma
    iv. Drummond La Loma LS
    v. MIM Newlands.
B. TCLP figures of all data for constituents of interest (except Cr presented in figure 3.4).
C. EN figures of all data for constituents of interest (except Mo presented in figure 3.5).

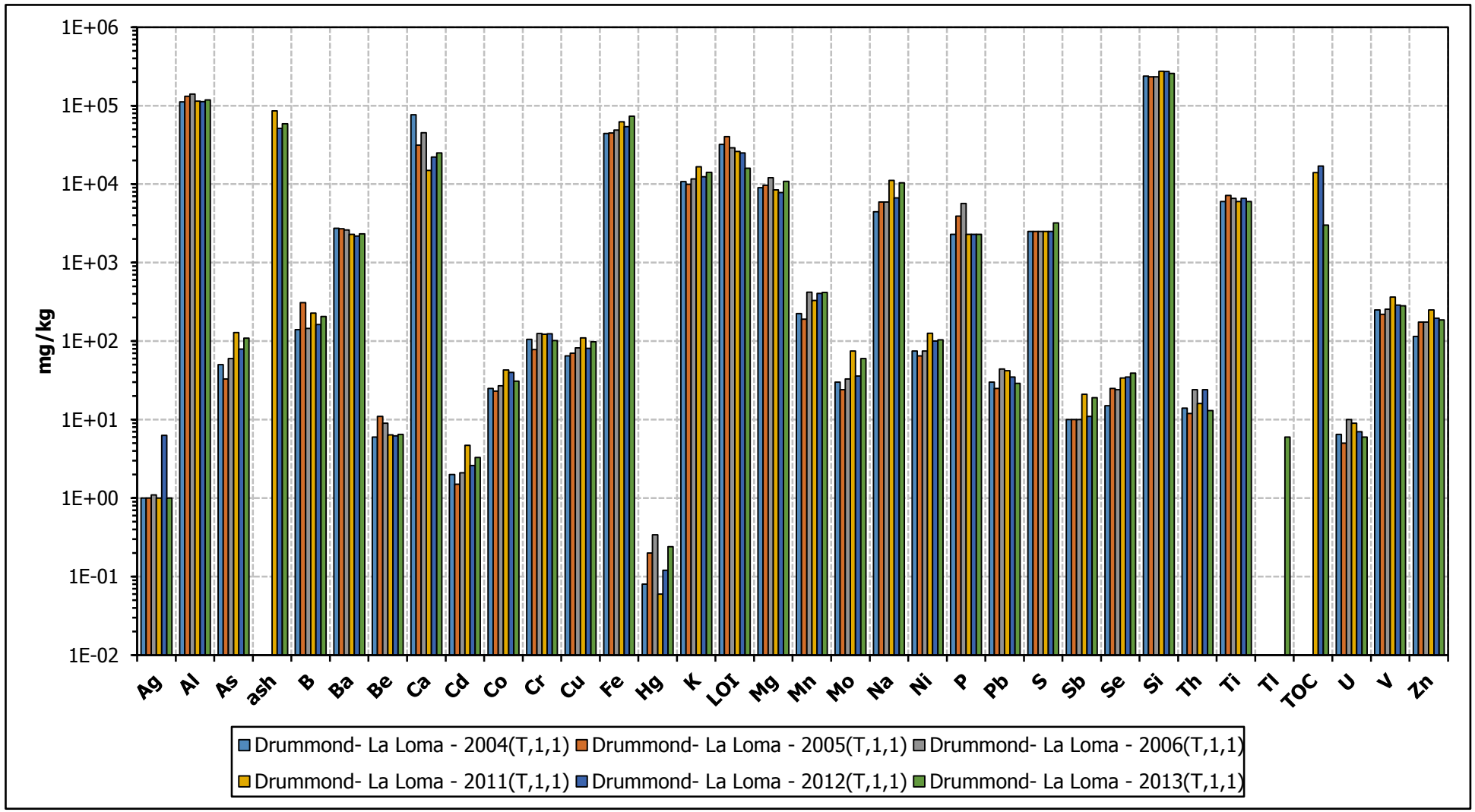
Appendix A–i: Total Content (TC) figure of Billiton BB Prime



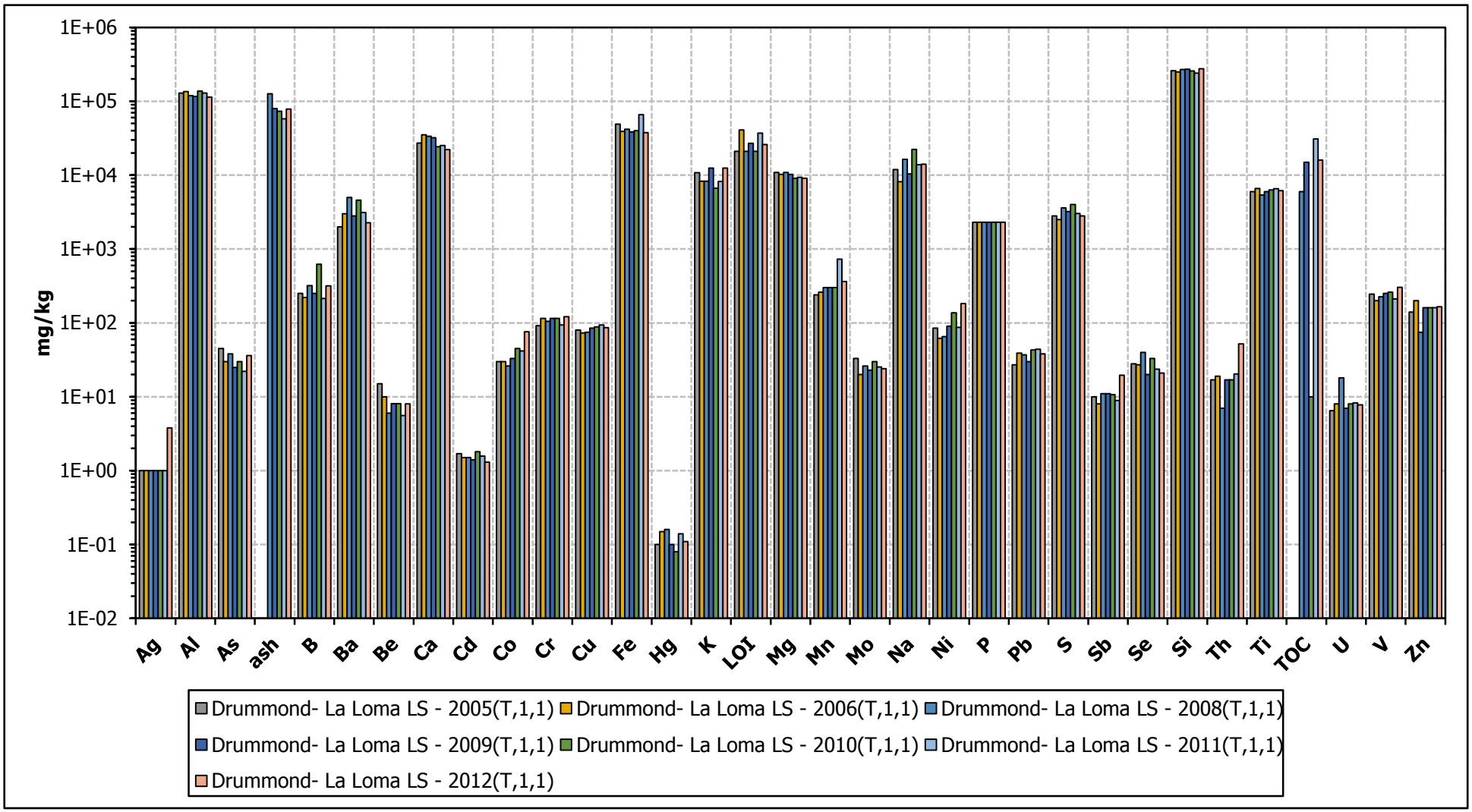
Appendix A–ii: Total Content (TC) figure Glencore Cal



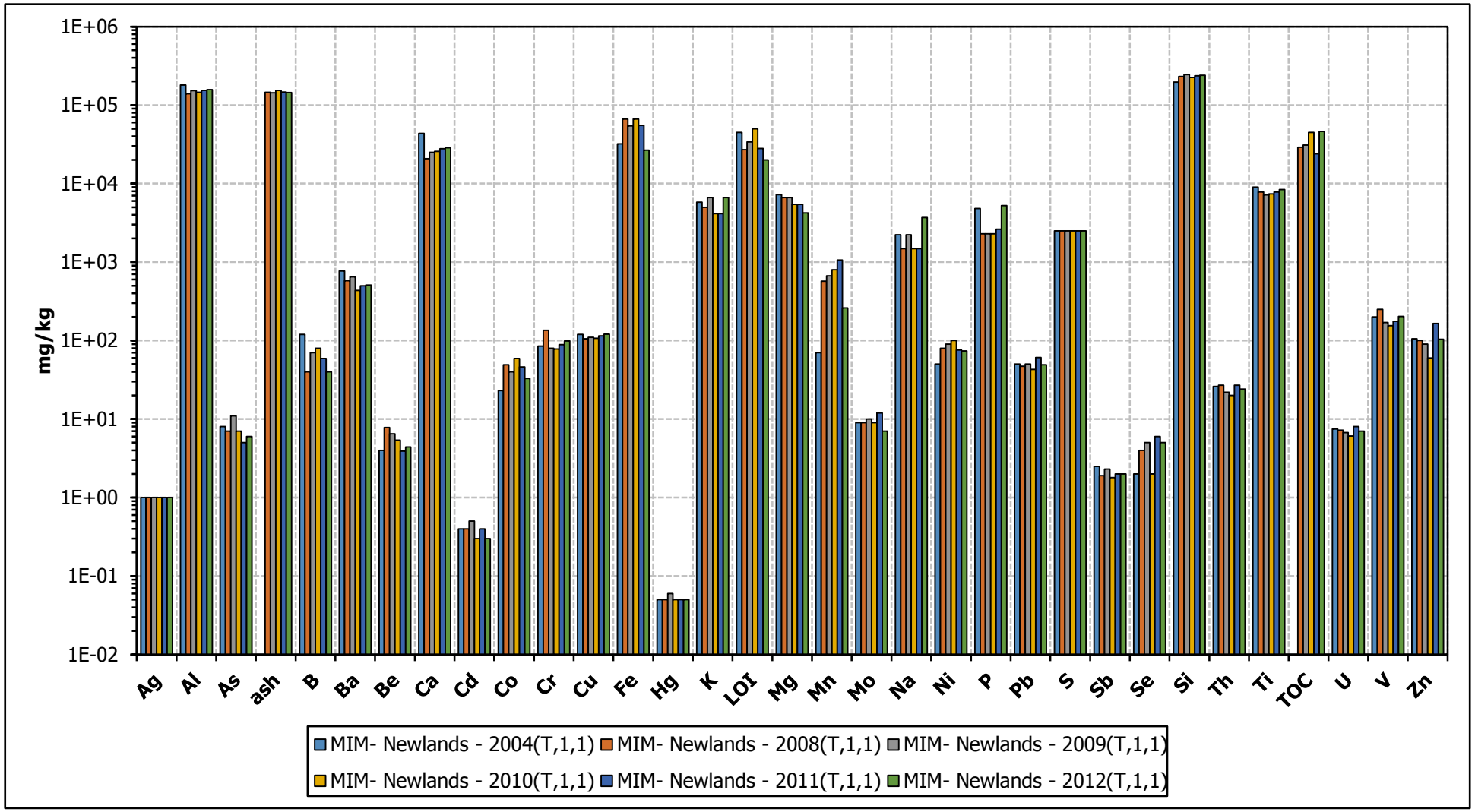
Appendix A–iii: Total Content (TC) figure of Drummond La Loma



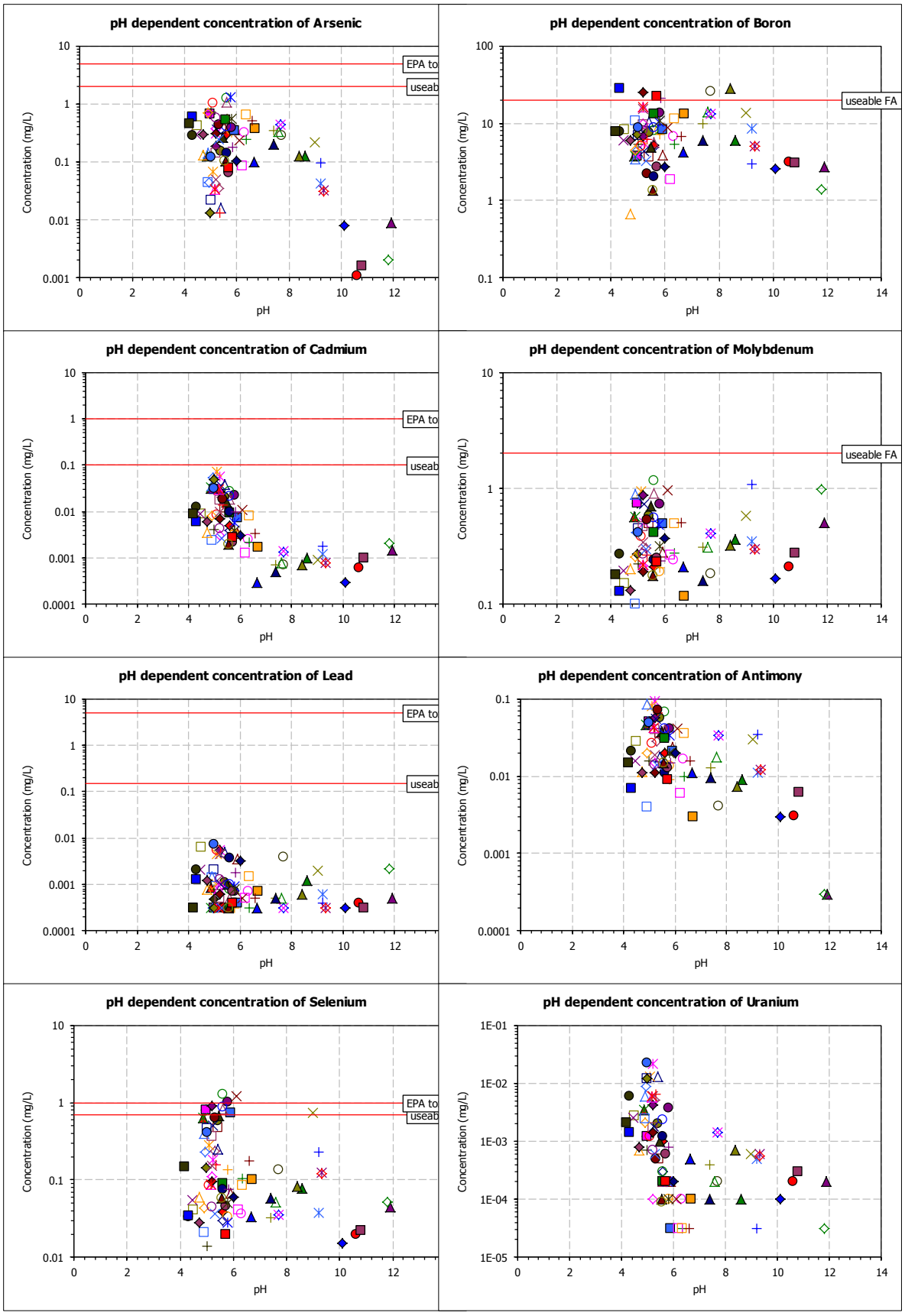
Appendix A–iv: Total Content (TC) figure of Drummond La Loma LS



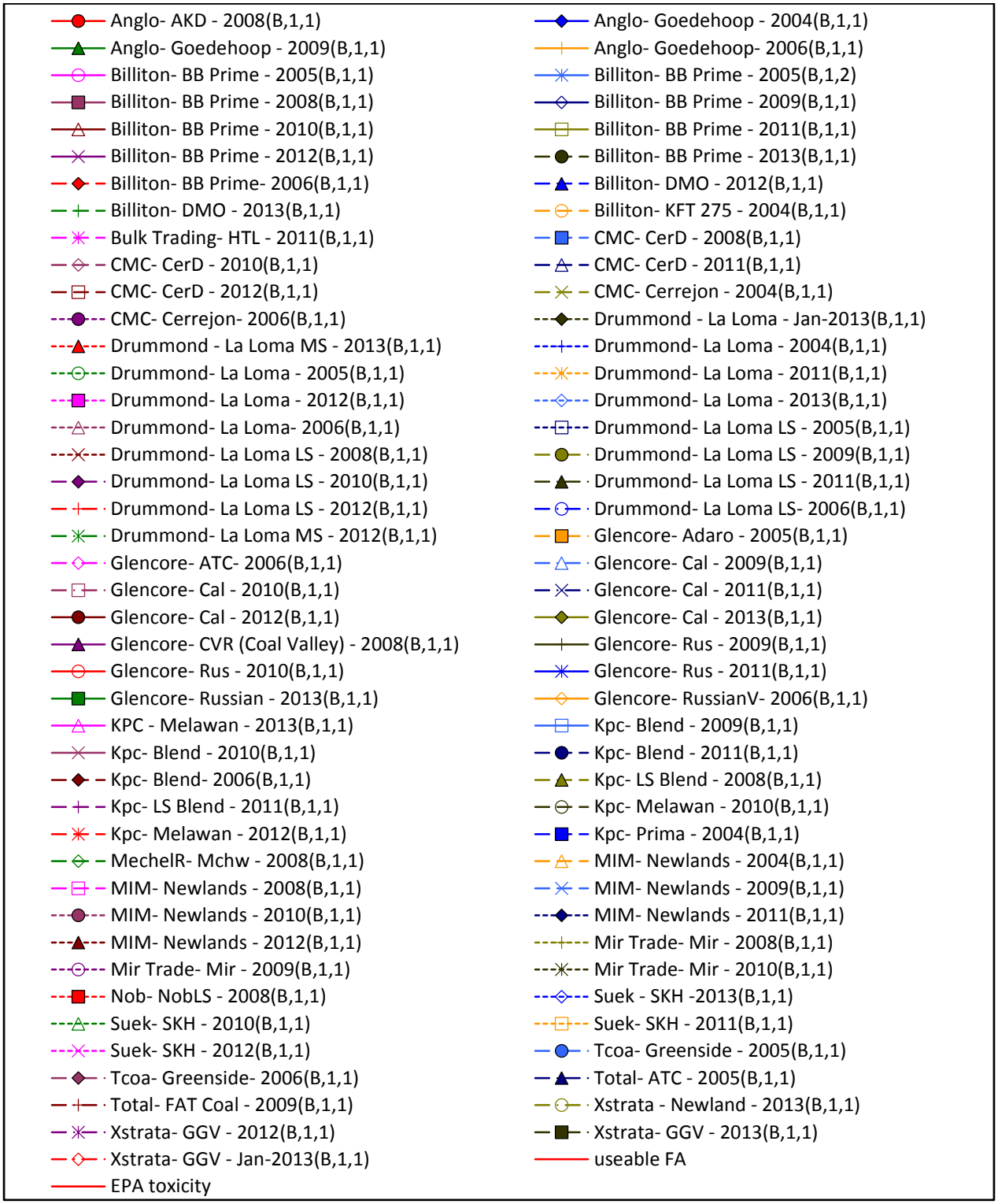
Appendix A–v: Total Content (TC) figure of NIM New Lands



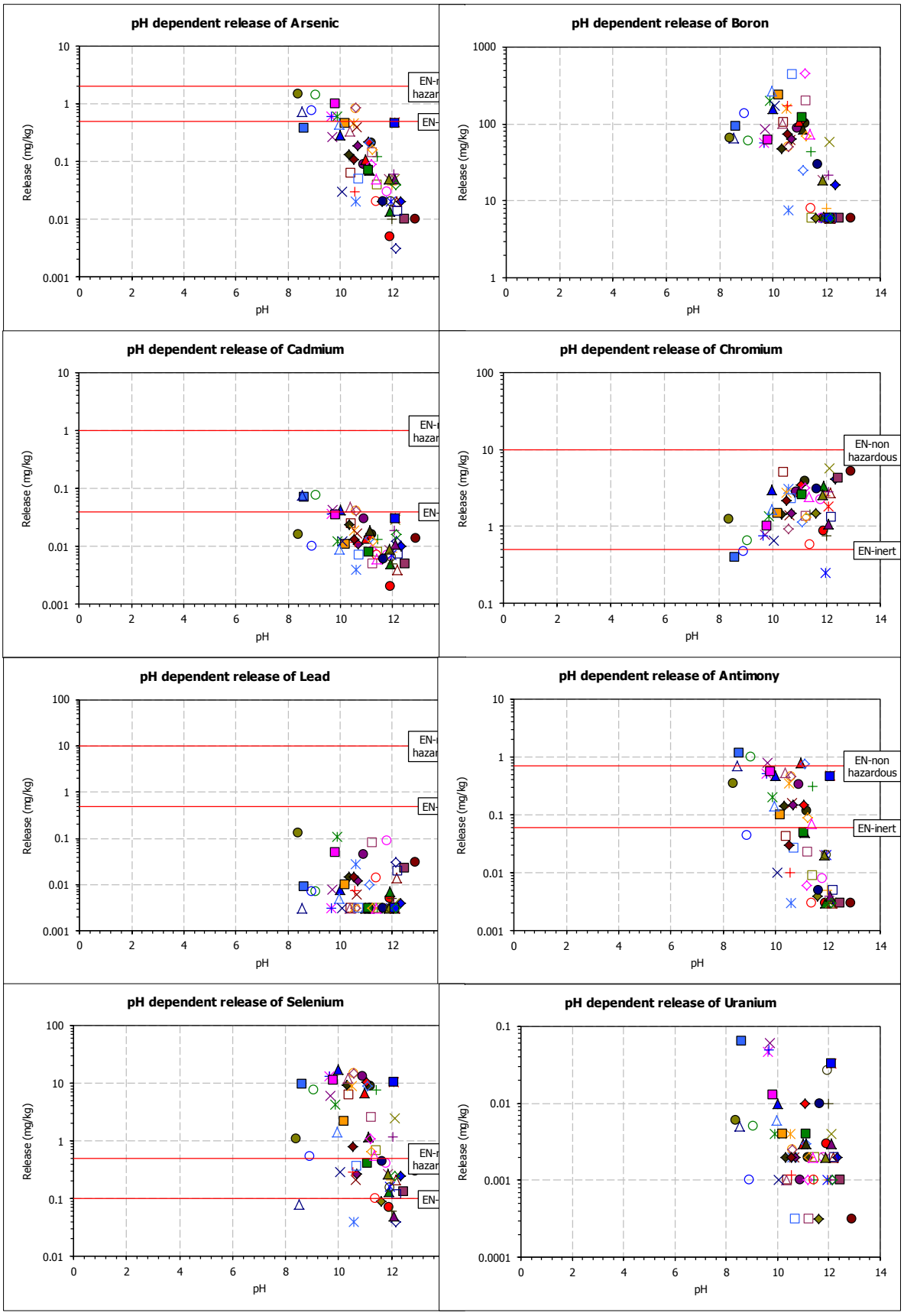
Appendix B – TCLP figures



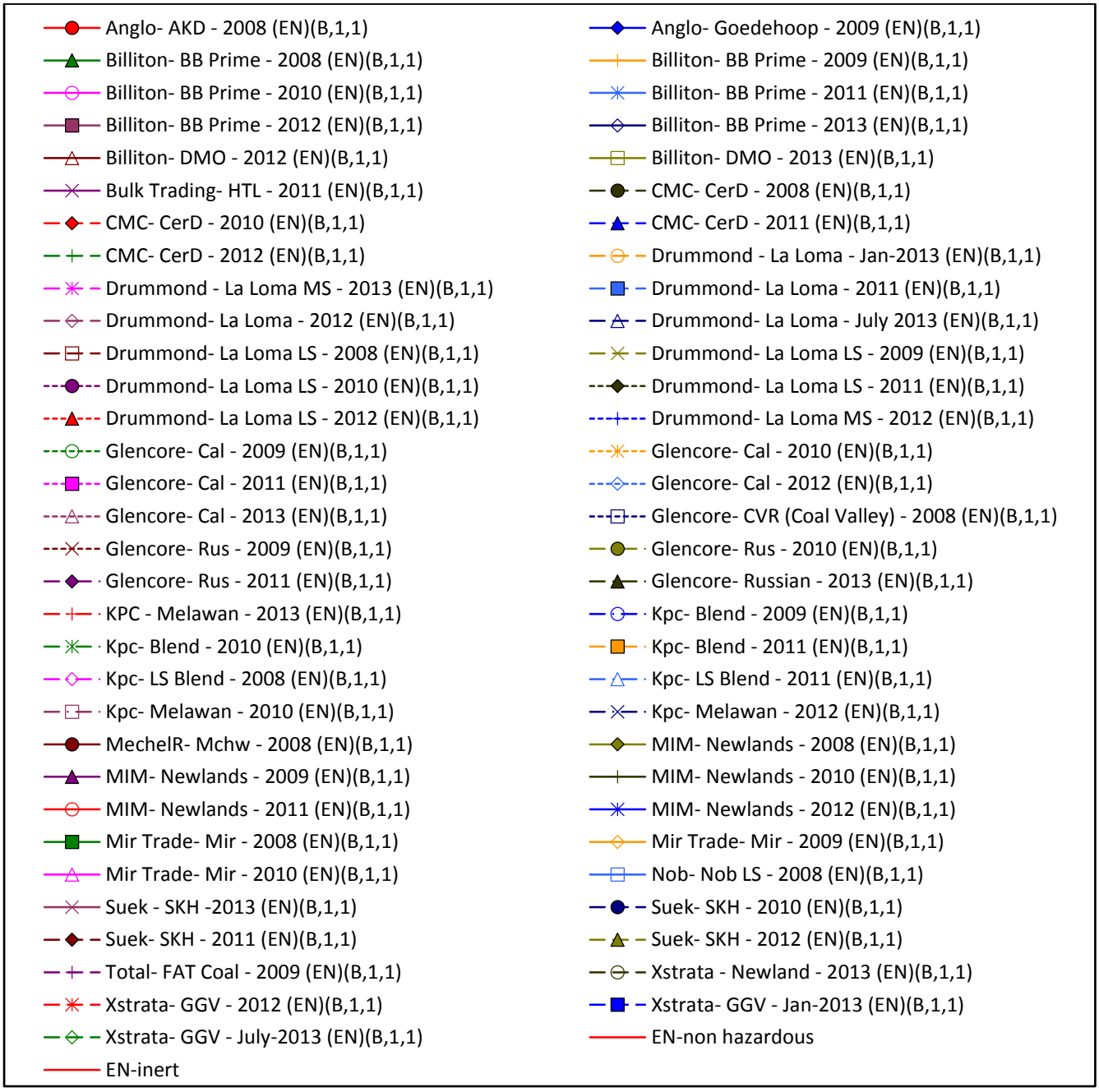
TCLP legend


Anglo- AKD - 2008(B,1,1)
Anglo- Goedehoop - 2004(B,1,1)
Anglo- Goedehoop - 2009(B,1,1)
Anglo- Goedehoop- 2006(B,1,1)
Billiton- BB Prime - 2005(B,1,1)
Billiton- BB Prime - 2005(B,1,2)
Billiton- BB Prime - 2008(B,1,1)
Billiton- BB Prime - 2009(B,1,1)
Billiton- BB Prime - 2010(B,1,1)
Billiton- BB Prime - 2011(B,1,1)
Billiton- BB Prime - 2012(B,1,1)
Billiton- BB Prime - 2013(B,1,1)
Billiton- BB Prime- 2006(B,1,1)
Billiton- DMO - 2012(B,1,1)
Billiton- DMO - 2013(B,1,1)
Billiton- KFT 275 - 2004(B,1,1)
Bulk Trading- HTL - 2011(B,1,1)
CMC- CerD - 2008(B,1,1)
CMC- CerD - 2010(B,1,1)
CMC- CerD - 2011(B,1,1)
CMC- CerD - 2012(B,1,1)
CMC- Cerrejon - 2004(B,1,1)
CMC- Cerrejon- 2006(B,1,1)
Drummond - La Loma - Jan-2013(B,1,1)
Drummond - La Loma MS - 2013(B,1,1)
Drummond- La Loma - 2004(B,1,1)
Drummond- La Loma - 2005(B,1,1)
Drummond- La Loma - 2011(B,1,1)
Drummond- La Loma - 2012(B,1,1)
Drummond- La Loma - 2013(B,1,1)
Drummond- La Loma- 2006(B,1,1)
Drummond- La Loma LS - 2005(B,1,1)
Drummond- La Loma LS - 2008(B,1,1)
Drummond- La Loma LS - 2009(B,1,1)
Drummond- La Loma LS - 2010(B,1,1)
Drummond- La Loma LS - 2011(B,1,1)
Drummond- La Loma LS - 2012(B,1,1)
Drummond- La Loma LS- 2006(B,1,1)
Drummond- La Loma MS - 2012(B,1,1)
Glencore- Adaro - 2005(B,1,1)
Glencore- ATC- 2006(B,1,1)
Glencore- Cal - 2009(B,1,1)
Glencore- Cal - 2010(B,1,1)
Glencore- Cal - 2011(B,1,1)
Glencore- Cal - 2012(B,1,1)
Glencore- Cal - 2013(B,1,1)
Glencore- CVR (Coal Valley) - 2008(B,1,1)
Glencore- Rus - 2009(B,1,1)
Glencore- Rus - 2010(B,1,1)
Glencore- Rus - 2011(B,1,1)
Glencore- Russian - 2013(B,1,1)
Glencore- RussianV- 2006(B,1,1)
KPC - Melawan - 2013(B,1,1)
Kpc- Blend - 2009(B,1,1)
Kpc- Blend - 2010(B,1,1)
Kpc- Blend - 2011(B,1,1)
Kpc- Blend- 2006(B,1,1)
Kpc- LS Blend - 2008(B,1,1)
Kpc- LS Blend - 2011(B,1,1)
Kpc- Melawan - 2010(B,1,1)
Kpc- Melawan - 2012(B,1,1)
Kpc- Prima - 2004(B,1,1)
MechelR- Mchw - 2008(B,1,1)
MIM- Newlands - 2004(B,1,1)
MIM- Newlands - 2008(B,1,1)
MIM- Newlands - 2009(B,1,1)
MIM- Newlands - 2010(B,1,1)
MIM- Newlands - 2011(B,1,1)
MIM- Newlands - 2012(B,1,1)
Mir Trade- Mir - 2008(B,1,1)
Mir Trade- Mir - 2009(B,1,1)
Mir Trade- Mir - 2010(B,1,1)
Nob- NobLS - 2008(B,1,1)
Suek - SKH -2013(B,1,1)
Suek- SKH - 2010(B,1,1)
Suek- SKH - 2011(B,1,1)
Suek- SKH - 2012(B,1,1)
Tcoa- Greenside - 2005(B,1,1)
Tcoa- Greenside- 2006(B,1,1)
Total- ATC - 2005(B,1,1)
Total- FAT Coal - 2009(B,1,1)
Xstrata - Newland - 2013(B,1,1)
Xstrata- GGV - 2012(B,1,1)
Xstrata- GGV - 2013(B,1,1)
Xstrata- GGV - Jan-2013(B,1,1)
useable FA
EPA toxicity

Appendix C – EN figures



EN legend


Anglo- AKD - 2008 (EN)(B,1,1)
Anglo- Goedehoop - 2009 (EN)(B,1,1)
Billiton- BB Prime - 2008 (EN)(B,1,1)
Billiton- BB Prime - 2009 (EN)(B,1,1)
Billiton- BB Prime - 2010 (EN)(B,1,1)
Billiton- BB Prime - 2011 (EN)(B,1,1)
Billiton- BB Prime - 2012 (EN)(B,1,1)
Billiton- BB Prime - 2013 (EN)(B,1,1)
Billiton- DMO - 2012 (EN)(B,1,1)
Billiton- DMO - 2013 (EN)(B,1,1)
Bulk Trading- HTL - 2011 (EN)(B,1,1)
CMC- CerD - 2008 (EN)(B,1,1)
CMC- CerD - 2010 (EN)(B,1,1)
CMC- CerD - 2011 (EN)(B,1,1)
CMC- CerD - 2012 (EN)(B,1,1)
Drummond - La Loma - Jan-2013 (EN)(B,1,1)
Drummond - La Loma MS - 2013 (EN)(B,1,1)
Drummond- La Loma - 2011 (EN)(B,1,1)
Drummond- La Loma - 2012 (EN)(B,1,1)
Drummond- La Loma - July 2013 (EN)(B,1,1)
Drummond- La Loma LS - 2008 (EN)(B,1,1)
Drummond- La Loma LS - 2009 (EN)(B,1,1)
Drummond- La Loma LS - 2010 (EN)(B,1,1)
Drummond- La Loma LS - 2011 (EN)(B,1,1)
Drummond- La Loma LS - 2012 (EN)(B,1,1)
Drummond- La Loma MS - 2012 (EN)(B,1,1)
Glencore- Cal - 2009 (EN)(B,1,1)
Glencore- Cal - 2010 (EN)(B,1,1)
Glencore- Cal - 2011 (EN)(B,1,1)
Glencore- Cal - 2012 (EN)(B,1,1)
Glencore- Cal - 2013 (EN)(B,1,1)
Glencore- CVR (Coal Valley) - 2008 (EN)(B,1,1)
Glencore- Rus - 2009 (EN)(B,1,1)
Glencore- Rus - 2010 (EN)(B,1,1)
Glencore- Rus - 2011 (EN)(B,1,1)
Glencore- Russian - 2013 (EN)(B,1,1)
KPC - Melawan - 2013 (EN)(B,1,1)
Kpc- Blend - 2009 (EN)(B,1,1)
Kpc- Blend - 2010 (EN)(B,1,1)
Kpc- Blend - 2011 (EN)(B,1,1)
Kpc- LS Blend - 2008 (EN)(B,1,1)
Kpc- LS Blend - 2011 (EN)(B,1,1)
Kpc- Melawan - 2010 (EN)(B,1,1)
Kpc- Melawan - 2012 (EN)(B,1,1)
MechelR- Mchw - 2008 (EN)(B,1,1)
MIM- Newlands - 2008 (EN)(B,1,1)
MIM- Newlands - 2009 (EN)(B,1,1)
MIM- Newlands - 2010 (EN)(B,1,1)
MIM- Newlands - 2011 (EN)(B,1,1)
MIM- Newlands - 2012 (EN)(B,1,1)
Mir Trade- Mir - 2008 (EN)(B,1,1)
Mir Trade- Mir - 2009 (EN)(B,1,1)
Mir Trade- Mir - 2010 (EN)(B,1,1)
Nob- Nob LS - 2008 (EN)(B,1,1)
Suek - SKH -2013 (EN)(B,1,1)
Suek- SKH - 2010 (EN)(B,1,1)
Suek- SKH - 2011 (EN)(B,1,1)
Suek- SKH - 2012 (EN)(B,1,1)
Total- FAT Coal - 2009 (EN)(B,1,1)
Xstrata - Newland - 2013 (EN)(B,1,1)
Xstrata- GGV - 2012 (EN)(B,1,1)
Xstrata- GGV - Jan-2013 (EN)(B,1,1)
Xstrata- GGV - July-2013 (EN)(B,1,1)
EN-non hazardous
EN-inert

תקציר

אפר פחם מרחף שהינו תוצר לוואי של ייצור חשמל משריפת פחם, מנוצל במלואו וכמעט באופן בלעדי בתעשיות המלט והבטון בישראל. אפיון האפר ותוצרי שימושו הוא כלי חשוב להערכת ההיבטים הסביבתיים ביישומיו השונים. אפיון כימי של אפר הפחם המתקבל ממנהלת אפר הפחם מתבצע במכון הגיאולוגי וכולל הרכב כימי כולל וכן שתי בדיקות מיצוי: מיצוי בשיטת Toxicity Characteristic Leaching Procedure (TCLP, שיטת EPA 1311) ומיצוי בשיטת Leaching of Granular Waste Materials and Sludges (EN 12,457-2). עד כה, כל תוצאות האפיון נצברו בקבצי אקסל, דבר הגורם לסרבול ניכר ולעבודה רבה בניתוח הנתונים והשוואתם. פיתוח וולידציה של מסגרת חדשה להערכת השפעות סביבתיות של תשטיפים (Leaching Environmental Assessment Framework; LEAF) בארצות הברית ובאירופה יצרו סטנדרטיזציה של שיטות מיצוי של הסוכנות להגנת הסביבה האמריקאית (USEPA) בשילוב עם התוכנה הייעודית LeachXS לניתוח וניהול נתונים והרצת תרחישי מודל. מספר דוגמאות אפר פחם נבדקו בשיטת LEAF לאפיון שחרור מתכות ברמות חומציות שונות (בשיטת האמריקאית או המקבילה האירופית). מטרות המחקר הנוכחי היו: (i) לימוד, הכרה ושימוש יעיל בשיטות המיצוי יחד עם שימוש בתוכנת LeachXS לניהול הנתונים וככלי להערכה, וכן (ii) לבנות מסד נתונים ב- LeachXS של כל תוצאות בדיקות אפר הפחם הישראלי ותוצריו מאז 2004, בשילוב עם מידע השוואתי ממקורות אחרים. הדו"ח הנוכחי מתמקד בייצור מסד נתונים ישראלי ב- LeachXS הכולל את כל נתוני האפר מהשנים 2004-2013. כמו כן צורות אופייניות להצגת נתונים והשוואתם תוך שימוש ב- LeachXS מודגמות בדוח זה.

המכון הגיאולוגי

משרד התשתיות הלאומיות
האנרגיה והמים

הטמעת נתוני אפר הפחם הישראלי ב- LeachXS

נדיה טויטש[1], אלון משה[1], אולגה ברלין[1]

דיויד ס. קוסון[2], פול פ.א.ב. סייגנטה[3], הנס א. ון דר סלוט[4]

1. המכון הגיאולוגי, ירושלים, ישראל
2. אוניברסיטת ונדרבילט, נאשוויל, טנסי, ארצות הברית
3. מכון לחקר אנרגיה ECN, פטן, הולנד
4. ייעוץ הנס ון דר סלוט, לנגהדייק, הולנד

דוח מס' GSI/19/2016 יוני 2017