

Supporting Information for

Anthropogenic Cycles of the Elements: A Critical Review

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S1 Principal sources of the cycle information

The sources of this large number of cycles are largely from four geographical areas.

USA: Most contributions come from two groups, the U.S. Geological Survey and the Center for Industrial Ecology at Yale University. The USGS centered most of its analyses on the United States and on the period of 1990-2005. It was the first to characterize cycles for zinc [1], cobalt [2], and vanadium [3], in the first part of the 1990s, and later reported about 25 cycles of metals at the single country level [4]. The Yale group has been active since 2000. It is unique in (1) providing many global and regional cycles based on aggregation of information from country or territory levels [5-12], as well as (2) reporting on pioneering dynamic cycles for up to many decades, such as for copper [13], tungsten [14], iron [15], and aluminum [16].

Europe: According to a report from European Environment Agency [17], seven countries (Austria, Denmark, Germany, the Netherlands, Norway, Sweden and Switzerland) are regarded as the most advanced in the field of MFA and SFA applications. However, some groups seem more active than others, such as the Center for Environmental Studies at Leiden University, which (1) developed the country level SFA framework almost simultaneously with the U.S. Geological Survey and applied this framework to cadmium, nitrogen, and chlorine [18-22], (2) proposed a series of indicators that could be derived from stocks and flows analysis of heavy metals, and then used them to supervise or promote sustainable development of these metals [23-25], and (3) developed dynamic modeling methods to track long-term fate or to conduct future scenario predictions of stocks and flows of metals or plastics [21, 26-29]. The Danish Environmental Protection Agency is also important in this regard because it has carried out SFA for more than three decades and has since reported more than 35 cycles of substances [30], although only about 15 of them are for metals [31]. Most of the metal cycles in Europe are for heavy metals, analyzing their emissions and potential environmental or health risks.

Japan: Not only environmental scientists (such as those in National Institute for Environmental Studies [32]) or metallurgists (such as those in Tohoku University [33, 34]), but also materials scientists (such as those from The University of Tokyo [35] and National Institute for Material Sciences [36]), are interested in and contribute to construction of cycles of elements in Japan. Almost all elemental cycle publications from Japan date from 2005, apply mainly to Japan or to its Asian neighbors, and are extremely comprehensive and detailed. Another feature of Japanese studies is the analyses of the interaction of different elements while they are passing through the anthroposphere together as alloys [33, 37, 38].

Mainland China: Tsinghua University, Nanjing University and some other Chinese institutions that specialize in metallurgy increasingly publish cycles on base metals at the China level [39-43], as well as nutrient elements at the city [44, 45], river basin [46] or national levels [39, 47], but have thus far not completed many such studies, and many of their publications are in Chinese. Considering China's rising role in global production, trade, and consumption of metals [7, 48], it is reasonable to expect more characterizations of metals cycles for China in the coming years.

S2 Listing and summary of each anthropogenic cycle of the elements

Table S 1 Global-level anthropogenic cycles of the elements

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
3	Lithium	Li	Global	2007	Static	No	2010	[49]	The planet analyzed as a whole without trade analysis.
5	Boron	B	Global	2000	Static	No	2002	[50]	Part of biogeochemical cycle
6	Carbon	C	Global	2001	Static	No	2007	[51]	Based on global input-output analysis
7	Nitrogen	N	Global	1860 & 1990s & 2050	Static	No	2004	[52]	Mainly on biogeochemical cycle
7	Nitrogen	N	Global	2001	Static	No	2007	[51]	Based on global input-output analysis.
9	Fluorine	F	Global	2001	Static	No	2007	[53]	Details on production processes.
13	Aluminum	Al	Global	2002	Static	No	2009	[54]	Anthrobiogeochemical cycle
13	Aluminum	Al	Global	2004	Static	No	2006	[55]	Based on a model in [56]. The planet analyzed as a whole.
13	Aluminum	Al	Global	2006	Static	No	2007	[57]	Based on a model in [56]. The planet analyzed as a whole.
13	Aluminum	Al	Global	2007	Static	No	2008	[58]	Based on a model in [56]. The planet analyzed as a whole.
13	Aluminum	Al	Global	2007	Static	No	2011	[59]	Excl. Mining and Recycling. Good design of flow diagram.
13	Aluminum	Al	Global	2008	Static	No	2009	[60]	Based on a model in [56]. The planet analyzed as a whole.
13	Aluminum	Al	Global	2009	Static	No	2010	[61]	Based on a model in [56]. The planet analyzed as a whole.
13	Aluminum	Al	Global	2003, 1970-2020	Dynamic	Yes	2006	[56]	Excellent dynamic model developed by experts from industry.
14	Silicon	Si	Global	1998-2020	Dynamic	No	2003	[62]	Product chain analysis.
15	Phosphorus	P	Global	2001	Static	No	2007	[51]	Based on global input-output analysis
15	Phosphorus	P	Global	2005	Static	No	2009	[63]	For food production and consumption system.
15	Phosphorus	P	Global	1970-2100	Dynamic	No	2010	[64]	Scenarios analysis as well as policy implications analysis.
23	Vanadium	V	Global	1700-2400	Dynamic	No	2008	[65]	Biogeochemical partly analyzed.
24	Chromium	Cr	Global	2000	Static	No	2006	[12]	Yale STAF. 9 regions, 54 countries or territories.
24	Chromium	Cr	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
26	Iron	Fe	Global	2000	Static	No	2007	[9]	Yale STAF. 9 regions, 68 countries or territories.

26	Iron	Fe	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
26	Iron	Fe	Global	2000&2005	Static	No	2010	[7]	Yale STAF. 8 regions, 51 countries or territories.
26	Iron	Fe	Global	2008	Static	No	2011	[59]	Excl. Mining and Recycling. Good design of flow diagram.
26	Iron	Fe	Global	1980-2050	Dynamic	Yes	2010	[66]	Stocks and flows scenarios for 42 countries/territories.
27	Cobalt	Co	Global	2005	Dynamic	Yes	2011	[67]	Yale STAF. Stocks and flows for U.S., Japan, China and Planet.
28	Nickel	Ni	Global	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 8 regions, 52 countries or territories.
28	Nickel	Ni	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
29	Copper	Cu	Global	1994	Static	No	2004	[5]	Yale STAF. 9 regions, 56 countries or territories.
29	Copper	Cu	Global	Mid-1990s	Static	No	2007	[69]	Anthrobiogeochemical cycle
29	Copper	Cu	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
30	Zinc	Zn	Global	1994	Static	No	2005	[10]	Yale STAF. 9 regions, 55 countries or territories.
30	Zinc	Zn	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
39	Yttrium	Y	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
47	Silver	Ag	Global	1997	Static	No	2005	[6]	Yale STAF. 9 regions, 64 countries or territories.
47	Silver	Ag	Global	1997	Static	No	2009	[54]	Anthrobiogeochemical cycle
49	Indium	In	Global	2004	Dynamic	Yes	2011	[72]	In Japanese, English abstract and figures. Also includes Japan cycle.
50	Tin	Sn	Global	1927-2005	Dynamic	Yes	2010	[73]	Cumulative flows for the planet as a whole provided.
57	Lanthanum	La	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
58	Cerium	Ce	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
59	Praseodymium	Pr	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
60	Neodymium	Nd	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
62	Samarium	Sm	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
63	Europium	Eu	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
64	Gadolinium	Gd	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
65	Terbium	Tb	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
66	Dysprosium	Dy	Global	2007	Static	No	2011	[70, 71]	Yale STAF. Without cycles at region, country or territory levels.
78	Platinum	Pt	Global	2005-2100	Dynamic	Yes	2006	[74]	Scenario predictions for stocks and flows.

82	Lead	Pb	Global	2000	Static	No	2008	[11]	Yale STAF. 8 regions, 52 countries or territories.
82	Lead	Pb	Global	2000	Static	No	2009	[54]	Anthrobiogeochemical cycle
82	Lead	Pb	Global	2000	Dynamic	Yes	2009	[75]	In-use stock and its input, output estimated by regions.

Table S 2 Continent-level or country group-level anthropogenic cycles of the elements

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
7	Nitrogen	N	Africa	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
7	Nitrogen	N	Asia	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
7	Nitrogen	N	Europe	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
7	Nitrogen	N	Latin America	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
7	Nitrogen	N	North America	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
7	Nitrogen	N	Oceania	early 1990s	Static	No	2004	[52]	Without details on anthropogenic cycle
13	Aluminum	Al	Europe	2002	Static	No	2005	[76]	Excellent and detailed analysis for WM&R stage.
13	Aluminum	Al	Europe	2004	Static	No	2007	[77]	Based on a model in [56].
13	Aluminum	Al	Europe	2005	Static	No	2008	[78]	Life cycle assessment included. Good data on loss flows.
13	Aluminum	Al	Europe	2003	Static	No	2010	[79]	For commercial vehicles only. Detailed analysis for EOL flows.
13	Aluminum	Al	Europe	2000-2050	Dynamic	Yes	2009	[80]	Scenarios for the U.S., Japan, Mainland China and Europe.
15	Phosphorus	P	Africa	2005	Static	No	2009	[63]	A rough estimate for food system.
15	Phosphorus	P	Europe	2006-2007	Static	No	2010	[81]	For EU 27.
15	Phosphorus	P	Europe	2000s	Static	No	2012	[82]	For EU 15.
17	Chlorine	Cl	Western Europe	1992	Static	No	1998	[83]	Partly based on [84-86] with more data collected and compared.
17	Chlorine	Cl	Western Europe	1992	Static	No	1997&1998	[84-86]	Many data gaps but detailed discussion about production process.
24	Chromium	Cr	Africa	2000	Static	No	2006	[12]	Yale STAF. 8 countries or territories.
24	Chromium	Cr	Antarctica	2000	Static	No	2006	[12]	Yale STAF.
24	Chromium	Cr	Asia	2000	Static	No	2006	[12]	Yale STAF. 11 countries or territories.
24	Chromium	Cr	CIS	2000	Static	No	2006	[12]	Yale STAF.
24	Chromium	Cr	Europe	2000	Static	No	2006	[12]	Yale STAF. 17 countries or territories.
24	Chromium	Cr	LAC	2000	Static	No	2006	[12]	Yale STAF. 7 countries or territories.
24	Chromium	Cr	Middle East	2000	Static	No	2006	[12]	Yale STAF. 5 countries or territories.

24	Chromium	Cr	North America	2000	Static	No	2006	[12]	Yale STAF. 3 countries or territories.
24	Chromium	Cr	Oceania	2000	Static	No	2006	[12]	Yale STAF. 2 countries or territories.
26	Iron	Fe	Africa	2000	Static	No	2007	[9]	Yale STAF. 8 countries or territories.
26	Iron	Fe	Africa	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 3 countries or territories.
26	Iron	Fe	Antarctica	2000	Static	No	2007	[9]	Yale STAF.
26	Iron	Fe	Asia	2000	Static	No	2007	[9]	Yale STAF. 13 countries or territories.
26	Iron	Fe	Asia	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 10 countries or territories.
26	Iron	Fe	CIS	2000	Static	No	2007	[9]	Yale STAF. 5 countries or territories.
26	Iron	Fe	CIS	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 3 countries or territories.
26	Iron	Fe	Europe	2000	Static	No	2007	[9]	Yale STAF. 22 countries or territories.
26	Iron	Fe	Europe	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 18 countries or territories.
26	Iron	Fe	LAC	2000	Static	No	2007	[9]	Yale STAF. 8 countries or territories.
26	Iron	Fe	LAC	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 7 countries or territories.
26	Iron	Fe	Middle East	2000	Static	No	2007	[9]	Yale STAF. 7 countries or territories.
26	Iron	Fe	Middle East	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 5 countries or territories.
26	Iron	Fe	North America	2000	Static	No	2007	[9]	Yale STAF. 3 countries or territories.
26	Iron	Fe	North America	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 3 countries or territories.
26	Iron	Fe	Oceania	2000	Static	No	2007	[9]	Yale STAF. 2 countries or territories.
26	Iron	Fe	Oceania	2000&2005	Static	No	2010	[7]	Yale STAF stainless steel. 2 countries or territories.
28	Nickel	Ni	Africa	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 3 countries or territories.
28	Nickel	Ni	Asia	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 10 countries or territories.
28	Nickel	Ni	CIS	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 3 countries or territories.
28	Nickel	Ni	Europe	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 17 countries or territories.
28	Nickel	Ni	LAC	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 8 countries or territories.
28	Nickel	Ni	Middle East	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 5 countries or territories.
28	Nickel	Ni	North America	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 3 countries or territories.
28	Nickel	Ni	Oceania	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF. 3 countries or territories.

29	Copper	Cu	Africa	1994	Static	No	2004	[5]	Yale STAF. 11 countries or territories.
29	Copper	Cu	Antarctica	1994	Static	No	2004	[5]	Yale STAF.
29	Copper	Cu	Asia	1994	Static	No	2004	[5]	Yale STAF. 13 countries or territories.
29	Copper	Cu	CIS	1994	Static	No	2004	[5]	Yale STAF. 3 countries or territories.
29	Copper	Cu	Europe	1994	Static	No	2004	[5]	Yale STAF. 12 countries or territories.
29	Copper	Cu	LAC	1994	Static	No	2004	[5]	Yale STAF. 6 countries or territories.
29	Copper	Cu	Middle East	1994	Static	No	2004	[5]	Yale STAF. 5 countries or territories.
29	Copper	Cu	North America	1994	Static	No	2004	[5]	Yale STAF. 3 countries or territories.
29	Copper	Cu	Oceania	1994	Static	No	2004	[5]	Yale STAF. 3 countries or territories.
29	Copper	Cu	North America	1900-1999	Dynamic	Yes	2005	[13]	Yale STAF.
29	Copper	Cu	Western Europe	1945-1999	Dynamic	Yes	2006	[87]	Excellent analysis of recycling rates and trade of final products.
30	Zinc	Zn	Africa	1994	Static	No	2005	[10]	Yale STAF. 6 countries or territories.
30	Zinc	Zn	Antarctica	1994	Static	No	2005	[10]	Yale STAF.
30	Zinc	Zn	Asia	1994	Static	No	2005	[10]	Yale STAF. 12 countries or territories.
30	Zinc	Zn	CIS	1994	Static	No	2005	[10]	Yale STAF. 3 countries or territories.
30	Zinc	Zn	Europe	1994	Static	No	2005	[10]	Yale STAF. 16 countries or territories.
30	Zinc	Zn	LAC	1994	Static	No	2005	[10]	Yale STAF. 6 countries or territories.
30	Zinc	Zn	Middle East	1994	Static	No	2005	[10]	Yale STAF. 6 countries or territories.
30	Zinc	Zn	North America	1994	Static	No	2005	[10]	Yale STAF. 3 countries or territories.
30	Zinc	Zn	Oceania	1994	Static	No	2005	[10]	Yale STAF. 2 countries or territories.
45	Rhodium	Rh	Europe	2004	Static	No	2008	[88]	Environmental impacts of production analyzed.
45	Rhodium	Rh	Europe	2005-2020	Dynamic	Yes	2009	[89]	Scenarios for stocks, flows, and environmental impact.
46	Palladium	Pd	Europe	2004	Static	No	2008	[88]	Environmental impacts of production analyzed.
46	Palladium	Pd	Europe	2005-2020	Dynamic	Yes	2009	[89]	Scenarios for stocks, flows, and environmental impact.
47	Silver	Ag	Africa	1997	Static	No	2005	[6]	Yale STAF. 15 countries or territories.
47	Silver	Ag	Antarctica	1997	Static	No	2005	[6]	Yale STAF.
47	Silver	Ag	Asia	1997	Static	No	2005	[6]	Yale STAF. 11 countries or territories.

47	Silver	Ag	CIS	1997	Static	No	2005	[6]	Yale STAF. 4 countries or territories.
47	Silver	Ag	Europe	1997	Static	No	2005	[6]	Yale STAF. 17 countries or territories.
47	Silver	Ag	LAC	1997	Static	No	2005	[6]	Yale STAF. 7 countries or territories.
47	Silver	Ag	Middle East	1997	Static	No	2005	[6]	Yale STAF. 5 countries or territories.
47	Silver	Ag	North America	1997	Static	No	2005	[6]	Yale STAF. 3 countries or territories.
47	Silver	Ag	Oceania	1997	Static	No	2005	[6]	Yale STAF. 2 countries or territories.
48	Cadmium	Cd	Europe	1987	Static	No	1994	[18]	Policy analysis based on detailed flows accounting.
78	Platinum	Pt	Europe	2004	Static	No	2008	[88]	Environmental impacts of production analyzed.
78	Platinum	Pt	Europe	2005-2020	Dynamic	Yes	2009	[89]	Scenarios for stocks, flows, and environmental impact.
82	Lead	Pb	Africa	2000	Static	No	2008	[11]	Yale STAF. 6 countries or territories.
82	Lead	Pb	Asia	2000	Static	No	2008	[11]	Yale STAF. 10 countries or territories.
82	Lead	Pb	CIS	2000	Static	No	2008	[11]	Yale STAF. 3 countries or territories.
82	Lead	Pb	Europe	2000	Static	No	2008	[11]	Yale STAF. 17 countries or territories.
82	Lead	Pb	LAC	2000	Static	No	2008	[11]	Yale STAF. 6 countries or territories.
82	Lead	Pb	Middle East	2000	Static	No	2008	[11]	Yale STAF. 5 countries or territories.
82	Lead	Pb	North America	2000	Static	No	2008	[11]	Yale STAF. 3 countries or territories.
s82	Lead	Pb	Oceania	2000	Static	No	2008	[11]	Yale STAF. 2 countries or territories.
82	Lead	Pb	Europe	1988-2040	Dynamic	Yes	2005	[27]	
92	Uranium	U	Europe	2007	Static	No	2011	[90]	

Table S 3 Country-level or territory-level anthropogenic cycles of the elements: United States

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
4	Beryllium	Be	Country (US)	2000	Static	No	2004	[91]	USGS
7	Nitrogen	N	Country (US)	1996	Static	No	2001	[92]	Very detailed discussion on production processes.
7	Nitrogen	N	Country (US)	1961-1997	Dynamic	No	2002	[93]	It could be regarded as a cycle although not cycle figures.
12	Magnesium	Mg	Country (US)	1998	Static	No	2001	[94]	USGS
13	Aluminum	Al	Country (US)	2000	Static	No	2005	[95]	USGS
13	Aluminum	Al	Country (US)	1975-2035	Dynamic	Yes	2009	[96]	Only for passenger vehicles. Energy use also analyzed.
13	Aluminum	Al	Country (US)	2000-2050	Dynamic	Yes	2009	[80]	Scenarios for the U.S., Japan, Mainland China and Europe.
13	Aluminum	Al	Country (US)	1900-2009	Dynamic	Yes	2011	[16]	Yale STAF. Comprehensive stocks and flows analysis.
15	Phosphorus	P	Country (US)	2007	Static	No	2011	[97]	Only for agricultural and food system.
16	Sulfur	S	Country (US)	2000	Static	No	2002	[98]	Historical data on both production and consumption available.
22	Titanium	Ti	Country (US)	2004	Static	No	2009	[99]	USGS
23	Vanadium	V	Country (US)	1991	Static	No	1994	[3]	USGS
24	Chromium	Cr	Country (US)	1989	Static	No	1994	[100]	USGS
24	Chromium	Cr	Country (US)	1998	Static	No	2001	[101]	USGS
24	Chromium	Cr	Country (US)	2000	Static	No	2006	[12]	Yale STAF
25	Manganese	Mn	Country (US)	1998	Static	No	2003	[102]	USGS
25	Manganese	Mn	Country (US)	1901-90, 1990	Static	No	1994	[103]	USGS
26	Iron	Fe	Country (US)	1998	Static	No	2003	[104]	USGS
26	Iron	Fe	Country (US)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (US)	1900-2004	Dynamic	Yes	2006	[15]	Yale STAF
26	Iron	Fe	Country (US)	2000&2005	Static	No	2010	[7]	Yale STAF
27	Cobalt	Co	Country (US)	1989	Static	No	1993	[2]	USGS
27	Cobalt	Co	Country (US)	1998	Static	No	2003	[105]	USGS

27	Cobalt	Co	Country (US)	2005	Dynamic	Yes	2011	[67]	Yale STAF. Stocks and flows for U.S., Japan, China and Planet.
28	Nickel	Ni	Country (US)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (US)	2004	Static	No	2009	[106]	USGS
29	Copper	Cu	Country (US)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (US)	2004	Static	No	2009	[107]	USGS
29	Copper	Cu	Country (US)	1900-2100	Dynamic	Yes	1999	[108]	One of the excellent pioneer dynamic studies.
30	Zinc	Zn	Country (US)	1994	Static	No	2005	[10]	USGS
30	Zinc	Zn	Country (US)	1998	Static	No	2001	[109]	USGS
30	Zinc	Zn	Country (US)	1850-1990	Static	No	1992	[1]	Yale STAF
32	Germanium	Ge	Country (US)	2000	Static	No	2005	[110]	USGS
33	Arsenic	As	Country (US)	1989	Static	No	1994	[111]	USGS
34	Selenium	Se	Country (US)	2004	Static	No	2009	[112]	USGS
41	Niobium	Nb	Country (US)	1998	Static	No	2003	[113]	USGS
42	Molybdenum	Mo	Country (US)	1998	Static	No	2003	[114]	USGS
47	Silver	Ag	Country (US)	1991	Static	No	1996	[115]	
47	Silver	Ag	Country (US)	2000	Static	No	2003	[116]	USGS
47	Silver	Ag	Country (US)	1997	Static	No	2005	[6]	Yale STAF
48	Cadmium	Cd	Country (US)	1989	Static	No	1994	[117]	USGS
48	Cadmium	Cd	Country (US)	2000	Static	No	2003	[118]	USGS
48	Cadmium	Cd	Country (US)	2004&2005	Static	No	2006	[119]	
50	Tin	Sn	Country (US)	1998	Static	No	2003	[120]	USGS
50	Tin	Sn	Country (US)	2005	Static	No	2010	[73]	Global-level dynamic analysis also available.
51	Antimony	Sb	Country (US)	2000	Static	No	2005	[121]	USGS
55	Cesium	Cs	Country (US)	2000	Static	No	2005	[122]	¹³⁷ Cs isotope only
73	Tantalum	Ta	Country (US)	1998	Static	No	2003	[123]	USGS
74	Tungsten	W	Country (US)	2000	Static	No	2005	[124]	USGS
74	Tungsten	W	Country (US)	1910-91, 1974-90	Static	No	1994	[125]	USGS

74	Tungsten	W	Country (US)	1975-2000	Dynamic	Yes	2008	[14]	Yale STAF
78	Platinum	Pt	Country (US)	1998	Static	No	2001	[126]	USGS
79	Gold	Au	Country (US)	1998	Static	No	2006	[127]	USGS
80	Mercury	Hg	Country (US)	2000	Static	No	2005	[128]	USGS
80	Mercury	Hg	Country (US)	1901-90, 1989/90	Static	No	1994	[129]	USGS
80	Mercury	Hg	Country (US)	1990/2000/2005	Static	No	2007	[130]	
80	Mercury	Hg	Country (US)	1990&1996	Static	No	2001	[131]	USGS. Some data at global level available.
82	Lead	Pb	Country (US)	1998	Static	No	2006	[132]	USGS
82	Lead	Pb	Country (US)	2000	Static	No	2008	[11]	Yale STAF

Table S 4 Country-level or territory-level anthropogenic cycles of the elements: European countries

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
7	Nitrogen	N	Country (FI)	average 1995-1999	Static	No	2004	[133]	Only for the system of Forestry Industry & Use of Wood Fuels
7	Nitrogen	N	Country (FI)	average 1995-1999	Static	No	2005	[134]	Only for the food system.
7	Nitrogen	N	Country (FI)	2004-2007	Static	Yes	2010	[135]	Only for the aquaculture system.
7	Nitrogen	N	Country (NL)	1986&1990&1995	Static	No	1998	[136]	Losses and emissions discussed in details.
7	Nitrogen	N	Country (NO)	average 1988-1991	Static	No	1997	[137]	Only for the food system. An agricultural cycle is included.
7	Nitrogen	N	Country (FI)	1900-2003	Dynamic	No	2007	[138]	Only for the energy system. Very briefly.
13	Aluminum	Al	Country (DE)	1990	Static	No	1998	[139]	Only for West Germany.
13	Aluminum	Al	Country (DK)	1994	Static	No	2000	[31]	DEPA. Production stage not included.
13	Aluminum	Al	Country (DE)	1986-2012	Dynamic	Yes	1999	[140]	One of the pioneer studies building dynamic lifespan models.
13	Aluminum	Al	Country (UK)	1958-2001	Dynamic	Yes	2004	[141]	Economic value along the material life cycle also analyzed.
15	Phosphorus	P	Country (AT)	2001	Static	No	2009	[142]	Including several sub-system cycles.
15	Phosphorus	P	Country (AT)	average 2004-2008	Static	No	2011	[143]	page 8 of reference
15	Phosphorus	P	Country (CH)	2006	Static	No	2010	[81]	
15	Phosphorus	P	Country (CH)	2009	Static	No	2011	[144]	page 15 of reference
15	Phosphorus	P	Country (FI)	average 1995-1999	Static	No	2004	[133]	Only for the system of Forestry Industry & Use of Wood Fuels
15	Phosphorus	P	Country (FI)	average 1995-1999	Static	No	2005	[134]	Only for the food system.
15	Phosphorus	P	Country (FI)	2004-2007	Static	Yes	2010	[135]	Only for the aquaculture system.
15	Phosphorus	P	Country (FR)	2006	Static	No	2011	[145]	page 4 of reference
15	Phosphorus	P	Country (FR)	average 2002-2006	Static	Yes	2011	[146]	Page 30 of reference
15	Phosphorus	P	Country (NL)	2005	Static	No	2010	[81]	
15	Phosphorus	P	Country (NL)	2005&2008	Static	No	2011	[147]	page 4, 5, 6, 7 of reference
15	Phosphorus	P	Country (UK)	2009	Static	No	2011	[148]	page 8 of reference
15	Phosphorus	P	Country (FI)	1900-2003	Dynamic	No	2007	[138]	Only for the energy system. Very briefly.

17	Chlorine	Cl	Country (NL)	1988	Static	No	1994	[19]	Only for CHCs
17	Chlorine	Cl	Country (NL)	1990	Static	No	1997	[149]	It is developed for debate on chlorine phasing out.
24	Chromium	Cr	Country (AT)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (BE&LU)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (CH)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (DE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (DK)	1982	Static	No	2000	[31]	DEPA. Production stage not included.
24	Chromium	Cr	Country (DK)	1999	Static	No	2003	[150]	DEPA. Production stage not included.
24	Chromium	Cr	Country (DK)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (ES)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (FI)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (FR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (GR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (IE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (IT)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (NL)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (NO)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (PL)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (PT)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (SE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (UK)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Territory (Flanders)	1998	Static	No	2004	[151]	Mainly about emissions analysis.
26	Iron	Fe	Country (AT)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (AT)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (BE&LU)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (BE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (BG)	2000	Static	No	2007	[9]	Yale STAF

26	Iron	Fe	Country (CH)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (CH)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CZ)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (DE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (DE)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (DK)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (DK)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (ES)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (ES)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (FI)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (FI)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (FR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (FR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (GR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (GR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (HU)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (IE)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (IT)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (IT)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (LU)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (NL)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (NL)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (NO)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (NO)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (PL)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (PL)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (PT)	2000	Static	No	2007	[9]	Yale STAF

26	Iron	Fe	Country (PT)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (RO)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SE)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (SI)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (SK)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (UK)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (UK)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (UK)	1954-2019	Dynamic	Yes	2000	[152, 153]	Analysis for both past and future. Energy/exergy flows analyzed.
26	Iron	Fe	Country (UK)	1970-2001	Dynamic	Yes	2007	[154, 155]	Stocks and flows analysis for the past.
26	Iron	Fe	Austrian Empire	1915-1918	Dynamic	Yes	2011	[156]	Including static cycles for 1915, 1916, 1917, and 1918.
27	Cobalt	Co	Country (DK)	1982	Static	No	2000	[31]	DEPA. Production stage not included.
28	Nickel	Ni	Country (AT)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (BE&LU)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (CH)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (DE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (DK)	1982	Static	No	2000	[31]	DEPA. Production stage not included.
28	Nickel	Ni	Country (DK)	1994	Static	No	2000	[31]	DEPA. Production stage not included.
28	Nickel	Ni	Country (DK)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (ES)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (FI)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (FR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (GR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (IE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (IT)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (NL)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (NO)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF

28	Nickel	Ni	Country (PL)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (PT)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (SE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (UK)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
29	Copper	Cu	Country (AT)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	BE&LU&NL	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (DE)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (DE)	1999	Static	No	2006	[157]	
29	Copper	Cu	Country (DK)	1994	Static	No	2000	[31]	DEPA. Production stage not included.
29	Copper	Cu	Country (ES)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (FR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (GR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (IE)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (IT)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (NL)	1990	Static	No	2000	[24]	Some useful indicators developed.
29	Copper	Cu	Country (PL)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (PT)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Scandinavia	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (UK)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (CH)	1900-2000	Dynamic	Yes	2007	[158]	
29	Copper	Cu	Austrian Empire	1915-1918	Dynamic	Yes	2010	[159]	Including static cycles for 1915, 1916, 1917, and 1918.
29	Copper	Cu	Country (CH)	1840-2060	Dynamic	Yes	2011	[160]	Scenario analysis of flows is conducted based on "stock-driven" model.
30	Zinc	Zn	Country (AT)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (BE&LU)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (DE)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (DK)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (ES)	1994	Static	No	2005	[10]	Yale STAF

30	Zinc	Zn	Country (FI)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (FR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (GR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (IE)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (IT)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (NL)	1990	Static	No	2000	[24]	Some useful indicators developed.
30	Zinc	Zn	Country (NL)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (NO)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (PL)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (PT)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (SE)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (UK)	1994	Static	No	2005	[10]	Yale STAF
33	Arsenic	As	Country (DK)	1982	Static	No	2000	[31]	DEPA. Production stage not included.
45	Rhodium	Rh	Country (DE)	2001	Static	Partly	2005	[161]	Detailed loss and recycling flows by sectors.
46	Palladium	Pd	Country (DE)	2001	Static	Partly	2005	[161]	Detailed loss and recycling flows by sectors.
47	Silver	Ag	Country (AT)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (BE&LU)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (BG)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (DE)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (DK)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (ES)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (FI)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (FR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (GR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (IT)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (NL)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (NO)	1997	Static	No	2005	[6]	Yale STAF

47	Silver	Ag	Country (PL)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (PT)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (RO)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (SE)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (UK&IE)	1997	Static	No	2005	[6]	Yale STAF
48	Cadmium	Cd	Country (AT)	2005	Static	No	2009	[162]	Policy implications well discussed.
48	Cadmium	Cd	Country (DK)	1990	Static	No	2000	[31]	DEPA. Production stage not included.
48	Cadmium	Cd	Country (DK)	1998	Static	No	2000	[31]	DEPA. Production stage not included.
48	Cadmium	Cd	Country (NL)	1990	Static	No	2000	[24]	Some useful indicators developed.
50	Tin	Sn	Country (DK)	1994	Static	No	2000	[31]	DEPA. Production stage not included.
51	Antimony	Sb	Country (CH)	2001	Static	No	2007	[163]	Detailed analysis for trade, waste management, and environment sub-systems.
78	Platinum	Pt	Country (DE)	2001	Static	Partly	2005	[161]	Detailed loss and recycling flows by sectors.
80	Mercury	Hg	Country (AT)	2005	Static	No	2009	[162]	Policy implications well discussed.
80	Mercury	Hg	Country (DK)	1982&1983	Static	No	2000	[31]	DEPA. Production stage not included.
80	Mercury	Hg	Country (DK)	1992&1993	Static	No	2000	[31]	DEPA. Production stage not included.
80	Mercury	Hg	Country (DK)	2001	Static	No	2003	[164]	DEPA. Production stage not included.
82	Lead	Pb	Country (AT)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (AT)	2005	Static	No	2009	[162]	Policy implications well discussed.
82	Lead	Pb	Country (BE&LU)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (CH)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (DE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (DK)	1985	Static	No	2000	[31]	DEPA. Production stage not included.
82	Lead	Pb	Country (DK)	1994	Static	No	2000	[31]	DEPA. Production stage not included.
82	Lead	Pb	Country (DK)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (ES)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (FI)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (FR)	2000	Static	No	2008	[11]	Yale STAF

82	Lead	Pb	Country (GR)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (IE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (IT)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (NL)	1990	Static	No	2000	[24]	Some useful indicators developed.
82	Lead	Pb	Country (NL)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (NO)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (PL)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (PT)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (SE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (UK)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (NL)	1988-2025	Dynamic	Yes	2004	[165]	Linked with social-economic indicators to model stocks & flows.
82	Lead	Pb	Country (NL)	1988-2025	Dynamic	No	2009	[28]	Non-intentional flows analyzed in details.

Table S 5 Country-level or territory-level anthropogenic cycles of the elements: Japan

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
3	Lithium	Li	Country (JP)	2006	Static	No	2008	[36]	Page 14 of reference
4	Beryllium	Be	Country (JP)	2006	Static	No	2008	[36]	Page 15 of reference
12	Magnesium	Mg	Country (JP)	2006	Static	No	2008	[36]	Page 16 of reference
13	Aluminum	Al	Country (JP)	2003	Static	Yes	2006	[166]	In Japanese
13	Aluminum	Al	Country (JP)	2003	Static	No	2007	[167]	Detailed analysis on aluminum dross and environmental burden.
13	Aluminum	Al	Country (JP)	2006	Static	No	2008	[36]	Page 17 of reference
13	Aluminum	Al	Country (JP)	Unknown	Static	No	2008	[36]	Page 51&52 of reference
13	Aluminum	Al	Country (JP)	2006	Static	No	2008	[36]	Page 6 of reference
13	Aluminum	Al	Country (JP)	Unknown	Static	No	2008	[36]	Page 84 of reference
13	Aluminum	Al	Country (JP)	1990-2050, 2003	Dynamic	Yes	2007	[37]	Alloy elements analyzed.
13	Aluminum	Al	Country (JP)	2000-2050	Dynamic	Yes	2009	[80]	Scenarios for the U.S., Japan, Mainland China and Europe.
15	Phosphorus	P	Country (JP)	2002	Static	No	2009	[168]	Including several sub-system cycles.
15	Phosphorus	P	Country (JP)	2005	Static	No	2011	[169]	Virtual phosphorus ore requirement analyzed.
17	Chlorine	Cl	Country (JP)	1995	Static	No	2000	[170]	In Japanese. With English abstract.
22	Titanium	Ti	Country (JP)	2006	Static	No	2008	[36]	Page 18 of reference
22	Titanium	Ti	Country (JP)	2003	Static	No	2008	[36]	Page 53 of reference
23	Vanadium	V	Country (JP)	2006	Static	No	2008	[36]	Page 19 of reference
23	Vanadium	V	Country (JP)	2000	Static	No	2008	[36]	Page 54 of reference
24	Chromium	Cr	Country (JP)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (JP)	2006	Static	No	2008	[36]	Page 20 of reference
24	Chromium	Cr	Country (JP)	Unknown	Static	No	2008	[36]	Page 56 of reference
24	Chromium	Cr	Country (JP)	1980-2005	Dynamic	Yes	2010	[38]	Analyzed as an alloy element of stainless steel.
24	Chromium	Cr	Country (JP)	1980-2030, 2005	Dynamic	Yes	2010	[171]	Chromium cycle associated with steel cycle.

25	Manganese	Mn	Country (JP)	2006	Static	No	2008	[36]	Page 21 of reference
25	Manganese	Mn	Country (JP)	2005	Static	No	2008	[34]	Manganese cycle associated with iron and steel cycle.
26	Iron	Fe	Country (JP)	Unknown	Static	No	2005	[172]	In Japanese. Scrap flows analyzed.
26	Iron	Fe	Country (JP)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (JP)	2006	Static	No	2008	[36]	Page 22 of reference
26	Iron	Fe	Country (JP)	2006	Static	No	2008	[36]	Page 5 of reference
26	Iron	Fe	Country (JP)	2000	Static	No	2008	[36]	Page 57 of reference
26	Iron	Fe	Country (JP)	2000 & 2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (JP)	1980-2000	Dynamic	Yes	2007	[173]	
26	Iron	Fe	Country (JP)	2003-2015	Dynamic	No	2007	[174]	The impact of scrap export on production discussed.
26	Iron	Fe	Country (JP)	2000-2030	Dynamic	No	2007	[175]	The impact of more efficient cycle on CO ₂ emissions discussed.
26	Iron	Fe	Country (JP)	1990-2030	Dynamic	Yes	2008	[176]	Scenarios for Japan, Mainland China, Korea and Taiwan region.
26	Iron	Fe	Country (JP)	1970-2005	Dynamic	Yes	2009	[177]	Both top-down and bottom-up results quantified.
26	Iron	Fe	Country (JP)	Before 2050	Dynamic	Yes	2009	[178]	In Japanese.
26	Iron	Fe	Country (JP)	1980-2005	Dynamic	Yes	2010	[38]	Stainless steel cycle.
27	Cobalt	Co	Country (JP)	2006	Static	No	2008	[36]	Page 23 of reference
27	Cobalt	Co	Country (JP)	2003	Static	No	2008	[36]	Page 58 of reference
27	Cobalt	Co	Country (JP)	2005	Dynamic	Yes	2011	[67]	Yale STAF. Stocks and flows for U.S., Japan, China and Planet.
28	Nickel	Ni	Country (JP)	2006	Static	No	2008	[36]	Page 24 of reference
28	Nickel	Ni	Country (JP)	2003	Static	No	2008	[36]	Page 59 of reference
28	Nickel	Ni	Country (JP)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (JP)	1970-2005	Dynamic	Yes	2009	[179]	Two static cycles for 1990 and 2005 are provided.
28	Nickel	Ni	Country (JP)	1980-2005	Dynamic	Yes	2010	[38]	Analyzed as an alloy element of stainless steel.
29	Copper	Cu	Country (JP)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (JP)	2006	Static	No	2008	[36]	Page 25 of reference
29	Copper	Cu	Country (JP)	2006	Static	No	2008	[36]	Page 3 of reference
29	Copper	Cu	Country (JP)	2006	Static	No	2008	[36]	Page 4 of reference

29	Copper	Cu	Country (JP)	2003	Static	No	2008	[36]	Page 60 of reference
29	Copper	Cu	Country (JP)	2005	Dynamic	Yes	2008	[180]	In Japanese
29	Copper	Cu	Country (JP)	1950-2005	Dynamic	Yes	2009	[35]	
30	Zinc	Zn	Country (JP)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (JP)	2006	Static	No	2008	[36]	Page 26 of reference
30	Zinc	Zn	Country (JP)	2003	Static	No	2008	[36]	Page 61 of reference
30	zinc	Zn	Country (JP)	2005	Static	No	2008	[181]	Zinc cycle associated with iron and steel cycle.
30	Zinc	Zn	Country (JP)	1970-2005	Dynamic	Yes	2009	[182]	
31	Gallium	Ga	Country (JP)	2006	Static	No	2008	[36]	Page 27 of reference
31	Gallium	Ga	Country (JP)	2003	Static	No	2008	[36]	Page 62 of reference
31	Gallium	Ga	Country (JP)	Unknown	Static	No	2008	[36]	Page 85 of reference
32	Germanium	Ge	Country (JP)	2006	Static	No	2008	[36]	Page 28 of reference
32	Germanium	Ge	Country (JP)	2000	Static	No	2008	[36]	Page 63 of reference
34	Selenium	Se	Country (JP)	2006	Static	No	2008	[36]	Page 29 of reference
38	Strontium	Sr	Country (JP)	2006	Static	No	2008	[36]	Page 30 of reference
40	Zirconium	Zr	Country (JP)	2006	Static	No	2008	[36]	Page 31 of reference
40	Zirconium	Zr	Country (JP)	2000	Static	No	2008	[36]	Page 64 of reference
41	Niobium	Nb	Country (JP)	2006	Static	No	2008	[36]	Page 32 of reference
41	Niobium	Nb	Country (JP)	2000	Static	No	2008	[36]	Page 65 of reference
42	Molybdenum	Mo	Country (JP)	2004	Static	No	2007	[33]	Molybdenum cycle associated with iron and steel cycle.
42	Molybdenum	Mo	Country (JP)	2006	Static	No	2008	[36]	Page 33 of reference
42	Molybdenum	Mo	Country (JP)	2003	Static	No	2008	[36]	Page 66 of reference
45	Rhodium	Rh	Country (JP)	1975-2008	Dynamic	Yes	2010	[183]	In Japanese. Only for rhodium used in autocatalysts.
46	Palladium	Pd	Country (JP)	2006	Static	No	2008	[36]	Page 34 of reference
46	Palladium	Pd	Country (JP)	2003	Static	No	2008	[36]	Page 55&67 of reference
46	Palladium	Pd	Country (JP)	1975-2008	Dynamic	Yes	2010	[183]	In Japanese. Only for palladium used in autocatalysts.
47	Silver	Ag	Country (JP)	1997	Static	No	2005	[6]	Yale STAF

47	Silver	Ag	Country (JP)	2006	Static	No	2008	[36]	Page 35 of reference
48	Cadmium	Cd	Country (JP)	2003	Static	No	2008	[36]	Page 69 of reference
48	Cadmium	Cd	Country (JP)	1988-2008	Dynamic	Yes	2012	[184]	Excellent analysis of the impact of zinc production on cadmium emissions.
49	Indium	In	Country (JP)	2004	Static	No	2007	[185]	Indium for flat panel displays in Japan
49	Indium	In	Country (JP)	2006	Static	No	2008	[36]	Page 10 of reference
49	Indium	In	Country (JP)	2006	Static	No	2008	[36]	Page 13 of reference
49	Indium	In	Country (JP)	2006	Static	No	2008	[36]	Page 36 of reference
49	Indium	In	Country (JP)	2003	Static	No	2008	[36]	Page 70 of reference
49	Indium	In	Country (JP)	2008	Dynamic	Yes	2011	[72]	In Japanese, English abstract and figures
50	Tin	Sn	Country (JP)	2006	Static	No	2008	[36]	Page 37 of reference
50	Tin	Sn	Country (JP)	2000	Static	No	2008	[36]	Page 71 of reference
51	Antimony	Sb	Country (JP)	2006	Static	No	2008	[36]	Page 38 of reference
51	Antimony	Sb	Country (JP)	2003	Static	No	2008	[36]	Page 72 of reference
51	Antimony	Sb	Country (JP)	1970-2015	Dynamic	Yes	2008	[186]	Scenario analysis is performed.
52	Tellurium	Te	Country (JP)	2006	Static	No	2008	[36]	Page 39 of reference
55	Cesium	Cs	Country (JP)	2006	Static	No	2008	[36]	Page 40 of reference
66	Dysprosium	Dy	Country (JP)	1987-2008	Dynamic	Yes	2010	[187]	in Japanese, Journal of the Japan Institute of Metals
72	Hafnium	Hf	Country (JP)	2006	Static	No	2008	[36]	Page 42 of reference
72	Hafnium	Hf	Country (JP)	2000	Static	No	2008	[36]	Page 73 of reference
73	Tantalum	Ta	Country (JP)	2006	Static	No	2008	[36]	Page 43 of reference
73	Tantalum	Ta	Country (JP)	2003	Static	No	2008	[36]	Page 74 of reference
74	Tungsten	W	Country (JP)	2006	Static	No	2008	[36]	Page 44 of reference
74	Tungsten	W	Country (JP)	2003	Static	No	2008	[36]	Page 75 of reference
75	Rhenium	Re	Country (JP)	2006	Static	No	2008	[36]	Page 45 of reference
78	Platinum	Pt	Country (JP)	2006	Static	No	2008	[36]	Page 46 of reference
78	Platinum	Pt	Country (JP)	2000	Static	No	2008	[36]	Page 76 of reference
78	Platinum	Pt	Country (JP)	2006	Static	No	2008	[36]	Page 9 of reference

78	Platinum	Pt	Country (JP)	1975-2008	Dynamic	Yes	2010	[183]	In Japanese. Only for platinum used in autocatalysts.
79	Gold	Au	Country (JP)	2006	Static	No	2008	[36]	Page 47 of reference
79	Gold	Au	Country (JP)	2003	Static	No	2008	[36]	Page 68&77 of reference
79	Gold	Au	Country (JP)	2006	Static	No	2008	[36]	Page 8 of reference
80	Mercury	Hg	Country (JP)	2003	Static	No	2008	[188]	Only for mercury used in fluorescent lamps.
80	Mercury	Hg	Country (JP)	2006	Static	No	2008	[36]	Page 48 of reference
80	Mercury	Hg	Country (JP)	2003	Static	No	2008	[36]	Page 78 of reference
81	Thallium	Tl	Country (JP)	2003	Static	No	2008	[36]	Page 81 of reference
82	Lead	Pb	Country (JP)	2006	Static	No	2008	[36]	Page 49 of reference
82	Lead	Pb	Country (JP)	2006	Static	No	2008	[36]	Page 7 of reference
82	Lead	Pb	Country (JP)	2002	Static	No	2008	[36]	Page 79 of reference
82	Lead	Pb	Country (JP)	Unknown	Static	No	2008	[36]	Page 83 of reference
82	Lead	Pb	Country (JP)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (JP)	1950-2050	Dynamic	Yes	2006	[189]	
82	Lead	Pb	Country (JP)	Around 1988-2007	Dynamic	Yes	2010	[190]	
83	Bismuth	Bi	Country (JP)	2006	Static	No	2008	[36]	Page 50 of reference
83	Bismuth	Bi	Country (JP)	2003	Static	No	2008	[36]	Page 80 of reference
-	Rare Earth	-	Country (JP)	2006	Static	No	2008	[36]	Page 41. Rare earth as a whole rather than by element.

Table S 6 Country-level or territory-level anthropogenic cycles of the elements: Mainland China

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
7	Nitrogen	N	Country (CN)	2004	Static	No	2007	[191]	Doctoral Dissertation. Only for Farming-Feeding system.
7	Nitrogen	N	Country (CN)	1982&1992&2002	Static	No	2008	[192]	Only for the food system.
7	Nitrogen	N	Country (CN)	2004	Static	No	2008	[193]	In the system of wheat production and consumption.
7	Nitrogen	N	Country (CN)	2004	Static	No	2008	[193]	In the system of rice production and consumption.
7	Nitrogen	N	Country (CN)	2004	Static	No	2008	[193]	In the system of maize production and consumption.
7	Nitrogen	N	Country (CN)	2006	Static	No	2009	[194]	In Chinese. Phosphorus flows analysis is conducted too.
7	Nitrogen	N	Country (CN)	2005	Static	No	2010	[195]	Only for the food chain. P is also analyzed.
7	Nitrogen	N	Country (CN)	1978-2050	Dynamic	Yes	2007	[191]	Doctoral Dissertation. Only for Farming-Feeding system.
13	Aluminum	Al	Country (CN)	2005	Static	No	2008	[196]	In Chinese
13	Aluminum	Al	Country (CN)	2003-2007	Static	No	2010	[197]	In Chinese
13	Aluminum	Al	Country (CN)	2001&2004&2007	Static	No	2010	[39]	
13	Aluminum	Al	Country (CN)	2000-2050	Dynamic	Yes	2009	[80]	Scenarios for the U.S., Japan, Mainland China and Europe.
13	Aluminum	Al	Country (CN)	1950-2009	Dynamic	Yes	2011	[48]	Comprehensive stocks and flows analysis.
15	Phosphorus	P	Country (CN)	1996	Static	No	2004	[198]	
15	Phosphorus	P	Country (CN)	2002	Static	No	2005	[199]	In Chinese
15	Phosphorus	P	Country (CN)	2000	Static	No	2006	[200]	
15	Phosphorus	P	Country (CN)	2004	Static	No	2007	[191]	Doctoral Dissertation. Only for Farming-Feeding system.
15	Phosphorus	P	Country (CN)	Pre-human/1950/2002	Static	No	2009	[201]	Metabolisms in different societal form are compared.
15	Phosphorus	P	Country (CN)	2006	Static	No	2009	[194]	In Chinese. Nitrogen flows analysis is conducted too.
15	Phosphorus	P	Country (CN)	2005	Static	No	2010	[195]	Only for the food chain. N is also analyzed. Use efficiencies analyzed.
15	Phosphorus	P	Country (CN)	2004	Static	No	2011	[202]	In the system of wheat production and consumption.
15	Phosphorus	P	Country (CN)	2004	Static	No	2011	[202]	In the system of rice production and consumption.
15	Phosphorus	P	Country (CN)	2004	Static	No	2011	[202]	In the system of maize production and consumption.

15	Phosphorus	P	Country (CN)	1978-2050	Dynamic	Yes	2007	[191]	Doctoral Dissertation. Only for Farming-Feeding system.
15	Phosphorus	P	Country (CN)	1980-2008	Dynamic	No	2011	[203, 204]	A framework similar to the 4-stage metal cycle framework is developed.
17	Chlorine	Cl	Country (CN)	2005	Static	No	2009	[47]	In Chinese
24	Chromium	Cr	Country (CN)	2000	Static	No	2006	[12]	Yale STAF
26	Iron	Fe	Country (CN)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (CN&HK)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CN)	1900-2100	Dynamic	Yes	2010	[205]	Only for residential buildings.
25	Iron	Fe	Country (CN)	1900-2009	Dynamic	Yes	2012	[206]	Scenarios for 2010-2100 provided.
25	Iron	Fe	Country (CN)	2010-2100	Dynamic	Yes	2012	[206]	Scenarios based on 1900-2009 cycles.
27	Cobalt	Co	Country (CN)	2005	Dynamic	Yes	2011	[67]	Yale STAF. Stocks and flows for U.S., Japan, China and Planet.
28	Nickel	Ni	Country (CN&HK)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF,
29	Copper	Cu	Country (CN)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (CN)	2002	Static	No	2005	[207]	In Chinese
29	Copper	Cu	Country (CN)	2004	Static	No	2008	[41]	
29	Copper	Cu	Country (CN)	2005	Static	No	2009	[42]	Energy/entropy also analyzed.
29	Copper	Cu	Country (CN)	1990-2005	Dynamic	Yes	2009	[208]	In Japanese
30	Zinc	Zn	Country (CN)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (CN)	2004	Static	No	2007	[209]	In Chinese
30	Zinc	Zn	Country (CN)	2006	Static	No	2010	[210]	
30	Zinc	Zn	Country (CN)	2008	Static	No	2011	[40]	Zinc cycle in the steel production process analyzed in details
47	Silver	Ag	Country (CN)	1997	Static	No	2005	[6]	Yale STAF
82	Lead	Pb	Country (CN)	1999	Static	No	2007	[211]	Yale STAF
82	Lead	Pb	Country (CN)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (CN)	2006	Static	No	2009	[43]	In Chinese

Table S 7 Country-level or territory-level anthropogenic cycles of the elements: African countries

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
24	Chromium	Cr	Country (BW)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (DZ)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (EG)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (KE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (MA)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (TN)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (ZA)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (ZW)	2000	Static	No	2006	[12]	Yale STAF
26	Iron	Fe	Country (BW)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (DZ)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (EG)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (LY)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (MA)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (MR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (NG)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (TN)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (ZA)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (ZA)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (ZW)	2000&2005	Static	No	2010	[7]	Yale STAF
28	Nickel	Ni	Country (BW)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (ZA)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (ZW)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
29	Copper	Cu	Country (BW)	1994	Static	No	2004	[5]	Yale STAF

29	Copper	Cu	Country (CG&CD)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (DZ)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (EG)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (MA)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (NA)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (OM)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (TN)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (ZA)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (ZM)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (ZW)	1994	Static	No	2004	[5]	Yale STAF
30	Zinc	Zn	Country (DZ)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (EG)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (MA)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (NA)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (TN)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (ZA)	1994	Static	No	2005	[10]	Yale STAF
47	Silver	Ag	Country (CI)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (CM)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (DZ)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (EG)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (ET)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (GH)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (KE)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (MA)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (NG)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (SD)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (TN)	1997	Static	No	2005	[6]	Yale STAF

47	Silver	Ag	Country (TZ)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (UG)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (ZA&NA)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (ZW)	1997	Static	No	2005	[6]	Yale STAF
82	Lead	Pb	Country (DZ)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (EG)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (KE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (MA)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (TN)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (ZA)	2000	Static	No	2008	[11]	Yale STAF

Table S 8 Country-level or territory-level anthropogenic cycles of the elements: other Asian countries or territories

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
3	Lithium	Li	Territory (TW)	2006	Static	No	2009	[212]	
13	Aluminum	Al	Territory (TW)	2006	Static	No	2009	[212]	
13	Aluminum	Al	Country (KR)	1980-2007	Dynamic	Yes	2010	[213]	
15	Phosphorus	P	Country (KR)	2005	Static	No	2009	[214]	Potential of phosphorus recovery from steel-making slag analyzed.
24	Chromium	Cr	Country (ID)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (IN)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (KR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (MY)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (PH)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (SG)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (TH)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Territory (HK)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Territory (TW)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Territory (TW)	2002	Static	No	2007	[215]	
25	Manganese	Mn	Country (KR)	2005	Static	No	2009	[214]	Potential of manganese recovery from steel-making slag analyzed.
26	Iron	Fe	Country (ID)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (ID)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (IN)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (IN)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (KR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (KR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (MY)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (MY)	2000&2005	Static	No	2010	[7]	Yale STAF

26	Iron	Fe	Country (PH)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (PH)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (PK)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SG)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SG)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (TH)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (TH)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (VN)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Territory (HK)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Territory (TW)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Territory (TW)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (KR)	1993-2020	Dynamic	Yes	2011	[216]	
27	Cobalt	Co	Territory (TW)	2006	Static	No	2009	[212]	
28	Nickel	Ni	Country (ID)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (IN)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (KR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (MY)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (PH)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (SG)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (TH)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Territory (TW)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Territory (TW)	2006	Static	No	2009	[212]	
29	Copper	Cu	Country (ID)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (IN)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (KP)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (KR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (MN)	1994	Static	No	2004	[5]	Yale STAF

29	Copper	Cu	Country (MY)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (PH)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (SG)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (TH)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Territory (HK)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Territory (TW)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Territory (TW)	2006	Static	No	2009	[212]	
29	Copper	Cu	Country (KR)	1990-2005	Dynamic	Yes	2009	[208]	
29	Copper	Cu	Territory (TW)	1990-2005	Dynamic	Yes	2009	[208]	
30	Zinc	Zn	Country (ID)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (IN)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (KP)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (KR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (MY)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (PH)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (SG)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (TH)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Territory (HK)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Territory (TW)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Territory (TW)	2009	Static	No	2011	[217]	Zinc flows in the steelmaking processes also described.
33	Arsenic	As	Territory (TW)	2007	Static	No	2010	[218]	IO table is applied, emissions are analyzed
33	Arsenic	As	Territory (TW)	2008	Static	Yes	2012	[219]	Emissions as well as risks are evaluated.
47	Silver	Ag	Country (ID)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (IN)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (KR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (MY)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (PH)	1997	Static	No	2005	[6]	Yale STAF

47	Silver	Ag	Country (SG)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (TH)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Territory (HK)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Territory (TW)	1997	Static	No	2005	[6]	Yale STAF
48	Cadmium	Cd	Territory (TW)	2002	Static	No	2007	[220]	
82	Lead	Pb	Country (ID)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (IN)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (KR)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (MY)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (PH)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (SG)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (TH)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Territory (TW)	2000	Static	No	2008	[11]	Yale STAF

Table S 9 Country-level or territory-level anthropogenic cycles of the elements: Commonwealth of Independent States

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
26	Iron	Fe	Country (BY)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (KZ)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (KZ)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (MD)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (RU)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (RU)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (UA)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (UA)	2000&2005	Static	No	2010	[7]	Yale STAF
28	Nickel	Ni	Country (KZ)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (RU)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (UA)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
29	Copper	Cu	Country (KZ)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (RU)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (UZ)	1994	Static	No	2004	[5]	Yale STAF
30	Zinc	Zn	Country (KZ)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (RU)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (UZ)	1994	Static	No	2005	[10]	Yale STAF
47	Silver	Ag	Country (KZ)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (RU)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (UA)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (UZ)	1997	Static	No	2005	[6]	Yale STAF
82	Lead	Pb	Country (KZ)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (RU)	2000	Static	No	2008	[11]	Yale STAF

82	Lead	Pb	Country (UA)	2000	Static	No	2008	[11]	Yale STAF
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Table S 10 Country-level or territory-level anthropogenic cycles of the elements: Latin American/Caribbean and other North American countries

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
24	Chromium	Cr	Country (AR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (BR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (CA)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (CL)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (CO)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (CU)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (MX)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (PE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (VE)	2000	Static	No	2006	[12]	Yale STAF
26	Iron	Fe	Country (AR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (AR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (BR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (BR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CA)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (CA)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CL)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (CL)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CO)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (CO)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (CU)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (DO)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (EC)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (MX)	2000	Static	No	2007	[9]	Yale STAF

26	Iron	Fe	Country (MX)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (PE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (PE)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (VE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (VE)	2000&2005	Static	No	2010	[7]	Yale STAF
28	Nickel	Ni	Country (AR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (BR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (CA)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (CL)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (CO)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (CU)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (DO)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (MX)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (PE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (VE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
29	Copper	Cu	Country (AR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (BR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (BR)	2005	Static	No	2010	[221]	
29	Copper	Cu	Country (CA)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (CL)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (CO)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (MX)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (PE)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (VE)	1994	Static	No	2004	[5]	Yale STAF
30	Zinc	Zn	Country (AR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (BR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (CA)	1994	Static	No	2005	[10]	Yale STAF

30	Zinc	Zn	Country (CL)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (CO)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (MX)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (PE)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (VE)	1994	Static	No	2005	[10]	Yale STAF
47	Silver	Ag	Country (AR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (BO)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (BR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (CA)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (CL)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (CO)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (MX)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (PE)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (VE)	1997	Static	No	2005	[6]	Yale STAF
82	Lead	Pb	Country (AR)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (BR)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (CA)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (CL)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (CO)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (MX)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (PE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (VE)	2000	Static	No	2008	[11]	Yale STAF

Table S 11 Country-level or territory-level anthropogenic cycles of the elements: Middle East countries

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
15	Phosphorus	P	Country (TR)	2001	Static	No	2009	[142]	
24	Chromium	Cr	Country (AE)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (IL)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (IR)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (SA)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (TR)	2000	Static	No	2006	[12]	Yale STAF
26	Iron	Fe	Country (AE)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (AE)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (IL)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (IL)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (IR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (IR)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (LB)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SA)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (SA)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (SY)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (TR)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (TR)	2000&2005	Static	No	2010	[7]	Yale STAF
28	Nickel	Ni	Country (AE)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (IL)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (IR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (SA)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (TR)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF

29	Copper	Cu	Country (AE)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (IL)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (IR)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (SA)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (TR)	1994	Static	No	2004	[5]	Yale STAF
30	Zinc	Zn	Country (AE)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (IL)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (IR)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (JO)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (SA)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (TR)	1994	Static	No	2005	[10]	Yale STAF
47	Silver	Ag	Country (AE)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (IL)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (IR)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (SA)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (TR)	1997	Static	No	2005	[6]	Yale STAF
82	Lead	Pb	Country (AE)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (IL)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (IR)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (SA)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (TR)	2000	Static	No	2008	[11]	Yale STAF

Table S 12 Country-level or territory-level anthropogenic cycles of the elements: Oceania countries

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
15	Phosphorus	P	Country (AU)	2006 or 2007	Static	No	2010	[222]	
24	Chromium	Cr	Country (AU)	2000	Static	No	2006	[12]	Yale STAF
24	Chromium	Cr	Country (NZ)	2000	Static	No	2006	[12]	Yale STAF
26	Iron	Fe	Country (AU)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (AU)	2000&2005	Static	No	2010	[7]	Yale STAF
26	Iron	Fe	Country (NZ)	2000	Static	No	2007	[9]	Yale STAF
26	Iron	Fe	Country (NZ)	2000&2005	Static	No	2010	[7]	Yale STAF
28	Nickel	Ni	Country (AU)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (NC)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
28	Nickel	Ni	Country (NZ)	2000&2005	Static	No	2008&2012	[8, 68]	Yale STAF
29	Copper	Cu	Country (AU)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (NZ)	1994	Static	No	2004	[5]	Yale STAF
29	Copper	Cu	Country (PG)	1994	Static	No	2004	[5]	Yale STAF
30	Zinc	Zn	Country (AU)	1994	Static	No	2005	[10]	Yale STAF
30	Zinc	Zn	Country (NZ)	1994	Static	No	2005	[10]	Yale STAF
47	Silver	Ag	Country (AU)	1997	Static	No	2005	[6]	Yale STAF
47	Silver	Ag	Country (NZ)	1997	Static	No	2005	[6]	Yale STAF
48	Cadmium	Cd	Country (AU)	1998&1999	Static	No	2007	[223]	
82	Lead	Pb	Country (AU)	2000	Static	No	2008	[11]	Yale STAF
82	Lead	Pb	Country (NZ)	2000	Static	No	2008	[11]	Yale STAF

Table S 13 City-level or region-level anthropogenic cycles of the elements

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
7	Nitrogen	N	Arizona-Phoenix	about 1996	Static	No	2001	[224]	N cycles in different eco-systems, like urban area, desert, agricultural area.
7	Nitrogen	N	City Huizhou	1998	Static	No	2008	[225]	
7	Nitrogen	N	Dairy Farm	average 1999-2002	Static	No	2004	[226]	A micro-level analysis. N&P.
7	Nitrogen	N	EIP Yixing	2008	Static	No	2010	[227]	At the industrial park level.
7	Nitrogen	N	Province of TH	1990-1992 & 2000-2002	Static	No	2010	[228]	Emissions analyzed.
7	Nitrogen	N	Rural Area of VN	2008	Static	No	2011	[229]	
7	Nitrogen	N	City Linköping	1870-2000	Dynamic	No	2006	[230]	City level. With two snapshot cycles for 1870 and 2000 shown.
15	Phosphorus	P	City Beijing	2008	Static	No	2011	[231]	The framework is too simplified.
15	Phosphorus	P	City Chaohu	2008	Static	No	2011	[232]	
15	Phosphorus	P	City Feixi	2008	Static	No	2012	[233]	
15	Phosphorus	P	City Hefei	2008	Static	No	2010	[45]	A framework similar to the 4-stage metal cycle framework is developed.
15	Phosphorus	P	City Lujiang	2008	Static	No	2011	[44]	
15	Phosphorus	P	City Madison	unknown	Static	No	2011	[234]	A figure in a poster.
15	Phosphorus	P	City Shucheng	2008	Static	No	2011	[235]	
15	Phosphorus	P	City Sydney	2000	Static	No	2005	[236]	Policy analysis based on scenarios modeling is performed.
15	Phosphorus	P	City Tianjin	2008	Static	No	2011	[231]	The framework is too simplified.
15	Phosphorus	P	Dairy Farm	average 1999-2002	Static	No	2004	[226]	A micro-level analysis. N&P.
15	Phosphorus	P	EIP Yixing	2008	Static	No	2010	[237]	At the industrial park level.
15	Phosphorus	P	Rural Area of VN	2008	Static	No	2011	[229]	
15	Phosphorus	P	Unteres Bünztal	1990	Static	No	1994	[238]	
15	Phosphorus	P	City Linköping	1870-2000	Dynamic	Yes	2008	[230]	City level. With four snapshot cycles for 1870, 1900, 1950, and 2000.
24	Chromium	Cr	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
28	Nickel	Ni	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.

29	Copper	Cu	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
30	Zinc	Zn	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
48	Cadmium	Cd	Finspang	1998	Static	Yes	2004	[243]	
48	Cadmium	Cd	Linköping	1998	Static	Yes	2004	[243]	
48	Cadmium	Cd	Stockholm	2003	Static	No	2008	[244]	
48	Cadmium	Cd	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
51	Antimony	Sb	Stockholm	2005	Static	Yes	2009	[245]	Stock, input, especially emissions estimated.
80	Mercury	Hg	Stockholm	2003	Static	No	2008	[244]	
80	Mercury	Hg	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
82	Lead	Pb	Unteres Bünztal	1990	Static	No	1994	[238]	
82	Lead	Pb	Stockholm	2002	Static	No	2008	[244]	
82	Lead	Pb	Stockholm	1900-1995, 1995	Dynamic	Yes	2001	[239-242]	Stock, input, especially emissions estimated.
82	Lead	Pb	Vienna	1991	Dynamic	Yes	2001	[246]	

Table S 14 River basin-level anthropogenic cycles of the elements

<i>Atomic No.</i>	<i>Element</i>	<i>Symbol</i>	<i>Spatial Boundary</i>	<i>Temporal Boundary</i>	<i>Static or Dynamic</i>	<i>Stock Estimated</i>	<i>Year Published</i>	<i>Reference</i>	<i>Notes and Comments</i>
7	Nitrogen	N	Da Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
7	Nitrogen	N	Delta Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
7	Nitrogen	N	Lo Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
7	Nitrogen	N	Thao Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
15	Phosphorus	P	Da Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
15	Phosphorus	P	Delta Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
15	Phosphorus	P	Dianchi Basin	2000	Static	No	2004	[46]	Aiming at reducing emissions.
15	Phosphorus	P	Lo Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
15	Phosphorus	P	Thao Sub-basin	about 1997	Static	No	2005	[247]	For four sub-river basins. N and P.
24	Chromium	Cr	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.
28	Nickel	Ni	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.
29	Copper	Cu	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.
30	Zinc	Zn	Seine	1994-2003	Static	Yes	2007	[248, 249]	Emissions analyzed in detail.
48	Cadmium	Cd	Rhine Basin	Mid-1980s	Static	No	1994	[250]	
48	Cadmium	Cd	Rhine Basin	Late-1990s	Static	No	1994	[250]	
48	Cadmium	Cd	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.
80	Mercury	Hg	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.
82	Lead	Pb	Seine	1994-2003	Static	Yes	2007	[248]	Emissions analyzed in detail.

S3 Statistics of cycles of the elements at different levels

Table S 15 Number of static (S) or dynamic (D) cycles of the elements at different levels

Atomic No.	Symbols	Global		Continent		USA		Europe		Japan		Mainland China		Africa		Other Asia		CIS		Other America		Middle East		Oceania		City		River Basin		Total	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
1	H																												0	0	
2	He																												0	0	
3	Li	1	0							1	0					1	0												3	0	
4	Be					1	0			1	0																		2	0	
5	B	1	0																										1	0	
6	C	1	0																										1	0	
7	N	4	0	6	0	1	1	7	1			9	1												7	1	4	0	38	4	
8	O																												0	0	
9	F	1	0																										1	0	
10	Ne																												0	0	
11	Na																												0	0	
12	Mg					1	0			1	0																		2	0	
13	Al	7	1	4	1	1	3	2	2	6	2	5	2			1	1												26	12	
14	Si	0	1																										0	1	
15	P	2	1	3	0	1	0	13	1	2	0	12	2			1	0					1	0	1	0	13	1	5	0	54	5
16	S					1	0																						1	0	
17	Cl			2	0			2	0	1	0	1	0																6	0	
18	Ar																												0	0	
19	K																												0	0	
20	Ca																												0	0	
21	Sc																												0	0	

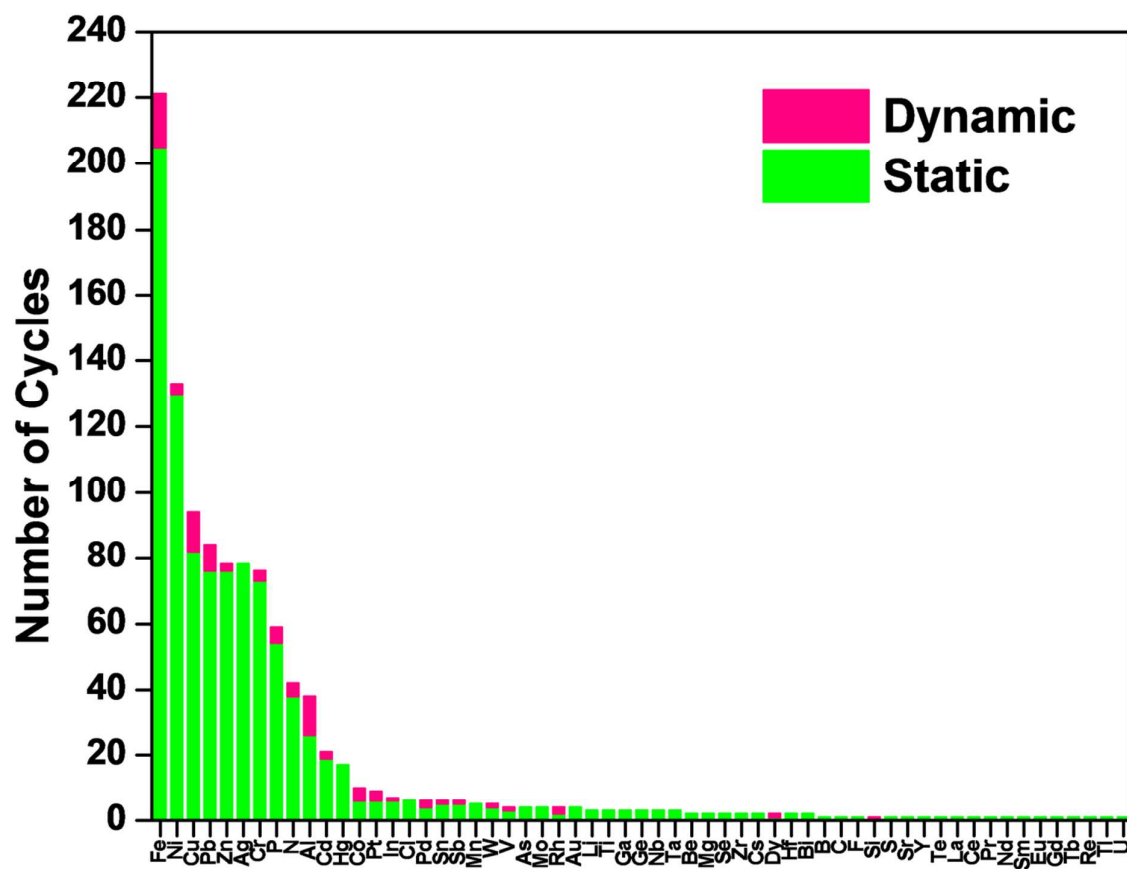


Figure S 1 Number of static (S) or dynamic (D) cycles of the elements

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