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NTC SAN DIEGO
SSIC #5090.3

ENVIRONMENTAL OFFICE
NAVAL TRAINING CENTER
33502 DECATUR ROAD, SUITE 120
SAN DIEGO, CA 92133-1449

RESTORATION ADVISORY BOARD

AGENDA

DATE:	**Tuesday evening, 12 July 1994**
TIME:	**6:30 - 8:30 PM**
LOCATION:	**NAVAL TRAINING CENTER, PUBLIC AFFAIRS OFFICER (PAO) AUDITORIUM, BUILDING #201** (Enter NTC Gate 1 at Lytton and Barnett; maps to building will be available from guard)
6:30 -6:45	WELCOME AND INTRODUCTIONS BRIEF OVERVIEW - Agenda and Meetings Objectives MINUTES APPROVAL - June 28
6:45-8:15	RAB MEMBER PRESENTATION ON ENVIRONMENTAL INVESTIGATIONS
8:15- 8:30	QUESTION AND ANSWER/PUBLIC COMMENT PERIOD

ENVIRONMENTAL OFFICE
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Subject: RESTORATION ADVISORY BOARD MEETING MINUTES

The ninth Restoration Advisory Board (RAB) meeting was held on **Tuesday, July 12, 1994**, at the Naval Training Center (NTC), PAO Auditorium #201 from 6:30 until 8:12 PM.

Mr. Phill Dyck, RAB Navy Co-Chair, called the meeting to order at 6:30 PM. As the RAB members have become familiar enough with each other to forgo introductions at each meeting, only the new attendees were asked to introduce themselves. The evening's agenda included minutes approval and a technical presentation.

Business Items

Approval of Minutes - It was moved and seconded to approve the minutes from the meeting of June 28, 1994; the motion was carried.

PRESENTATION ON THE ENVIRONMENTAL INVESTIGATION PROCESS

Mr. Dyck introduced the speaker for the evening, RAB member John Walton. Dr. Walton is an NTC neighbor and environmental consultant and has a Ph. D. in Chemistry.

Dr. Walton stated that he knows the environmental industry and could explain the environmental investigation process to RAB members in an understandable fashion. Mr. Larry Shaw, Dr. Walton's colleague and fellow RAB member, would follow with a discussion of Phase I Environmental Site Assessment (ESA). Time permitting, Dr. Walton indicated he would discuss organic chemistry to help explain environmental contamination. The presentation was accompanied by overheads and handouts.

The following is a summary of Dr. Walton's and Mr. Shaw's presentations.

Regardless of applicable law (RCRA or CERCLA), the environmental investigation process proceeds through similar, well-defined steps: Phase I and Phase II Environmental Site Assessment (ESA), Remedial Investigation/Feasibility Study (RI/FS), Remedial Action Plan (RAP), and Remediation. The steps are the same from law to law, but the names of each step may differ: e.g., under RCRA a Phase I ESA is a RCRA Facility Assessment ; under CERCLA it is a Preliminary Assessment. Likewise, for Phase II ESA, RCRA requires a RCRA Facility Investigation and CERCLA requires a

Site Investigation. The environmental investigation process always begins with Phase I and may or may not proceed further, depending on the result of the initial investigation.

A Phase I ESA is a historical and records search of the site and adjacent sites to determine the presence or likelihood of a release of hazardous substances. The outcome of the investigation is a "decision that a site has been or is likely to have been subject to a release, or no determination that known or suspected release constitutes contamination requiring remediation". All reports are presented in a well-defined format.

Before Phase II ESA fieldwork can begin, a Work Plan and a site-specific Health and Safety Plan (HASP) are developed, which the Phase II ESA follows. A Phase II ESA is the collection of surface and subsurface samples that are subjected to a broad spectrum of chemical analyses to determine if and which contaminants are present and the nature of the subsurface. The work is carried out by specialists: e.g., the HASP is written by a Certified Industrial Hygienist, lab specialists complete the chemical analyses, fieldwork is supervised by geologists, etc. If contamination is present, further investigation is warranted. The results and recommendations of the study are presented in a Phase I report.

Next, an RI/FS characterizes the site. Systematic random sampling is used to determine lateral and vertical extent of contamination from which a preliminary selection of remediation methodology is developed. The results of the RI frequently suggest an obvious choice of remediation method. The outcome is a definition of the extent of contamination and preliminary remedial method selection. In lieu of an FS, a "presumptive remedy" approach is often used because the universe of contaminants at certain kinds of sites is fairly predictable, and the study of the full range of possible remedies that was once standard practice under the FS is not time- or cost-effective. A presumptive remedy is a generic remedial solution based on lots of previous experience with similar classes of sites (e.g., landfills, underground tanks) with similar problems.

Recommended remediation is then discussed in a RAP, which compares remedial alternatives and provides clients, regulatory agencies, and the public with alternatives and a recommended remedial method. Factors to consider in making these recommendations include: risks to health and environment, cost, liability, treatment effectiveness, remediation time, impact on site operations, acceptance by regulators, etc.

Remedial Action applies the methodology from the RAP to the actual cleanup of the affected site. Before Remedial Action can begin, a Work Plan, site-specific HASP, and a community HASP are completed. Permits from a variety of regulatory agencies (e.g., Air Pollution Control District, Regional Water Quality Control Board, Department of Toxic Substances Control, etc.) are obtained and a Verification Sampling Plan is prepared. When work is finished a Closure Report is completed which explains that no further action required.

Dr. Walton introduced Larry Shaw, who spoke on Phase I ESA and American Society of Testing & Materials (ASTM) standards. Mr. Shaw stressed keeping in mind "recognized environmental conditions" when reviewing a Preliminary Assessment. An ESA should include records review, site visit, interviews, and a report. The report presents information on site ownership, historical uses of the site, surrounding properties, sensitive receptors, and regulatory compliance issues.

Dr. Walton then discussed environmental chemistry, focusing on organic chemistry and kinds of contaminants often encountered at hazardous waste sites; for example, chlorinated compounds, benzene/xylene/toluene, polycyclic aromatic hydrocarbons, and pesticides. The possibility of using bioremediation with some of these substances was briefly discussed. Dr. Walton's handout included a section (Appendix B: Contaminant Groups) from a document called Remediation Technologies Screening Matrix, July 1993, USEPA and USAF.

Mr. Dyck thanked Dr. Walton and Mr. Shaw for their presentations. There were no further announcements, and the meeting was adjourned at 8:12.

The Environmental Investigation Process

Process Overview: In general, regardless of the applicable law, i.e. RCRA, CERCLA, etc, the process proceeds through similar well-defined steps

Process Steps

Phase I Environmental Site Assessment
aka RFA, RCRA Facility Assessment
PA, CERCLA Preliminary Assessment

Phase II Environmental Site Assessment
aka RFI, RCRA Facility Investigation
SI, CERCLA Site Investigation

Remedial Investigation/Feasibility Study

Remedial Action Plan

Remediation

The process always starts with Step 1 and may or may not proceed further depending on the result of the initial investigation.

Phase I Environmental Site Assessment

Overview: Historical and records search of the subject site and adjacent sites.

Purpose: Determine the presence or the likelihood of a release at the subject site.

Outcome: Decision that site has been or likely to have been subject to a release. No determination that known or suspected release constitutes contamination requiring remediation.

Documents: Final report in a well-defined format.

Phase II Environmental Site Assessment

Overview: Collection of judgmental samples of surface and subsurface (soil & water) followed by broad spectrum of chemical analysis

Purpose: Determine if contaminants and which contaminants are present

Outcome:

1) Are contaminants present
2) Which contaminants present
3) Nature of the subsurface

If contamination is present further investigation is warranted

Documents:

Before field work
- Work Plan
- Specific Health & Safety Plan

After
- Results and recommendations

Documents typically go through a number of revisions, a draft document is assembled and reviewed by the client. After client comments a final document is sent to the LEA (Lead Regulatory Agency). A revised final report incorporating LEA comments becomes the working document

Remedial Investigation/Feasibility Study

Overview: Use systematic random sampling to perform site characterization. Feasibility studies deserve special attention!

Purpose: Determination of the lateral and vertical extent of contamination. Frequently, the results of the investigation suggest an obvious choice of remediation methodology.

Outcome: Definition of the extent of contamination, and preliminary selection of remediation methodology.

Documents:

- Before field work
  - Work Plan
  - Site Specific HASP
- After field work
  - Report:
    - History
    - What was done
    - What it means, RISKS
    - What to do next

Remedial Action Plan

Overview: Present alternatives, compare alternatives, make selection of remedial alternative based on operative concerns. Factors considered include:

- Risks to public health and environment
- Cost
- Client liability
- Effectiveness of treatment
- Time required for remediation technique
- Impact on site operations
- Regulatory agency acceptance
- etc

Purpose: Provide the client and the regulatory agencies with alternatives and a recommended choice for remediation of a site.

Outcome: Course of action for elimination of environmental issues at the site.

Documents: Remedial Action Plan – draft, final revised

Remedial Action

<u>Overview:</u> Applying methodology from RAP to the actual clean-up of the impacted site.

<u>Purpose:</u> Pretty obvious

<u>Outcome:</u> A site which poses "no" threat to the public health or the environment.

Documents:

Before
- Work Plan
- Site specific HASP
- Community HASP
- Permits, APCD, LEA, RWQCB, DTSC, Fire Dept., Planning Dept., etc
- Verification Sampling Plan

After
- Closure Report

Environmental Chemistry

Classes of Chemical Species

Inorganics: substances made up of elements from the left and center of the periodic table, often including elements from the far right

Organics: substances composed of Carbon, C, and hydrogen, H, often including other elements from the right side of the periodic table. Especially problematic when other elements means a halogen.

Fig. 1.1. Transition and alkali metals and non-metals essential for life.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ne
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Ln	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

O Bulk biological elements
□ Trace elements essentials for life
⬚ Possibly essential trace elements

APPENDIX B: CONTAMINANT GROUPS

Major contaminant groups used in the *Matrix* are:

(1) Halogenated volatiles
(2) Halogenated semivolatiles
(3) Non-halogenated volatiles
(4) Non-halogenated semivolatiles
(5) Fuel Hydrocarbons
(6) Pesticides
(7) Inorganics

These major groups include the contaminants listed below. These are not comprehensive lists, but they contain examples of contaminants encountered at many sites.

(1) Halogenated Volatiles

Bromodichloromethane
Bromoform
Bromomethane
Carbon tetrachloride
Chlorodibromomethane
Chloroethane
Chloroform
Chloromethane
Chloropropane
Cis-1,2-dichloroethylene
Cis-1,3-dichloropropene
Dibromomethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethene
1,1-Dichloroethylene
Dichloromethane
1,2-Dichloropopane
Ethylene dibromide
Fluorotrichloromethane (Freon 11)
Hexachloroethane
Monochlorobenzene
1,1,2,2-Tetrachloroethane
Tetrachloroethylene (Perchloroethylene)
1,2-Trans-dichloroethylene
Trans-1,3-dichloropropene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)
Vinyl chloride

(2) Halogenated Semivolatiles

Bis(2-chloroethoxy)ether
1,2-Bis(2-chloroethoxy)ethane
Bis(2-chloroethoxy)methane
Bis(2-chloroethoxy)phthalate
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
4-Bromophenyl phenyl ether
4-Chloroaniline
p-Chloro-m-cresol
2-Chloronapthalene
2-Chlorophenol
4-Chlorophenyl phenylether
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3-Dichlorobenzidine

Halogentated Semivolatiles (Con'd.)

2,4-Dichlorophenol
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Pentachlorophenol
Polychlorinated biphenyls (PCBs)
Tetrachlorophenol
1,2,4-Trichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

(3) Non-Halogentated Volatiles

Acetone
Acrolein
Acrylonitrile
n-Butyl alcohol
Carbon disulfide
Cyclohexanone
Ethyl acetate
Ethyl ether
2-Hexanone
Isobutanol
Methanol
Methyl ethyl ketone
Methyl isobutyl ketone
4-Methyl-2-pentanone
Styrene
Tetrahydrofuran
Vinyl acetate

(4) Non-Halogentated Semivolatiles

Benzidine
Benzoic acid
Benzyl alcohol
Bis(2-ethylhexyl)phthalate
Bis phthalate
Butyl benzyl phthalate
Dibenzofuran
Di-n-butyl phthalate
Diethyl phthalate
Dimethyl phthalate
4,6-Dinitro-2-methylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-n-octyl phthalate
1,2-Diphenylhydrazine
Isophorone
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
2-Nitrophenol
4-Nitrophenol
n-Nitrosodimethylamine
n-Nitrosodiphenylamine
n-Nitrosodi-n-propylamine
Phenyl napthalene

(5) Fuel Hydrocarbons

Acenaphthene
Anthracene
Benz(a)anthracene
Benzene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(ghi)perylene
Benzo(a)pyrene
Chrysene
Cis-2-butene
Cresols
Cyclohexane
Cyclopentane
Dibenzo(a,h)anthracene
2,3-Dimethylbutane
3,3-Dimethyl-1-butene
Dimethylethylbenzene
2,2-Dimethylheptane
2,2-Dimethylhexane
2,2-Dimethylpentane
2,3-Dimethylpentane
2,4-Dimethylphenol
Ethylbenzene
3-Ethylpentane
Fluoranthene
Fluorene

Indeno(1,2,3-c,d)pyrene
Isobutane
Isopentane
2-Methyl-1,3-butadiene
3-Methyl-1,2-butadiene
2-Methyl-butene
2-Methyl-2-butene
3-Methyl-1-butene
Methylcyclohexane
Methylcyclopentane
2-Methylheptane
3-Methylheptane
3-Methylhexane
Methylnapthalene
2-Methylnapthalene
2-Methylpentane
3-Methylpentane
3-Methyl-1-pentene
2-Methylphenol
4-Methylphenol
Methylpropylbenzene
M-Xylene
Napthalene
N-Butane
N-Decane
N-Dodecane
N-Heptane
N-Hexane
N-Hexylbenzene
Nitrobenzene
N-Nonane
N-Octane
N-Pentane
N-Propylbenzene
N-Undecane
O-Xylene
1-Pentene
Phenanthrene
Phenol
Propane
P-Xylene
Pyrene
Pyridine
1,2,3,4-Tetramethylbenzene
1,2,4,5-Tetramethylbenzene
Toluene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,2,4-Trimethyl-5-ethylbenzene
2,2,4-Trimethylheptane
2,3,4-Trimethylheptane
3,3,5-Trimethylheptane
2,4,4-Trimethylhexane
3,3,4-Trimethylhexane
2,2,4-Trimethylpentane
2,3,4-Trimethylpentane
Trans-2-butene
Trans-2-pentene

(6) Pesticides

Aldrin
Bhc-alpha
Bhc-beta
Bhc-delta
Bhc-gamma
Chlordane
4,4'-DDD
4,4'-DDE
4,4'-DDT
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin aldehyde
Ethion
Ethyl parathion
Heptachlor
Heptachlor epoxide
Malathion
Methylparathion
Parathion
Toxaphene

(7) Inorganics

Aluminum
Antimony
Arsenic
Asbestos
Barium
Beryllium

Bismuth
Cadmium
Calcium
Chromium
Cobalt
Copper
Cyanide
Fluorine
Iron
Lead
Magnesium
Manganese
Mercury
Metallic cyanides
Nickel
Potassuim
Selenium
Sodium
Tin
Vanadium
Zinc

REMEDIATION TECHNOLOGIES SCREENING MATRIX

NOTE: There are factors that may limit the applicability and effectiveness of any of the technologies and processes listed below. These factors are discussed in the *Remediation Technologies Screening Matrix Reference Guide*. This Matrix should always be used in conjunction with the *Reference Guide*, which contains additional information that can be useful in identifying potentially applicable technologies.

	Reference Guide Page Number	Status — (F)ull-scale or (P)ilot-scale	Contaminants/Pollutants Treated [a]		Overall Cost	Capital (Cap) or O&M Intensive?	Commercial Availability	Typically Part of a Treatment Train? (excludes off-gas treatment)	Residuals Produced — (S)olid, (L)iquid, or (V)apor?	Minimum Contaminant Concentration Achievable	Addresses (T)oxicity, (M)obility, or (V)olume?	Long-Term Effectiveness/ Permanence?	Time to Complete Cleanup	System Reliability/ Maintainability	Awareness of Remediation Consulting Community	Regulatory/Permitting Acceptability	Community Acceptability
SOIL, SEDIMENT AND SLUDGE																	
In Situ Biological Processes																	
Biodegradation	21	F	3,4,5	1,2,6	○	O&M	■	No	None	○	T	Yes	△	△	○	△	■
Bioventing	23	F	3,4,5	1,2,6	■	Neither	■	No	None	■	T	Yes	○	■	○	○	■
In Situ Physical/Chemical Processes																	
Soil Vapor Extraction (SVE)	25	F	1,3,5		■	O&M	■	No	L	○	V	Yes	○	■	■	■	■
Soil Flushing	27	P	1,3,7	2,4-6	I	O&M	■	No	L	△	V	Yes	△	○	○	△	○
* Solidification/Stabilization	29	F	7	2,4,6	■	Cap	■	No	S	NA	M	I	■	■	○	○	○
Pneumatic Fracturing (enhancement)	31	P		1-7	■	Neither	△	Yes	None	NA	M	Yes	NA	■	△	I	I
In Situ Thermal Processes																	
Vitrification	33	P	7	1-6	△	Both	△	No	L	NA	M	Yes	■	△	○	△	△
Thermally Enhanced SVE	35	F	2,4,6	1,3,5	○	Both	○	No	L	○	V	Yes	■	○	○	○	○
Ex Situ Biological Processes (assuming excavation)																	
Slurry Phase Biological Treatment	37	F	3,5	1,2,4,6	○	Both	○	No	None	○	T	Yes	○	○	○	■	○
Controlled Solid Phase Bio. Treatment	39	F	3,5	1,2,4,6	■	Neither	■	No	None	○	T	Yes	○	■	■	■	○
* Landfarming	41	F	3,5	1,2,4,6	■	Neither	■	No	None	○	T	Yes	△	■	■	○	○
Ex Situ Physical/Chemical Processes (assuming excavation)																	
Soil Washing	43	F	2,4,5,7	1,3,6	○	Both	○	Yes	S,L	○	V	Yes	■	○	○	○	■
* Solidification/Stabilization	45	F	7	2,4,6	■	Cap	■	No	S	NA	M	I	■	■	■	○	○
Dehalogenation (Glycolate)	47	F	2,6	1	△	Both	○	No	L	■	T	Yes	△	△	○	○	○
Dehalogenation (BCD)	49	F	2,6	1	I	I	△	No	V	I	T	Yes	I	I	△	I	I
Solvent Extraction (chemical extraction)	51	F	2,4,6	1,3,5	△	Both	○	Yes	L	○	V	Yes	△	○	○	○	○
Chemical Reduction/Oxidation	53	F	7	3-6	○	Neither	■	Yes	S	NA	T,M	I	■	■	○	○	○
Soil Vapor Extraction (SVE)	55	F	1,3		■	Neither	■	No	L	○	V	Yes	○	■	■	○	○
Ex Situ Thermal Processes (assuming excavation)																	
Low Temperature Thermal Desorption	57	F	1,3,5	2,4,6	■	Both	■	Yes	L	■	V	Yes	■	○	■	○	○
High Temperature Thermal Desorption	59	F	2,4,6	1,3,5	○	Both	■	Yes	L	■	V	Yes	■	○	○	○	○
Vitrification	61	F	7	1-6	△	Both	○	No	L	NA	M	Yes	○	○	○	△	△
* Incineration	63	F	2,4,6	1,3,5	△	Both	■	No	L,S	■	T	Yes	■	○	■	○	△
Pyrolysis	65	P	2,4,6	1,3,5	△	Both	△	No	L,S	■	T	Yes	■	I	△	○	△
Other Processes																	
* Natural Attenuation	67	NA	3,4,5	1,2,6	■	Neither	■	No	None	I	T	Yes	△	■	○	△	△
Excavation and Off-Site Disposal	71	NA		1-7	△	Neither	■	No	NA	NA	M	No	■	■	■	△	■
GROUNDWATER																	
In Situ Biological Processes																	
Oxygen Enhancement with H_2O_2	73	F	3,4,5	1,2,6	○	O&M	■	No	None	■	T	Yes	○	△	■	○	■
Co-metabolic Processes	75	P	1,2	3-6	○	O&M	△	No	None	■	T	Yes	○	△	△	I	I
Nitrate Enhancement	77	P	3,4,5	1,2,6	■	Neither	△	No	None	■	T	Yes	○	○	△	△	○
Oxygen Enhancement with Air Sparging	79	F	3,4,5	1,2,6	■	Neither	■	No	None	■	T	Yes	○	■	○	○	■
In Situ Physical/Chemical Processes																	
* Slurry Walls (containment only)	81	F		1-7	■	Cap	■	NA	NA	NA	M	I	■	■	■	△	○
Passive Treatment Walls	83	P	1,2,7	3,4,5	I	Cap	△	No	S	I	T	I	△	I	△	I	I
Hot Water or Steam Flushing/Stripping	85	P	2,4,5	1,3	○	Cap	○	Yes	L,V	○	V	Yes	■	△	△	○	○
Hydrofracturing (enhancement)	87	P		1-7	○	Neither	I	Yes	None	NA	M	Yes	■	■	△	■	○
Air Sparging	89	F	1,3,5		■	Neither	■	Yes	V	○	V	Yes	■	■	○	■	■
Directional Wells (enhancement)	91	F		1-7	I	Neither	△	Yes	L,S	NA	NA	Yes	■	○	○	■	■
Dual Phase Extraction	93	F	1,3,5		○	O&M	■	Yes	L,V	○	V	Yes	○	○	■	○	■
Vacuum Vapor Extraction	95	P	1,2,5	3,4,6,7	○	Cap	△	No	L,V	■	V	Yes	○	■	△	○	■
* Free Product Recovery	97	F	4,5		■	Neither	■	No	L	NA	V	Yes	■	○	■	■	■
Ex Situ Biological Processes (assuming pumping)																	
Bioreactors	99	F	3,4,5	1,2,6	■	Cap	■	No	S	○	T	Yes	NA	○	○	■	○
Ex Situ Physical/Chemical Processes (assuming pumping)																	
* Air Stripping	101	F	1,3	2,4,5	■	O&M	■	No	L,V	■	V	Yes	NA	○	■	△	○
* Carbon Adsorption (liquid phase)	103	F	2,4	1,5-7	△	O&M	■	No	S	■	V	Yes	NA	■	■	■	■
UV Oxidation	105	F	1,2,6	3,5	○	Cap	■	No	None	■	T	Yes	NA	△	○	○	○
Other Processes																	
* Natural Attenuation	107	NA	3,4,5	1,2,6	■	Neither	■	No	None	I	T	Yes	△	■	○	△	△
AIR EMISSIONS/OFF-GAS TREATMENT																	
* Carbon Adsorption (vapor phase)	111	F	1-6		■	Neither	■	NA[b]	S	■	V	Yes	NA	■	■	○	■
* Catalytic Oxidation (non-halogenated)	113	F	3,4,5		■	Neither	■		None	■	T	Yes	NA	■	■	■	■
Catalytic Oxidation (halogenated)	115	F	1,2		■	Neither	○		None	■	T	Yes	NA	○	△	○	○
Biofiltration	117	F	3,5	1	■	Neither	○		None	■	T	Yes	NA	○	△	I	I
* Thermal Oxidation	119	F	3,4,5		■	Neither	■		None	■	T	Yes	NA	■	■	■	○

[a] The listing of contaminant groups is intended as a general reference only. A technology may treat only selected compounds within the contaminant groups listed. Further investigation is necessary to determine applicability to specific contaminants.

[b] The definition of this factor is not applicable to these technologies. They are, by design, the final step in treatment processes.

* Conventional technologies/processes

Contaminant Codes

1 - Halogenated volatile organics
2 - Halogenated semivolatile organics
3 - Non-halogenated volatile organics
4 - Non-halogenated semivolatile organics
5 - Fuel hydrocarbons
6 - Pesticides
7 - Inorganics

Target contaminants are listed first and in bold type

Rating Codes

■ Better
○ Average
△ Worse
I Inadequate information
NA Not applicable

oxidation states in compounds: important, most important (for easier reading, arabic numerals are used instead of the correct roman ones)

electron configuration

atomic number

name (IUPAC)

- element essential to all biological species investigated
- essential to at least one biological species
- biological function suggested
- ( ) essential to humans
- ○ suggested to be essential to humans

atomic radius in pm (half the interatomic distance for the element; α-Fe in this example)
covalent radius for single bonds in pm (after Pauling; radii for polar and multiple bonds are shorter)
ionic radius in pm with oxidation number / coordination number (Cr, Mn, Fe, Co: values for high-spin complexes)
van der Waals radius in pm

reduction potential E° in V with number (n) of electrons for:

$E^{n+} + ne^- \rightleftarrows E(s)$ (metals)

$E + ne^- \rightleftarrows E^{n-}$

$EO_{n/2} + nH^+ + ne^- \rightleftarrows E(s) + n/2\ H_2O$

$1/2\ O_2(g) + 2H^+ + 2e^- \rightleftarrows H_2O(l)$

electronegativity (Allred and Rochow)

abundance (mass fraction in %) of the element in the earth's lithosphere (upper 16 km) plus hydrosphere (oceans) plus atmosphere; mass fraction calculated from natural radioactive series or other natural nuclear reactions

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A IA	2A IIA	3A IIIB	4A IVB	5A VB	6A VIB	7A VIIB	8 VIII	8 VIII	8 VIII	1B IB	2B IIB	3B IIIA	4B IVA	5B VA	6B VIA	7B VIIA	0 VIIIA
1s 1, −1 37.3 30 0 (1, g) 1 **H** Hydrogen ● 0.88																	1s² 2 **He** Helium 4·10⁻⁷
[He] 2s 1 152 123 3 0.4(1) 3 **Li** Lithium ● 6·10⁻⁶	[He] 2s² 111.3 89 −1.85(2) 4 **Be** Beryllium 5·10⁻⁶											[He] 2s² 2p 3 79.5 81 5 **B** Boron ● 2·10⁻⁶	[He] 2s² 2p² 4, 2, −4 77.2 d 77 6 **C** Carbon ◉ 2.5 0.09	[He] 2s² 2p³ 5, 4, 3, 2, −3 54.9 70 7 **N** Nitrogen ◉ 0.03	[He] 2s² 2p⁴ −2, −1 60.4 66 8 **O** Oxygen ◉ 49.4	[He] 2s² 2p⁵ −1 70.9 64 9 **F** Fluorine ◉ 0.03	[He] 2s² 2p⁶ 10 **Ne** Neon 5·10⁻⁷
[Ne] 3s 1 185.8 157 −2.71(1) 11 **Na** Sodium ◉ 2.64	[Ne] 3s² 159.9 136 −2.372(2) 12 **Mg** Magnesium ◉ 1.94											[Ne] 3s² 3p 3 143.2 125 −1.662(3) 13 **Al** Aluminium 7.57	[Ne] 3s² 3p² 4, −4 117.6 117 14 **Si** Silicon ◉ 25.8	[Ne] 3s² 3p³ 5, 3, −3 110.5w 110 15 **P** Phosphorus ◉ 0.09	[Ne] 3s² 3p⁴ 6, 4, 2, −2 103.5 104 16 **S** Sulfur ◉ 0.05	[Ne] 3s² 3p⁵ 7, 5, 3, 1, −1 99.4 99 17 **Cl** Chlorine ◉ 0.19	[Ne] 3s² 3p⁶ 18 **Ar** Argon 4·10⁻⁷
[Ar] 4s 1 227.2 203 −2.93(1) 19 **K** Potassium ◉ 2.4	[Ar] 4s² 197.4 174 2.87(2) 20 **Ca** Calcium ◉ 3.39	[Ar] 3d 4s² 3 160.6 144 −2.077(3) 21 **Sc** Scandium 5·10⁻⁴	[Ar] 3d² 4s² 4, 3 144.8 132 −1.63(2) 22 **Ti** Titanium 0.41	[Ar] 3d³ 4s² 5, 4, 3, 2, 0 131.1 122 −1.175(2) 23 **V** Vanadium ◉ 0.01	[Ar] 3d⁵ 4s 6, 3, 2, 0 124.9 118 −0.744(3) 24 **Cr** Chromium ◉ 0.02	[Ar] 3d⁵ 4s² 7, 6, 4, 3, 2, 0, −1 136.7 118 −1.185(2) 25 **Mn** Manganese ◉ 0.09	[Ar] 3d⁶ 4s² 6, 3, 2, 0, −2 124.1 116 −0.447(2) 26 **Fe** Iron ◉ 4.7	[Ar] 3d⁷ 4s² 3, 2, 0, −1 125.3 116 −0.28(2) 27 **Co** Cobalt ◉ 4·10⁻⁵	[Ar] 3d⁸ 4s² 3, 2, 0 124.6 115 −0.257(2) 28 **Ni** Nickel ◉ 0.01	[Ar] 3d¹⁰ 4s 2, 1 127.8 117 0.342(2) 29 **Cu** Copper ◉ 0.01	[Ar] 3d¹⁰ 4s² 2 133.5 125 −0.762(2) 30 **Zn** Zinc ◉ 0.01	[Ar] 3d¹⁰ 4s² 4p 3 122.1 125 −0.56(3) 31 **Ga** Gallium 1.8·10⁻⁵	[Ar] 3d¹⁰ 4s² 4p² 4 122.5 122 0.24(2) 32 **Ge** Germanium 6·10⁻⁴	[Ar] 3d¹⁰ 4s² 4p³ 5, 3, −3 124.5g 121 33 **As** Arsenic ◉ 6·10⁻⁴	[Ar] 3d¹⁰ 4s² 4p⁴ 6, 4, −2 116 117 34 **Se** Selenium ◉ 8·10⁻⁵	[Ar] 3d¹⁰ 4s² 4p⁵ 7, 5, 3, 1, −1 114.5 114 35 **Br** Bromine ● 6·10⁻⁶	[Ar] 3d¹⁰ 4s² 4p⁶ 2 36 **Kr** Krypton 2·10⁻⁷
[Kr] 5s 1 247.5 216 −2.98(1) 37 **Rb** Rubidium ● 0.03	[Kr] 5s² 215.1 191 −2.89(2) 38 **Sr** Strontium ● 0.01	[Kr] 4d 5s² 3 177.6 162 −2.372(3) 39 **Y** Yttrium 3·10⁻⁵	[Kr] 4d² 5s² 1 159.0 145 −1.099(3) 40 **Zr** Zirconium 0.02	[Kr] 4d³ 5s 5, 3 142.9 134 41 **Nb** Niobium 2·10⁻⁷	[Kr] 4d⁵ 5s 6, 5, 4, 3, 2, 0 136.3 130 −0.200(3) 42 **Mo** Molybdenum ◉ 1.3·10⁻⁵	[Kr] 4d⁵ 5s 7 135.2 127 0.400(2) 43 **Tc** Technetium 1.4·10⁻¹⁰	[Kr] 4d⁷ 5s 8, 6, 4, 3, 2, 0, −2 132.5 125 0.455(2) 44 **Ru** Ruthenium 2·10⁻⁶	[Kr] 4d⁸ 5s 5, 4, 3, 1, 2, 0 134.5 125 0.758(3) 45 **Rh** Rhodium 1.5·10⁻⁷	[Kr] 4d¹⁰ 4, 2, 0 137.6 128 0.951(2) 46 **Pd** Palladium 1.4·10⁻⁶	[Kr] 4d¹⁰ 5s 2, 1 144.5 134 0.800(1) 47 **Ag** Silver 1.1·10⁻⁵	[Kr] 4d¹⁰ 5s² 2 148.9 141 −0.403(2) 48 **Cd** Cadmium ● 3·10⁻⁵	[Kr] 4d¹⁰ 5s² 5p 3 162.6 150 −0.338(3) 49 **In** Indium 1.5·10⁻⁵	[Kr] 4d¹⁰ 5s² 5p² 4, 2 140.5 140 −0.138(2) 50 **Sn** Tin 3·10⁻³	[Kr] 4d¹⁰ 5s² 5p³ 5, 3, −3 145 141 51 **Sb** Antimony 7·10⁻⁵	[Kr] 4d¹⁰ 5s² 5p⁴ 6, 4, −2 143.2 137 52 **Te** Tellurium 10⁻⁵	[Kr] 4d¹⁰ 5s² 5p⁵ 7, 5, 1, −1 133.1 133 53 **I** Iodine ◉ 6·10⁻⁶	[Kr] 4d¹⁰ 5s² 5p⁶ 2, 4, 6 54 **Xe** Xenon 2·10⁻⁷
[Xe] 6s 1 268.5 253 2.92(1) 55 **Cs** Caesium 6·10⁻⁶	[Xe] 6s² 217.3 198 2.912(7) 56 **Ba** Barium ● 0.03	57 to 71 **La – Lu**	[Xe] 4f¹⁴ 5d² 6s² 1 156.4 144 72 **Hf** Hafnium 4·10⁻⁷	[Xe] 4f¹⁴ 5d³ 6s² 5 143.0 134 73 **Ta** Tantalum 8·10⁻⁷	[Xe] 4f¹⁴ 5d⁴ 6s² 6, 5, 4, 3, 2, 0 137 130 74 **W** Tungsten ● 6·10⁻⁷	[Xe] 4f¹⁴ 5d⁵ 6s² 7, 6, 4, 2, −1 137.1 128 75 **Re** Rhenium 10⁻⁷	[Xe] 4f¹⁴ 5d⁶ 6s² 8, 6, 4, 3, 2, 0, −2 133.8 126 76 **Os** Osmium 10⁻⁶	[Xe] 4f¹⁴ 5d⁷ 6s² 6, 4, 3, 2, 1, 0, −1 135.7 127 1.156(3) 77 **Ir** Iridium 10⁻⁷	[Xe] 4f¹⁴ 5d⁸ 6s² 4, 2, 0 137.3 130 1.118(2) 78 **Pt** Platinum 5·10⁻⁷	[Xe] 4f¹⁴ 5d¹⁰ 6s 3, 1 144.2 134 1.498(3) 79 **Au** Gold 5·10⁻⁷	[Xe] 4f¹⁴ 5d¹⁰ 6s² 2, 1 159.3 144 0.851(2) 80 **Hg** Mercury 4·10⁻⁵	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p 3, 1 170.0 155 −0.336(1) 81 **Tl** Thallium 3·10⁻⁵	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p² 4, 2 175.0 154 −0.1262(2) 82 **Pb** Lead ● 2·10⁻⁵	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p³ 5, 3 154.5 146 0.23(3) 83 **Bi** Bismuth 2·10⁻⁵	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁴ 6, 4, 2 167.3 146 84 Polonium	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁵ 7, 5, 3, 1, −1 145 85 Astatine	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁶ 2 86 Radon
[Rn] 7s 1 87 Francium	[Rn] 7s² 2.92(2) 88 Radium	89 to 103 **Lr**	[Rn] 5f¹⁴ 6d² 7s² 104 Unq	[Rn] 5f¹⁴ 6d³ 7s² 105 Unp	[Rn] 5f¹⁴ 6d⁴ 7s² 106 Unh	107 Uns	108 Uno	109 Une									

6	[Xe] 5d 6s² 3 187.0 169 −2.522(3) 57 **La** Lanthanum 2·10⁻⁵	[Xe] 4f² 6s² 4, 3 182.5 165 −2.483(3) 58 **Ce** Cerium 4·10⁻⁵	[Xe] 4f³ 6s² 4, 3 182.0 165 −2.35(3) 59 **Pr** Praseodymium 5·10⁻⁶	[Xe] 4f⁴ 6s² 3 181.4 164 −2.431(3) 60 **Nd** Neodymium 2·10⁻⁵	[Xe] 4f⁵ 6s² 3 163 −2.29(3) 61 **Pm** Promethium 10⁻¹⁸	[Xe] 4f⁶ 6s² 3, 2 162.9 113 −2.30(3) 62 **Sm** Samarium 8·10⁻⁶	[Xe] 4f⁷ 6s² 3, 2 199.5 185 −2.407(3) 63 **Eu** Europium 10⁻⁵	[Xe] 4f⁷ 5d 6s² 3 178.7 161 −2.29(3) 64 **Gd** Gadolinium 6·10⁻⁶	[Xe] 4f⁹ 6s² 4, 3 176.3 159 −2.30(3) 65 **Tb** Terbium 9·10⁻⁵	[Xe] 4f¹⁰ 6s² 3 175.2 159 −2.29(3) 66 **Dy** Dysprosium 4·10⁻⁶	[Xe] 4f¹¹ 6s² 3 174.3 158 −2.33(3) 67 **Ho** Holmium 10⁻⁶	[Xe] 4f¹² 6s² 3 173.4 157 −2.31(3) 68 **Er** Erbium 2·10⁻⁶	[Xe] 4f¹³ 6s² 3, 2 172.4 156 −2.31(3) 69 **Tm** Thulium 2·10⁻⁵	[Xe] 4f¹⁴ 6s² 3, 2 194.0 174 −2.22(3) 70 **Yb** Ytterbium 3·10⁻⁶	[Xe] 4f¹⁴ 5d 6s² 3 171.8 156 −2.30(3) 71 **Lu** Lutetium 7·10⁻⁵
7	[Rn] 6d 7s² 3 187.8 −2.13(3) 89 Actinium	[Rn] 6d² 7s² 4 179.8 165 −1.90(4) 90 **Th** Thorium 10⁻⁵	[Rn] 5f² 6d 7s² 5, 4 156.1 −1.49(3) 91 **Pa** Protactinium 9·10⁻⁷	[Rn] 5f³ 6d 7s² 6, 5, 4, 3 138.5 142 −1.798(3) 92 **U** Uranium 3·10⁻⁶	[Rn] 5f⁴ 6d 7s² 6, 5, 4, 3 130.0 137 −1.856(3) 93 **Np** Neptunium 4·10⁻¹²	[Rn] 5f⁶ 7s² 6, 5, 4, 3 151.9 175 −2.031(3) 94 **Pu** Plutonium 2·10⁻¹⁸	[Rn] 5f⁷ 7s² 6, 5, 4, 3 185 −2.07(3) 95 **Am** Americium	[Rn] 5f⁷ 6d 7s² 4, 3 185 −2.06(3) 96 **Cm** Curium	[Rn] 5f⁹ 7s² 4, 3 183 −1.97(3) 97 **Bk** Berkelium	[Rn] 5f¹⁰ 7s² 4, 3 181 −2.01(3) 98 **Cf** Californium	[Rn] 5f¹¹ 7s² 3 −1.98(3) 99 **Es** Einsteinium	[Rn] 5f¹² 7s² 3 −1.95(3) 100 **Fm** Fermium	[Rn] 5f¹³ 7s² 3 −1.66(3) 101 **Md** Mendelevium	[Rn] 5f¹⁴ 7s² 3, 2 −1.78(3) 102 **No** Nobelium	[Rn] 5f¹⁴ 6d 7s² 3 −2.06(3) 103 **Lr** Lawrencium

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oxidation states in compounds: important, most important (for easier reading, arabic numerals are used instead of the correct roman ones)

electron configuration

atomic number

name (IUPAC)

- element essential to all biological species investigated
- essential to at least one biological species
- biological function suggested
- ( ) essential to humans
- ○ suggested to be essential to humans

atomic radius in pm (half the interatomic distance for the element; α-Fe in this example)
covalent radius for single bonds in pm (after Pauling; radii for polar and multiple bonds are shorter)
ionic radius in pm with oxidation number / coordination number (Cr, Mn, Fe, Co: values for high-spin complexes)
van der Waals radius in pm

reduction potential E° in V with number (n) of electrons for:

$E^{n+} + ne^- \rightleftarrows E(s)$ (metals)

$E + ne^- \rightleftarrows E^{n-}$

$EO_{n/2} + nH^+ + ne^- \rightleftarrows E(s) + n/2\ H_2O$

$1/2\ O_2(g) + 2H^+ + 2e^- \rightleftarrows H_2O(l)$

electronegativity (Allred and Rochow)

abundance (mass fraction in %) of the element in the earth's lithosphere (upper 16 km) plus hydrosphere (oceans) plus atmosphere; mass fraction calculated from natural radioactive series or other natural nuclear reactions

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A IA	2A IIA	3A IIIB	4A IVB	5A VB	6A VIB	7A VIIB	8 VIII	8 VIII	8 VIII	1B IB	2B IIB	3B IIIA	4B IVA	5B VA	6B VIA	7B VIIA	0 VIII
1s; 1, −1; 37.3; 30; 0.11, 0																	1s²
1 H Hydrogen ●																	2 He Helium
[He] 2s; 1; 152; 123; −3.04(1)	[He] 2s²; 111.3a; 89; −1.85(2)											[He] 2s² 2p; 3; 79.5; 81; 1.1; 10⁻⁵	[He] 2s² 2p²; 4, 2, −4; 77.2d; 77; 1.5; 15⁻⁴	[He] 2s² 2p³; 5, 4, 3, 2, −3; 54.9; 70; 1.0; 10⁻⁴	[He] 2s² 2p⁴; −2, −1; 50.4; 66; 3.5; 118⁻²	[He] 2s² 2p⁵; −1; 70.9; 64; 3.9; 133⁻¹	[He] 2s² 2p⁶
3 Li Lithium ●	4 Be Beryllium											5 B Boron ●	6 C Carbon ◉	7 N Nitrogen ◉	8 O Oxygen ◉	9 F Fluorine ◉	10 Ne Neon
[Ne] 3s; 1; 185.8; 157; −2.71(1)	[Ne] 3s²; 159.9; 136; −2.372(2)											[Ne] 3s² 3p; 3; 143.2; 125; 2.0; 54⁻⁴; −1.662(3)	[Ne] 3s² 3p²; 4, −4; 117.6; 117; 1.7; 40⁻⁴	[Ne] 3s² 3p³; 5, 3, −3; 110.5w; 110; 2.1; 10⁻⁴	[Ne] 3s² 3p⁴; 6, 4, 2, −2; 103.5; 104; 2.4; 184⁻²	[Ne] 3s² 3p⁵; 7, 5, 3, 1, −1; 99.4; 99; 2.8; 181⁻¹	[Ne] 3s² 3p⁶
11 Na Sodium ●	12 Mg Magnesium ◉											13 Al Aluminium	14 Si Silicon ◉	15 P Phosphorus ◉	16 S Sulfur ◉	17 Cl Chlorine ◉	18 Ar Argon
[Ar] 4s; 1; 227.2; 203; −2.93(1)	[Ar] 4s²; 197.4a; 174; 2.87(2)	[Ar] 3d 4s²; 3; 160.6; 144; −2.077(3)	[Ar] 3d² 4s²; 1, 3; 144.8a; 132; −1.63(2)	[Ar] 3d³ 4s²; 5, 4, 3, 2, 0; 131.1; 122; 1.6; 39⁻¹; −1.175(2)	[Ar] 3d⁵ 4s; 6, 3, 2, 0; 124.9a; 118; 1.6; 64⁻¹; −0.744(3)	[Ar] 3d⁵ 4s²; 7, 6, 4, 3, 2, 0, −1; 136.7γ; 118; 1.6; 83⁻²; −1.185(2)	[Ar] 3d⁶ 4s²; 6, 3, 2, 0, −2; 124.1a; 116; 1.6; 78⁻²; −0.447(2)	[Ar] 3d⁷ 4s²; 3, 2, 0, −1; 125.3; 116; 1.7; 75⁻²; −0.28(2)	[Ar] 3d⁸ 4s²; 3, 2, 0; 124.6; 115; 1.8; 69⁻²; −0.257(2)	[Ar] 3d¹⁰ 4s; 2, 1; 127.8; 117; 1.9; 46⁺¹; 0.342(2)	[Ar] 3d¹⁰ 4s²; 2; 133.5; 125; 1.6; 73⁻²; −0.762(2)	[Ar] 3d¹⁰ 4s² 4p; 3; 122.1; 125; 1.8; 62⁻³; −0.56(3)	[Ar] 3d¹⁰ 4s² 4p²; 4; 122.5; 122; 2.1; 53⁻⁴; 0.24(2)	[Ar] 3d¹⁰ 4s² 4p³; 5, 3, −3; 124.5g; 121; 2.4; 58⁻³; 0.3(3)	[Ar] 3d¹⁰ 4s² 4p⁴; 6, 4, −2; 116; 117; 2.5; 198⁻²; 0.9(2)	[Ar] 3d¹⁰ 4s² 4p⁵; 7, 5, 3, 1, −1; 114.5; 114; 2.8; 196⁻¹	[Ar] 3d¹⁰ 4s² 4p⁶
19 K Potassium ●	20 Ca Calcium ◉	21 Sc Scandium	22 Ti Titanium	23 V Vanadium ◉	24 Cr Chromium ◉	25 Mn Manganese ◉	26 Fe Iron ◉	27 Co Cobalt ◉	28 Ni Nickel ◉	29 Cu Copper ◉	30 Zn Zinc ◉	31 Ga Gallium	32 Ge Germanium	33 As Arsenic ◉	34 Se Selenium ◉	35 Br Bromine ●	36 Kr Krypton
[Kr] 5s; 1; 247.5; 216; −2.98(1)	[Kr] 5s²; 215.1a; 191; −2.89(2)	[Kr] 4d 5s²; 3; 177.6; 162; −2.372(3)	[Kr] 4d² 5s²; 1; 159.0; 145; −1.099(3)	[Kr] 4d³ 5s; 5, 3; 142.9; 134; 1.5; 61⁻³; −0.200(3)	[Kr] 4d⁵ 5s; 6, 5, 4, 3, 2, 0; 136.3; 130; 1.8; 64⁻¹; 0.455(2)	[Kr] 4d⁶ 5s; 7; 135.2; 127; 1.9; 56⁻²; 0.400(2)	[Kr] 4d⁷ 5s; 8, 6, 4, 3, 2, 0, −2; 132.5; 125; 2.2; 68⁺²; 0.455(2)	[Kr] 4d⁸ 5s; 5, 4, 3, 1, 2, 0; 134.5; 125; 2.2; 67⁺³; 0.758(3)	[Kr] 4d¹⁰; 4, 2, 0; 137.6; 128; 2.2; 86⁺²; 0.951(2)	[Kr] 4d¹⁰ 5s; 2, 1; 144.5; 134; 1.9; 63⁺¹; 0.800(1)	[Kr] 4d¹⁰ 5s²; 2; 148.9; 141; 1.7; 95⁺²; −0.403(2)	[Kr] 4d¹⁰ 5s² 5p; 3; 162.6; 150; 1.7; 80⁺³; −0.338(3)	[Kr] 4d¹⁰ 5s² 5p²; 4, 2; 140.5a; 140; 1.8; 69⁺⁴; −0.138(2)	[Kr] 4d¹⁰ 5s² 5p³; 5, 3, −3; 145; 141; 1.9; 76⁻³; 0.7(3)	[Kr] 4d¹⁰ 5s² 5p⁴; 6, 4, −2; 143.2; 137; 2.0; 221⁻²; 1.9(2)	[Kr] 4d¹⁰ 5s² 5p⁵; 7, 5, 1, −1; 133.1; 133; 2.2; 220⁻¹; 3.1(3)	[Kr] 4d¹⁰ 5s² 5p⁶
37 Rb Rubidium ●	38 Sr Strontium ●	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum ◉	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium ●	49 In Indium	50 Sn Tin ◉	51 Sb Antimony	52 Te Tellurium	53 I Iodine ◉	54 Xe Xenon
[Xe] 6s; 1; 265.5; 253; −2.92(1)	[Xe] 6s²; 217.4; 198; −2.912(2)	57 to 71	[Xe] 4f¹⁴ 5d² 6s²; 1; 156.4a; 144; 1.3; 71⁻⁴	[Xe] 4f¹⁴ 5d³ 6s²; 5; 143.0; 134; 1.5; 68⁻³	[Xe] 4f¹⁴ 5d⁴ 6s²; 6, 5, 4, 3, 2, 0; 137; 130; 1.7; 66⁻¹	[Xe] 4f¹⁴ 5d⁵ 6s²; 7, 6, 4, 2, −1; 137.1; 128; 1.9; 63⁻¹; 0.9(4)	[Xe] 4f¹⁴ 5d⁶ 6s²; 8, 6, 4, 3, 2, 0, −2; 133.8; 126; 2.2; 63⁻²; 0.8(4)	[Xe] 4f¹⁴ 5d⁷ 6s²; 6, 4, 3, 2, 1, 0, −1; 135.7; 127; 2.2; 68⁻¹; 1.156(3)	[Xe] 4f¹⁴ 5d⁹ 6s; 4, 2, 0; 137.3; 130; 2.2; 60⁺²; 1.118(2)	[Xe] 4f¹⁴ 5d¹⁰ 6s; 3, 1; 144.2; 134; 1.9; 137⁺¹; 1.498(3)	[Xe] 4f¹⁴ 5d¹⁰ 6s²; 2, 1; 150.3; 144; 1.7; 119⁺²; 0.851(2)	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p; 3, 1; 170.0a; 155; 2.0; 80⁺³; −0.336(1)	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p²; 4, 2; 175.0; 154; 2.2; 119⁺⁴; −0.1262(2)	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p³; 5, 3; 154.5; 146; 2.0; 96⁻³; 0.23(3)	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁴; 6, 4, 2; 167.3a; 146; 2.2; 221⁻²	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁵; 7, 5, 3, 1, −1; 145; 2.2; 62⁻¹	[Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁶
55 Cs Caesium	56 Ba Barium ●		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten ●	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead ●	83 Bi Bismuth	84 Polonium	85 Astatine	86 Radon
[Rn] 7s; 1; 270; 260; 2.92(2)	[Rn] 7s²; 2.92(2)	89 to 103	[Rn] 5f¹⁴ 6d² 7s²; 2; 156a; 144; 1.3; 86⁻⁴	[Rn] 5f¹⁴ 6d³ 7s²; 5; 149; 134; 1.5; 75⁻³	[Rn] 5f¹⁴ 6d⁴ 7s²; 6, 5, 4, 3, 2, 0; 137; 130; 1.7; 75⁻¹												
87 Francium	88 Radium		104 Unnilquadium	105 Unnilpentium	106 Unnilhexium	107 Unnilseptium	108 Unniloctium	109 Unnilennium									

6	[Xe] 5d 6s²; 3; 187.0a; 169; −2.522(3); 57 La Lanthanum	[Xe] 4f² 6s²; 4, 3; 182.5; 165; −2.483(3); 58 Ce Cerium	[Xe] 4f³ 6s²; 4, 3; 182.0a; 165; −2.35(3); 59 Pr Praseodymium	[Xe] 4f⁴ 6s²; 3; 181.4; 164; −2.431(3); 60 Nd Neodymium	[Xe] 4f⁵ 6s²; 3; 163; −2.29(3); 61 Pm Promethium	[Xe] 4f⁶ 6s²; 3, 2; 162.9a; 185; −2.30(3); 62 Sm Samarium	[Xe] 4f⁷ 6s²; 3, 2; 199.5; 185; −2.407(3); 63 Eu Europium	[Xe] 4f⁷ 5d 6s²; 3; 178.7; 161; −2.29(3); 64 Gd Gadolinium	[Xe] 4f⁹ 6s²; 4, 3; 176.3; 159; −2.30(3); 65 Tb Terbium	[Xe] 4f¹⁰ 6s²; 3; 175.2; 159; −2.29(3); 66 Dy Dysprosium	[Xe] 4f¹¹ 6s²; 3; 174.3; 158; −2.33(3); 67 Ho Holmium	[Xe] 4f¹² 6s²; 3; 173.4; 157; −2.31(3); 68 Er Erbium	[Xe] 4f¹³ 6s²; 3, 2; 172.4; 156; −2.31(3); 69 Tm Thulium	[Xe] 4f¹⁴ 6s²; 3, 2; 191.0; 174; −2.22(3); 70 Yb Ytterbium	[Xe] 4f¹⁴ 5d 6s²; 3; 171.8; 156; −2.30(3); 71 Lu Lutetium
7	[Rn] 6d 7s²; 3; 187.8; −2.13(3); 89 Actinium	[Rn] 6d² 7s²; 4; 179.8a; 165; −1.90(4); 90 Thorium	[Rn] 5f² 6d 7s²; 5, 4; 156.1; −1.49(3); 91 Protactinium	[Rn] 5f³ 6d 7s²; 6, 5, 4, 3; 138.5a; 142; −1.798(3); 92 Uranium	[Rn] 5f⁴ 6d 7s²; 6, 5, 4, 3; 130.0a; 131; −1.856(3); 93 Np Neptunium	[Rn] 5f⁶ 7s²; 6, 5, 4, 3; 151.3γ; −2.031(3); 94 Pu Plutonium	[Rn] 5f⁷ 7s²; 6, 5, 4, 3; −2.07(3); 95 Am Americium	[Rn] 5f⁷ 6d 7s²; 4, 3; −2.06(3); 96 Cm Curium	[Rn] 5f⁹ 7s²; 4, 3; −1.97(3); 97 Bk Berkelium	[Rn] 5f¹⁰ 7s²; 4, 3; −2.01(3); 98 Cf Californium	[Rn] 5f¹¹ 7s²; 3; −1.98(3); 99 Es Einsteinium	[Rn] 5f¹² 7s²; 3; −1.95(3); 100 Fm Fermium	[Rn] 5f¹³ 7s²; 3; −1.66(3); 101 Md Mendelevium	[Rn] 5f¹⁴ 7s²; 3; −1.78(3); 102 No Nobelium	[Rn] 5f¹⁴ 6d 7s²; 3; −2.06(3); 103 Lr Lawrencium

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ENVIRONMENTAL SITE ASSESSMENT (ESA) aka Phase I

The process by which a person or entity seeks to determine if a particular parcel or real property is subject to any *RECOGNIZED ENVIRONMENTAL CONDITIONS.*

"Recognized environmental conditions is defined as the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat or a release of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater, or surface water of the property."

Objectives:

- **locate onsite recognized environmental conditions associated with present or past practices involving use, storage, or disposal of hazardous materials**
- **locate offsite recognized environmental conditions that could or are currently migrating onto subject site**
- **determine potential liabilities from offsite contamination on neighboring properties.**

Four Components:

• Records Review • Interviews • Site Visit • Report

1) Records Review

- EHS/Leaking Underground Storage Tank (LUST)
- RWQCB - Notice of Violations
- DTSC/HWLIST - Releases of Hazardous Waste
- CERCLIS - Comprehensive Environmental Response, Compensation and Liability Information System - EPA
- NPL - National Priorities List - EPA

Approximate Minimum Search Distance (miles)

- Federal NPL site list 1.0
- Federal CERCLIS list 0.5
- Federal RCRA RSD ..... property/adjoining properties
  facilities list
- Federal ERNS list ..... property only
- State lists of hazardous waste sites 1.0
  or remediation (NPL and CERCLIS equivalents)
- State landfill and/or solid waste 0.5
  disposal site lists
- State leaking UST lists 0.5
- State registered ..... property/adjoining properties
  UST Lists

2) Site Visit

Visually and physically observe the property and any structure(s) located on the property.

- **Current uses of adjoining properties**
- **Evidence of past uses of the property**
- **Current uses of the property**
- **Topographic conditions of the property**
- **Storage tanks - appurtenances**
- **Odors**
- **Pools of liquid**
- **Drums**
- **Pits, ponds, lagoons**
- **Stained or soiled pavement**
- **Stressed vegetation - other than lack of water**

3) Interviews

Obtain information indicating recognized environmental conditions in connection with the property.

- **Site Manager (identify prior to site visit) asked if there are any of the following documents available:**
  - **Environmental Site Assessments**
  - **Environmental Audits**
  - **Environmental Permits (i.e. Solid Waste Disposal, Hazardous Waste Disposal, Wastewater, NPDES)**
  - **Registration for underground or above ground storage tanks**
  - **Material Safety Data Sheets - MSDS**
  - **Community Right-to-Know Plan**
  - **Safety Plans - Spill Prevention Countermeasure and Control Plans SPCC**
  - **Notices or correspondence from any government agency relating to past or current violations of environmental laws**
  - **Geotechnical Studies**
  - **Any proceedings involving the property: past, pending or threatened litigation relevant to recognized environmental conditions**

3) Interviews - Cont'd

- **Local Government Officials**
  - **Fire department that serves property**
  - **Local office of State Health Department**
  - **Local office of Environmental Health Services (EHS)**
  - **Regional Water Quality Control Board (RWQCB)**
  - **Air Pollution Control District (APCD)**

4) Report

- Report Format
  - Site Ownership
    - Physical setting using USGS 7.5 mm topo map
    - Physical setting using information from site visit
  - Historical Uses
  - Surrounding Properties - current & historical uses
  - Sensitive Receptors
    - wells, surface water, residences
  - Regulatory Compliance Issues
    - permits, USTs, transfer storage disposal facilities