



Air-Force Wide Occurrence of Emerging COCs in Groundwater & Soil



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Introduction

Various federal and state regulatory agencies have identified an expanding list of emerging contaminants of concern (ECOCs). Some of these ECOCs include: perchlorate, NDMA, RDX, 1,4-dioxane, 1,2,3-trichloropropane, methyl *tert*-butyl ether (MTBE), polybrominated diphenyl ethers (PBDEs), bis(2-ethylhexyl)phthalate or BEHP, hexavalent chromium, and naphthalene. Little is known about some of these constituents from a risk viewpoint. Some are unregulated and some are naturally occurring. A challenging issue for environmental managers, is how widespread are they in the environment and do the levels require programs and funding to manage risk or cleanup. This study identified about 100 emerging COCs from a review of the literature. They make up about a third of the 300 constituents that have been detected in community water supply systems across the U.S. Constituent categories include: pesticides, solvents, petroleum fuel components, munitions/explosives, metals, polynuclear aromatic hydrocarbons (PAHs), dioxins/furans, radiological chemicals, and others.



Fig. 1. Aerial photo of Brooks-City Base, Texas. The typical Air Force base covers about 5,000 acres (20 km²), has a flightline, and stores mostly fuels and solvents typical of a large industrial complex.

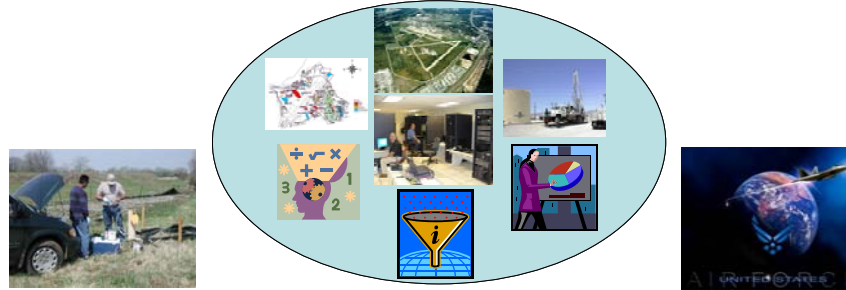
The objective of this study is to address: 1) the spatial distribution and frequency of detection of the emerging COCs across the Air Force both in groundwater and soil, 2) representative levels detected at Air Force installations that will be insightful for innovative cleanup technologies, 3) the tendency for detected levels to exceed EPA Region 9 Preliminary Remediation Goals (PRGs), and 4) identification of other constituents frequently detected at installations that could be of *potential* interest to the Air Force.

What is an Emerging COC?

- Perceived as an environmental threat
- Known or anticipated to occur at waste sites
- May not be commonly monitored
- May not be regulated
- Limited risk data is available (i.e. PRGs)
- Environmental criteria are evolving

What are Some of the More Commonly Recognized Emerging COCs?

- Perchlorate
- 1,4-Dioxane
- NDMA
- RDX
- MTBE
- Polybrominated diphenyl ethers (PBDEs)
- Chromium (VI)
- Naphthalene
- 1,2,3-Trichloropropane



Objectives

- Spatial distribution and frequency of detection of emerging COCs across the Air Force
- Summary of concentrations detected for selected emerging COCs
- Tendency for detected concentrations to exceed environmental criteria
- Identification of *additional* chemicals of *potential* interest to the Air Force

Categories of Emerging COCs

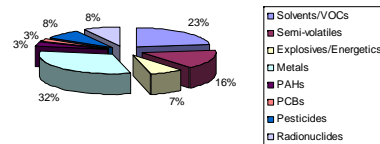


Fig. 2. The list of emerging COCs derived from the environmental literature subdivided by contaminant categories.

Methods

The analysis was based on querying the Air Force's Environmental Resources Program Information Management System (ERPIMS), a large central database that has approximately 45 million analytical records. Information derived from the ERPIMS database in this study includes data gathered from 160 installations, about 6500 sites, 42,000 wells, and 45,000 boreholes. It is one of the largest environmental databases in the US and perhaps the world.

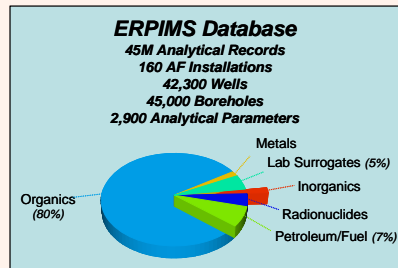


Fig. 3. The ERPIMS database stores analytical results on about 3,000 parameters. Most of the analytical data pertains to organics and petroleum-related compounds such as fuels.



Fig 4. The ERPIMS database stores data on a Sun Microsystems Solaris® computer.

About half of the analytes sampled for across the Air Force are detected. Slightly more constituents are sampled for and detected in soil versus groundwater. Over 1,000 constituents have been detected Air-Force wide in groundwater and soil.

All Analytes Sampled & Detected Air-Force Wide By Media

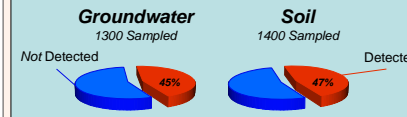


Fig. 5. Summary of all detects and non-detects in groundwater and soil for all constituents sampled at Air Force installations.

Several internet resources were reviewed to derive the list of about 100 emerging COCs including: U.S. EPA Drinking Water Contaminant Candidate List 2, the U.S. Geological Survey, the Environmental Council of the States (ECOS), and the Department of Defense (Materials of Evolving Regulatory Interest Team [MERIT]). About half of these COCs fell into two broad categories: 1) solvents and volatile organic compounds (VOCs), and 2) metals.



Fig. 6. Example of direct push technology for capturing soil and groundwater data.

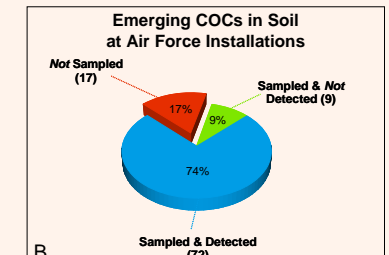
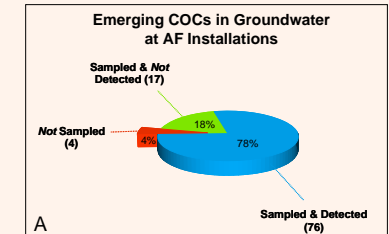
Analysis

The list of emerging COCs was compared to what has been detected at Air Force installations in the ERPIMS database. About 80% of the constituents identified in the environmental literature have been sampled for at Air Force bases. The rate at which any particular COC was detected varies depending on the constituent and the media. Detect rates (count of detects/total samples) for the emerging COCs were higher for soil than groundwater. Some of the constituents that were *not* sampled for corporately across the Air Force are found below; most of these pertain to soil.

ECOCs Not Sampled For

Constituent	Media
4-NONYL PHENOL	Groundwater, Soil
POLYBROMINATED DIPHENYL ETHERS	Groundwater, Soil
DCPA ACID METABOLITES (a)	Groundwater
PHTHALIC ANHYDRIDE	Groundwater
CYANAZINE	Soil
DIPHENYL ETHER (PHENYLETHER)	Soil
FONOPHOS	Soil
HEXAZINONE	Soil
METHYL MERCURY	Soil
METOLACHLOR	Soil
METRIBUZIN	Soil
MOLINATE	Soil
RADIUM-224, RADIUM-228	Soil
TERBACIL	Soil
TERBUFOS	Soil
TUNGSTEN	Soil

Fig. 7. Emerging COCs not sampled for at Air Force bases and the corresponding media not sampled.



Figs. 8A & 8B. Pie charts of emerging COCs in association with groundwater and soil.



Air-Force Wide Occurrence of Emerging COCs in Groundwater & Soil

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Analysis (contd)

Where were the emerging COCs most commonly detected across the Air Force? For both groundwater and soil, the most common site types showing detects of the emerging COCs included landfills and spill sites.

Detects of ECOCs in Groundwater & Soil at Air Force Sites

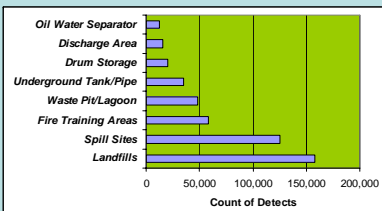


Fig. 9. Common site types where emerging COCs were detected in groundwater and soil.

Most of the individual ECOCs were detected but 75% of the data tends to be non-detects. Some ECOCs were sampled for, but have never been detected at Air Force installations. The pesticides Diazinon for groundwater and Linuron for soil are examples. Only 20 ECOCs exceeded PRGs but only a small portion of samples (typically less than 1%) actually were detected above PRGs.

ECOCs Not Detected

Constituent	Media
ERYTHRENE (1,3-BUTADIENE)	Groundwater, Soil
FORMALDEHYDE	Groundwater, Soil
RADIUM-223	Groundwater, Soil
ACETOCHLOR	Groundwater
CYANAZINE	Groundwater
DIAZINON	Groundwater
EPIC 2-ETHYL-4-(4-N-PROPYLTHIOCARBAMATE)	Groundwater
FOAMKIDS	Groundwater
METHYL MERCURY	Groundwater
METOLACHLOR	Groundwater
METRIBUZIN	Groundwater
MOLINATE	Groundwater
RADIUM-224	Groundwater
TERBACIL	Groundwater
TERBUFOS	Groundwater
TRIETHYLENE GLYCOL	Groundwater
TUNGSTEN	Groundwater
1,3-DICHLOROPROPENE (CIS AND TRANS)	Soil
LINURON	Soil
RADIUM-226	Soil
SIMAZINE	Soil

Fig. 10. ECOCs not detected Air-Force wide.

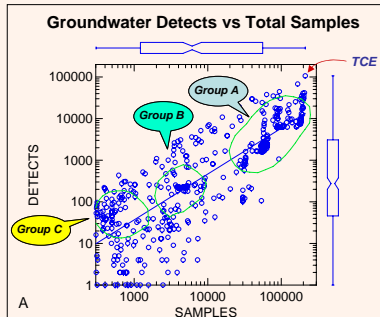
Emerging COCs Detected Above PRGs

Constituent	Matrix
Aluminum	Groundwater & Soil
Arsenic	Groundwater & Soil
Antimony	Groundwater & Soil
Cadmium	Groundwater & Soil
Lead	Groundwater & Soil
Manganese	Groundwater & Soil
Vanadium	Groundwater & Soil
Diuron	Groundwater & Soil
PCE, TETRACHLOROETHYLENE	Groundwater & Soil
1,2,3-TRICHLOROPROPANE	Groundwater & Soil
1,2,4-TRIMETHYLBENZENE	Groundwater & Soil
Naphthalene	Groundwater
Perchlorate	Groundwater
Aldrin	Soil
Chromium (VI)	Groundwater
DDE, (1,1-bis(4-CHLOROPHENYL)-2,2-CHLOROETHENE)	Soil
Nickel	Groundwater
NDMA, N-NITROSODIMETHYLAMINE	Soil
MTBE, tert-BUTYL METHYL ETHER	Groundwater
2,4,6-TRICHLOROPHENOL	Groundwater

Fig. 11. ECOCs detected above PRGs by media.

Groundwater

When detects are plotted against the total number of samples, individual constituents cluster into three major contaminant groups.



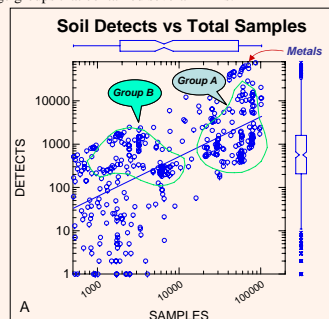
Constituent Groups Detected in Groundwater

Category	Constituent Class	Selected Analytes
Group A	Petroleum/fuel related Solvents PAHs Metals Pesticides	MTBE, PCE, PCA, 1,1,1-TCA, Naphthalene, benzo(a)pyrene, Arsenic, lead, manganese, aluminum, 1,4-Dichlorobenzene
Group B	Energetics, propellants Solvent stabilizers	RDX, HMX, perchlorate 1,4-dioxane
Group C	Antifreeze	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin Ethylene glycol

Fig. 12A and 12B. Groundwater detects grouped by ECOC class and selected analytes. Each data point represents a discrete ECOC.

Soil

When detects of soil were plotted, constituents clustered into two large groups that contained several PAHs.



Constituent Groups Detected in Soil

Category	Constituent Class	Selected Analytes
Group A	PAHs Energetics, propellants Pesticides	Naphthalene, benzo(a)pyrene, chrysene, pyrene, fluorene, phenanthrene, 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, Aldrin, 2,4,6-Trichlorophenol, 1,4-Dichlorobenzene, Aldrin
Group B	Petroleum, gas additives Energetics, propellants Dioxins	MTBE, chloroethane, mesitylene, n-propylbenzene, RDX, HMX, TNT, 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin, Octachlorodibenzo-p-dioxin

Figs 13A and 13B. Soil detects grouped by ECOC class and selected analytes. Constituent classes can overlap multiple groups.

Additional Constituents

As a consequence of this ECOCs study, additional constituents of potential interest (COPIs) to the Air Force were identified based on number of detects and concentrations that exceeded PRGs. The most common constituent classes for these chemicals are petroleum fuels for groundwater, and PAHs and dioxins/furans for soil. Detect rates for these constituents were typically less than 10%.

Potentials of Additional Constituents of Potential Interest to the Air Force

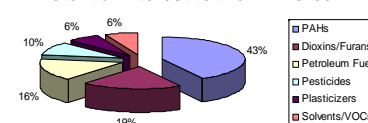


Fig. 14. Categories of additional constituents detected in groundwater and soil at Air Force installations.

Additional COPIs Exceeding PRGs

Constituent	Matrix
BENZO(a)PYRENE	Groundwater, soil
OCTACHLORODIBENZO-p-DIOXIN	Groundwater, soil
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	Groundwater, soil
1,3,5-TRIMETHYLBENZENE (MESITYLENE)	Groundwater, soil
1-METHYLNAPHTHALENE	Groundwater, soil
2-METHYLNAPHTHALENE	Groundwater, soil
BENZO(a)ANTHRACENE	Groundwater, soil
BENZO(k)FLUORANTHENE	Groundwater, soil
CHRYSENE	Groundwater, soil
INDENO(1,2,3-c,d)PYRENE	Groundwater, soil
BENZO(b)FLUORANTHENE	Groundwater, soil
CHLOROFORM	Groundwater
1,2,3,6,7,8-HEXACHLORODIBENZO-p-DIOXIN	Soil
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	Soil
n-PROPYLBENZENE	Groundwater
SEC-BUTYLBENZENE	Groundwater
CHLOROBENZENE	Groundwater
CHLOROETHANE	Groundwater
n-BUTYLBENZENE	Groundwater
BENZO(g,h,i)PERYLENE	Soil
PHENANTHRENE	Soil

Fig. 15. Additional constituents of potential interest detected above PRGs by media.

Summary Statistics

Groundwater Summary Statistics ECOCs and COPIs Exceeding PRGs

Constituent	Bases w/ Detects	Wells w/ Detects	Median Detect	Sample Size (n)	Detect Rate	Units
BANANASE	114	16	10.0	10,000	9%	ug/L
LEAD	114	16	10.0	10,000	9%	ug/L
ANTHRACENE	111	16	10.0	10,000	9%	ug/L
ALUMINUM	109	16	10.0	10,000	9%	ug/L
NICKEL	111	16	10.0	10,000	9%	ug/L
TETRACHLOROETHYLENE(D)	111	16	10.0	10,000	9%	ug/L
VANADIUM	111	16	10.0	10,000	9%	ug/L
MARTHALENE	111	16	10.0	10,000	9%	ug/L
CADMIUM	111	16	10.0	10,000	9%	ug/L
1,2,4-TRIMETHYLBENZENE	98	16	10.0	10,000	9%	ug/L
1,3,5-TRIMETHYLBENZENE (MESITYLENE)	98	16	10.0	10,000	9%	ug/L
SEC-BUTYLBENZENE	14	16	10.0	10,000	9%	ug/L
BENZO(b)FLUORANTHENE	14	16	10.0	10,000	9%	ug/L
n-PROPYLBENZENE	14	16	10.0	10,000	9%	ug/L
CHLOROBENZENE	14	16	10.0	10,000	9%	ug/L
CHLOROETHANE	14	16	10.0	10,000	9%	ug/L
n-BUTYLBENZENE	14	16	10.0	10,000	9%	ug/L
BENZO(g,h,i)PERYLENE	14	16	10.0	10,000	9%	ug/L
PHENANTHRENE	14	16	10.0	10,000	9%	ug/L
PERCHLORATE	14	16	10.0	10,000	9%	ug/L

Fig. 16. Summary statistics for ECOCs and COPIs that exceed PRGs in groundwater.

Soil Summary Statistics ECOCs and COPIs Exceeding PRGs

Constituent	Bases w/ Detects	Wells w/ Detects	Median Detect	Sample Size (n)	Detect Rate	Units
LEAD	114	16	10.0	10,000	9%	ug/L
ANTHRACENE	111	16	10.0	10,000	9%	ug/L
VANADIUM	111	16	10.0	10,000	9%	ug/L
MANGANESE	111	16	10.0	10,000	9%	ug/L
ALUMINUM	111	16	10.0	10,000	9%	ug/L
CADMIUM	111	16	10.0	10,000	9%	ug/L
CHRYSENE	111	16	10.0	10,000	9%	ug/L
BENZO(b)FLUORANTHENE	111	16	10.0	10,000	9%	ug/L
PERCHLORATE	111	16	10.0	10,000	9%	ug/L
ANTHRACENE	111	16	10.0	10,000	9%	ug/L
INDENO(1,2,3-c,d)PYRENE	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
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1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,6,7,8-HEPTACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN	111	16	10.0	10,000	9%	ug/L
1,2,3,4,6,7,8-						