GG 101 Exam #2
Average = 73.7%, Standard Deviation = 12.6%

Approximate Letter Grade
- >90 A
- 80-89 B
- 70-79 C
- 60-69 D
- <60 F

Course Grades (October 28, 2010)
Average = 69.3%, Standard Deviation = 11.9%

Approximate Letter Grade
- >85 A
- 75-84 B
- 65-74 C
- 55-64 D
- <55 F
Final Grade & Field Trips!

- 75% of your final grade will be based on the two best Exam scores and
- The remaining 25% of your final grade will be based on the 21 (out of 24) Chapter Test homework grades
- Up to 10% extra credit is available if you actively participate on a field trip
  - November 13 – Wai‘anae (Pacific Aggregate Quarry)
    - Five open slots
  - December 4 – North Shore

Oil

- **Exxon Valdez**, Alaska
  - March 1989
  - Second worst oil spill in U.S. history
  - Ran aground
  - >250,000 barrels of oil spilled
  - Area was one of most pristine and ecologically rich in world
  - Short-term impacts:
    - Many seabirds and mammals were killed
    - Fishing and tourism disrupted
  - Long-term impacts: ???
Deepwater Horizon

- Well sealed on 15th of July after ~84 days
- 4,400,000 (±20%) barrels of oil released
  - ~800,000 barrels additional collected on sea floor
- Exceeds the Exxon Valdez oil spill by several orders of magnitude
- Good News? – Responders intercepted 25% of the released oil

Gulf Oil Spill

A Lot of Oil on the Loose, Not So Much to Be Found

13 August 2010 VOL 329 SCIENCE www.sciencemag.org
NOAA report, several papers

- Political spin and media hype transformed the scientists’ message even before it was released.
- According to one CNN reporter, the interagency report led by Department of the Interior and NOAA said that of the 4.9 million barrels of oil spilled, “75% has been cleaned up by Man or Mother Nature”
- Nothing in the report supports that interpretation!

- 25% more-or-less accounted
- What of the 75%?
- One interpretation, “raising the flag and declaring victory is premature,” (Samantha Joye, University of Georgia)
- Another finds that three-quarters of the oil is gone from the gulf or is dispersed in the water in its most easily degraded form.
  - The remaining oil “is degrading quickly right now,” (Edward Overton, LSU)
- How did the 75% of the spill that remained enter the environment?
  - Oily scum on the surface?
  - More readily degraded microscopic droplets at depth?
  - Vapors into the atmosphere?
Adding up uncertainties

- “Residual oil”
  - What could not be measured or estimated but is left to float as tarballs or be washed ashore
- Range from 13% to 39% by a simple accounting from charts in NOAA report
- Fraction in subsurface plumes
  - What is your image of the subsurface plumes of oil?
    - Oil concentration within 10 km of well 1-2 ppm, >10 km away oil levels ppb (40 ppm considered a spill)
- BP also sprayed 1.1 million gallons of chemical dispersants

Chemical Dispersants?

- Usually used in small quantities on the surface of the ocean to break up slicks
- Dispersants – fairly nasty chemical detergents
  - Break up globs of oil into microscopic droplets that are more readily devoured by microbes
- Every drop of oil at surface is a potential threat to coastal ecosystems, fish and marine mammals
- Risk to undersea life like eggs, larvae, fish, coral and other bottom dwellers is unknown
- Would giving microbes a feast starve the water of oxygen and create dead zones?
Tracking Hydrocarbon Plume Transport and Biodegradation at Deepwater Horizon

Richard Camilli,1,2 Christopher M. Reddy,2 Dana R. Yoerger,1 Benjamin A. S. Van Mooy,2 Michael V. Jakuba,1 James C. Kinsey,1 Cameron P. McIntyre,2 Sean P. Sylva,2 James V. Maloney4

The Deepwater Horizon blowout is the largest offshore oil spill in history. We present results from a subsurface hydrocarbon survey using an autonomous underwater vehicle and a ship-cabled sampler. Our findings indicate the presence of a continuous plume of oil, more than 35 kilometers in length, at approximately 1100 meters depth that persisted for months without substantial biodegradation. Samples collected from within the plume reveal monoaromatic petroleum hydrocarbon concentrations in excess of 50 micrograms per liter. These data indicate that monoaromatic input to this plume was at least 5500 kilograms per day, which is more than double the total source rate of all natural seeps of the monoaromatic petroleum hydrocarbons in the northern Gulf of Mexico. Dissolved oxygen concentrations suggest that microbial respiration rates within the plume were not appreciably more than 1 micromolar oxygen per day.

Deep-Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria

Terry C. Hazen,1,3 Eric A. Dubinsky,4 Todd Z. DeSantis,4 Gary L. Andersen,1 Yvette M. Piceno,1 Navjeet Singh,1 Janet K. Janssen,2 Alexander Probst,2 Sharon E. Borglin,2 Julian L. Fortney,1 William T. Stringfellow,12 Markus Bill,1 Mark E. Conrad,1 Lauren M. Tom,1 Krystle L. Chavarria,1 Thana R. Alus1,2 Regina Lamendella,1 Dominique C. Joyner,1 Chelsea Spier,2 Jacob Baelum,1 Manfred Auer,3 Marcia L. Zempla1,2 Romy Chakrabarty,3 Eric L. Sonnenbath,1 Patrik D’haeseleer,4 Hoi-Ying N. Holman,1 Shariff Osman,1 Zhenmei Lu,3 Joy D. Van Nostrand3,3 Ye Deng,3 Jiahong Zhou1,3 Olivia U. Mason1

The biological effects and expected fate of the vast amount of oil in the Gulf of Mexico from the Deepwater Horizon blowout are unknown owing to the depth and magnitude of this event. Here, we report that the dispersed hydrocarbon plume stimulated deep-sea indigenous γ-Proteobacteria that are closely related to known petroleum degraders. Hydrocarbon-degrading genes coincided with the concentration of various oil contaminants. Changes in hydrocarbon composition with distance from the source and incubation experiments with environmental isolates demonstrated faster-than-expected hydrocarbon biodegradation rates at 5°C. Based on these results, the potential exists for intrinsic bioremediation of the oil plume in the deep-water column without substantial oxygen drawdown.
Propane Respiration Jump-Starts Microbial Response to a Deep Oil Spill

David L. Valentine,1,∗ John D. Kessler,2 Molly C. Redmond,1 Stephanie D. Mendes,1 Monica B. Heintz,1 Christopher Farwell,1 Lei Hu,2 Franklin S. Kinnaman,1 Shari Yvon-Lewis,2 Mengran Du,2 Eric W. Chan,2 Fenix Garcia Tigrejos,2 Christie J. Villanueva1

The Deepwater Horizon event resulted in suspension of oil in the Gulf of Mexico water column because the leakage occurred at great depth. The distribution and fate of other abundant hydrocarbon constituents, such as natural gases, are also important in determining the impact of the leakage but are not yet well understood. From 11 to 21 June 2010, we investigated dissolved hydrocarbon gases at depth using chemical and isotopic surveys and on-site biodegradation studies. Propane and ethane were the primary drivers of microbial respiration, accounting for up to 70% of the observed oxygen depletion in fresh plumes. Propane and ethane trapped in the deep water may therefore promote rapid hydrocarbon respiration by low-diversity bacterial blooms, priming bacterial populations for degradation of other hydrocarbons in the aging plume.

Would we expect this behavior in Prince William Sound, Alaska?

Fig. 1. (A) Locations of the sampling stations relative to the well head, overlaid on a Google Earth image of the site. (B) Depth distribution for oxygen from station H1, displaying the in situ sensor data (solid line) and data from Winkler titrations (green circles). (C) Contour plot of methane concentration along a transect from H3 to H6. Note the log scale. (D) Contour plot of the dissolved oxygen anomaly along a transect from H3 to H6.
Heavy Metals

- Lead, mercury, zinc, and cadmium
  - Metals can dissolve and become incorporated into plants, crops, and thus animals and humans
- Sources: some natural, others burning fossil fuels, incinerating waste, processing metals
- Human activity has increased mercury levels in the atmosphere 2-3x and 1.5% per year
  - Particles in the atmosphere get rained out and soak into soil

Hg accumulation rate measured in peat bogs in Greenland
Heavy Metals

- What characteristic of the so-called heavy metals causes them to be especially hazardous to humans and other animals high in food webs?
- Heavy metals accumulate in the body
  - They are not readily excreted
  - Therefore, their concentrations tend to increase in higher trophic positions in food webs

Bioaccumulation
X. gladius (66.7 kg)
L. guttatus (40.9 kg)
T. obesus (39.3 kg)
K. pelamis (7.61 kg)
T. albacares (21.1 kg)
C. hippurus (6.1 kg)

Hg in Hawaii Pelagic Fish

Median Depth of Occurrence (m)

THg (ug/kg)
Arsenic in U.S. Ground Water

- Counties with arsenic concentrations exceeding 10 μg/L in 10% or more of samples.
- Counties with arsenic concentrations exceeding 5 μg/L in 10% or more of samples.
- Counties with arsenic concentrations exceeding 3 μg/L in 10% or more of samples.
- Counties with fewer than 10% of samples exceeding 3 μg/L, representing areas of lowest concentration.
- Counties with insufficient data in the USGS database to make estimates.

Water Resources
Sources of water that are useful or potentially useful to humans.

Distribution of Earth's Water
- Salarine (oceans) 97%
- Icecaps and Glaciers 8.7%
- Ground water 20.1%
- Surface water 0.3%
- Freshwater
- River 2%
- Lakes 87%
- Surface water (liquid)

All water on Earth
- Unconventional 10%
- Water usable by humans 1%
- Groundwater 69%
- Lakes 0.65% Rivers 0.02%
Major Processes in the water cycle
- evaporation
- precipitation
- transpiration
- surface runoff
- subsurface groundwater flow

Groundwater
- Nearly half the population of the US uses groundwater as a primary source of drinking water
- Major source is infiltration of precipitation

Amount depends on:
- topography
- soil and rock type
- amount of precipitation
- vegetation
- land use
Why is groundwater such a valuable resource?

1. Abundant - 70 times more in the subsurface than in surface reservoirs

2. Because groundwater moves so slowly it is stored in the earth and remains available even in dry periods

3. In some regions groundwater flows from humid environments to dry ones, making water available

An aquifer is a rock unit that stores a lot of water and allows that water to flow easily. In order for a rock to be a good aquifer, it must have a high porosity and permeability.
Soils and rocks are not completely solid

**Porosity**: portion of volume of a material that consists of open spaces

**Permeability**: measure of the speed at which fluid can travel through a porous medium

Imagine two vertical pipes, one filled with gravel, one with sand. Out of which one will the water flow faster?

- Frictional resistance associated with low-permeability geologic material can block or slow the flow of water
- Imagine steadily adding water to a potted plant
- If the soil in the pot is very fine grained, the water level in the soil will remain higher as the water is draining through the soil than if the soil is coarse grained
- In both cases, the water will eventually drain out the holes at the bottom of the pot at the same rate as you are adding water at the top
**Porous Sandstone**

- Sand grain
- Pore space

**Cemented Sandstone**

- Cementing mineral
Well-sorted Sandstone

Poorly-sorted Sandstone
Groundwater
Table

Soil
Weathered
bedrock
Porous
bedrock
(sandstone)

Unsaturated
zone

Water and
air in pore
spaces

Groundwater
table

Water fills
all pore
spaces

Saturated
zone

The Hydrologic Cycle

This diagram shows the major components of the ground water or "hydrologic" cycle on most tropical Pacific islands. Arrows show the movement of the rainfall and other precipitation that recharges aquifers and the general soil drainage of ground water flow toward the oceans. Water vapor is also shown returning to the atmosphere, where it again becomes precipitation.
**More groundwater terms**

*aquifer*: body of rock that is sufficiently water permeable to yield economically significant quantities to wells and springs

*aquitard*: body of rock that retards but does not prevent flow of water to or from an adjacent aquifer

*aquiclude*: body of relatively impermeable rock that is capable of absorbing water slowly but does not transmit it rapidly enough to supply a well or spring

---

**Confined Aquifer** – an aquifer that is bounded on top and bottom by an aquiclude.

Water in confined aquifers are under pressure. A well or a spring that is connected to a confined aquifer may cause an artesian well. This is a well or a spring that flows without pumping.
If there is a small section of aquiclude within the unsaturated zone of an aquifer, some water may be trapped above it. This trapped water is called a "perched water table".
High-Level Ground-Water Systems

Perched system

A low-permeability horizontal layer results in a perched aquifer.

Dike-imounded system

Volcanic-dikes compartmentalize ground-water bodies.

Ground water may occur at elevations high above sea level on some tropical Pacific islands. High-level ground-water bodies can form where a low-permeability geologic barrier or structure blocks or slows the movement of ground water, either vertically downward or horizontally toward the shoreline.

Vertically extantion freshwater-lens systems

A regional low-permeability geologic formation results in a vertically extant freshwater lens.

System created by low-permeability geologic structure

A low-permeability geologic structure of unknown origin forms an impediment that slows the downward flow of ground water.

Explanation

- Freshwater
- Brackish water
- Saltwater
- Water table
- Ground-water flow
- Volcanic-dikes
- Fault movement
- High-permeability strata/crust
- Low-permeability strata/crust

- Unsaturated
- Saturated
- Uncompressed
- Compressed
Confined Aquifer

Dakota confined aquifer system
Rates of groundwater movement

- Slow to very slow (depending on permeability)
- Generally within the range of 10 to 100 cm per day

Darcy’s Law

\[ Q = \frac{AK(h_1 - h_2)}{l} \]

- \( Q \) = discharge (m\(^3\)/sec)
- \( A \) = cross-sectional area (m\(^2\))
- \( K \) = coefficient of permeability (m/sec)
- \( h_1 \) = beginning height (m)
- \( h_2 \) = ending height (m)
- \( l \) = length of flow (m)
Darcy’s Law

**Darcy’s Law**

Volume of water flowing in a certain time is proportional to:

\[ Q = K \times \frac{h}{l} \]

where:
- \( Q \): Volume of water flowing in a given time
- \( A \): Cross-sectional area through which water flows
- \( K \): Hydraulic conductivity (a measure of permeability)
- \( h \): Vertical drop between two points
- \( l \): Distance the flow travels

---

**Hydraulic Conductivity on Tropical Pacific Islands**

The permeability of an aquifer is typically described in terms of its hydraulic conductivity, which accounts for both the permeability of a geologic formation and the fluid properties of the water flowing through it. This table shows examples of hydraulic-conductivity values for some common aquifer materials found on tropical Pacific islands.

<table>
<thead>
<tr>
<th>Aquifer material</th>
<th>Location</th>
<th>Hydraulic conductivity in feet per day (ft/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Volcanic-fm complexes</td>
<td>Hawaiian Islands</td>
<td>0.11 – 0.1</td>
</tr>
<tr>
<td>* Basalt volcanic rock</td>
<td>Lihu'e Basin, Island of Kauai</td>
<td>0.3</td>
</tr>
<tr>
<td>* Volcanic-ash breccias</td>
<td>Hawaiian Islands</td>
<td>1 – 500</td>
</tr>
<tr>
<td>* Atoll Island Holocene-age sedimentary deposits</td>
<td>Marshall Islands</td>
<td>20 – 200</td>
</tr>
<tr>
<td>(sand- to boulder-sized coral-reef debris)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Atoll Island Pleistocene-age marina limestone</td>
<td>Marshall Islands</td>
<td>2,000 – 3,000</td>
</tr>
<tr>
<td>* Layered volcanic rock (mostly basalt)</td>
<td>Island of Hawaii</td>
<td>1,000 – 10,000</td>
</tr>
<tr>
<td>* Uplifted marine limestone</td>
<td>Mariana Islands</td>
<td>100 – 150,000</td>
</tr>
</tbody>
</table>
When a well is drawing out water from the water table, the region around the well becomes unsaturated. This is called a cone of depression.

In Urban areas, we sometimes draw water from wells faster than it is being recharged by precipitation. This causes some aquifers to dry up.

Near coastal areas, too much pumping can cause salt water to contaminate the aquifer and therefore the drinking water.
As water is drawn out of aquifers, the small pore spaces that were once filled with water sometimes cave in. This causes the rocks to be more compressed, and the surface topography drops. This is called subsidence.
Groundwater can cause underground erosion to rocks!

Remember that water is naturally acidic due to carbonic acid

\[
\text{Carbon Dioxide + Water} = \text{Carbonic Acid}
\]

Water can cause underground erosion to soft rocks such as limestone, halite (salt), and gypsum. Remember that halite and gypsum are sedimentary rocks called evaporites.

Underground cavities are called caves.

When caves collapse, they can cause a depression at the surface called a sinkhole.
Karst topography in Eastern Europe

Karst Topography in China
In caves, as water (with lots of dissolved calcite in it) evaporates, it precipitates calcite forming **stalactites** and **stalagmites**.

- 70% of fresh water used for agriculture
- 20% used for industry
- 10% used for household purposes
Shortages for household use a local effect

Move water to the people
Water Use

In major urban areas

• Overwithdrawal of groundwater
• Overuse of local surface water
• Threats of local urban landfills to the water supply, e.g., Long Island, NY

• Water import issues and problems: What is distance to transport? How much water available? From where? Conflicts with other areas, litigations, and long-range planning
Colorado River Compact

- 1922 agreement among seven U.S. states in the basin of the Colorado River
  - Governed allocation of rights to Colorado River water
  - Division of water between Upper and Lower Basin States

<table>
<thead>
<tr>
<th></th>
<th>Upper Basin: 293 m³ s⁻¹</th>
<th>Lower Basin: 293 m³ s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>52% 152 m³ s⁻¹</td>
<td>58% 172 m³ s⁻¹</td>
</tr>
<tr>
<td>Utah</td>
<td>23% 68 m³ s⁻¹</td>
<td>37% 109 m³ s⁻¹</td>
</tr>
<tr>
<td>Wyoming</td>
<td>14% 41 m³ s⁻¹</td>
<td>1% 2 m³ s⁻¹</td>
</tr>
<tr>
<td>New Mexico</td>
<td>11% 33 m³ s⁻¹</td>
<td>4% 12 m³ s⁻¹</td>
</tr>
<tr>
<td>Arizona</td>
<td>1% 2 m³ s⁻¹</td>
<td>1% 2 m³ s⁻¹</td>
</tr>
<tr>
<td>Nevada</td>
<td>0% 12 m³ s⁻¹</td>
<td>0% 12 m³ s⁻¹</td>
</tr>
</tbody>
</table>

Water Conservation

- Engineering technology and structure (canals): Regulating irrigation and reducing evaporation
- Better technologies in power plants and other industries: Less use of water due to improved efficiency
- Increased water reuse and recycling
Water Management

Needs for water management

- Increasing demand for water use (population and economic development)
- Water supply problems in semiarid and arid regions
- Water supply problems in megacities
- Water traded as a commodity: Capital, market, and regulations?

Aspects to be considered:

- Natural environmental factors: Geologic, geographic, and climatic
- Human environmental factors: Economic, social, and political

Strategies

- More surface water use in wet years, more groundwater use in dry years
- Reuse and recycle water on regular basis as well as in emergencies
Groundwater in Hawaii

- ‘Īao aquifer, Maui – A freshwater lens stressed by rising demand
  - Source of more than half of the domestic water supply for the island of Maui

‘Īao Aquifer

- Formed by highly permeable layered volcanic rocks
- Low-permeability coastal deposits (mix of eroded volcanic material, coral-reef debris, and marine sediments) block or slow the discharge of freshwater into the ocean
  - Results in the formation of a thick freshwater lens
- Average annual rainfall in the area ranges from <30 to >350 inches
  - Recharge from this rainfall and fog drip has been estimated to be about 42 percent
ʻĪao Aquifer

- Ground-water pumpage increased from <2 million gallons per day (Mgal/d) in 1950 to >20 Mgal/d in 1995
  - In response water-table levels declined to half of their estimated predevelopment levels in parts of the aquifer
  - The decline in water-table levels has been mirrored by a shrinking of the freshwater lens and increasing salinity in several wells
- The average pumpage during 2002 was ~17 Mgal/d
  - Water-table levels appeared to be stabilizing in response to decreased pumping
  - But the freshwater-saltwater transition zone was still moving upward
ʻĪao Aquifer – Sustainable Yield

- Most current estimate is 20 Mgal/d
  - Probably far too high an estimate
- Construction of a numerical model of groundwater flow is required to provide a more precise analysis of aquifer sustainability
  - Also needed to determine the effect of changing land-use practices on the extent of groundwater recharge
- Will Maui (and other parts of Hawaii) run out of freshwater?

Reverse Osmosis

Desalination through osmosis
Contamination of ground water is a very important issue because it is difficult to clean an aquifer once it has been polluted.
Contamination of a surface water reservoir by polluted groundwater

A.

B. Selenium-bearing runoff and groundwater draining from mountains

Evaporation and transpiration concentrate salts in soil

Potential level of water table without drain system

Canal draining to Kesterson Reservoir

Soils flushed by irrigation water that percolates downward

Clay aquiclue
Purification of contaminated groundwater

Groundwater Pollution

- U.S. Geological Survey National Water-Quality Assessment Program
- Groundwater Pollution difficult to detect
- Groundwater has long-term residency
- Difficult and expensive to clean aquifers
- Therefore: careful management and protection of resources important
A special case: Groundwater

- What forms of pollution can affect groundwater?
  - All of them except thermal pollution!
- Renewal time of groundwater is important
  - Rivers: 12-20 days
  - Soil Moisture: 280 days
  - Groundwater: 300 years

Groundwater Pollution

<table>
<thead>
<tr>
<th>TABLE 13.3 Common Sources of Groundwater Pollution and Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaks from storage tanks and pipes</td>
</tr>
<tr>
<td>Leaks from waste-disposal sites such as landfills</td>
</tr>
<tr>
<td>Seepage from septic systems and cesspools</td>
</tr>
<tr>
<td>Accidental spills and seepage (train or truck accidents, for example)</td>
</tr>
<tr>
<td>Seepage from agricultural activities such as feedlots</td>
</tr>
<tr>
<td>Intrusion of saltwater into coastal aquifers</td>
</tr>
<tr>
<td>Leaching and seepage from mine spoil piles and tailings</td>
</tr>
<tr>
<td>Seepage from spray irrigation</td>
</tr>
<tr>
<td>Improper operation of injection wells</td>
</tr>
<tr>
<td>Seepage of acid water from mines</td>
</tr>
<tr>
<td>Seepage of irrigation return flow</td>
</tr>
<tr>
<td>Infiltration of urban, industrial, and agricultural runoff</td>
</tr>
</tbody>
</table>
Groundwater Pollution

- Once detected, have to drill series of wells to determine the length and width of the pollution “plume”
  - Map the water table height at the various well locations to determine which way the water is flowing
- Sample water from the plume to isolate contaminants
- Combine all information to determine source

Groundwater doesn’t stay in one place
Groundwater Pollution

- >70,000 chemicals are used; effects of many are not known
- Each year another 700-800 new chemicals are produced
- 55 million tons of hazardous chemical wastes are produced in the US each year
- The 20 most abundant compounds in groundwater at industrial waste disposal sites include TCE, benzene, vinyl chloride...all are carcinogens, and also affect liver, brain, and nervous system.

Groundwater Pollution Treatments

<table>
<thead>
<tr>
<th>TABLE 13.4 Methods of Treating Groundwater and Vadose-Zone Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction Wells</td>
</tr>
<tr>
<td>Pumping out contaminated water and treatment by filteration, oxidation, air stripping (vaporization of contaminant in an air column), or biological processes</td>
</tr>
</tbody>
</table>

Bioremediation is proving pretty effective in terms of cost and is very environmentally friendly.
Groundwater in Hawaii

- The Lahaina District has several public and private sources of domestic and agricultural water supply
  - Domestic water is supplied mainly from wells but includes some surface water
  - Agricultural water is mainly surface water that is occasionally augmented with ground water from wells

Municipal Wastewater Discharge

- In Lahaina several million gallons per day of “reclaimed water” (treated and disinfected wastewater effluent) are injected into a volcanic rock aquifer
- The main question is where and how the effluent discharges to the nearshore coastal environment
Tracing Wastewater
Tracing Wastewater

- Nutrients
  - Nitrate, phosphate, ammonium

- Pharmaceuticals
  - Caffeine (stimulant), carbamazepine (anticonvulsant), diphenhydramine (antihistamine), sulfamethoxazole (antibiotic)

- Waste indicator compounds
  - 1,4-dichlorobenzene (deodorizer), musk oil, benzopenone (fragrance used in mousse), DEET, plasticizers, fire retardants, etc.