

**Landfill Gas, Leachate,  
Regional Boards and  
Regulated Groundwater**



# Landfill Gas, Leachate, Regional Boards and Regulated Groundwater



Adam Harris  
Engineering Geologist  
**(NOT A LAWYER)**  
State Water Resources Control Board  
[aharris@waterboards.ca.gov](mailto:aharris@waterboards.ca.gov)



OUT OUT!!  
YOU DEMONS OF  
BIOGEOCHEMISTRY !!

Geologists like to start  
with some voodoo

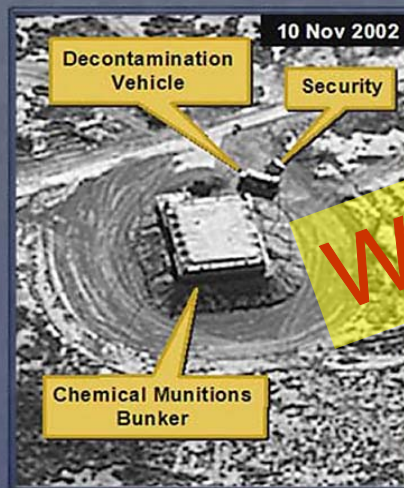




So what do the regional water boards care about landfill gas? It's MSW, not WMD!



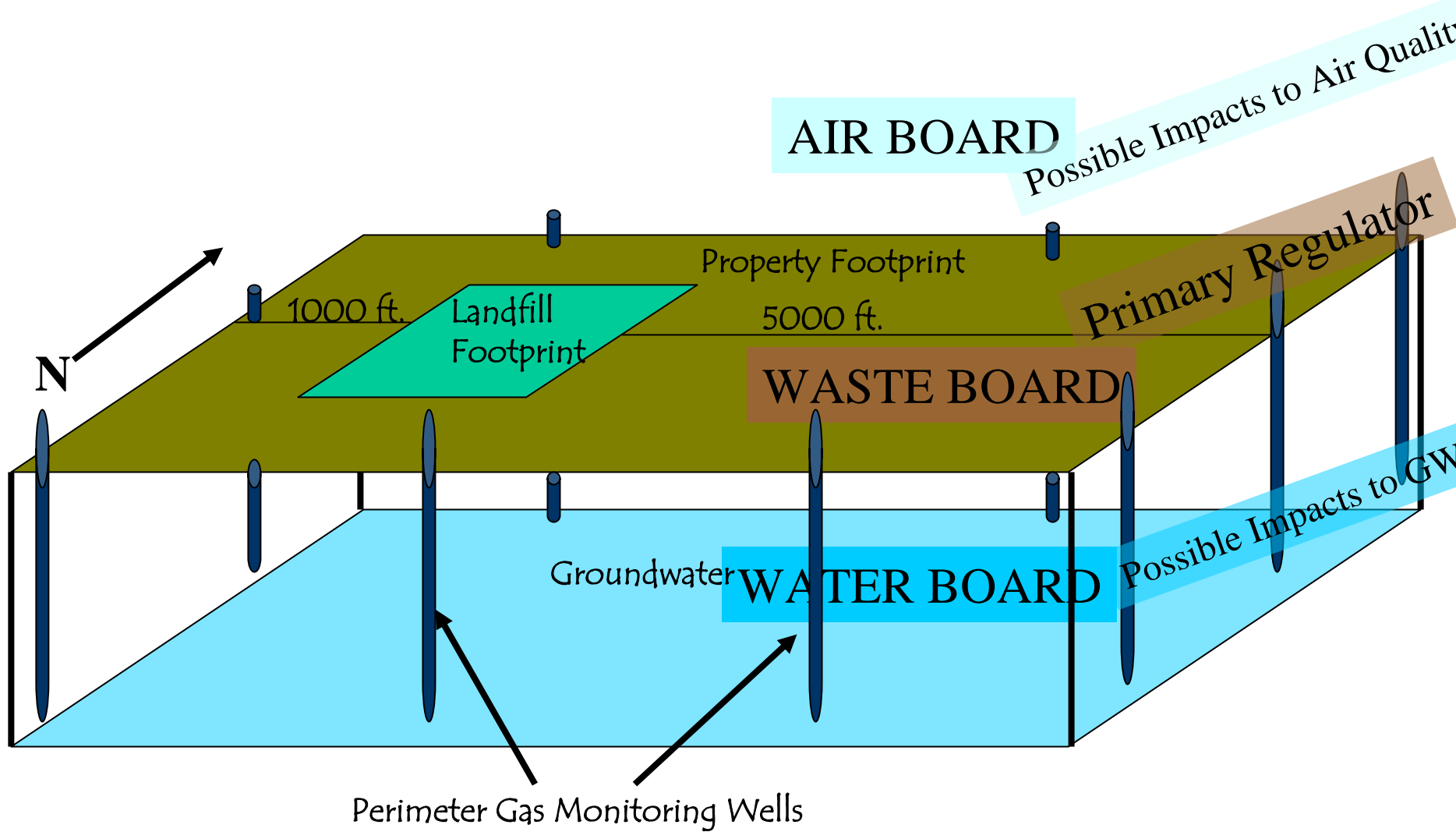
### Sanitization of Ammunition Depot at Taji



Haven't you read Title 27 ???  
I have -in fact- I invented it!

(Sorry folks but I couldn't find Kerry doing anything funny-and  
and I really looked hard)





-Title 27 (and other regs) recognize that landfill gas is regulated by at least 3 CAL/EPA agencies (CIWMB / SWRCB / CARB)

-Based (in part) on the affected media (Air, soil, or water)

Title

boards

How can I get out of writing these WDRs?

1. What is in LFG?
2. Where is it going?



**DILBERT**  
By Scott Adams

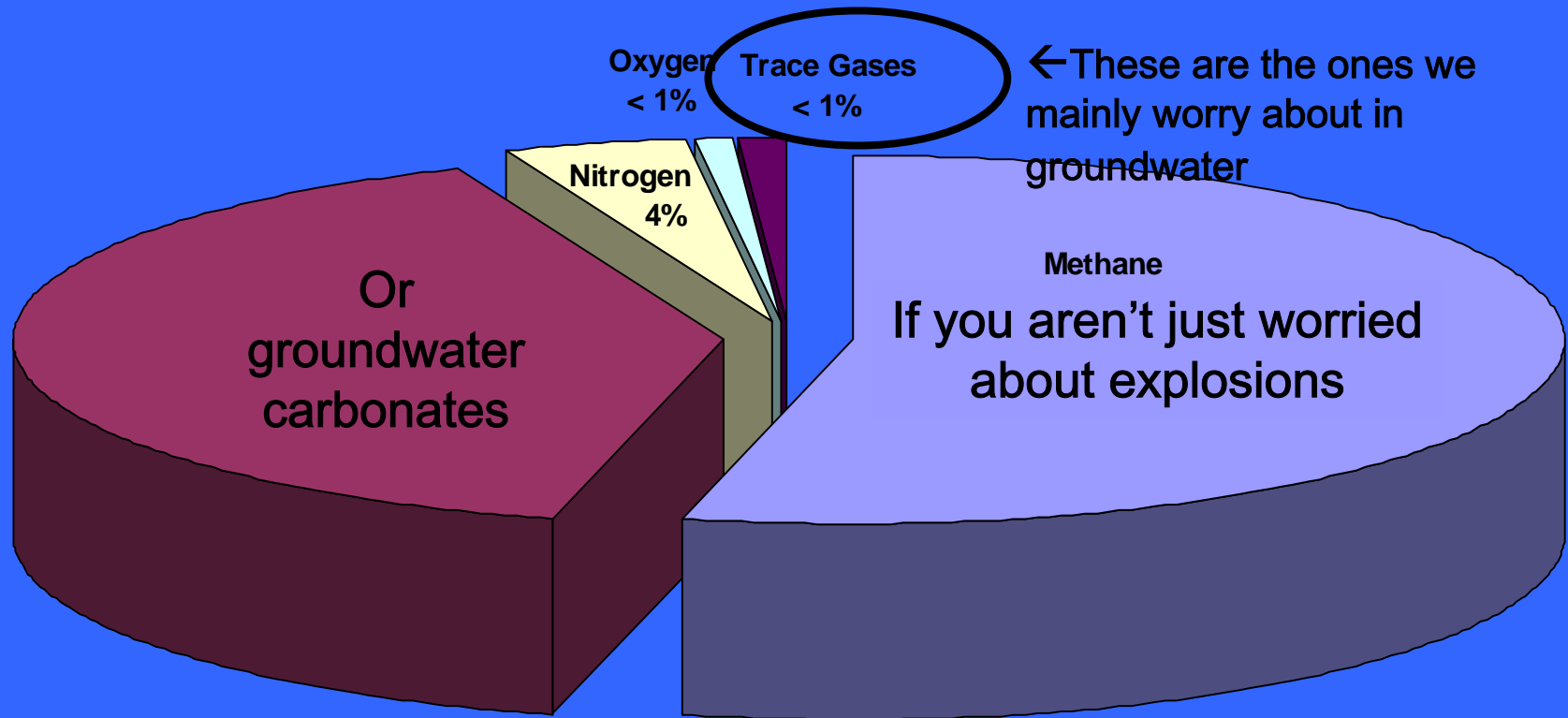


## So what's in landfill gas?

- Methane 55-65%  
v/v
- CO<sub>2</sub> 45-35% v/v
- Nitrogen <1% v/v
- Oxygen <1% v/v
- Trace Gases <1%  
v/v

# Small percentages of landfill gas can be the **\*BIG\*** problem (for GW!)

Average Composition of Landfill Gas



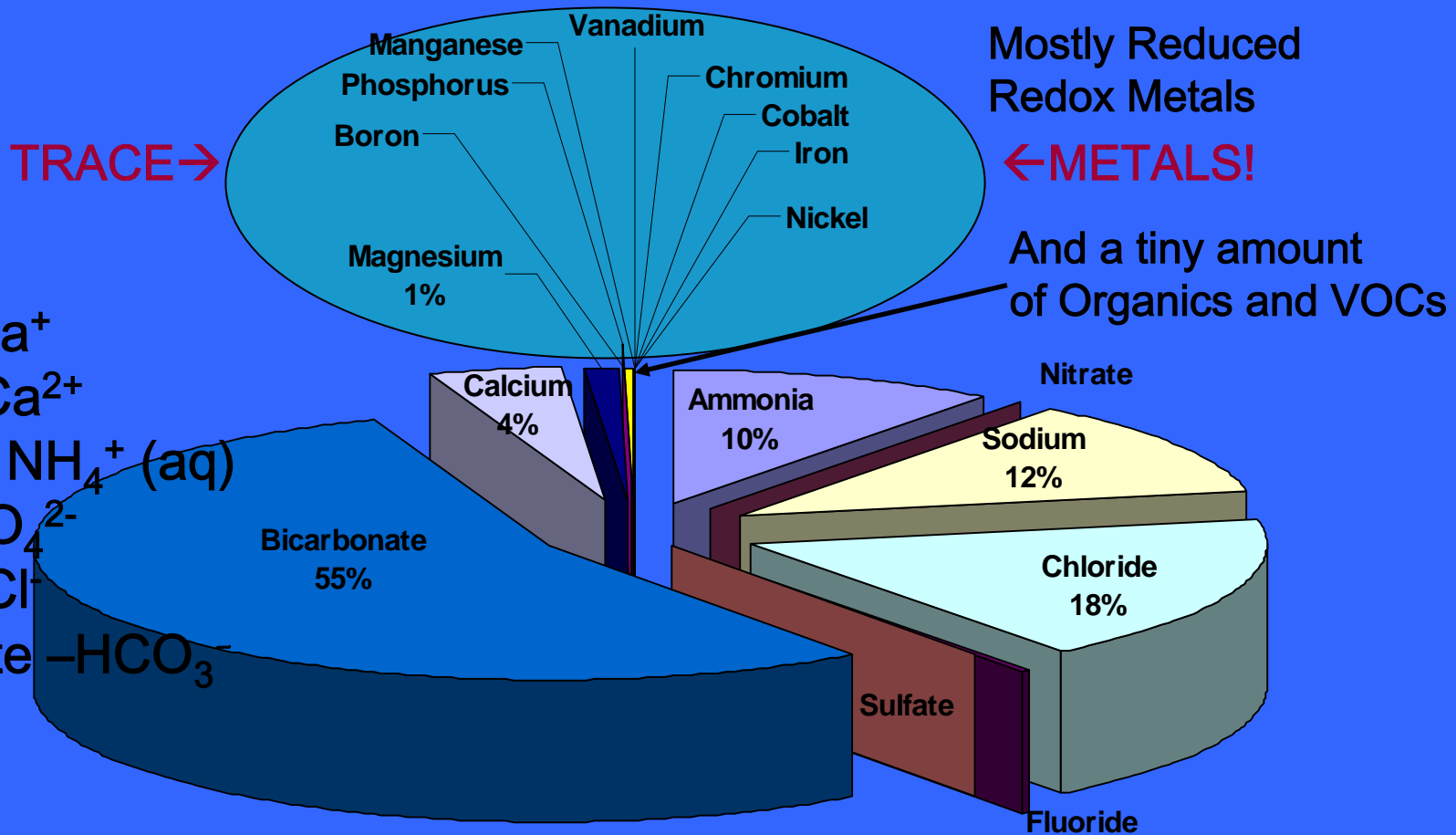
Methyl iodide; Iodomethane  
4-Methyl-2-pentanone; Methyl isobutyl ketone  
Styrene  
1,1,1,2-Tetrachloroethane  
1,1,2,2-Tetrachloroethane  
Tetrachloroethylene; Tetrachloroethene;  
Perchloroethylene  
Toluene  
1,1,1-Trichloroethane; Methylchloroform  
1,1,2-Trichloroethane  
Trichloroethylene; Trichloroethene  
Trichlorofluoromethane; CFC-11  
1,2,3-Trichloropropane  
Vinyl acetate Vinyl chloride  
Xylenes

**ALL IN THAT “<1% TRACE GASES”**

**(Remember that 1% is 10,000 parts per million (10,000,000 ppb!))**

# Leachate Contains Salts Plus Trace Metals, Organics and VOCs

Composition of Groundwater Leachate at One Landfill



## Salts

Sodium-  $\text{Na}^+$

Calcium-  $\text{Ca}^{2+}$

Ammonia-  $\text{NH}_4^+$  (aq)

Sulfate-  $\text{SO}_4^{2-}$

Chloride-  $\text{Cl}^-$

Bicarbonate-  $\text{HCO}_3^-$

40 CFR Pt. 258 App. II

Leachate  
 \*can\* result  
 in trace  
 organics,  
 metals and  
 VOCs in GW

Aldrin →  
 (insecticide)

Arsenic →  
 Benzene →

Lindane →  
 (pesticide)

Common Name <sup>2</sup>	CAS RN <sup>3</sup>	Chemical abstracts service index name <sup>4</sup>	Sug- gested methods <sup>5</sup>	PQL (µ g/L) <sup>6</sup>
Acrolein	107-02-8	2-Propenal	8030	5
Acrylonitrile	107-13-1	2-Propenenitrile	8260	100
Aldrin	309-00-2	1,4:5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro- 1,4,4a,5,8,8a-hexahydro- (1α,4α,4β,5α,8α,8β)-	8030 8260 8080 8270	5 200 0.05 10
Allyl chloride	107-05-1	1-Propene, 3-chloro-	8010	5
Aminobiphenyl	92-67-1	[1,1'-Biphenyl]-4-amine	8260	10
Anthracene	120-12-7	Anthracene	8270 8100	20 200
Antimony	(Total)	Antimony	8270 6010 7040	10 300 2000
Arsenic	(Total)	Arsenic	7041 6010 7060	30 500 10
Barium	(Total)	Barium	7061 6010 7080	20 20 1000
Benzene	71-43-2	Benzene	8020 8021	2 0.1
Benzo[a]anthracene; Benzanthracene	56-55-3	Benzo[a]anthracene	8260 8100	5 200
Benzo[b]fluoranthene	205-99-2	Benzo[j]acephenanthrylene	8270 8100	10 200
Benzo[k]fluoranthene	207-08-9	Benzo[k]fluoranthene	8270 8100	10 200
Benzo[ghi]perylene	191-24-2	Benzo[ghi]perylene	8270 8100	10 200
Benzo[a]pyrene	50-32-8	Benzo[a]pyrene	8270 8100	10 200
Benzyl alcohol	100-51-6	Benzenemethanol	8270	20
Beryllium	(Total)	Beryllium	6010 7090	3 50
alpha-BHC	319-84-6	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3β,4α,5β,6β)-	8080 8270	0.05 10
beta-BHC	319-85-7	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2β,3α,4β,5α,6β)-	8080 8270	0.05 20
delta-BHC	319-86-8	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3α,4β,5α,6β)-	8080 8270	0.1 20
gamma-BHC; Lindane	58-89-9	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3β,4α,5α,6β)-	8080 8270	0.05 20
Bis(2-chloroethoxy)methane	111-91-1	Ethane, 1,1'-[methylenebis(oxy)]bis[2- chloro-	8110	5
Bis(2-chloroethyl) ether; Dichloroethyl ether	111-44-4	Ethane, 1,1'-oxybis[2-chloro-	8270 8110	10 3
Bis(2-chloro-1-methylethyl) ether; 2,2'- dichlorodiisopropyl ether; DCIP. See note 7	108-60-1	Propane, 2,2'-oxybis[1-chloro-	8270 8110	10 10
Bis(2-ethylhexyl) phthalate	117-81-7	1,2-Benzenedicarboxylic acid, bis(2- ethylhexyl) ester.	8060	20
Bromochloromethane; Chlorobromomethane.	74-97-5	Methane, bromochloro-	8021 8260	0.1 5
Bromodichloromethane; Dibromochloromethane.	75-27-4	Methane, bromodichloro-	8010 8021 8260	1 0.2 5
Bromoform; Tribromomethane	75-25-2	Methane, tribromo-	8010 8021 8260	2 15 5
4-Bromophenyl phenyl ether	101-55-3	Benzene, 1-bromo-4-phenoxy-	8110 8270	25 10
Butyl benzyl phthalate; Benzyl butyl phthalate.	85-68-7	1,2-Benzenedicarboxylic acid, butyl phenylmethyl ester.	8060 8270	5 10
Cadmium	(Total)	Cadmium	6010 7130	40 50
Carbon disulfide	75-15-0	Carbon disulfide	7131 8260	1 100

Gas

Geologists think  
leachate

GW

- VOCs plus salts, metals  
and organics –

Yes its the tire program  
But I liked the picture!

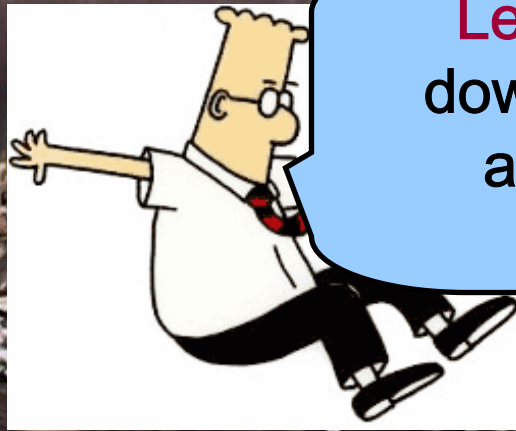


**DILBERT**  
By Scott Adams

# Gas and Leachate Transport



**Gas** is mainly transported by pressure gradients. Could go anywhere.



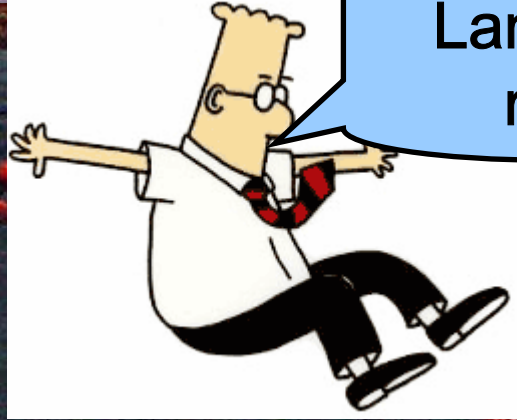
**Leachate** is transported downward to groundwater and with groundwater gradients



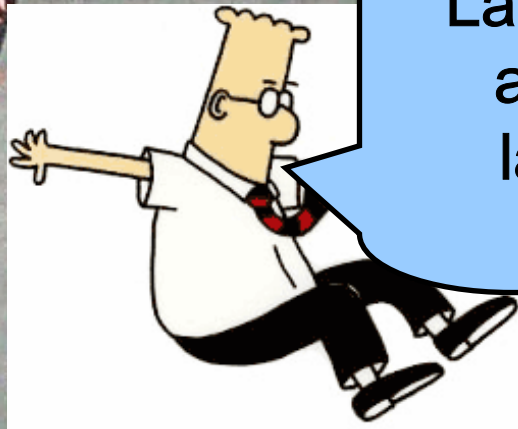
Is perimeter gas monitoring sufficient to determine if usable groundwater may be impacted?

**MAYBE (stay tuned!)**

# Getting Gas into GW 1. Gas Can Condense to Liquid



Landfill Gas moves in the path of least resistance -away from the source

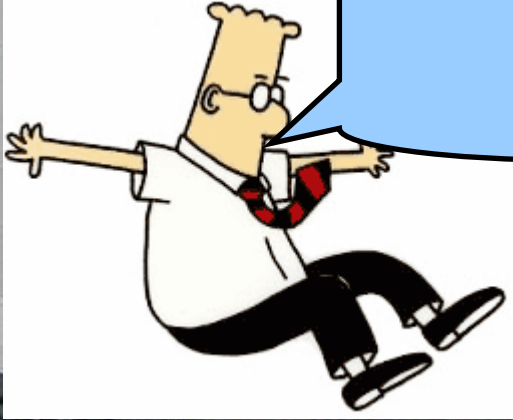


Landfill gas can condense as it moves from warm landfill material to cold surrounding soil.

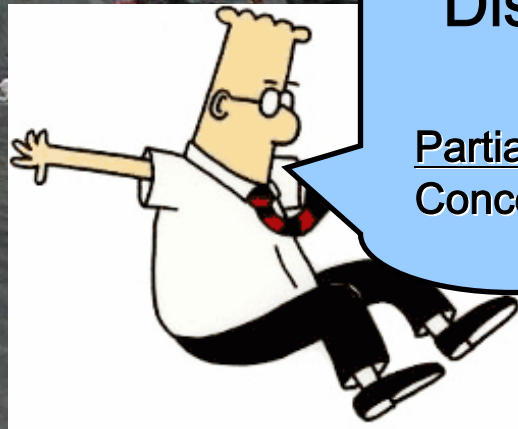


Condensed landfill gas with concentrated VOCs mixes easily with groundwater

# Getting Gas into GW 2. Equilibrium Partitioning



VOCs in landfill gas can also dissolve directly into groundwater



Dissolution is governed by Henry's Law- where  
$$\text{Partial pressure of a gas} = \text{Some ratio} \times \text{Concentration in Water}$$

1. Condensation and
  2. Equilibrium partitioning
- are the major mechanisms to get gas into GW



# POTENTIAL FOR CONTAMINATION (From Prosser and Janacek, 1995)

1. VOC concentrations vary widely in each landfill.
2. Establishing a minimum control level for LFG at the perimeter based on protection of groundwater does not seem practical.
3. Factors that can affect the potential for groundwater contamination include:
  - LFG generation rates
  - Liner and formation permeabilities
  - Distance to groundwater
  - VOC attenuation by soil bacteria.
  - Temperature differences between landfill and surrounding soil.
4. To quantify the mass of contamination that can be discharged from a landfill before experiencing significant groundwater contamination (defined as levels of VOCs in groundwater at or above the MCL) is difficult.
5. Each site is unique and should be treated accordingly.

**IMPORTANT BUT BORING LOOKING SLIDE**

# Landfill Gas and GW

## RB Requirements for Additional Monitoring

The SWRCB expects that Regional Boards may require some landfills to include additional gas monitoring as part of WDRs

on a site specific basis



**DILBERT**  
By Scott Adams

# POTENTIAL FOR CONTAMINATION (From Prosser and Janacek, 1995)

1. VOC concentrations vary widely in each landfill.
2. Establishing a minimum control level for LFG at the perimeter based on protection of groundwater does not seem practical.
3. Factors that can affect the potential for groundwater contamination include:
  - LFG generation rates
  - Liner and formation permeabilities
  - Distance to groundwater
  - VOC attenuation by soil bacteria.
  - Temperature differences between landfill and surrounding soil.
4. To quantify the mass of contamination that can be discharged from a landfill before experiencing significant groundwater contamination (defined as levels of VOCs in groundwater at or above the MCL) is difficult.
5. Each site is unique and should be treated accordingly.

**AGAIN THAT BORING SLIDE**

**PORTER COLOGNE...ARTICLE 2.  
ADMINISTRATIVE ENFORCEMENT  
AND REMEDIES BY THE STATE BOARD**

**§ 13320. Review by state board of regional board  
action**

(a) Within 30 days of any action or failure to act by a regional board ....any aggrieved person may petition the state board to review that action or failure to act....The state board may, on its own motion, at any time, review the regional board's action or failure to act and also any failure to act...

(b) The evidence before the state board shall consist of the record before the regional board, and any other relevant evidence which, in the judgment of the state board, should be considered to effectuate and implement the policies of this division.

