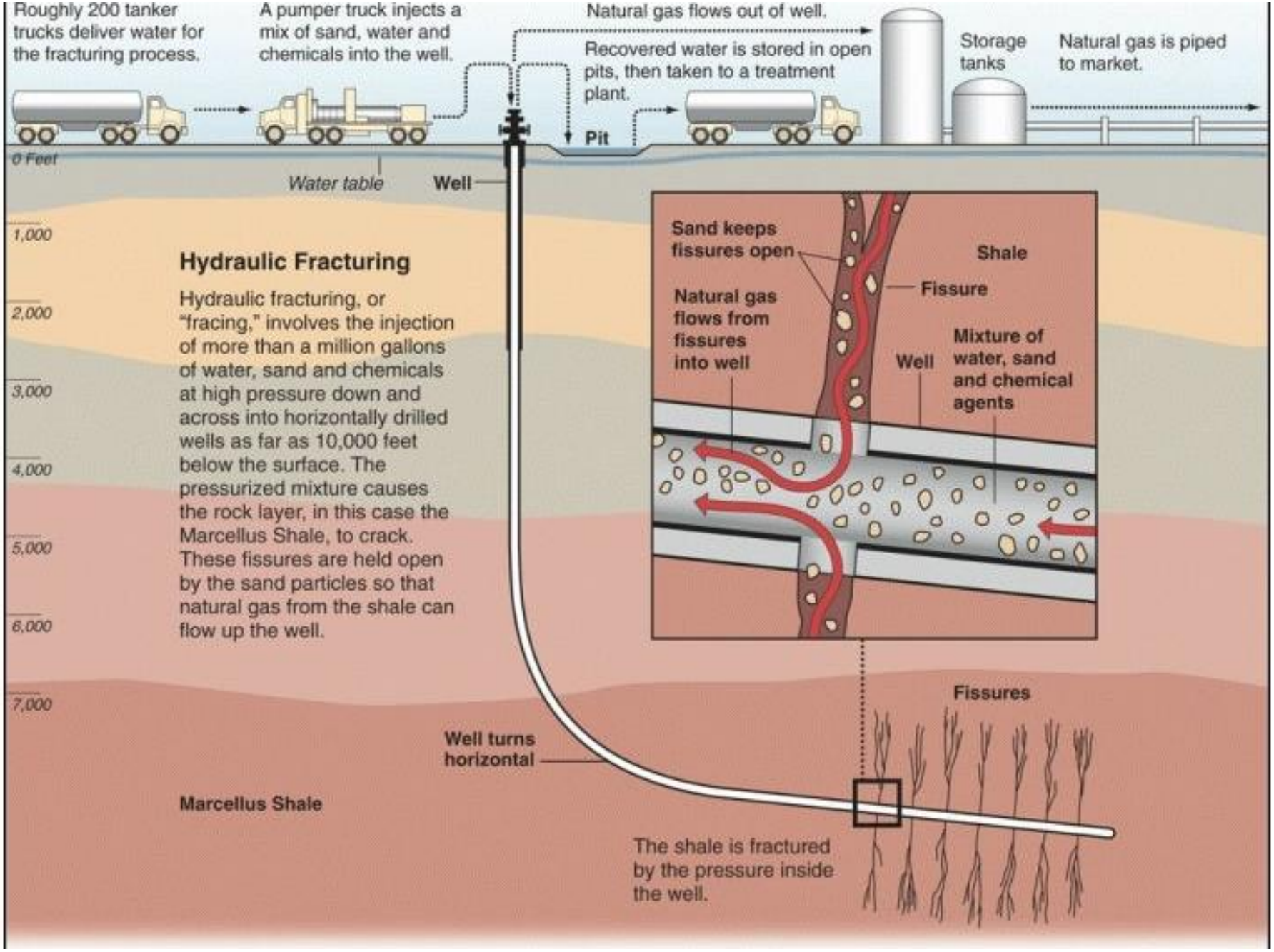
Public Health England

Shale gas: Potential impacts on air quality

Andrew Kibble
PHE CRCE Wales


Roughly 200 tanker trucks deliver water for the fracturing process.
A pumper truck injects a mix of sand, water and chemicals into the well.
Natural gas flows out of well.
Recovered water is stored in open pits, then taken to a treatment plant.
Pit
Storage tanks
Natural gas is piped to market.
0 Feet
Water table
Well
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Hydraulic Fracturing
Hydraulic fracturing, or "fracing," involves the injection of more than a million gallons of water, sand and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layer, in this case the Marcellus Shale, to crack. These fissures are held open by the sand particles so that natural gas from the shale can flow up the well.
Sand keeps fissures open
Shale
Fissure
Natural gas flows from fissures into well
Well
Mixture of water, sand and chemical agents
Fissures
Well turns horizontal
Marcellus Shale
The shale is fractured by the pressure inside the well.

Public Health England

Background

Shale gas extraction (fracking) is not "new"

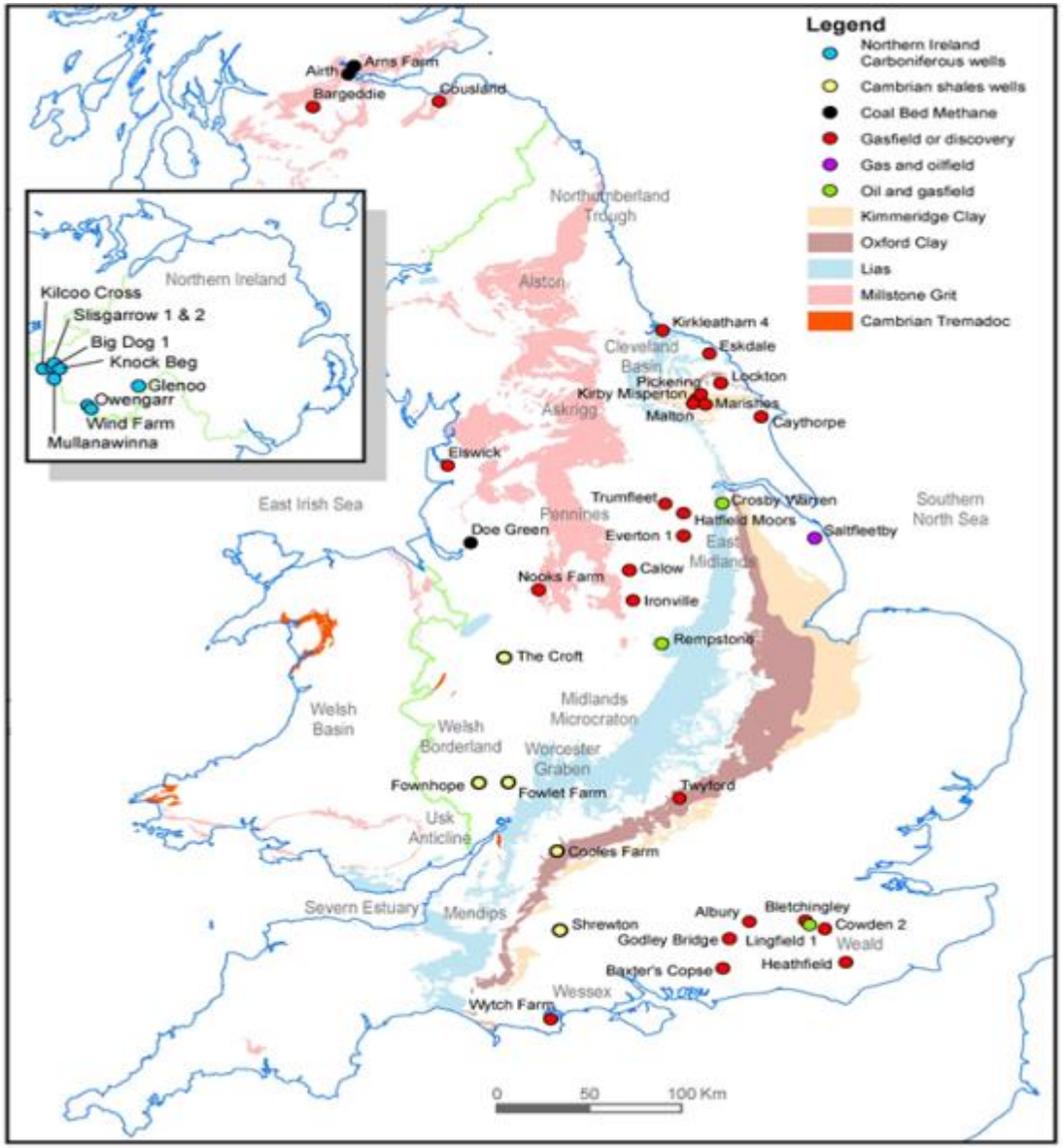
Scale and use of chemicals

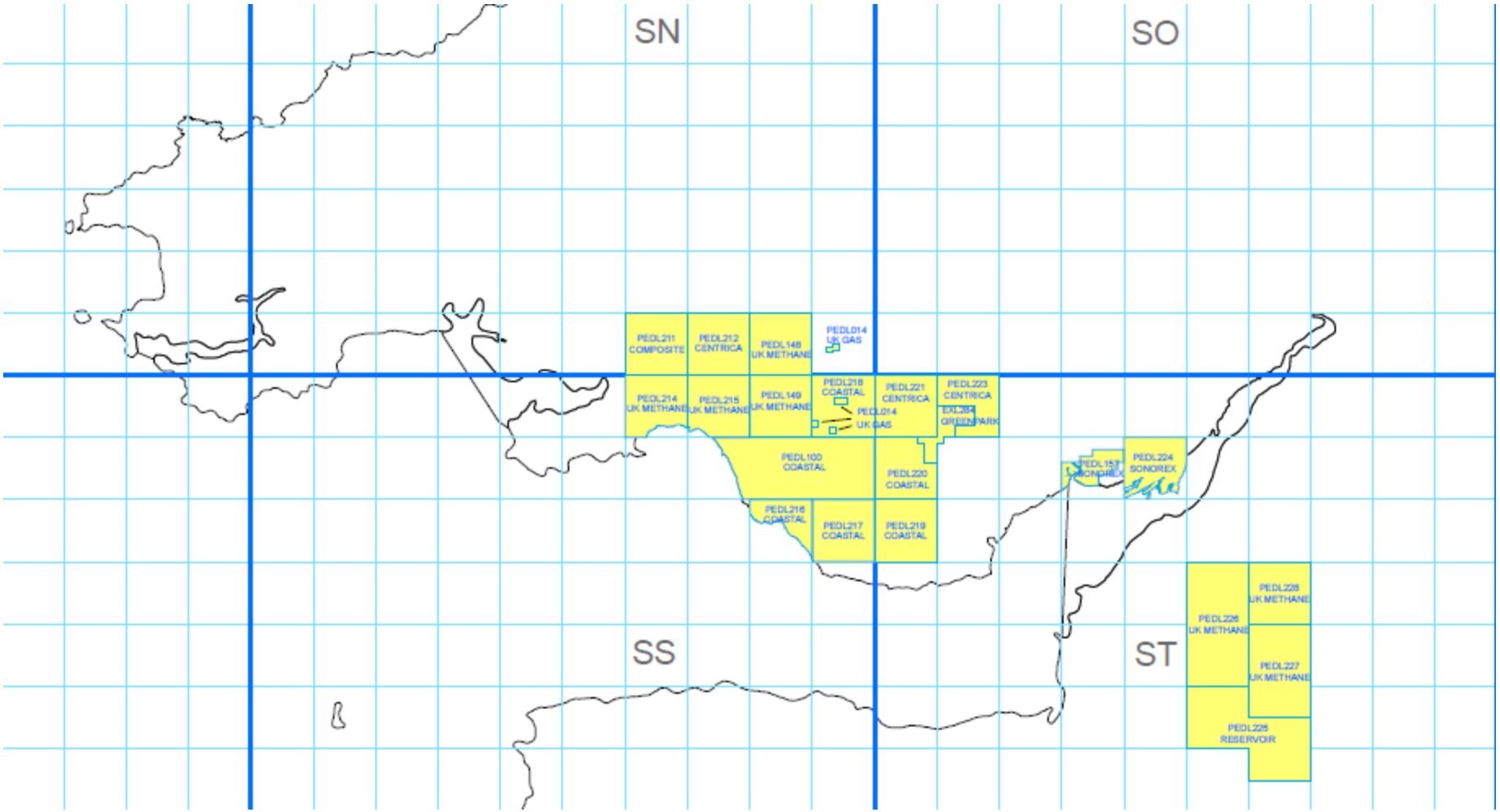
Limited fracking in UK (only 1 borehole)

Currently we do not know whether shale gas extraction is commercially viable

Existing legislation for on- and off-shore gas and oil drilling

Public Health England




SN
SO
SS
ST
PEDL211 COMPOSITE
PEDL212 CENTRICA
PEDL146 UK METHANE
PEDL014 UK GAS
PEDL214 UK METHANE
PEDL215 UK METHANE
PEDL149 UK METHANE
PEDL218 COASTAL
PEDL014 UK GAS
PEDL221 CENTRICA
PEDL223 CENTRICA
EXL284 GREENPARK
PEDL100 COASTAL
PEDL220 COASTAL
PEDL157 SONOREX
PEDL224 SONOREX
PEDL216 COASTAL
PEDL217 COASTAL
PEDL219 COASTAL
PEDL228 UK METHANE
PEDL226 UK METHANE
PEDL227 UK METHANE
PEDL225 RESERVOIR

Public Health England

What is in shale gas

Mainly methane, some carbon dioxide

Wet and dry shale gas

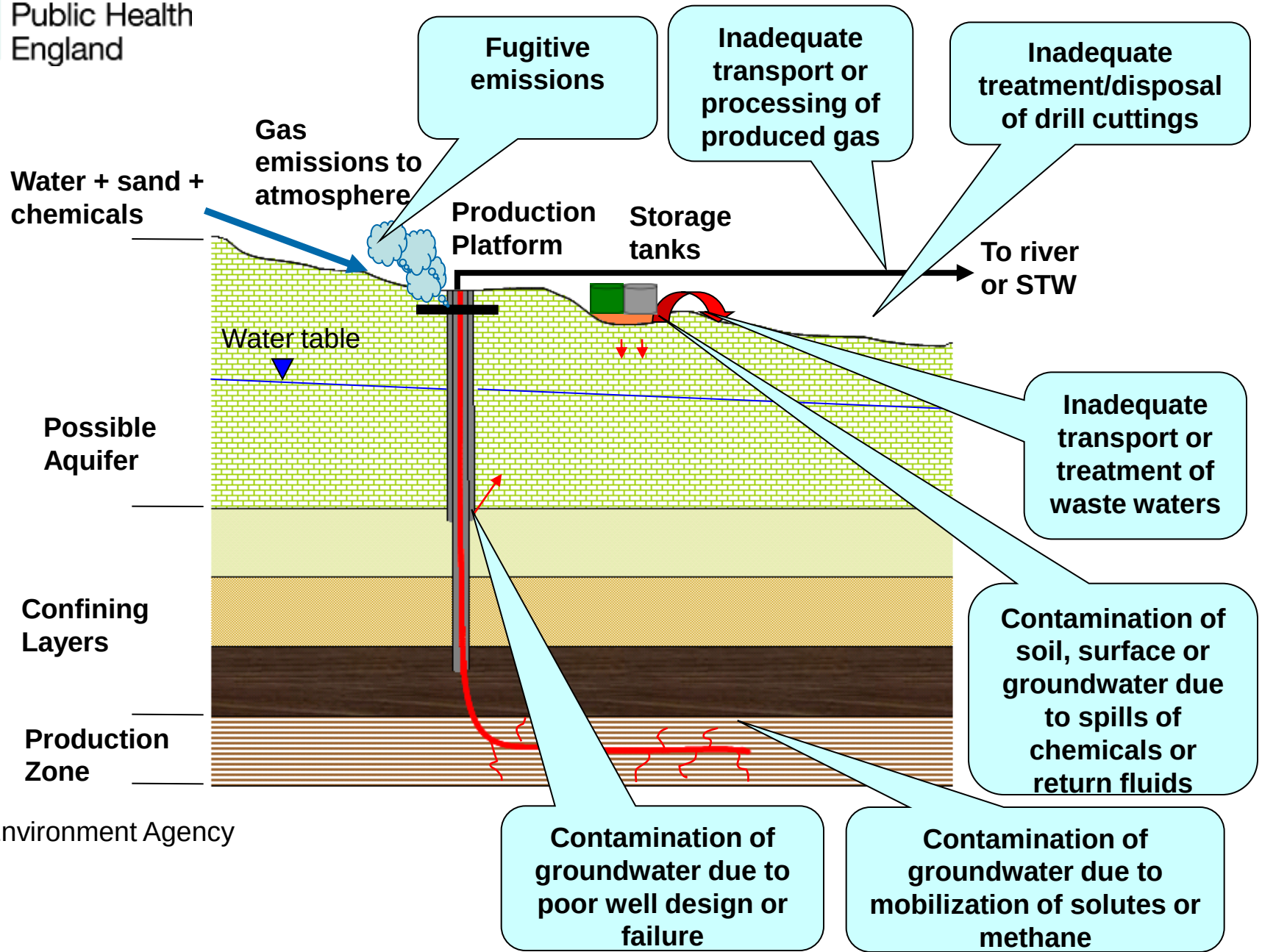
- Wet gas contains hydrocarbons such as ethane and butane (natural gas liquids)
- Wet shale gas has the potential to emit more VOCs during capture and processing.

Trace amount of hydrogen sulphide, sulphur dioxide

Radon and other radionuclides

Environmental risks of shale gas extraction

Public Health England



Public Health England

Potential Emissions to Air

- Direct emissions from engines during drilling and fracking operations and compressors used to capture and transport the gas on site. Pollutants may include particulate matter (PM), carbon monoxide (CO), NO_x including nitrogen dioxide (NO_2).
- Emissions from the venting of condensate and oil tanks on site. Pollutants may include a range of volatile organic compounds (VOCs).
- Emissions from gas capture and flaring. Pollutants may include methane, No_x, PM and other gases (e.g. VOCs).
- Fugitive emissions associated with operational infrastructure e.g. storage tanks, leaks from pumps, valves, pipe connectors etc.
- Dust emissions from sand (silica).

Public Health England

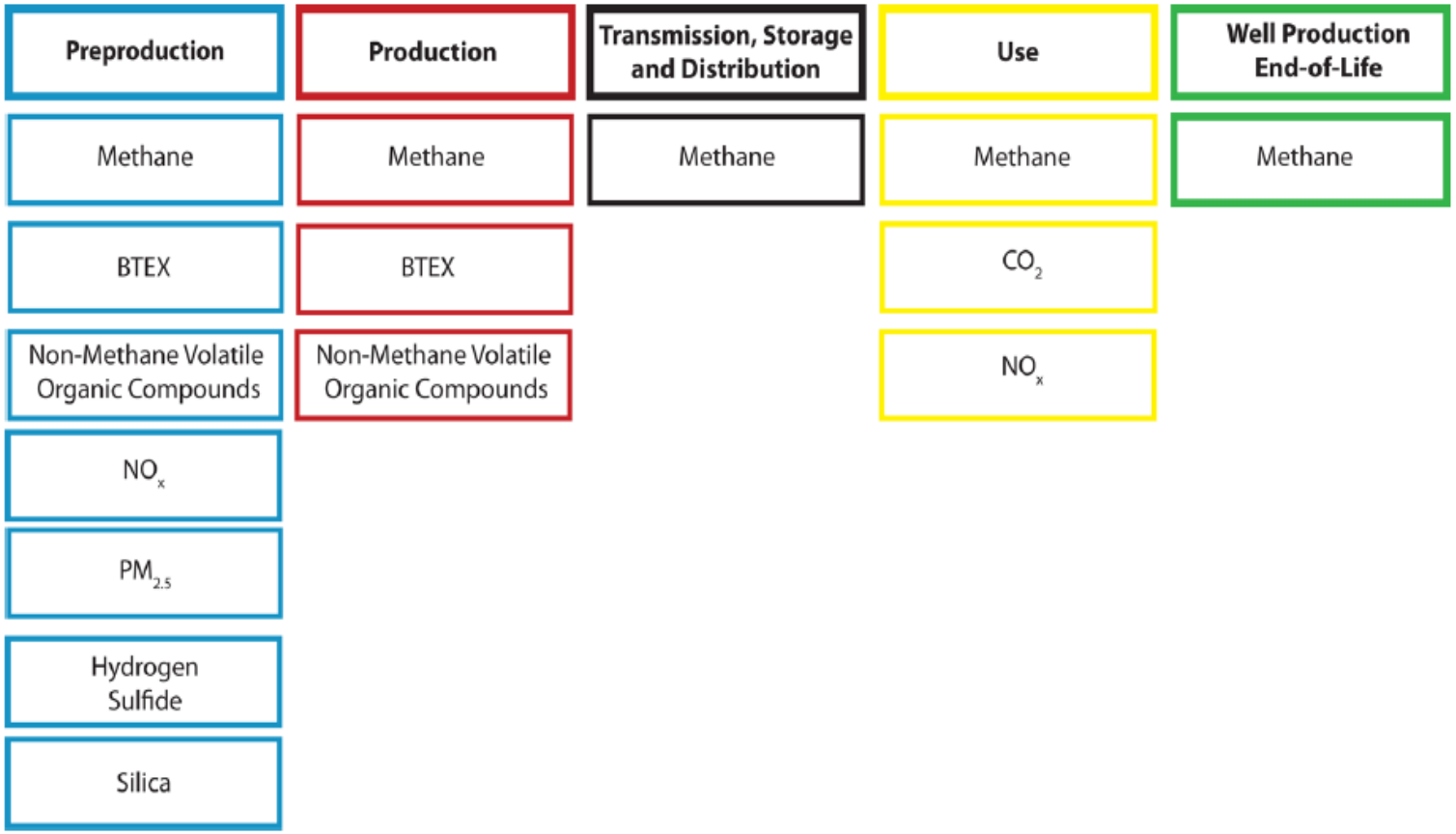


Figure 1. Potential species emitted to the atmosphere during specific stages of the natural gas life cycle.

Moore et al, EST 2014

Source	NOx	VOC	PM	Air Toxics	Data Quality
Well development					
Drill Rigs	●	○	●	●	Medium
Frac Pumps	●	○	●	●	Medium
Truck Traffic	●	○	●	●	Medium
Completion Venting		●		●	Poor
Frac ponds		○		?	Poor
Gas Production					
Compressor Stations	●	○	○	●	Medium
Wellhead compressors	○	○	○	○	Medium
Heaters and dehydrators		○	○	○	Medium
Blowdown venting		●		●	Poor
Condensate Tanks		●		○	Poor
Fugitives		●		○	Poor
Pneumatics		○		○	Poor

● = major source ○ = minor source

Carnegie Mellon

Public Health England

VOCs

- Sampling identified 70 VOCs in the vicinity of the compressor stations, functioning well, condensate tanks (Zelinska et al, 2010)
- Principal component analysis (PCA) from monitoring in residential areas of Texas identified 7 chemicals (o-xylene, ethylbenzene, 1,2,4-trimethylbenzene, m- and p-xylene, 1,3,5-trimethylbenzene, toluene and benzene) as a potential pollution signature of shale gas extraction (Rich et al, 2014)
- Light alkanes have also been identified as a key component of a shale gas source signature (Gilman, 2012; Petron, 2012, McKenzie, 2012).
- Colborn et al collected air samples between July 2010 to Oct 2011 close to a well pad with 16 vertical wells that underwent hydraulic fracturing during the sampling period

Public Health England

Air Quality Emissions

Chemical	Rich (median)	McKenzie (median)	Petron (median)	Colborn (mean)	Gilman (median)
Methane (ppm)	2.7		1.81-1.89	2.47	
Ethane (ppm)	1.4			0.02	0.02
Pentane (ppb)	1.4	3.09	0.01-0.48	1.5	2
Propane (ppm)	1.4		0.1-3.0	0.09	0.02
Toluene (ppb)	2.55	0.48		1.2	0.29
Benzene (ppb)	0.89	0.3	0.02-0.1	0.5	0.21
m/p Xylenes (ppb)	1.68	0.2		0.4	0.075
Hexane (ppb)	1.4	1.14		0.9	0.6
Trimethylbenzene (ppb)	0.59	0.024		0.2-0.3	
Methylene chloride (ppb)	0.3			206.2	

Public Health England

Ozone

Shale gas emissions may contribute to local and regional ozone, especially in areas with high density of drilling wells

VOCs and NO_x emissions in Haynesville Shale (NE Texas, NW Louisiana) are projected to impact regional ozone levels by 2020 (Kemball-Cook S et al 2012)

Shale gas may contribute 12% of NO_x and VOCs emissions in Marcellus shale area by 2020 (Roy et al, 2014).

Counties in Pennsylvania with a high density of wells, NO_x emissions could range from 20–40 times that allowed for a single ‘major’ emission source (Litovitz et al, 2013).

Picture is more complicated, ozone levels in Dallas/Fort Worth have not increased despite significant increase in drilling wells

Public Health England

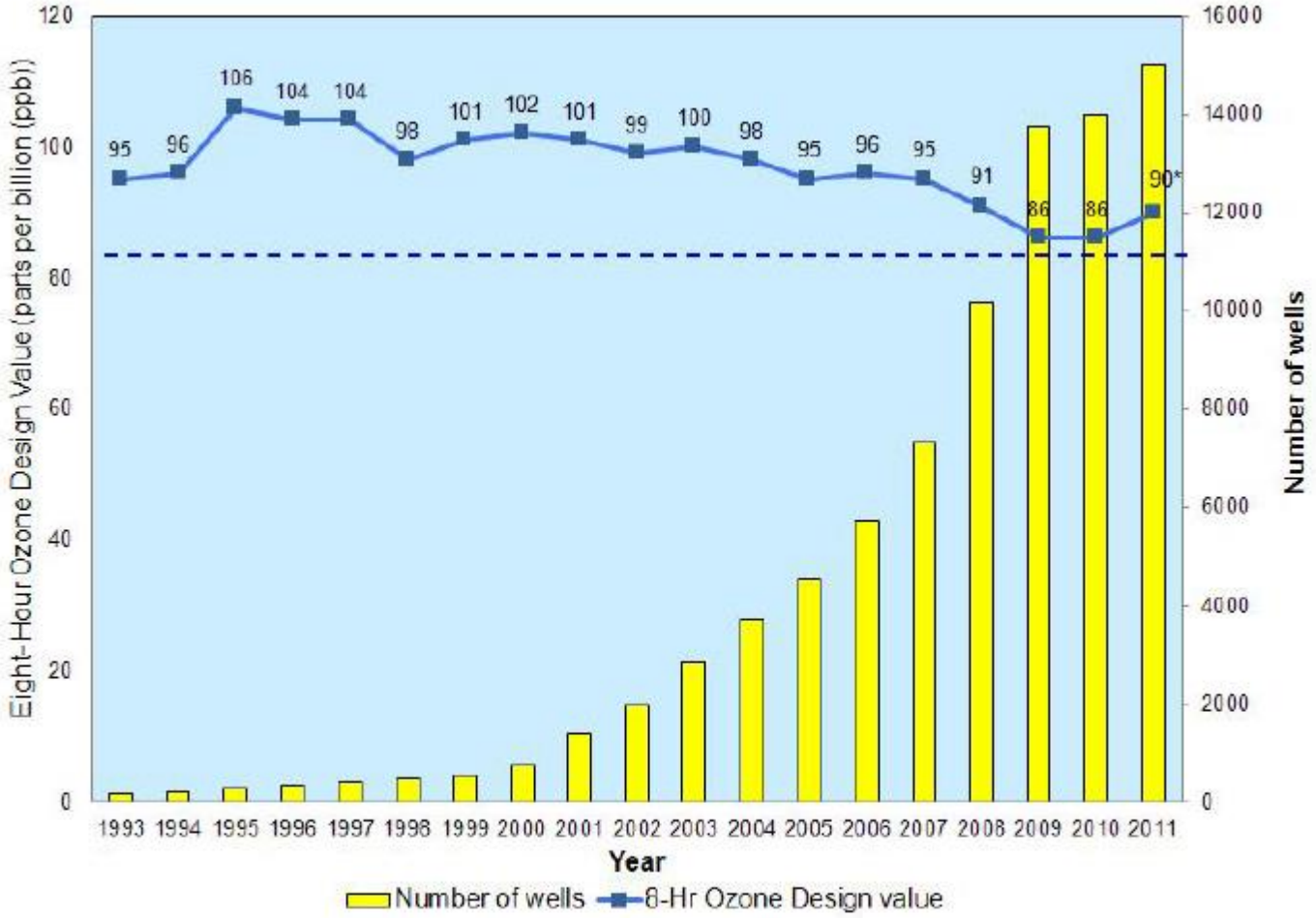


FIGURE 5-2 Dallas–Fort Worth area ozone design values and Barnett Shale production.
SOURCE: Honeycutt, 2012.

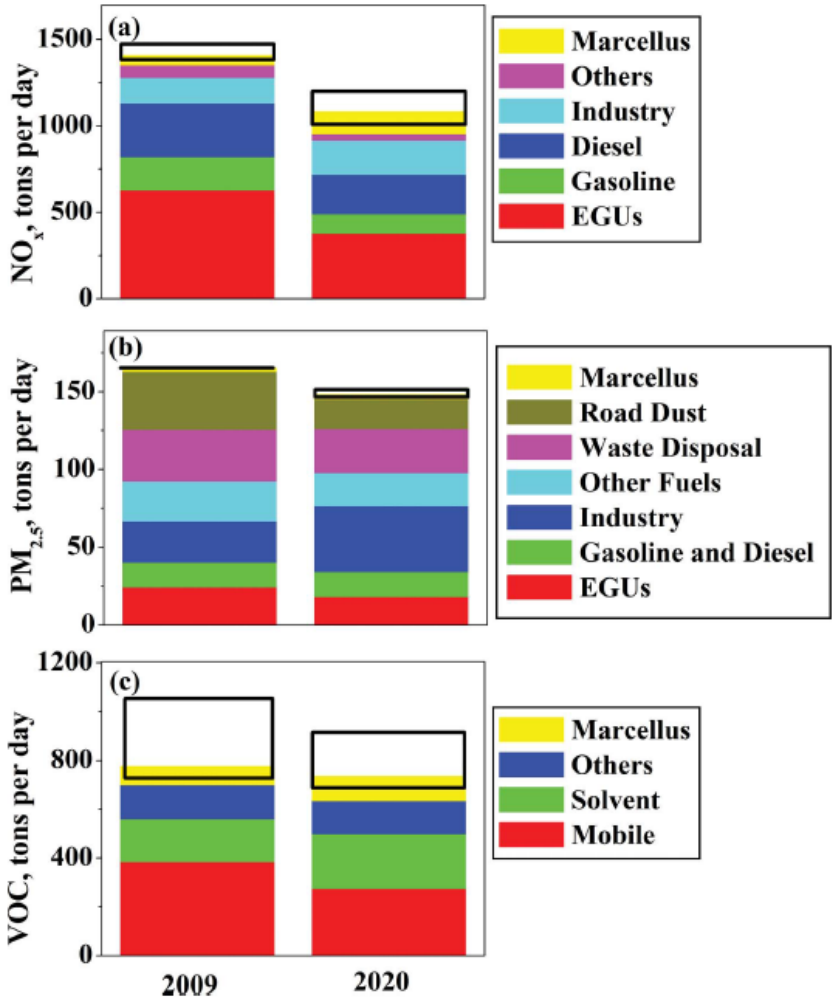


Figure 6. Source-resolved emissions of (a) NO_x, (b) $PM_{2.5}$, and (c) VOCs for the Marcellus region (Figure 1b). The 2020 emissions correspond to the average of the baseline controls scenario. The open black squares denote the 95% confidence intervals on the estimated Marcellus emissions. The cumulative distributions of emissions are plotted in Figure S19. VOCs correspond to anthropogenic VOC emissions.

Public Health England

Radiological pollutants

- Potential for radon gas to be present in natural gas extracted from UK shale, as is the case with existing natural gas supplies.
- Using the existing UK model, it is estimated that natural gas containing radon at the upper end of the range (2,923 Bq m^{-3}) reported by the USGS (Rowan and Kraemer, 2012) would give individual exposures of about 60 µSv/year representing about 2% of the UK average individual radiation exposure from all sources
- Myers T, 2012 concluded that, based on the depth of target shales, any radon released is likely to decay before it reaches any ground water supply via advection.
- UK has established capability to measure radon levels in various media including indoor air, water and natural gas (UK radon 2012).

Public Health England

Health Studies

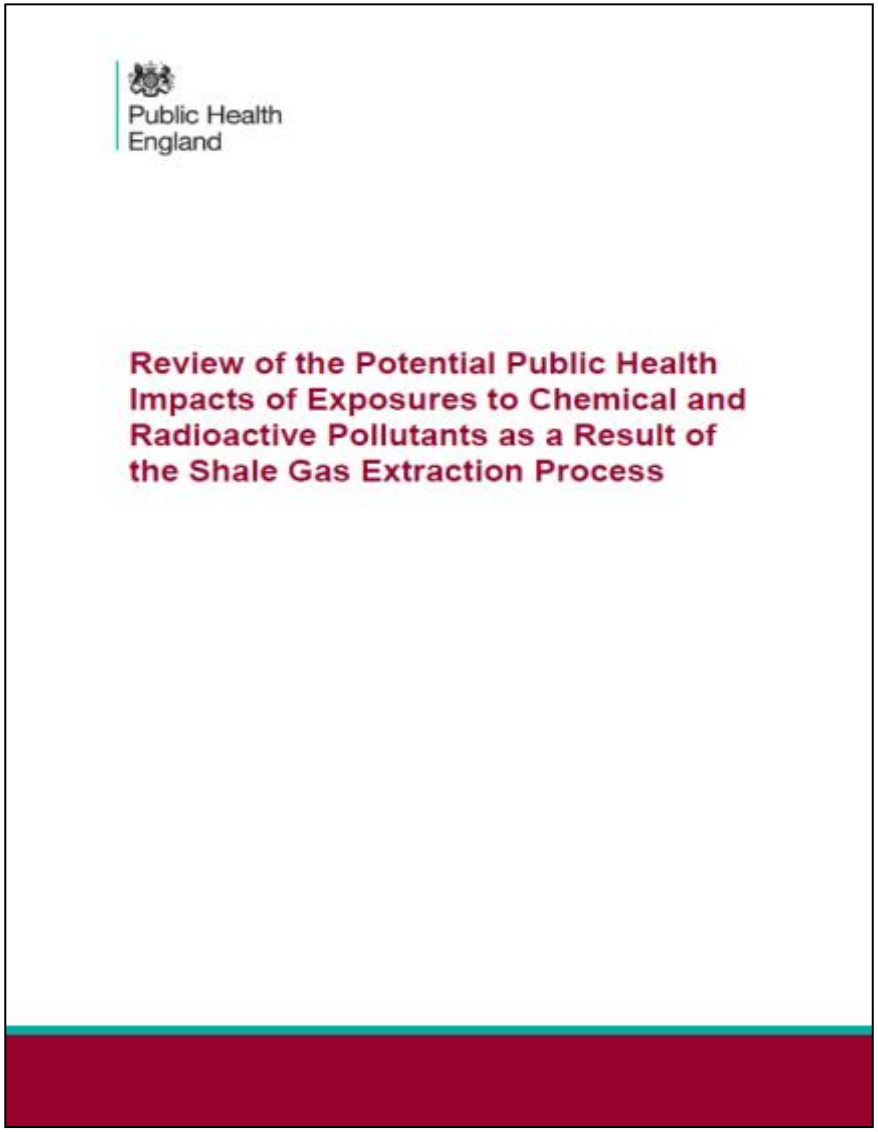
A limited but increasing number of health studies, mostly on air pollution

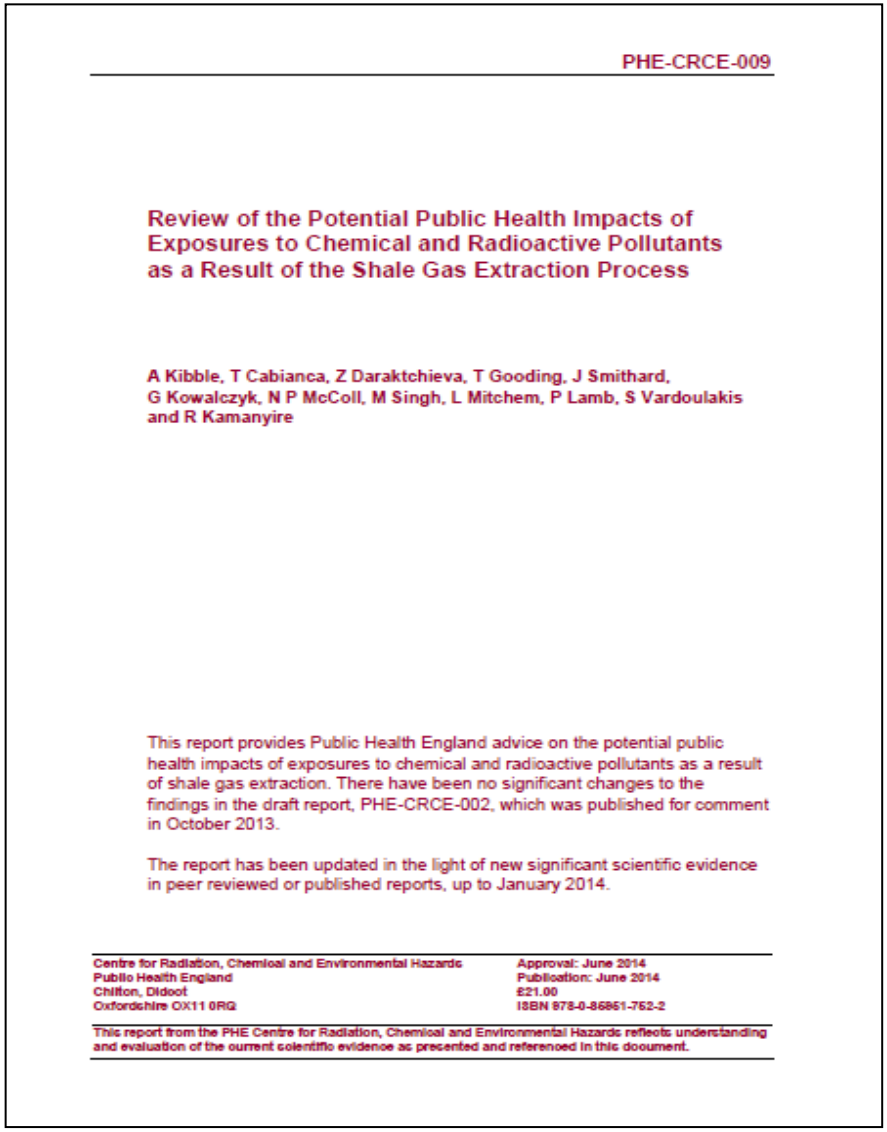
McKenzie et al (2012) estimated cancer risks and chronic non-cancer risks were greater for residents living within half a mile of the nearest well pads.

Dish, Texas 2013 small exposure assessment study (air) - blood VOC levels similar to general population

Fryzek et al, 2013 found no difference in the incidence of childhood cancer before and after drilling for shale gas although the time period was too short to adequately assess the risk

McKenzie et al (2014) reported a link between maternal exposure to air pollutants from shale gas extraction activities and birth outcomes such as congenital heart defects, neural tube defects and low birth weight.





PHE-CRCE-009

http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317141035385

Public Health England

Key Recommendations (air)

PHE / Public Health Wales will continue to work with regulators to ensure all aspects of shale gas extraction and related activities are properly risk assessed as part of the planning and permitting process.

Baseline environmental monitoring is needed to facilitate the assessment of the impact of shale gas extraction on the environment and public health. Many states in the USA have introduced emission inventories and region-wide air monitoring programmes

Effective environmental monitoring is needed throughout the lifetime of development, production and post-production.

Broader public health and socioeconomic impacts such as increased traffic...are considered.

The type and composition of the gas extracted is likely to vary depending on the underlying geology and this necessitates each site to be assessed on a case by case basis.

Public Health England

Summary

Many sources of air pollutants

- Drilling, engines, compressors, traffic, fugitive

Complex mixture of small sources of emissions

Different emission profiles during different parts of the shale gas production cycle

Cumulative emissions may be important (NO_x and VOCs = regional ozone)

Case by case assessment

Emissions inventories

Regulation

Public Health England

Acknowledgements

R Kamyanire

T Cabianca

Z Daraktchieva

T Gooding

J Smithard

G Kowalczyk

N P McColl

M Singh

L Mitchem

P Lamb

S Vardoulakis