Potential Public Health risks associated with Application P/12/0521/FUL

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Introduction

Morag Parnell worked as a General Practitioner for 20 years, 8 years in Community Paediatrics, and in 2004, co-founded the Women's Environmental Network Scotland (WENS), with the objective of campaigning for the primary prevention of cancer and other illness.

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In order to demonstrate the significant health risks posed by outdated regulatory frameworks, this paper will first outline the current state-of-the-art regarding low level exposures to industrial toxins.

Next, it will relate these failings to the current Proposal to extract gas in Falkirk Local Authority. Using data from Dart's current testing regime (covering only a narrow range of the potentially hazardous substances associated with CBM production), it will explore some impact scenarios, including one associated with the current Application. Lastly, it will take a brief look at a wider range of dangerous contaminants linked to CBM and their health risks.

There are numerous reasons for objecting to the exploration and recovery of "unconventional gas". WENS focus is on the potential effects on the health of humans and other species and the contribution to Climate Change. We have been at pains to show the link between these two aspects of pollution - that of polluting the atmosphere with greenhouse gases and pollution of our bodies with the products of burning fossil fuels and from producing and using the hundreds of everyday products derived from them. Two sides of one coin.

The seriousness of the climate problems facing us is now agreed by global scientific consensus, and has been clearly expressed by several prominent experts, such as former World Bank Chief Economist and Chair of the Grantham Research Institute on Climate Change and the Environment (LSE), Nicholas Stern[1]; Chief Economic Advisor to the International Energy Authority, Fatih Birol[2]; former Chief Scientific Advisor to UK Government, David King[3]; and the majority of the world's climatologists.

The inevitable conclusion is that it is no longer acceptable to invest new money and resources into the recovery of fossil fuels. Resources have no long-term viability, current rates of consumption are almost certain to cause environmental collapse, and extraction is set to grow ever more expensive and ecologically destructive. To possess this knowledge and still pursue this route is suicidal folly. Investment must be directed to energy conservation and renewable sources of energy, which we know will mitigate environmental harm and last indefinitely.

The seriousness of the implications for Public Health is outlined below.

Recent Evidence on Toxic Exposure. Before considering the known and suspected health effects of some of the many dangerous substances known to be used in CBM recovery, it is worthwhile to briefly outline some recent evidence regarding the effects of toxic exposure. Without a general context, it's too easy to assume that "permitted" levels is equivalent to "safe" levels. This is not so.

[1] H Stewart and L Elliot, "Nicholas Stern: 'I Got It Wrong on Climate Change – It's Far, Far Worse'," *The Guardian*, 2013, http://www.guardian.co.uk/environment/2013/jan/27/nicholas-stern-climate-change-davos.

[2] "HARDtalk: Fatih Birol - Chief Economist, International Energy Agency," *BBC*, 2013, http://www.bbc.co.uk/iplayer/episode/b01prkpt/HARDtalk_Fatih_Birol_Chief_Economist_International_Energy_Agency/.

[3] "Global Warming 'Biggest Threat'," *BBC*, January 9, 2004, sec. Science/Nature, http://news.bbc.co.uk/1/hi/3381425.stm.

"Permitted" levels are calculated using a cost / benefit analysis which accepts exposures to toxins in the workplace and in the wider environment to occur at levels which still allow some individual harm at the cost of what is considered to be a more universal gain.

Recent scientific evidence, however, shows this approach to be outmoded. We are being exposed to a battery of health hazards from occupational and environmental chemicals, which contribute significantly to our modern day epidemics, including cancer, and a range of disorders: neurological, learning, attentional, behavioural, reproductive, immune system, growth, metabolism, obesity, type 2 diabetes, and respiratory.

Since the 90s, when the first real research on the devastating effects of toxins on the biological integrity of wildlife and laboratory animal populations became publicly available[4], those diseases which were linked to specific exposures are now being observed in human populations, and are following similar increasing trends[5] [6] [7]. The evidence cited demonstrates that our toxic exposure from breathing, drinking, eating and absorption through our skin, is ubiquitous[8], detectable from pre-conception to sperm and ova, and particularly damaging during certain "windows of vulnerability" such as in the foetus, in infancy, in puberty and in pregnancy.

The Myth of "Safe" Levels of Exposure. Whilst we have a good understanding of the effects of high levels of toxic exposure on humans from industrial accidents (e.g. Minamata, Chernobyl, Bhopal, Seveso), drug tragedies (e.g. Diethylstilboestrol, Thalidomide), alcohol and tobacco, and other situations (e.g. use of X-rays during pregnancy), the effects of low level exposure have been more difficult to assess in the past.

However, medical, scientific and technological advances in the last few decades have enabled detailed research on the effects of low doses of carcinogens and endocrine disrupters in animals and humans. These studies demonstrate clearly that the idea of a cutoff point below which no harm is assumed is misleading.

That there is no safe dose of a carcinogen is now generally accepted by medical establishments[9], including the WHO. Risk may be very small but it never disappears, even at the lowest levels of exposure[10]. This doesn't mean illness from any dose is inevitable, or that there isn't a relationship between risk and dosage, but even the smallest dose under a particular, often random, combination of factors may cause cancer to develop.

At very low doses – parts per billion (ppb), or trillion (ppt) – substances with properties similar to hormones (endocrine disrupters or EDCs) can also have far-reaching effects, by programming an individual for future serious illness. These mechanisms differ from the direct toxic effects of high doses.

Many carcinogens, endocrine disrupters and other toxins are also "bioaccumulative"[11]. This means they attain concentrations within living organisms, particularly those higher up the food chain (such as us), which are several orders of magnitude greater than their concentrations in the environment[12].

The combined effects of multiple carcinogens and endocrine disrupters, repeated exposure, bioaccumulation, and the vulnerable periods mentioned above, make a new approach essential.

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[4] Theo Colborn, Theo Colburn, and John Peter Meyers, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?--A Scientific Detective Story*, Reprint (Plume Books, 1997).

[5] A Kortenkamp et al., "State of the Art Assessment of Endocrine Disrupters" (European Commission, 2011).

[6] Laura N. Vandenberg et al., "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Nonmonotonic Dose Responses," *Endocrine Reviews* 33, no. 3 (June 1, 2012): 378–455, doi:10.1210/er.2011-1050.

[7] "WHO | State of the Science of Endocrine Disrupting Chemicals - 2012," *WHO*, accessed March 20, 2013, http://www.who.int/ceh/publications/endocrine/en/index.html.

[8] K Cook, "EWG's 10 Americans Presentation (full-length)" (Environmental Working Group, 2011), http://www.ewg.org/news/videos/ewgs-10-americans-presentation-full-length.

[9] J Wilson, "Thresholds for Carcinogens: a Review of the Relevant Science and Its Implications for Regulatory Policy," in *What Risk?*, 1997, 31.

[10] "Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2," accessed April 2, 2013, http://www.nap.edu/openbook.php?isbn=030909156X.

[11] "Bioaccumulation," *Wikipedia, the Free Encyclopedia*, March 27, 2013, http://en.wikipedia.org/w/index.php?title=Bioaccumulation&oldid=546434903.

[12] J.A. Smith, P.J. Witkowski, and T.V. Fusillo, "Manmade Organic Compounds in the Surface Waters of the United States--A Review of Current Understanding" (U.S. Geological Survey Circular 1007, 1988).

Risks associated with Dart's Proposal and Current Operations

Because CBM extraction is new to the UK, we must also look to data from operations in Australia and the US for guidance on potential toxic contaminants[13] as well as subjecting the current UK regime to a more responsible examination. It is important to note that some of the disorders mentioned above (particularly, those involving reproduction and cancer) entail long latency periods and, thus, the most serious health effects of unconventional gas extraction may yet to be seen.

The combined and cumulative effects of exposure to multiple toxins in modern life both exacerbate the potential risks of CBM and make it increasingly difficult to sift out its effects from those associated with other sources. Thus it would seem wise to adopt the Precautionary Principle: a statutory requirement under EU law which states that, if an action has a suspected risk of causing harm to the public or to the environment then, in the absence of scientific consensus that it is harmful, those proposing the act must first prove that it is not[14].

Toxins associated with Natural Gas Extraction. Colborn and colleagues have compiled a list of 944 products, containing 632 chemicals, which are used in all natural gas operations[15]. *Only 353 currently have Chemical Abstract Service (CAS) numbers* (IDs assigned to all chemicals with disclosed substance information and described in the open scientific literature). Of the CAS accredited substances.

- 75% affect skin and eyes and respiratory and digestive system;
- 40-50% affect the brain and nervous , immune , renal and cardiovascular systems;
- 37% affect the endocrine system; and
- 25% could cause mutations and cancer.

(NB. Totals add up to more than 100% because many of the chemicals have multiple effects).

Gas mining and the burning of fossil fuels also release, and concentrate, Normally Occurring Radioactive Materials ('Norms') such as Thorium, Radium, Uranium, Potassium and their decay products. Many Norms have very long half-lives and so persist in the environment for decades, sometimes centuries. The dangers of exposure to ionising radiation from these materials are well documented. All are Group 1 Carcinogens and, as such, there is no safe dose.

To date the only information publicly available about the toxins produced by Dart's operations are measurements of chemicals in their "treated" produced water. No consideration is given to the substances potentially involved in drilling, flaring, drying of the gas, toxicant extraction, equipment use, accidental spills and leaks, fugitive emissions and other air pollution, or the underground migration of toxic gases and liquids.

Thus, for the remainder of the paper, we must focus primarily on data taken from two sources about "treated" water from exploratory activities in PEDL133. The first is the information Dart publicly report on their website (available at the time of writing) in relation to testing which took place in December 2012[16]. The second is a table showing average levels of contaminants found in Dart's tests over 2009. This is not publicly available but was requested by WENS from SEPA under EIRS 2004[17].

As the current paper is underpinned by the Precautionary Principle[18], when a chemical appears in both reports, we have used the more precise statistic or the one that indicates the highest levels of discharge. Nevertheless, when drawing from the 2009 table, we have always employed the overall average concentration figure for each chemical, rather than cherry picking the well test that represents the highest levels.

[13] Mariann Lloyd-Smith, "Toxic Chemicals in Unconventional Gas Exploration and Production" (National Toxics Network, 2012), http://www.ntn.org.au/wp/wp-content/uploads/2013/02/NTN-Toxics-in-UG-Activities-Briefing.pdf.
[14] "The Precautionary Principle" (Europa, 2011), http://europa.eu/legislation_summaries/consumers/consumer_safety/l32042_en.htm.
[15] T Colborn, "Chemicals in Natural Gas Operations" (TEDX, 2013), http://www.endocrinedisruption.com/chemicals.introduction.php.
[16] "Additional Abstraction Information" (Dart Energy Scotland, 2012), http://www.dartenergyscotland.com/additional-abstraction-info.html.
[17] "The Environmental Information (Scotland) Regulations 2004" (Scottish Government, 2004), http://www.legislation.gov.uk/ssi/2004/520/contents/made.
[18] "The Precautionary Principle."

Treated Produced Water. In CBM processes, as pressure within the coal declines due to pumping water out of the coal bed ("dewatering"), both the gas and "produced water" come to the surface through tubing. Dart treat this "produced" water to remove a range of highly toxic contaminants, before releasing the "treated" water into the Forth River.

Only information about contaminants left in the "treated water" is given by Dart. It should be noted that we have no information on the concentrations of toxins in the "untreated" water. Those removed are sent to an appropriate licensed site. Because these chemicals have an economic value and could be used in the production of a host of consumer goods, we should be alert to their fate.

Health Risks of 15 Chemicals in Dart's Treated Produced Water. The test results pertain to the measured concentrations of 15 toxins in their "treated water". Of these chemicals, over two thirds are endocrine disrupters[19] and a third are Group 1 carcinogens[20], which, as we have seen, can have significant health risks even at *minute* doses - parts per billion or parts per trillion. To give some idea of the tininess of these amounts, one part per billion and one part per trillion are equivalent to one drop of water diluted into 1, or 20, Olympic-sized swimming pools, respectively.

All 15 chemicals appear in the Agency for Toxic Substances and Disease Registry's (ATSDR) priority list of hazardous substances *"which are determined to pose the most significant potential threat to human health due to their known or suspected toxicity"*[21]. Four of them feature in the Top 10: Arsenic, Cadmium, Mercury and Benzene.

The impacts of the Top 4 hazardous chemicals are covered in the table below (fig i). Appendix 1 details the significant risks associated with the other 11 toxins, and Appendix 2 looks at other hazardous chemicals commonly associated with CBM operations, but which don't appear in the report.

The impacts shown in fig i (below), and the Appendices, have been drawn from the Toxicant and Disease Database of the Collaborative on Health and the Environment (the CHE)[22], which summarises the evidential links between chemical contaminants and human diseases and conditions. The classifications of "Strong", "Good' and "Limited" Evidence are based on the following criteria drawn up by a team of scientists working at the CHE (for full details see[23]).

- **Strong Evidence:** Causal association with disease has been verified, toxicity is well-accepted by the medical community, and / or chemicals have been determined by the International Agency for Research on Cancer (IARC) to have sufficient evidence for causing cancer in humans.
- **Good Evidence**: Association with disease have been established through epidemiological studies or via strong corroborating evidence from animal studies, and / or chemicals have been determined by the IARC or the Office of Environmental Health Hazard Assessment (OHHEA, Proposition 65[24]) to have sufficient evidence for causing cancer or reproductive / developmental disorders in animals, although only limited evidence currently exists for a link in humans.
- **Limited Evidence:** There is only a weak association with disease from cases involving only a few exposed individuals, epidemiological studies that have given mixed or equivocal results, or reports which clearly demonstrate toxicity in animals where no human data exist, and / or the IARC or EPA (US Environmental Protection Agency) determine that there is only limited or inadequate evidence that the chemicals cause cancer in either humans or animals.

[19] "TEDX List of Potential Endocrine Disruptors" (TEDX, 2013), http://www.endocrinedisruption.com/endocrine.TEDXList.overview.php.
[20] "List of IARC Group 1 Carcinogens," *Wikipedia, the Free Encyclopedia*, February 28, 2013, http://en.wikipedia.org/w/index.php?title=List_of_IARC_Group_1_carcinogens&oldid=541123728.
[21] "Priority List of Hazardous Substances" (Agency for Toxic Substances and Disease Registry, 2013), http://www.atsdr.cdc.gov/spl/.
[22] "CHE Toxicant and Disease Database" (CHE, 2012), http://www.healthandenvironment.org/tddb/.
[23] S Janssen, G Solomon, and T Schettler, "About the Toxicant and Disease Database" (The Collaborative on Health and the Environment, 2011), http://www.healthandenvironment.org/tddb_about.
[24] "Proposition 65" (Office of Environmental Health Hazard Assessment, 1983), http://www.oehha.org/prop65.html.

Fig i. Health Impacts of the 4 Most Hazardous Chemicals in Dart's Test Report

Toxin	Strong Evidence	Good Evidence	Limited Evidence
Arsenic ***(#1 on ATSDR Priority List)***	*Angiosarcoma (hepatic)* *Arrhythmias* *Bladder cancer* *Contact dermatitis - irritant* *Diabetes - Type II* *Hearing loss* *Hyperkeratosis / hyperpigmentation* *Lung cancer* *Peripheral neuropathy* *Skin cancer (non-melanoma)* *Skin ulceration*	*Adult-onset leukemias** *Alopecia (hair loss)* *Anemia (including hemolytic)* *Aplastic anemia* *Bronchitis - chronic* *Cardiomyopathy* *Cirrhosis* *Congenital malformations - general* *Coronary artery disease, peripheral vascular disease, atherosclerosis* *Fetotoxicity (miscarriage / spontaneous abortion, stillbirth)* *Hepatocellular cancer (liver cancer)* *Hepatoportal sclerosis* *Hypertension (high blood pressure)* *Low birth weight / small for gestational age / intra-uterine growth retardation* *Myocardial infarction (heart attack)* *Nasal septal perforation* *Neural tube defects / CNS malformations** *Pneumonitis (hypersensitivity)* *Raynaud's phenomenon* *Renal (kidney) cancer* *Skeletal malformations** *Steatosis (fatty liver)*	*Acute tubular necrosis* *Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay* *COPD (chronic obstructive pulmonary disease)* *Genito-urinary malformations (includes male and female)* *Immune suppression** *Metal fume fever* *Myelodysplastic syndrome (pre-leukemia)* *Neurosthenia (organic affective syndrome)* *Uterine cancer*
Mercury ***(#3 on ATSDR Priority List)***	*Acute tubular necrosis* *Behavioral problems** *Bronchitis - acute* *Cerebral palsy* *Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay* *Contact dermatitis - irritant* *Decreased coordination / dysequilibrium** *Hearing loss* *Minamata disease* *Peripheral neuropathy* *Pneumonitis (hypersensitivity)* *Psychiatric disturbances (disorientation, hallucinations, psychosis, delirium, paranoias, anxiety/depression, emotional lability, mood changes, euphoria)* *Seizures* *Spasticity / myoclonus*	*Altered sex ratio* *Anemia (including hemolytic)* *Aplastic anemia* *Autoimmune antibodies (positive ANA, anti-DNA, RF, etc.)* *Chronic renal disease* *Congenital malformations - general* *Coronary artery disease, peripheral vascular disease, atherosclerosis* *Cranio-facial malformations** *Decreased vision (includes blindness, retinopathy, optic neuropathy)* *Delayed growth* *Fetotoxicity (miscarriage / spontaneous abortion, stillbirth)* *Glomerulonephritis* *Immune suppression** *Low birth weight / small for gestational age / intra-uterine growth retardation* *Menstrual disorders (abnormal bleeding, short cycles, long cycles, irregular cycles, painful periods)* *Neural tube defects / CNS malformations** *Pneumonia* *Pulmonary edema*	*ALS (Lou Gehrig's disease)* *Brain cancer - adult** *Erectile dysfunction* *Hormonal changes (levels of circulating sex hormones - FSH/LH, Inhibin, and/or estrogens, progesterones, androgens, prolactin)* *Hypertension (high blood pressure)* *Myocardial infarction (heart attack)* *Nephrotic syndrome* *Neurosthenia (organic affective syndrome)* *Pulmonary fibrosis* *Reduced fertility - female (infertility and subfertility)* *Reduced fertility - male (infertility and subfertility)* *Renal (kidney) cancer* *Scleroderma* *Thyroid disorders - hypothyroidism*
Cadmium ***(#6 on ATSDR Priority List)***	*Acute tubular necrosis* *Chronic renal disease* *Itai-itai disease* *Lung cancer* *Olfactory alterations (hyposmia, anosmia, dysomias)* *Osteoporosis* *Pneumonitis (hypersensitivity)* *Renal stones*	*Anemia (including hemolytic)* *Cardiomyopathy* *COPD (chronic obstructive pulmonary disease)* *Coronary artery disease, peripheral vascular disease, atherosclerosis* *Hormonal changes (levels of circulating sex hormones - FSH/LH, Inhibin, and/or estrogens, progesterones, androgens, prolactin)* *Nephrotic syndrome* *Osteomalacia* *Pneumonia* *Reduced fertility - male (infertility and subfertility)*	*Abnormal sperm (morphology, motility, and sperm count)* *ADD/ADHD, hyperactivity* *Arrhythmias* *Autoimmune antibodies (positive ANA, anti-DNA, RF, etc.)* *Brain cancer - adult** *Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay* *Cranio-facial malformations** *Fetotoxicity (miscarriage / spontaneous abortion, stillbirth)* *Genito-urinary malformations (male and female)* *Hypertension (high blood pressure)* *Hypoactivity* *Immune suppression** *Menstrual disorders (abnormal bleeding, short cycles, long cycles, irregular cycles, painful periods)* *Metal fume fever* *Neural tube defects / CNS malformations** *Oral clefts (cleft lip and palate)* *Pancreatic cancer* *Peripheral neuropathy* *Prostate cancer* *Pulmonary edema* *Pulmonary fibrosis* *Renal (kidney) cancer* *Soft tissue sarcoma** *Testicular cancer*

Fig i. Health Impacts of the 4 Most Hazardous Chemicals in Dart's Test Report (cont)

Benzene ***(#7 on ATSDR Priority List)***	*Acute non-lymphocytic leukemia* *Anemia (including hemolytic)* *Aplastic anemia* *Immune suppression** *Myelodysplastic syndrome (pre-leukemia)* *Thrombocytopenia*	*Arrhythmias* *Autoimmune antibodies (positive ANA, anti-DNA, RF, etc.)* *Hearing loss* *Menstrual disorders (abnormal bleeding, short cycles, long cycles, irregular cycles, painful periods)* *Preterm delivery* *Renal (kidney) cancer* *Scleroderma*	*Acute lymphocytic leukemia* *Asthma - irritant* *Bone cancer/Ewings sarcoma* *Brain cancer - adult** *Breast cancer* *Cardiac congenital malformations** *Chronic lymphocytic leukemia* *Gallbladder cancer* *Hepatocellular cancer (liver cancer)* *Lung cancer* *Lymphoma (non-Hodgkin's)* *Multiple myeloma* *Nasopharyngeal / sino-nasal cancer* *Neural tube defects / CNS malformations** *Peripheral neuropathy*

Estimated Discharge Volumes for 7 Toxins per Litre. Fig ii (below) shows the concentrations for the 7 toxins which Dart publicly report on their website (available at the time of writing[25]) as a comparison with levels "permitted' by the World Health Organisation for drinking water. The amounts are shown in ***micrograms per litre*** (one millionth of a gram). On face value, apart from *Arsenic and Benzene, which exceed "permitted" levels, there is no apparent risk (*the statistic for Arsenic is the average from the 2009 test results[26], which exhibited significantly higher concentrations than the published report).

Fig ii. Results for the 7 toxins in "treated water" publicly reported by Dart.

Chemicals Tested For	WHO's "permitted levels" (micrograms per litre)	Dart's concentration levels (micrograms per litre)
Arsenic (#1 on ATSDR Priority List)	*10.00µgs*	*59.00µgs*
Mercury (#3 on ATSDR Priority List)	*6.00µgs*	*0.55µgs*
Cadmium (#6 on ATSDR Priority List)	*3.00µgs*	*0.74µgs*
Benzene (#7 on ATSDR Priority List)	*10.00µgs*	*12.00µgs*
Xylene	500.00µgs	2.00µgs
Toluene	700.00µgs	15.00µgs
Ethylbenzene	300.00µgs	1.00µgs

Estimated Daily Discharge Volumes for the 15 Toxins. Now let us see what levels of these chemicals, together with the additional 8 drawn from the 2009 test reports, **in grammes**, this could represent per well per day (see fig iii below). We have used a daily discharge volume of 40m³ of treated water, which is the average of the amount that Dart state on their website was extracted from two wells on the date of the 2012 test, i.e. 83m³/2 (publicly available at the time of writing)[27].

Also included in this table are additional columns which indicate whether a chemical is an endocrine disrupter (EDC), or a Group 1 or 2 carcinogen (G1-C and G2-C, respectively) generally recognised by the medical establishment, as well as the total discharge volumes for each. Chemicals are also ordered by risk from top to bottom, according to the ATSDR priority list (which, it should be noted, is based on *existing* evidence). Although we must hold in mind the minute doses that most of these chemicals require to trigger disease, superficially, these quantities still seem insignificant.

[25] "Additional Abstraction Information" (Dart Energy Scotland, 2012), http://www.dartenergyscotland.com/additional-abstraction-info.html
[26] C Everitt, "F0183627- Response to Request for Information Under FOI" (SEPA, 2013).
[27] "CBM Water Abstraction and Discharge Licences" (Dart Energy Scotland, 2013), http://www.dartenergyscotland.co.uk/coal-bed-methane-process/water-abstraction-and-discharge-licences.html.

Fig iii. Results for the 15 Toxins scaled up to the daily discharge level of a single well

Chemicals Tested for	Dart's Concentration Levels	G1-C	G2-C	EDC
Arsenic (#1 on ATSDR Priority List)	*2.36gms*	*Y*		*Y*
Mercury (#3 on ATSDR Priority List)	*0.02gms*			*Y*
Cadmium (#6 on ATSDR Priority List)	*0.03gms*	*Y*		*Y*
Benzene (#7 on ATSDR Priority List)	*0.48gms*	*Y*		*Y*
Cobalt	0.20gms			Y
Nickel	0.24gms	Y		Y
Xylene	0.08gms			Y
Zinc	4.92gms			
Chromium	0.08gms	Y		
Toluene	0.60gms		Y	Y
Ethylbenzene	0.04gms		Y	
Iron	103.64gms			
Aluminium	1.20gms			Y
Manganese	15.88gms			Y
Fluoride	8.84gms			Y
TOTAL VOLUME:	138.61gms	3.19gms	0.64gms	29.93gms

Conservative Estimates for the Discharge Volumes of the 15 Toxins over the Lifecycle of the Current Application and Existing Wells. Considering the potential impacts of a single well, it is astonishing that neither Falkirk Council, nor planning application documentation, are able to clarify *precisely* how many production wells are represented by Dart's proposed PEDL133 operation.

In the absence of clear information, we will assume that (i) Dart currently owns 16 production wells, as stated on their website at the time of writing, i.e. 5 at Airth, 10 acquired from Composite Energy, plus an additional drilled recently by Dart[28]; and (ii) the present Application entails a further 10 production wells, i.e. 9 stated explicitly by Dart, and another one near Airth implied by their development maps, and which presumably falls under *"additional drilling operations"* (Dart Planning Statement 2.4). This brings us to a tentative total of 26.

The literature does not seem to offer an average overall produced, or treated, water volume for a single CBM well. However, it does suggest that the volume of water produced by a single well varies considerably according to its location (even within the same field) and decreases significantly over course of its lifetime, particularly, in the first few years[29]. Moreover, we also do not know the age of the wells used for the 2012 test. However, we can conjecture that 40m³ is a reasonable ballpark daily output for an early PEDL133 well as it would allow Dart to operate 22 new wells easily under the 880m³ daily abstraction limit[30] currently permitted by the licence for their total operation, and many more if the wells were of varying ages.

Thus, for all subsequent calculations *we will assume a consistent discharge volume of 40m³ for each well for a period of 2 years*. Until clearer information is made available, this seems a reasonable underestimation of the total water a well lasting *"up to 25 years* (Dart Planning Statement 1.18)*"* might be expected to produce.

Whilst we appreciate the amount of toxicants will vary according to volumes of extracted water, the nature of the geology and the number of operational days, we can still use the data to approximate the **kilogram** quantities of the 15 chemicals that could be discharged over the lifetime of the 26 existing and planned production wells (see fig iv).

[28] "Airth Natural Gas Production Project" (Dart Energy Scotland, 2013), http://www.dartenergyscotland.co.uk/assets/pedl133.html.
[29] "Water Production and Disposal," in *Coalbed Methane* (Halliburton Company, 2007), pp421–459, http://www.halliburton.com/public/pe/contents/Books_and_Catalogs/web/CBM/H06263_Chap_09.pdf.
[30] "CBM Water Abstraction and Discharge Licences" (Dart Energy Scotland, 2013), http://www.dartenergyscotland.co.uk/coal-bed-methane-process/water-abstraction-and-discharge-licences.html

This conservative estimate represents *over two and a half tonnes of toxic contaminants* released into the Forth River, including *over half a tonne of EDCs,* and *over 50kgs of the Top 4 most hazardous chemicals*.

We can no longer ignore low dose exposures, equivalent to drops in swimming pools, particularly to children and pregnant women. Considering the scientific knowledge we possess about the bioaccumulative impacts of such chemicals on health and biological integrity, to "permit" this discharge into our environment is a failure of a duty of care to the public and the natural world.

Fig iv. Results for the 15 Toxins scaled up to the lifecycle of the 26 existing and planned wells

Chemicals Tested for	Dart's Concentration Levels	G1-C	G2-C	EDC
Arsenic (#1 on ATSDR Priority List)	*44.79kgs*	*Y*		*Y*
Mercury (#3 on ATSDR Priority List)	*0.42kgs*			*Y*
Cadmium (#6 on ATSDR Priority List)	*0.56kgs*	*Y*		*Y*
Benzene (#7 on ATSDR Priority List)	*9.11kgs*	*Y*		*Y*
Cobalt	3.80kgs			Y
Nickel	4.56kgs	Y		Y
Xylene	1.52kgs			Y
Zinc	93.38kgs			
Chromium	1.52kgs	Y		
Toluene	11.39kgs		Y	Y
Ethylbenzene	0.76kgs		Y	
Iron	1967.09kgs			
Aluminium	22.78kgs			Y
Manganese	301.40kgs			Y
Fluoride	167.78kgs			Y
TOTAL VOLUME:	2630.85kgs	60.54kgs	12.15kgs	568.10kgs

Conservative Future Scenario for the Discharge Volumes of the 15 Toxins over the Lifecycle of the PEDL133. Whilst not directly relevant to the current Proposal, it is worthwhile to explore one further future scenario.

The well density of a CBM field is often higher than a conventional natural gas field. One US section (640 acres) typically contains 8 CBM wells, compared with only one well per section for conventional gas[31]. The gas field covered by Dart's current licence, PEDL133, covers 81,545 acres (330km²)[32]. This is equivalent to 127 US sections, and, thus, has a potential upper limit of over a 1000 wells.

However, we have anecdotal evidence that Dart have admitted aspirations for at least 100[33] to 300 wells in the area. To maintain our principle of moderation, we will assume the former figure for our final estimate (see fig v below).

Here, we have potential overall volumes of 10 tonnes of toxic contaminants, over 2 tonnes of known endocrine disrupters and carcinogens, and almost quarter of a tonne of the Top 4 discharged into our local environment.

We must remind that *this is from the treated water alone*, and does not consider the toxins which evidence has linked to all aspects of CBM operations, such as the waste from water treatment, the chemicals involved in general

[31] J Michael Evans, "International Oil and Gas BMP Project: Coalbed Methane" (Gestches-Wilkinson Center for Natural Resources, Energy and the Environment. University of Colorado Law School., 2007), http://www.oilandgasbmps.org/resources/cbm.php.
[32] "Airth Natural Gas Production Project."
[33] Fred, "Huge Gas Plans for Airth: 100 Wells, Compulsory Purchse Orders and Fracking Not Ruled Out!" (Frack Off Scotland, 2012), http://frack-off.org.uk/huge-gas-plans-for-airth-100-rigs-compulsory-purchase-orders-and-fracking-not-ruled-out/.

operations, fugitive emissions and other air pollution, and the contamination of soil, aquifers and waterways through the underground migration of toxic gases and liquids.

A human and environmental disaster!

Fig v. Results for the 15 Toxins scaled up to a Conservative Future Scenario for PED133

Chemicals Tested for	Dart's Concentration Levels	G1-C	G2-C	EDC
Arsenic (#1 on ATSDR Priority List)	*172.28kgs*	*Y*		*Y*
Mercury (#3 on ATSDR Priority List)	*1.61kgs*			*Y*
Cadmium (#6 on ATSDR Priority List)	*2.16kgs*	*Y*		*Y*
Benzene (#7 on ATSDR Priority List)	*35.04kgs*	*Y*		*Y*
Cobalt	14.60kgs			Y
Nickel	17.52kgs	Y		Y
Xylene	5.84kgs			Y
Zinc	359.16kgs			
Chromium	5.84kgs	Y		
Toluene	43.80kgs		Y	Y
Ethylbenzene	2.92kgs		Y	
Iron	7565.72kgs			
Aluminium	87.60kgs			Y
Manganese	1159.24kgs			Y
Fluoride	645.32kgs			Y
TOTAL VOLUME:	10118.65kgs	232.84kgs	46.72kgs	2185.01kgs

Conclusion

The current paper outlined recent scientific evidence that obliterates the idea that "permitted levels" means "safe levels", and demonstrated how infinitesimally small quantities of some chemicals, particularly carcinogens and endocrine disrupters, can constitute a significant risk to the health of humans and animals. Using Dart's data on 15 toxins measured in their Treated Produced Water (all with links to endocrine disruption, cancer, or other diseases and disorders), it shows how the cumulative, discharge quantities estimated for the current Proposal constitute an unacceptable hazard to local people and natural environment. Considering the scientific knowledge we now possess, we can reach no conclusion other than that the risks to health and life associated with Proposal far outweigh its economic benefits, and that our conscience and duty of care demands that we ban all CBM operations in Falkirk Local Authority with immediate effect.

APPENDIX 1. Health impacts of the other 11 CBM Toxins reported by Dart

Toxin	Strong Evidence	Good Evidence	Limited Evidence
Cobalt	Asthma - allergen, sensitizer Cardiomyopathy Contact dermatitis - irritant Hard metal disease Hearing loss Pneumonitis (hypersensitivity) Rhinitis - allergic Thyroid disorders – hypothyroidism	Arrhythmias Lung cancer Pancreatitis Sarcoidosis Soft tissue sarcoma*	
Nickel	Asthma - allergen, sensitizer Contact dermatitis - irritant Lung cancer Nasopharyngeal / sino-nasal cancer Olfactory alterations (hyposmia, anosmia, dysomias) Pneumonitis (hypersensitivity) Rhinitis - allergic	Immune suppression* Laryngeal cancer Nasal septal perforation Pneumonia Pulmonary edema Pulmonary fibrosis Stomach cancer	Arrhythmias Fetotoxicity (miscarriage / spontaneous abortion, stillbirth) Mesothelioma Metal fume fever Myelodysplastic syndrome (pre-leukemia) Myocardial infarction (heart attack) Prostate cancer Renal (kidney) cancer Soft tissue sarcoma*
Xylene	Arrhythmias Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay Fetotoxicity (miscarriage / spontaneous abortion, stillbirth) Hearing loss Hormonal changes (levels of circulating sex hormones - FSH/LH, Inhibin, and/or estrogens, progesterones, androgens, prolactin) Menstrual disorders (abnormal bleeding, short cycles, long cycles, irregular cycles, painful periods) Scleroderma	Acute hepatocellular injury (hepatitis) Brain cancer - adult* Colorectal cancer Delayed growth Peripheral neuropathy Stomach cancer	
Zinc	Contact dermatitis - irritant Pneumonitis (hypersensitivity) Skin ulceration	Pneumonia Pulmonary edema	Testicular cancer
Chromium	Acute tubular necrosis Asthma - allergen, sensitizer Bronchitis - acute Contact dermatitis - irritant Nasal polyps Nasal septal perforation Pneumonitis (hypersensitivity) Rhinitis - allergic Skin ulceration	Brain cancer - adult* Chronic renal disease COPD (chronic obstructive pulmonary disease) Photosensitivity Pulmonary fibrosis Stomach cancer	Abnormal sperm (morphology, motility, and sperm count) Adult-onset leukemias* Autoimmune antibodies (positive ANA, anti-DNA, RF, etc.) Bladder cancer Esophageal cancer Immune suppression* Pancreatic cancer Prostate cancer Reduced fertility - male (infertility and subfertility) Renal (kidney) cancer Soft tissue sarcoma*
Toluene	Cranio-facial malformations* Fetal alcohol syndrome / fetal solvent syndrome	Acute tubular necrosis Arrhythmias Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay Delayed growth Fetotoxicity (miscarriage / spontaneous abortion, stillbirth) Hearing loss Hormonal changes (levels of circulating sex hormones - FSH/LH, Inhibin, and/or estrogens, progesterones, androgens, prolactin) Low birth weight / small for gestational age / intra-uterine growth retardation Menstrual disorders (abnormal bleeding, short cycles, long cycles, irregular cycles, painful periods) Reduced fertility - female (infertility and subfertility) Scleroderma	Abnormal sperm (morphology, motility, and sperm count) Acute hepatocellular injury (hepatitis) Asthma - irritant Brain cancer - adult* Color vision disturbance Colorectal cancer Decreased coordination / dysequilibrium* Genito-urinary malformations (includes male and female) Immune suppression* Neural tube defects / CNS malformations* Neurosthenia (organic affective syndrome) Peripheral neuropathy Stomach cancer

Toxin	Strong Evidence	Good Evidence	Limited Evidence
Ethyl Benzene[34]		Sleepiness, fatigue, headache, eye, nasal and throat irritation, chest constriction, tearing of the eyes, and difficulty in breathing. Neurological effects including impaired muscle coordination, salivation, and reduced activity.	Kidney Cancer Developmental Defects Testicular Tumours Effects on blood cell types
Iron	Pneumoconiosis	Alzheimer's Brain cancer - adult* Diabetes - Type II Parkinson's disease / movement disorders Soft tissue sarcoma*	
Aluminum	Asthma - allergen, sensitizer Bronchitis - chronic Lung cancer Pulmonary fibrosis	Decreased coordination / dysequilibrium* Dementia Osteomalacia Pneumonitis (hypersensitivity) Seizures Spasticity / myoclonus	Abnormal sperm (morphology, motility, and sperm count) ALS (Lou Gehrig's disease) Alzheimer's Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay Coronary artery disease, peripheral vascular disease, atherosclerosis Parkinson's disease / movement disorders Porphyria (toxic) Pulmonary edema Sarcoidosis
Manganese	Cholestasis Parkinson's disease / movement disorders	ADD/ADHD, hyperactivity Bronchitis - acute Decreased coordination / dysequilibrium* Peripheral neuropathy Pneumonia Pneumonitis (hypersensitivity) Psychiatric disturbances (disorientation, hallucinations, psychosis, delirium, paranoias, anxiety/depression, emotional lability, mood changes, euphoria)	ALS (Lou Gehrig's disease) Arrhythmias Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay COPD (chronic obstructive pulmonary disease) Delayed growth Erectile dysfunction Fetotoxicity (miscarriage / spontaneous abortion, stillbirth) Hormonal changes (levels of circulating sex hormones - FSH/LH, Inhibin, and/or estrogens, progesterones, androgens, prolactin) Metal fume fever Neural tube defects / CNS malformations* Neurosthenia (organic affective syndrome) Peripheral neuropathy Reduced fertility - male (infertility and subfertility) Skeletal malformations*
Fluoride	Glomerulonephritis Osteoporosis Osteosclerosis	Bone cancer/Ewings sarcoma Cognitive impairment (includes impaired learning, impaired memory, and decreased attention span) / mental retardation / developmental delay Lung cancer Pneumoconiosis Pulmonary fibrosis Thyroid disorders – hypothyroidism	

[34] "Ethylbenzene: Health Information Summary" (New Hampshire Department of Enviromental Services, 2004), http://des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-ehp-5.pdf.

APPENDIX 2. Impacts of a Selection of other CBM Toxins[35] not reported by Dart/SEPA.

*Naphthaline *does* appear in the report but was excluded because levels were not as significant as those selected.

Toxin	Strong Evidence	Good Evidence	Limited Evidence
***Naphthaline**	Methemoglobinemia	Anemia (including hemolytic) Cataracts	Nasopharyngeal / sino-nasal cancer
Dichloromethane	Arrhythmias, Myocardial infarction (heart attack)	Brain cancer - adult* Fetotoxicity (miscarriage / spontaneous abortion, stillbirth), Reduced fertility - male (infertility and subfertility)	breast cancer, Hepatocellular cancer (liver cancer), Lung cancer, Pancreatic cancer Peripheral neuropathy, Prostate cancer
2-Butoxy Ethanol		Haemolytic anaemia with damage to spleen, bone marrow, kidneys , eyes, immune system and cancer.	
Ethylene Glycol	Abnormal sperm (morphology, motility, and sperm count), Fetotoxicity (miscarriage / spontaneous abortion, stillbirth),Reduced fertility - male (infertility and subfertility)	Acute tubular necrosis, Congenital malformations - general Cranio-facial malformations*, Reduced fertility - female (infertility and subfertility)	
Methanol	Acute tubular necrosis, Decreased vision (includes blindness, retinopathy, optic neuropathy)	Pancreatitis, Parkinson's disease / movement disorders	
Acrylonitrile		Acrylonitrile is highly flammable & toxic. It undergoes explosive polymerisation. The burning material releases fumes of hydrogen cyanide and oxides of nitrogen. It is classified as a Class 2B carcinogen (possibly carcinogenic) by the International Agency for Research on Cancer (IARC),[2] and workers exposed to high levels of airborne acrylonitrile are diagnosed more frequently with lung cancer than the rest of the population. Acrylonitrile increases cancer in high dose tests in male and female rats and mice.	Brain cancer - adult*,, Breast cancer, Colorectal cancer, , Lung cancer Pancreatic cancer, Prostate cancer, Stomach cancer.
Glutaraldehyde	Asthma - allergen, sensitizer		
Acetaldehyde	Asthma - allergen, sensitizer	Laryngeal cancer Nasopharyngeal / sino-nasal cancer Oral cancer	

[35] "CHE Toxicant and Disease Database."