Table 2. Unwanted/trace compounds in fuel gases, and their consequences

		Landfill gas	Sewage digester	Bio-gas	Coal bed/ mine methane	Shale gas	Associated petroleum gas	Natural gas – well head	Natural gas – delivered
		A	B	C	D	E	F	G	H
Long chain hydrocarbons		See *Note (h)*							
Hydrogen sulphide		See *Note (i)*							
Water		See *Note (j)*							
Non-methane organic compounds (NMOC) *Note (k)*	ppm	<1			Long chain hydrocarbons obviously occur but so can naturally occurring radioactive materials (NORM)				0
Ammonia *Note (l)*	ppm	<1	<1		0	0	0	0	0
Carbon dioxide		See *Note (q)*							
Oxides of nitrogen (NO_x) *Note (m)*	mg/Nm^3		This is an engine related matter rather than a gas one. Manufacturers deal with this. It is, of course, an important issue from a regulatory point of view. Typically the limit is set at around 200						
Halogenated compounds *Note (n)*	mg/Nm^3	<200	0	0	0	0			
Silicon *Note (o)*	mg/Nm^3	0 – 140			0				
Solids *Note (p)*	mg/Nm^3		Very variable						<<1

Notes:

(h) Long chain hydrocarbons are valuable and usually removed for sale separately from the gas. For in-field use the engine has to deal with them and issues surrounding liquid ingress as well as reduction in methane number need to be considered. They are not an issue with gases A, B, C, H and only very minor with D.

(i) Hydrogen sulphide, or other sulphur compounds, are not normally found in quantity in gases A, B, C, D, H but can be found in any source of unprocessed natural gas even if it is not present at initial exploration. Bacterial action can generate the gas in the reservoir during production. Natural gas contaminated with hydrogen sulphide is known as "sour gas". As mentioned in Table 1 hydrogen sulphide is a major factor in many forms of corrosion when water is present, frequently necessitating the use of more exotic materials than would be used in its absence. It is also extremely toxic to humans. Hydrogen sulphide is always a component of sewage digester gas in varying concentrations. It can occur, usually at lower concentration, in landfill gas and biogas. Engine manufacturers will only tolerate very low levels of hydrogen suphide, see Table 3.

(j) Water in an engine is an issue with respect to liquid ingress potentially causing damage and promoting corrosion particularly when hydrogen sulphide is present or, certain organic compounds, found in landfill that can combine with the water to form corrosive acids. It also wastes energy due to its conversion to steam. Water in gases E, F, G is likely to be very saline and presents additional corrosion problems. Water is relatively easy to remove.

(k) These apply particularly to landfill gas and can include a large range of compounds ranging from acrylonitrile though to xylenes. Although many of these compounds can pass through the engine safely some can be hazardous environmental pollutants (HEP) and others, such as volatile organic compounds (VOC), can react with sunlight to form smog but this is not normally a problem if the engine combustion is normal. In a similar way US EPA regulates seven hazardous air pollutants (HAP): asbestos; beryllium; mercury; vinyl chloride; benzene; arsenic; and radon/ radionuclides. All of these can occur in landfill gas.

(l) Ammonia is not normally a problem, apart from the pungent smell, but it does burn to form NO_x.

(m) A common consideration for gas burning devices particularly gas turbines and engines.

(n) Normally only found in landfill gas and sewage gas. Can cause corrosion and under specific combustion conditions can form dioxins and furans both of which are toxic

(o) Silicon occurs with gases A and B and should be removed before the gas reaches the engine/filters etc.

(p) Apart from gas H all gases can contain solids. Gases A, D, E, F are particularly prone to solids. Solids must be removed before the gas enters the engine but, fortunately, solids are easy to remove.

(q) High levels of carbon dioxide can be a problem to some engines since it can result in high temperatures in the vicinity of the exhaust valve.