Fracking wastewater

Water use

Hydraulic fracturing (or fracking) makes use of large quantities of water into which chemicals and proppant (mainly sand) is mixed. The process starts by drilling a vertical well which, when it reaches the shale deposits it is turned horizontally. A "necklace" of shaped explosive charges is inserted, which when detonated produce a series of holes in the pipe. The fracking water is pumped at a high pressure (depending on the depth), which forced from the holes, produces "fractures" in the shale, which are then "propped" open by the proppant, mainly sand, to prevent the fractures from closing and to let the oil or gas in the shale to be released once the hydraulic pressure is released.

Once the hydraulic pressure is released, some, but not all, of the injected water flows back to the surface as "flowback", which contains some of the recovered oil or gas from the shale and which is then separated from it, though not totally. The initial flowback of around 800 to 1000 cubic metres a day tails off and is followed by the "produced" water which then replaces it with "formation" water. Part of the returning water can be treated on the well pad with a trailer-mounted treatment plant and be re-used.

The amount of production water used for fracking varies from 8,000 to 23,000 cubic metres per well (2 million to 6 million US gallons).

Wastewater composition

A mixture of the returned flowback and produced water contains some of the added chemicals and proppant, but also dissolved toxic metal salts, some radioactive, from the shales into which the initial water was injected. There is also a certain amount of dissolved methane and other petroleum compounds in it, including volatile organic compounds (VOCs). The biggest problem is the raised salinity expressed in total dissolved solids (TDS), which can be many times more than that of seawater.

Wastewater handling by the wells

In the US wastewater is stored adjacent to the drilling pad in lined open pits (impoundments, or lagoons) prior to disposal. This is highly problematic as the dissolved gas and petroleum compounds evaporate and cause severe health problems. Liners can leak and rain downpours would lead to overflow and local ground contamination. Some sites have more than one impoundment, which can be the size of a football pitch. Some impoundments have caught fire with lightning strikes, because of the petroleum content.

Open pits are prohibited in the UK and double-skinned tanks are deployed for the on-site storage of the wastewater. There will have to be multiple tanks to cover the initial chemicals and sand addition, to contain the flowback and produced water, to hold treated wastewater for re-use and to hold concentrate from the re-use treatment plant for disposal.

Methane and volatile organic compounds (VOCs) come up in a mixture with the flowback and produced water. On the drill pad is a separation plant to route the gas initially to the flarestack and then to the export pipeline. The process is not 100% efficient and there will be residual methane and VOCs in the wastewater.

As the returned water will displace the atmosphere in the enclosed tanks the tops will be connected to a flare stack to burn off the dissolved methane and other petroleum compounds. The tanks holding the flowback and produced water should be equipped with heaters to boil off the residual dissolved methane and VOCs to facilitate their destruction in the flarestack. The smoke, smells, flickering and noise from the flare can also be a health hazard, but less than if released unburned.

In the US the evaporation of the volatile organic compounds from the open pits has led to the huge health problems of neighbouring people and animals, covered up by leasing and royalty "gagging" agreements. VOCs can be benzene, ethylbenzene, toluene, xylenes, *n*-hexane, carbonyl sulphide, ethylene glycol and/or 2.2.4-trimethylpentane.

There are two main means of wastewater disposal, deep well injection of it untreated and by transfer to a treatment works.

Deep well injection

In the US the wastewater is trucked to regulated deep injection wells, which are tested and classified by the EPA for specific uses. Fracking fluids are handled in Class II wells. Although there are thousands in use they are insufficient to handle the vast amounts of wastewater arising from fracking operations. There was a major explosion at an injection well at Denver in April 2015 when lightning ignited the dissolved gas and petroleum in a delivery of wastewater.

The practice is prohibited in the UK and even if it wasn't there is not an established regulatory infrastructure as in the US. If subsequently allowed, there would have to be seismic exploration and drilling to find suitable deep porous rocks able to store the fluids securely. There has been some re-injection in redundant conventional wells, but the number of these would be insufficient for the intensive fracking intended. Re-injection into shales is not practical as they are not porous enough, but in any case cannot proceed until production from the well ceases.

Oklahoma has recently become the most earthquake-prone state in the US which scientists say are due to the re-injection of wastewater as part of the fracking process. In Ohio in March 2014 there were dozens of earthquakes, including one of a magnitude of 3.0. Oklahoma suffered 138 earthquakes of magnitude 1.5 or greater in October 2016 alone, adding up to 2,199 over the year - including its largest quake ever, one of 5.8 magnitude in September 2016.

Treatment plants

The initial test drilling by Cuadrilla in Lancashire resulted in 8,000 cubic metres being trucked to United Utilities Davyhulme works on the side of the Manchester Ship Canal in 300 road tanker movements. What happened to it there is not revealed, but the works has since declined to request a permit for further inputs.

In the treatment works, the suspended solids, together with some precipitated dissolved solids as sludge are settled in sand or filtered and the sand and filter cake together with the filter aids are sent to landfill. If the sludge is radioactive it has to be sent to a specialist low level radioactive repository.

Some of the toxic metals are as salts in solution as part of the total dissolved solids, some insoluble as part of the suspended solids content of the wastewater.

Chemical precipitation is widely used for the removal of metals and other inorganics, suspended solids, fats, oils, greases, and some other organic substances from wastewater. Precipitation is a method of causing contaminants that are either dissolved or suspended in solution to settle out of solution as a solid precipitate, which can then be filtered, centrifuged, or otherwise separated from the liquid portion.

Chemical precipitation is used for removal of heavy metals such as Fe, Al, Ca, Mg, Mn, Zn, Si, Sr, B, Pb, Cr and As from wastewater. The chemicals used are lime, ferrous sulphate, ferric chloride and alum for precipitation and polymers as filter aids. The pH for removal of most of heavy metals by chemical precipitation is 8 except for Ca, Sr and B when it is pH 10 or higher. The removal efficiencies vary for each metal salt as do the chemicals needed. As the pH must be adjusted for optimum precipitation of a particular metal, it cannot be appropriate for all of those in solution.

The environment quality standards (EQSs) for the discharge of priority substances (such as mercury and cadmium present in the Cuadrilla Preese Hall wastewater) are as low as 0.07 μg/l and 0.9 μg/l to 1.5 μg/l respectively. Chemical precipitation and the following separation of the produced suspended solids is unlikely to be sufficient to meet the standards. Moreover, for the range of heavy metals likely to be present, the cocktail of chemical additives and pH adjustments will vary between wells at different locations, so that the management of fracking wastewater treatment presents considerable challenges and costs. The high salinity may prevent the use of lime as it will precipitate some of the hardness yielding an increased load on the filtration equipment.

Subsequent to the availability of the wastewater analytical results the treatment plant will have to submit a 'bespoke' treatment plan and a quotation for the costs of it. Moreover, as the toxic salts and NORM in the flowback and produced water when treated will scale up the pipework and equipment, the treatment plant may have to install a dedicated plant line for fracking wastewater with cleaning-in-place (CIP) to maintain its flow. The methane and VOCs dissolved in the wastewater may also be problematic and should be removed before transport to avoid explosive and health problems at the treatment plant .

Also the high salinity of the treated water means it cannot be disposed of into an upper estuary, whereby the upper waters are less saline than the sea or even into the sea, unless it can be diluted with perhaps five times its volume with other less saline effluent streams.

Municipal sewage works are unable to take in fracking wastewater. EA has nominated four treatment plants with permits, viz., Castle Environmental at Stoke-on-Trent, FCC Environment at Leeds and Sheffield and Bran Sands at Middlesbrough. The Stoke-on-Trent, Leeds and Sheffield plants discharge into the Trent, Aire and Don rivers respectively and are therefore unlikely to be able to dispose of the high fracking wastewater salinity. Limited quantities could be treated by dilution with other treated effluents, but although the concentration of the toxic metal salts and organic compounds would be reduced, the actual quantities of the dangerous substances released into the rivers would not change and could build up in the bottom sediments.

Permits

The flowback and produced water must be analysed before the issuing of an EA permit for disposal. The selected ultimate disposal method, deep injection well (if there ever is one) or treatment works needs a permit for acceptance of it. It also needs permits for the disposal of the treated water, for the transport of the sludge and filter aids to landfill, the transport of the radioactive sludge and for the acceptance by the low level radioactive repository. As until fracking flowback and produced water arise at the pad surface it cannot be analysed, but the analysis of the Preese Hall wastewater is available and gives an indication of the likely analysis of the wastewater from the four new test drillings nearby in Lancashire.

EA states *"All flowback waters produced from hydraulic fracturing activities (at both the exploration and production phase) must be treated and disposed of at a permitted facility. There are no exceptions to this rule. Treatment and disposal must be conducted in line with all of the conditions of the environmental permits, including conditions for priority substances (dangerous substances)."*

Bran Sands waste treatment plant

The Northumbrian Water Bran Sands treatment works at Middlesbrough is equipped with sewage sludge handling with anaerobic digestion and has an industrial treatment section capable of 200,000 cubic metres per day which may be augmented with additional facilities for treating fracking wastewater. It currently discharges into a creek joining the Tees near its mouth and could alternatively, with a pipeline, discharge the high salinity effluents far out to sea, but the toxic salts and radioactivity would have to be removed beforehand. Fish in the area of discharge would be examined for toxic metal and organic substances in their flesh.

Bran Sands has a comprehensive "Consent to Discharge" for its sewage and industrial effluent, but its lists of dangerous substances need augmenting with EA's table of their concentration limits. The allowable levels of concentration of the toxic metals in solution are for some as onerous as below a microgram per litre of discharge fluids.

Bran Sands has a permit for disposal of radioactivity from its treatment of wastewater from off-shore oil and gas rigs landed by ships at its works. The Bran Sands plant is currently the most likely treatment works in the UK able to take in fracking wastewater in sufficient quantities, but is 130 miles from the test drillings in Lancashire. The 9,000 cubic metres of wastewater per well would require 350 or so road tanker journeys to it.

Cuadrilla enquired as to Bran Sand's ability to take in its wastewater, but an operator cannot submit a requested sample of it until the first flowback occurs and it can be analysed. The added chemicals will arise in the flowback, while the toxic metal salts and high salinities arise in the ensuing produced water, so that a full analysis will not be immediately possible. However, Cuadrilla published its analysis of the wastewater from its aborted Preese Hall test drilling, which enables an assessment of the treatment process to be made.

See Appendix 1

Shale gas operators have to demonstrate to EA that they have a written agreement from a company with a radioactive substances activity permit that can treat and dispose of their waste for the EA permit application process to be validated. No such agreement can be signed between Cuadrilla and Northumbrian Water, the owner of Bran Sands, until sufficient flowback has arisen, analysed and stored on the drilling pad while and until the necessary permits are issued.

Processing of high TDS wastewater

The limit for treatment of high TDS by reverse osmosis (RO) is 40,000 mg/l. The osmotic pressure to be reversed rises with the TDS, making the construction of the membrane modules for higher TDSs impractical. Cuadrilla's Preese Hall wastewater had a mean TDS of 170,000 mg/l with an osmotic pressure of around 160 bar, so if the new drillings are similar RO will not be an appropriate method of reduction of its TDS before disposal. The only possible practical method is evaporation and crystallisation. A mechanical vapour compression (MVC) process is available trailer-mounted and could be used on site for wastewater treatment with partial re-use. The compressor, driven by a diesel engine, provides the evaporation heat.

Quantity of wastewater to be treated

The question is how much wastewater will be treated if fracking is established to provide a substantial amount of the UK's natural gas consumption? Until a field operationally matures, the recovery factor and ultimate well recovery (EUR) will not be known.

Natural gas consumption in the UK in 2015 was 2,400 bcf, with production around 1,400 bcf, with a deficit of 1,000 bcf. With an ultimate estimated recovery of 4 bcf/well it requires, once steady state production is achieved, 250 wells to be drilled a year to fill the deficit. The final amount of flowback and produced water together can be 22,000 x 40% = 9,000 cubic metres per well. The quantity of fracking wastewater for treatment is then 9,000 x 250 = 2.25 million cubic metres a year, or 6,000 cubic metres per day.

In the case of the test drillings, the initial water input is 800 to 900 cubic metres per day, with 25% of the 9,000 cubic metres returning in the first few days amounting to 2,250 cubic metres. A trailer-mounted evaporator/crystalliser could process 200 cubic metres/day, requiring a 2,000 cubic metres tank to hold the flowback for treatment over 10 days, with a similar size tank to take the distilled water for reuse.

Operator requirement

The question of handling the flowback and produced water from fracking operations in the UK remains an unsettled question, unresolved by the Shale Gas Task Force, nor by the Cuadrilla Planning Inspector's appeal report.* The responsibility for nominating a waste disposal facility with the ability and capacity to take the flowback fluid is primarily the responsibility of the operator. If the operator is unable to identify *"… somewhere to take the waste it would have to take the necessary measures to ensure that no further waste of this type is generated …"* (sic)*

The problem is that for every well the analysis of the flowback and produced water is unique for it and cannot be determined until the fracturing is complete. A large proportion of the injected production water, with its chemical additives, returns to the surface together with the minerals and metal salts (and possibly some radioactivity) it brings up from the shale with the gas, NGLs and oil.

If fracking is established then hundreds, if not thousands of wells, will be drilled and it will be impossible to specify a "bespoke" treatment solution for each one after it has been drilled and fracked. Operators would find their operations frozen just when gas production is needed to justify their investment.

What is needed is a universal treatment facility able to cater for all the possible variations in wastewater content. Also a mobile, universal treatment plant will be needed to cater for the wastewater arising from the exploratory well drilling to establish whether in a particular area fracking is viable. If trailer-mounted, as is available, it can then move to the next test drilling.

The only type of treatment plant that can be deemed as universal is the Zero Liquid Discharge type in which after pre-treatment an evaporator/crystalliser process produces distilled water for re-use and a sludge for disposal in landfill.

Once it is clear that an industry can be established, then the necessary capital can be raised for a centralised treatment facility.

ZLD providers

Antero Resources announced it is stepping up its recycling efforts in the Marcellus/Utica by hiring Veolia Water Technologies Inc. to build a new shale wastewater recycling facility in Doddridge County, West Virginia. The facility, which will cost Antero $275 million, will process 60,000 barrels (9,500 m^3) of wastewater per day. A central ZLD treatment plant this size would cater for 300 well drillings per year.

GE offers complete thermal and non-thermal ZLD solutions to manage tough-to-treat wastewaters. GE's proprietary evaporators, brine concentrators, and crystallisers can help recover more than 95% of your plant's wastewater while reducing the remaining brine as a product or solid.

Aquatech has an unparalleled depth of experience in ZLD, which include more than 160 installations, including stand-alone thermal/evaporative processes, membrane processes, or hybrid systems. Zero-liquid discharge (ZLD) is a water treatment process in which all wastewater is purified and recycled; therefore, leaving zero discharge at the end of the treatment cycle. ZLD is an advanced wastewater treatment method that includes ultrafiltration, reverse osmosis, evaporation/crystallisation, and fractional electro-deionisation.

GEA Zero Liquid Discharge for Environmental Protection. A global environmental awareness and focus on conserving water and water pollution has led to increasingly stringent regulations on the use and discharge of industrial water. GEA's zero liquid discharge (ZLD) technology is ideally placed to enable many sectors of industry to clean and recycle their process water.

Eureka Resources at Standing Stone has a gas well wastewater treatment facility, located outside the town of Williamsport in Pennsylvania. Low salinity wastewater is treated with RO, while higher salinities are subject to evaporation and crystallisation. Sales of salt for industrial purposes and acceptably treated water for re-use offset the input costs.

Energy inputs

The whole process of fracking and the handling of the wastewater is energy intensive, particularly the use of the chain of coupled high pressure pumps for the hydraulic injection of the fluid into the shale. (Up to 100 MPa; 15,000 psi). Wastewater handling adds further energy intensity to the process with the energy requirements for evaporation plus crystallisation (or RO) and its road tanker transport.

There are additional energy costs for the provision and management of the double-skinned tanks over those of the open pits common in the US and considerable energy losses in the initial flaring of the product until it can be piped away.

If injection wells are eventually conceded then the transport to them and the high pressure pumping needed for the injection will incur energy inputs.

It may well be that the overall energy inputs will exceed the energy in the natural gas recovered and only fracking for "wet" gas (with NGLs) and oil will be viable.

US practice

The reason fracking got away in the US is because Dick Cheney brokered a "holiday" from EPA regulation by freeing it from the Safe Drinking Water Act. (The so-called

"Halliburton Loophole"). The horrific consequences for water resources in the US are now evident, but the industry is resisting tighter regulation and states have banned local fracking bans.

Fracking for gas in the US has led to huge financial "impairments" for the pioneers, especially BHP Billiton, BP, BG, Shell and Statoil even with the lax imposition of regulation.

Conclusion

To facilitate the treatment of fracking wastewater if fracking for gas in the Bowland-Hodder play a universal process catering for the different compositions associated with particular locations is needed. This means the adoption of Zero Liquid Discharge processes based on evaporation and crystallisation. Due to the high chloride content of the wastewater the materials of construction of the vessels, pipework and heat exchanger tubing will nevertheless be expensive.

Such can be located central to a number of fracking locations and require no access to a watercourse as the only liquid leaving the plant is distilled water which can be re-used.

However, the energy requirement for the treatment process and the associated transport and disposal options may exceed the energy content of the gas produced, as may the costs of handling the wastewater exceed the sales revenue.

Work is needed, perhaps by a multi-faculty university investigation, to evaluate the economics of the whole fracking process, including dealing with the wastewater.

So tight regulation in the UK with its prohibition of open pits and deep well injection may mean that fracking for gas in the UK will be uneconomic, ruling out the Bowland-Hodder shale which principally contains just gas.

It means more intensive surveying in order to locate occurrences of "wet" gas with natural gas liquids and ethane or oil.

John Busby

Appendix 1

Cuadrilla Preese Hall Wastewater Analytical Results

Column1	Column2	Column3	Column4	Column5	Column6	Column7	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	olumn	Column23	olumn	olumn25
	Free Ammonia	pH	Alkalinity as HCO_3	Suspended Solids	Dissolved Solids	COD	Silver	Arsenic	Barium	Vanadium	Cobalt	Chromium	Manganese	Iron	Mercury	Nickel	Copper	Zinc	Cadmium	Lead	Fluoride	Chloride	Sulphate	Nitrate
	(mg/l)		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
	70.00	6.10	71.00	230.00	96000.00	120.00	<1.0	0.52	9.50	<5.0	0.02	<0.0	1.70	<1.3	<0.20	0.17	<0.08	<0.50	<0.08	<0.02	<50	53000.00	<500	<100
	70.00	6.00	61.00	250.00	120000.00	420.00	<1.0	0.60	9.20	<5.0	0.02	<0.0	1.80	<1.3	<0.20	0.20	<0.08	<0.50	<0.08	<0.02	<50	60000.00	<500	<100
	51.00	6.10	62.00	1100.00	94000.00	240.00	<1.0	0.48	11.00	<5.0	0.02	<0.0	1.80	<1.3	<0.20	0.16	<0.08	<0.50	<0.08	<0.02	<50	48000.00	<500	<100
	70.00	6.00	55.00	480.00	130000.00	480.00	<1.0	0.69	13.00	<5.0	0.03	<0.0	1.90	<1.3	<0.20	0.23	<0.08	<0.50	<0.08	<0.02	<50	66000.00	<500	<100
	83.00	6.00	41.00	550.00	140000.00	480.00	<1.0	0.77	15.00	<5.0	0.04	<0.0	2.00	<1.3	<0.20	0.24	<0.08	<0.50	<0.08	<0.02	<50	74000.00	<500	<100
	83.00	6.10	50.00	340.00	150000.00	540.00	<1.0	0.75	15.00	<5.0	0.03	<0.0	2.10	6.20	<0.20	0.23	<0.08	<0.50	<0.08	<0.02	<50	72000.00	<500	<100
	72.00	5.50	92.00	880.00	140000.00	480.00	<1.0	0.71	17.00	<5.0	0.04	<0.0	2.60	<1.3	<0.20	0.24	<0.08	<0.50	<0.08	<0.02	<50	72000.00	<500	<100
	88.00	5.50	88.00	350.00	170000.00	1260.00	<1.0	0.88	21.00	<5.0	0.04	<0.0	2.00	4.20	<0.20	0.25	<0.08	<0.50	<0.08	<0.02	<50	85000.00	570.00	<100
	96.00	5.80	121.00	1700.00	200000.00	960.00	<1.0	0.87	13.00	<5.0	0.03	<0.0	2.00	4.70	<0.20	0.25	<0.08	<0.50	<0.08	<0.02	<50	82000.00	<500	<100
	140.00	5.90	122.00	1600.00	160000.00	1020.00	<1.0	0.89	23.00	<5.0	0.03	<0.0	1.60	8.00	<0.20	0.24	<0.08	<0.50	<0.08	<0.02	<50	83000.00	<500	<100
	100.00	6.00	131.00	2000.00	170000.00	1200.00	<1.0	0.98	22.00	<5.0	0.03	<0.0	1.70	9.50	<0.20	0.26	<0.08	<0.50	<0.08	<0.02	<50	88000.00	<500	<100
	100.00	6.00	133.00	1500.00	180000.00	1080.00	<1.0	0.99	26.00	<5.0	0.03	<0.0	1.80	10.00	<0.20	0.27	<0.08	<0.50	<0.08	<0.02	<50	90000.00	<500	<100
	100.00	5.70	101.00	2200.00	160000.00	1080.00	<1.0	1.10	26.00	<5.0	0.04	<0.0	1.90	13.00	<0.20	0.29	<0.08	<0.50	<0.08	<0.02	<50	91000.00	<500	<100
	100.00	5.70	94.00	2000.00	180000.00	960.00	<1.0	1.00	26.00	<5.0	0.03	<0.0	1.90	12.00	<0.20	0.28	0.14	<0.50	<0.08	<0.02	<50	91000.00	<500	<100
	100.00	5.90	96.00	1900.00	180000.00	1920.00	<1.0	1.10	30.00	<5.0	0.03	<0.0	2.00	15.00	<0.20	0.29	<0.08	<0.50	<0.08	<0.02	<50	94000.00	<500	<100
	110.00	5.90	96.00	1900.00	190000.00	1500.00	<1.0	1.10	19.00	<5.0	0.04	<0.0	2.20	16.00	<0.20	0.33	0.10	<0.50	<0.08	<0.02	<50	96000.00	<500	<100
	100.00	6.00	106.00	2600.00	180000.00	1200.00	<1.0	1.10	24.00	<5.0	0.04	<0.0	2.20	23.00	<0.20	0.31	0.08	<0.50	<0.08	<0.02	<50	95000.00	<500	<100
	130.00	6.10	112.00	1700.00	180000.00	1740.00	<1.0	1.00	25.00	<5.0	0.05	<0.0	2.00	22.00	<0.20	0.88	<0.08	<0.50	<0.08	<0.02	<50	97000.00	<500	<100
	130.00	5.40	52.00	1600.00	200000.00	2220.00	< 1.0	1.40	17.00	< 5.0	0.04	0.30	2.80	16.00	< 0.20	0.61	0.30	< 0.50	0.12	0.06	< 50	97000.00	< 500	< 100
	110.00	5.40	52.00	810.00	200000.00	2520.00	< 1.0	1.20	18.00	< 5.0	0.04	0.00	2.30	16.00	< 0.20	0.39	0.08	< 0.50	< 0.08	< 0.02	< 50	99000.00	< 500	< 100
	110.00	5.40	49.00	2300.00	200000.00	2940.00	< 1.0	1.20	19.00	< 5.0	0.05	0.00	2.30	16.00	< 0.20	0.40	0.12	< 0.50	< 0.08	0.03	< 50	98000.00	< 500	< 100
	110.00	5.40	52.00	1700.00	210000.00	3240.00	< 1.0	1.30	19.00	< 5.0	0.04	0.00	2.50	16.00	< 0.20	0.41	0.15	< 0.50	< 0.08	< 0.02	< 50	99000.00	< 500	< 100
	110.00	5.40	51.00	1700.00	210000.00	2160.00	< 1.0	1.30	19.00	< 5.0	0.04	0.00	2.50	18.00	< 0.20	0.43	0.09	< 0.50	< 0.08	< 0.02	< 50	100000.00	< 500	< 100
	110.00	5.40	61.00	1900.00	210000.00	1500.00	< 1.0	1.30	20.00	< 5.0	0.04	0.00	2.50	16.00	< 0.20	0.42	0.09	< 0.50	< 0.08	< 0.02	< 50	99000.00	< 500	< 100
Min	**51.00**	**5.40**	**41.00**	**230.00**	**94000.00**	**120.00**	**0.00**	**0.48**	**9.20**	**0.00**	**0.02**	**0.00**	**1.60**	**4.20**	**0.00**	**0.16**	**0.08**	**0.00**	**0.12**	**0.03**	**0.00**	**48000.00**	**570.00**	**0.00**
Max	**140.00**	**6.10**	**133.00**	**2600.00**	**210000.00**	**3240.00**	**0.00**	**1.40**	**30.00**	**0.00**	**0.05**	**0.30**	**2.80**	**23.00**	**0.00**	**0.88**	**0.30**	**0.00**	**0.12**	**0.06**	**0.00**	**100000.00**	**570.00**	**0.00**
Mean	**97.63**	**5.78**	**81.21**	**1387.08**	**168750.00**	**1302.50**	**<1.0**	**0.97**	**19.03**	**<5.0**	**0.04**	**0.05**	**2.09**	**13.42**	**<0.20**	**0.32**	**0.13**	**<0.50**	**0.12**	**0.05**	**<50.0**	**84541.67**	**570.00**	**<100.00**

1000.00 mg/l	0.1%
100.00 mg/l	0.01%
10.0 mg/l	0.001%
1.0 mg/l	0.0001%

ENVIRONMENTAL QUALITY STANDARDS

HAZARDOUS POLLUTANTS

Priority substances (PS) are harmful substances. Priority hazardous substances (PHS) are a subset of these and are considered extremely harmful. Many priority and priority hazardous substances were previously categorised as “List 1” substances in the DSD. The EQSs for priority and priority hazardous substances are set by Europe through the EQSD, a daughter Directive of WFD which may also be referred to as the Priority Substances Directive.

Specific pollutants (SP) are those pollutants which are released in significant quantities into water bodies in each individual European Member State. Member States are required to set their own EQSs for these substances to achieve “good ecological status”. Many specific pollutants were previously categorised as “List 2” under the DSD. Specific pollutants are identified by an indicative list under Annex 8 of the WFD.

Other pollutants (OP) There are eight “other pollutants” which were included in List 1 of the DSD but are not included in the categories above. However, EQSs for these substances are included in the EQSD.

Other substances There were 12 “other substances” which were listed in Part 6 of “The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010”. These standards were not carried forward by the 2015 Directions, but are now listed as operational standards.

Table 1 - Priority Hazardous Substances (PHS), Priority Substances (PS) and Other Pollutants (OP)

Note: The EQSs values for most substances are expressed as total concentrations in the whole water sample. However, the EQSs for metals refers to dissolved concentrations, i.e. the dissolved fraction of a water sample obtained by filtration through a 0.45 µm filter or any equivalent pre-treatment, or the bioavailable concentration. EQS may be revised over time, due to new legislation or new scientific information. The Regulators will update the data in this guidance from time to time, and the Operator should ensure that they use the most up to date of these benchmarks.

		Inland Surface Waters(ii)			**Other Surface Waters (TraC Waters)**			
No	**Name of substance**	**AA-EQS (i) µg/l**	**MAC-EQS (iii) µg/l**		**AA-EQS (i) µg/l**	**MAC-EQS (iii) µg/l**	Biota standards	**Category**
1	Alachlor	0.3	0.7		0.3	0.7		**PS**
2	Anthracene	0.1	0.1		0.1	0.1		**PHS**
3	Atrazine	0.6	2.0		0.6	2.0		**PS**
4	Benzene	10	50		8	50		**PS**
5	Brominated diphenylethers(iv) (pBDE)		0.14			0.014	0.0085 µg/kg in fish	**PHS**

6	Cadmium and its compounds (depending on water hardness classes) (v) *Dissolved*	≤0.08(Class 1) 0.08 (Class 2) 0.09 (Class 3) 0.15 (Class 4) 0.25 (Class 5)	≤0.45(Class 1) 0.45 (Class 2) 0.6 (Class 3) 0.9 (Class 4) 1.5 (Class 5)		0.2			**PHS**
6a	Carbon tetrachloride (vi)	12			12			**OP**
7	C10-13 Chloroalkanes	0.4	1.4		0.4	1.4		**PHS**
8	Chlorfenvinpho s	0.1	0.3		0.1	0.3		**PS**
9	Chlorpyrifos (Chlorpyrifosethyl)	0.03	0.1		0.03	0.1		**PS**
9a	Cyclodiene pesticides: Aldrin (vi) Dieldrin (vi) Endrin (vi) Isodrin (vi)	∑ = 0.01			∑ = 0.005			**OP**

		Inland Surface Waters(ii)			**Other Surface Waters (TraC Waters)**			
No	**Name of substance**	**AA-EQS (i) µg/l**	**MAC-EQS (iii) µg/l**		**AA-EQS (i) µg/l**	**MAC-EQS (iii) µg/l**	Biota standards	**Category**
9b	DDT total (vi), (vii)	0.025			0.025			**OP**
	para-para-DDT (vi)	0.01			0.01			**OP**
10	1,2-Dichloroethane	10			10			**PS**
11	Dichloromethane	20			20			**PS**
12	Di(2ethylhexyl)phthalate (DEHP)	1.3			1.3			**PHS**
13	Diuron	0.2	1.8		0.2	1.8		**PS**
14	Endosulphan	0.005	0.01		0.0005	0.004		**PHS**
15	Fluoranthene	0.0063	0.12		0.0063	0.12	30 µg/kg in crustaceans or molluscs	**PS**
16	Hexachlorobenzene		0.05			0.05	10 µg/kg in fish	**PHS**

17	Hexachlorobutadiene		0.6			0.6	55 µg/kg in fish	**PHS**
18	Hexachlorocyclohexane	0.02	0.04		0.002	0.02		**PHS**
19	Isoproturon	0.3	1.0		0.3	1.0		**PS**
20	Lead and its compounds *Dissolved*	1.2 (bioavailable)	14		1.3	14		**PS**
21	Mercury and its compounds *Dissolved*		0.07			0.07	20 µg/kg In fish	**PHS**
22	Naphthalene	2	130		2	130		**PS**
23	Nickel and its compounds *Dissolved*	4 (bioavailable)	34		8.6	34		**PS**
24	Nonylphenol (4-Nonylphenol)	0.3	2.0		0.3	2.0		**PHS**
25	Octylphenol ((4-(1,1',3,3'-Tetramethylbutyl) - phenol))	0.1			0.01			**PS**
26	Pentachlorobenzene	0.007			0.0007			**PHS**
27	Pentachlorophenol	0.4	1		0.4	1		**PS**

		Inland Surface Waters[(ii)]			**Other Surface Waters (TraC Waters)**			
No	**Name of substance**	**AA-EQS [(i)] µg/l**	**MAC-EQS [(iii)] µg/l**		**AA-EQS [(i)] µg/l**	**MACEQS [(iii)] µg/l**	Biota standards	**Category**
28	Polyaromatic Hydrocarbons (PAH) [(viii)]							**PHS**
	Benzo(a)pyrene (BaP)	1.7×10^{-4}	0.27		1.7×10^{-4}	0.027	5 µg/kg BaP in crustaceans or molluscs	**PHS**
	Benzo(b)-fluoranthene		0.017			0.017		**PHS**
	Benzo(k)fluoranthene		0.017			0.017		**PHS**

	Benzo(g,h,i)perylene		$8.2x10^{-3}$			$8.2x10^{-4}$		**PHS**
	Indeno(1,2,3cd)-pyrene							**PHS**
29	Simazine	1	4		1	4		**PS**
29a	Tetrachloroethylene (vi)	10			10			**OP**
29b	Trichloro- ethylene (vi)	10			10			**OP**
30	Tributyltin compounds (Tributyltincation)	0.0002	0.0015		0.0002	0.0015		**PHS**
31	Trichlorobenzenes	0.4			0.4			**PS**
32	Tricholoromethane (chloroform)	2.5			2.5			**PS**
33	Trifluralin	0.03			0.03			**PHS**

Notes:

(i) This parameter is the annual average value of the Environmental Quality Standard expressed as the arithmetic mean of the concentrations measured at each representative monitoring point within the water body at different times during the year. Unless otherwise specified, it applies to the total concentration of all isomers.

(ii) Inland surface waters encompass rivers and lakes and related artificial or heavily modified water bodies.

(iii) This parameter is the Environmental Quality Standard expressed as a maximum allowable concentration (EQS – MAC). Where the MAC – EQS are marked as “not applicable”, the AA EQS values are considered protective against short-term pollution

peaks in continuous discharges since they are significantly lower than the values derived on the basis of acute toxicity.

(iv) The EQS is the sum of the concentrations of congener numbers 28, 47, 99, 100, 153, and 154.

Names for these congeners are respectively:

2,4,4'-tribromodiphenyl ether (PBDE28)
2,2',4,4'-tetrabromodiphenyl ether (PBDE47)
2,2',4,4',5-pentabromodiphenyl ether (PBDE99)
2,2',4,4',6-pentabromodiphenyl ether (PBDE100)
2,2',4,4',5,5'-hexabromodiphenyl ether (PBDE153)
2,2',4,4',5,6'-hexabromodiphenyl ether (PBDE154)

where PBDE stands for polybrominated diphenylether

For discharges containing one or more of these substances, the concentrations should be added together before assessing EQS compliance.

(v) For cadmium and its compounds (No.6) the EQS values vary dependent upon the hardness of the water as specified in five class categories (Class 1:<40mg CaCO3/l, Class 2: 40 to <50 mg CaCO3/l, Class 3: 50 to <100 mg CaCO3/l, Class 4: 100 to <200 mg CaCO3/l, Class 5 ≥200 mg CaCO3/l).

(vi) This substance is not a priority substance but one of the other pollutants for which the EQS are identical to those laid down in the legislation that applied prior to the entry into force of this Directive.

(vii) DDT total comprises the sum of the isomers 1,1,1 – trichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 50-29-3; EU Number 200-024-3); 1,1,1-trichloro-2 (ochlorophenyl)-2-(p-chlorophenyl)ethane (CAS number 789-02-6; EU Number 212-3325); 1,1 –dichloro-2,2 bis (p chlorophenyl) ethylene (CAS number 72-55-9; EU Number 200-784-6); and 1,1 –dichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 72 54-8; EU Number 200-783-0).

(viii) For the group of priority substances of polyaromatic hydrocarbons (PAH) (No 28), the biota EQS and corresponding AA-EQS in water refer to the concentration of benzo(a)pyrene, on the toxicity of which they are based. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water.

Table 2 - Specific pollutants and substances with operational EQSs

		Inland Surface Waters			**Other Surface Waters (TraC Waters)**		
	Name of substance	**AA-EQS µg/l**	**MAC-EQS µg/l**		**AA-EQS µg/l**	**MAC-EQS µg/l**	**Category**
1	**2-4-D (2-4 Dichlorophenoxyacetic acid)**	0.3	1.3 (95 percentile)		0.3	1.3 (95 percentile)	**Specific pollutant**
2	**2-4-dichlorophenol**	4.2	140 (95 percentile)		0.42	6 (95 percentile)	**Specific pollutant**
3	**3,4 dichloroaniline**	0.2	5.4 (95 percentile)		0.2	5.4 (95 percentile)	**Specific pollutant**
4	**4-chloro-3methyl-phenol**	40			40		**Operational**
5	**Abamectin**	0.01	0.03		0.003	0.01	**Operational**
6	**Ammonia (un-ionised)**				21		**Specific pollutant**
7	**Arsenic**	50			25		**Specific pollutant**
8	**Azinphos methyl (dissolved)**	0.01			0.01		**Operational** [(i)]
9	**Bentazone**	500			500		**Operational**
10	**Benzyl butyl phthalate**	7.5	51 (95 percentile)		0.75	10 (95 percentile)	**Specific pollutant**
11	**Biphenyl**	25			25		**Operational**
12	**Boron**	2000			7000		**Operational** [(i)]
13	**Bromine (total residual oxidant)**	2	5			10	**Operational**
	Bromoxynil	100	1000		100	1000	**Operational**
14							
15	**Carbendazim**	0.15	0.7				**Specific pollutant**
16	**Chloride**	250000					**Operational**
17	**Chlorine**	2 (total available)	5 (95 percentile conc of total available)			10 (95 percentile conc of total residual oxidant)	**Specific pollutant**

18	**Chloronitro Toluenes**	10			10		**Operational**
19	**2 – chlorophenol**	50			50		**Operational**
20	**3 – chlorophenol** **4 – chlorophenol** **Total & individual monochlorophenols**	50	250		50	250	**Operational**
21	**Chlorothalonil**	0.035	1.2				**Specific pollutant**
22	**Chlorotoluron**	2	20		2		**Operational**
23	**Chlorpropham**	10	40		10	40	**Operational**
24	**Chromium (III) (dissolved)** [iv]	4.7	32 (95 percentile)				**Specific pollutant**

		Inland Surface Waters			**Other Surface Waters (TraC Waters)**		
	Name of substance	**AA-EQS µg/l**	**MAC-EQS µg/l**		**AA-EQS µg/l**	**MAC-EQS µg/l**	**Category**
25	**Chromium (VI) (dissolved)** [iv]	3.4			0.6	32 (95 percentile)	**Specific pollutant**
26	**Cobalt (dissolved)**	3	100		3	100	**Operational**
27	**Copper (dissolved)**	1 µg/l bioavailable			3.76 µg/l dissolved, where DOC ≤1mg/l 3.76 + (2.677 x ((DOC/2) – 0.5)) µg/l dissolved, where DOC >1mg/l		**Specific pollutant**
28	**Coumaphos**	0.03	0.1		0.03	0.1	**Operational**
29	**Cyanide**	1	5 (95 percentile)		1	5 (95 percentile)	**Specific pollutant**
30	**Cyfluthrin** [ii]		0.001 (95 percentile)			0.001 (95 percentile)	**Operational** [i]
31	**Cypermethrin**	0.0001	0.0004 (95 percentile)		0.0001	0.0004 (95 percentile)	**Specific pollutant** [i]
32	**Demetons**	0.5			0.5		**Operational** [i]
33	**Diazinon**	0.01	0.02 (95 percentile)		0.01	0.26 (95 percentile)	**Specific pollutant**
34	**Dibutyl phthalate**	8	40		8	40	**Operational**
35	**Dichlorobenzene** **(Sum of all dichlorobenzene isomers)**	20	200		20	200	**Operational**
36	**Dichlorvos**	0.001			0.04	0.6	**Operational** [iii]
37	**Diethyl phthalate**	200	1000		200	1000	**Operational**
38	**Diflubenzuron**	0.001	0.015		0.005	0.1	**Operational**
39	**Dimethoate**	0.48	4 (95 percentile)		0.48	4 (95 percentile)	**Specific pollutant**
40	**Dimethyl phthalate**	800	4000		800	4000	**Operational**

41	**Dioctyl phthalate**	20	40		20	40	**Operational**
42	**Doramectin**	0.001	0.01		0.001	0.1	**Operational**
43	**EDTA**	400	4000		400	4000	**Operational**
44	**Fenchlorphos**	0.03	0.1		0.03	0.1	**Operational**
45	**Fenitrothion**	0.01			0.01		**Operational**
46	**Flucofuron[ii]**		1 (95 percentile)			1 (95 percentile)	**Operational [i]**
47	**Fluoride (dissolved)**	1000 (<50mg/l $CaCO_3$) 5000 (>50mg/l $CaCO_3$)	3000 (<50mg/l $CaCO_3$) 15000 (>50mg/l $CaCO_3$)		5000	15000	**Operational**
48	**Formaldehyde**	5	50				**Operational**
49	**Glyphosate**	196	398 (95 percentile)		196	398 (95 percentile)	**Specific pollutant**
50	**Hydrogen sulphide**	0.25	1.0			10	**Operational**

		Inland Surface Waters			Other Surface Waters (TraC Waters)		
	Name of substance	**AA-EQS µg/l**	**MAC-EQS µg/l**		**AA-EQS µg/l**	**MAC-EQS µg/l**	**Category**
51	**Ioxynil**	10	100		10	100	**Operational**
52	**Iron (dissolved)**	1000			1000		**Specific pollutant**
53	**Ivermectin**	0.0001	0.001		0.001	0.01	**Operational**
54	**Linuron**	0.5	0.9 (95 percentile)		0.5	0.9 (95 percentile)	**Specific pollutant**
55	**Malachite green**	0.5	100		0.5	100	**Operational**
56	**Malathion**	0.01			0.02		**Operational**
	Mancozeb	2	20		2	20	**Operational**
57	**Maneb**	3	30		3	30	**Operational**
58	**Manganese**	123 µg/l bioavailable					**Specific pollutant**
59	**MCPA**	12 (pH<7) 80 (pH>7)	80 (pH<7) 800 (pH>7)		80	800	**Operational**
60	**Mecoprop**	18	187 (95 percentile)		18	187 (95 percentile)	**Specific pollutant**
61	**Methiocarb**	0.01	0.77 (95 percentile)				**Specific pollutant**
62	**Mevinphos**		0.02				**Operational [i]**
63	**Nitrilotriacetic acid (NTA)**	1000	10000		3000	30000	**Operational**
64	**Omethoate**	0.01					**Operational [i]**
65	**PCSDs[ii]**		0.05 (95 percentile)			0.05 (95 percentile)	**Operational [i]**
66	**Pendimethalin**	0.3	0.58 (95 percentile)				**Specific pollutant**
67	**Permethrin**	0.001	0.01 (95 percentile)		0.0002	0.001 (95 percentile)	**Specific pollutant**
68	**pH**		6-9 (95 percentile)			6-8.5 (95 percentile)	**Operational**
69	**Phenol**	7.7	46 (95 percentile)		7.7	46 (95 percentile)	**Specific pollutant**

70	**Pirimicarb**	1	5		1	5	**Operational**
71	**Pirimiphosmethyl**	0.015	0.05		0.015	0.05	**Operational**
72	**Prochloraz**	4	40		4	40	**Operational**
73	**Propetamphos**	0.03	0.1		0.03	0.1	**Operational**
74	**Propyzamide**	100	1000		100	1000	**Operational**
75	**Silver (dissolved)**	0.05	0.1		0.5	1	**Operational**
76	**Sulcofuron**(ii)		25 (95 percentile)			25 (95 percentile)	**Operational** (i)
77	**Sulphate**	400,000					**Operational**
	Styrene	50	500		50	500	**Operational**
78	**Tecnazene (total)**	1	10		1	10	**Operational**
79	**Tetrachloroethane**	140	1848 (95 percentile)				**Specific pollutant**
80	**Thiabendazole**	5	50		5	50	**Operational**
81	**Tin (inorganic)**	25 (total)			10 (dissolved)		**Operational**
82	**Toluene**	74	380 (95 percentile)		74	370 (95 percentile)	**Specific pollutant**

		Inland Surface Waters			**Other Surface Waters (TraC Waters)**		
	Name of substance	**AA-EQS µg/l**	**MAC-EQS µg/l**		**AA-EQS µg/l**	**MAC-EQS µg/l**	**Category**
83	**Total anions**	250,000					**Operational**
84	**Triallate**	0.25	5		0.25	5	**Operational**
85	**Triazaphos**	0.005			0.005		**Operational** (i)
86	**Tributyl phosphate**	50	500		50	500	**Operational**
87	**1,1,1trichloroethane**	100			100		**Operational**
88	**Triclosan**	0.1	0.28 (95 percentile)		0.1	0.28 (95 percentile)	**Specific pollutant**
89	**Triphenyltin and its derivatives**		0.02			0.008	**Operational**
90	**1,1,2trichloroethane**	400			300		**Operational**
91	**Vanadium**	20 (0-200 mg/l $CaCO_3$) 60 (200+ mg/l $CaCO_3$)			100		**Operational** (i)
92	**Xylene**	30			30		**Operational**
93	**Zinc**	10.9 bioavailable plus Ambient Background Concentration (µg/l) dissolved (v)			6.8 dissolved plus Ambient Background Concentration (µg/l) (v)		**Specific pollutant**

Notes:

(i) These substances were classed as List 2 under the Dangerous Substances Directive but have not been classified under WFD/EQS. The EQSs for these substances should be treated as operational EQSs for the purposes of this guidance.

(ii) These five substances are mothproofing agents.

(iii) Cypermethrin and dichlorvos will be Priority Substances (with revised standards) from December 2018

(iv) The EQSs for Cr III and Cr VI can be summed (i.e. added together) to give an EQS for chromium if the proportions of CR III and Cr VI in a sample are not known.

(v) In respect of dissolved zinc, the Appropriate Agency must apply the Ambient Background concentration for freshwaters in Table 3 below. For saltwater, an Ambient Background Concentration of 1.1 µg/l is recommended. In order to assess compliance with the EQS for zinc, the relevant ambient background concentration is subtracted from the measured dissolved concentration.