DIGITAL ADDENDA 1A

Table A.1: Substances commonly used in drilling and fracking fluids, and an indication of their toxicity levels.

Compiled from US EPA 2015a and US EPA 2015b.

Additive type	Function	Types of chemical used	Toxicity
Thickeners	increase viscosity of the fracking fluid, making high-pressure pumping more efficient; suspension of proppants	carboxymethylcellulose, xanthan gum, guar gum, glycol	ethylene glycol (radiator fluid) extremely toxic
Deflocculants	thinning agents used to reduce viscosity or prevent flocculation (sometimes incorrectly called "dispersants")	acrylates, polyphosphates, lignosulphonates	acrylates may be toxic; acrylamide is a known neurotoxin
Friction reducers, lubricants	additives used to produce "slick water", which reduces friction in the wellbore, increasing fluid-flow velocity	petroleum distillate, used as a carrier fluid for poly-acrylamides or polyacrylics	petroleum distillates contain hazardous chemicals; polyacrylamide not toxic but breaks down to toxic acrylamides
Weighting agents	increase weight of muds, prevent ingress of water into the well being drilled; prevents blow-outs	barium sulphate (barite)	extremely insoluble so not classified by USEPA as hazardous
Fluid-loss additives	reduce loss of drilling fluids into permeable rock formations	diesel, particulates, sand	diesel contains hazardous chemicals
Clay control	Prevent swelling and migration of formation clays, which can cause reduced permeability and productivity by clogging pore spaces in the formation	KCl; quaternary amines (= quaternary ammonium compounds: QACs)	QACs toxic to aquatic organisms at environmentally relevant concentrations (Tezel, 2009)
Gelling agents	Increase fluid viscosity; increase the ability of the fluid to carry proppant and help to minimise fluid loss.	Hydroxy-ethyl cellulose (HEC) HEC and carboxy-methyl-hydroxy-ethyl cellulose (CMHEC); guar gum; foams/ poly-emulsions using N_2, CO_2 or a hydrocarbon (e.g. propane), diesel or condensate; ethylene glycol	Diesel and condensate (ultra-light fuel oil) contain hazardous chemicals; ethylene glycol (radiator fluid) extremely toxic
Cross-linkers	Increase molecular weight of polymers by cross-linking, thereby increasing viscosity, elasticity and ability of the fluid to transport proppant	guar and CMHEC based gels; Boric acid and B salts of Ca and Mg; metals including Titanium, Zirconium, Iron, Chromium & Aluminium; organic borate complexes; ethylene glycol; methanol	Some metals toxic at low concentrations; borates used in insecticides and antibiotics, and "toxic for reproduction" (EU regulations); ethylene glycol (radiator fluid) extremely toxic; methanol highly toxic
Buffers	Adjust pH to allow for dispersion, hydration and crosslinking of the fracking-fluid polymers	Combinations of sodium bicarbonate; formic acid; sodium carbonate; fumaric acid; sodium hydroxide; hydrochloric acid; monosodium phosphate; magnesium oxide	formic and fumaric acids mildly toxic; hydrochloric acid corrosive, causes severe burns when concentrated
Surfactants	Reduce the surface tension of the fracturing fluid to improve fluid recovery; prevent formation of emulsions; can be used as emulsifiers, foaming agents, defoaming agents, and dispersants.	EGMBE (ethylene glycol monobutyl ether) and BGMBE (butylene glycol monobutyl ether)	toxicity of both EGMBE and BGMBE low but "potentially toxic inert, with high priority for testing" (USEPA)

Additive type	Function	Types of chemical used	Toxicity
Viscosity stabilisers	Stabilise the fluid at high temperatures	methanol (used at 5 to 10% of the fluid volume) and sodium thiosulfate	methanol highly toxic
Scale inhibitors	Prevent scale deposits in pipes	sodium polycarboxylates including co-polymers of acrylamide and sodium acrylate; phosphonic acid salts	acrylates may be toxic; acrylamide is a known neurotoxin
Acids	Restore permeability lost as a result of the drilling process or initiate fracturing, achieve greater fracture penetration, and reduce clogging of the pore spaces and fractures by dissolving minerals and clays.	hydrochloric acid (concentrations up to 15%) and hydrofluoric acid	both acids corrosive, cause severe burns when concentrated
Biocides	Minimise decomposition of gelling polymers by aerobic bacteria; prevent anaerobic sulphate- reducing bacteria, which can "sour" a well and produce corrosive hydrogen sulphide gas	quaternary amines, amides and aldehydes (= quaternary ammonium compounds: QACs); glutaraldehyde; chloro-phenates [= chlorophenols?]; isothiazolinone; ozone; chlorine as hypochlorous acid, chlorine dioxide; UV light	Biocides are by their nature toxic: QACs (Tezel, 2009) and isothiazolinone toxic to aquatic organisms at environmentally relevant concentrations; glutaraldehyde (similar to formaldehyde) and chlorophenols highly toxic
(Gel) breakers	Reduce viscosity and facilitate blowback of fluid after fracking	oxidisers: ammonium persulfate, sodium persulfate; calcium and magnesium peroxides; acids: acetic or hydrochloric acid; enzymes: hemicellulase, cellulase, amylase and pectinase	Persulphates irritants and toxic; peroxides unstable and sometimes explosive; hydrochloric acid corrosive, cause severe burns when concentrated
Corrosion inhibitors	Protect iron and steel equipment and well-bore components from corrosive acids	e.g. N,n-dimethyl formamide	N,n-dimethyl formamide a hazardous chemical; thought to cause birth defects
Radioactive tracers	Show the injection profile and locations of fractures	Antimony-124, argon-41, cobalt-60, iodine-131, iridium-192, lanthanum-140, manganese-56, scandium-46, sodium-24, silver-110m, technetium-99m, xenon-133	Radioactive tracers pose negligible risk to the public when handled, transported, stored and used according to appropriate guidelines.
Scale inhibitors, iron control	Increase the solubility of metals, particularly iron, so controlling rust, sludges, and mineral scales	citric and acetic acids; ethylene glycol	ethylene glycol (radiator fluid) extremely toxic
Oxygen scavengers	Control rust by removing oxygen from the fluid	ammonium bisulphite	ammonium bisulphite "hazardous to health"
		volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene and xylene - (BTEX compounds)	effects on CNS; human carcinogens

Table A.2: Chemicals that may not be added to fracking fluids in South Africa (DMR 2015).

NOTE that the heading of the list refers to "chemicals regulated under Safe Drinking Water Act …", but this seems to be an Australian Act (there is no such Act in South Africa, where drinking water is regulated under SANAS 421).

1- Methylnaphthalene
2- Butanone
2- Hexanone
2- Methylnaphthalene
2- Methylphenol
2- Pyrrolidone
3- Methylphenol
4- Methylphenol
4- Methylphenol
Acetaldehyde
Acetone
Acetonitrile
Acetophenone
Acrylamide
Aniline
Benzene
Benzidine
Benzyl chloride
Bromomethane
Chloroethane
Copper
Cumene (isopropylbenzene)
Di (2- [Incomplete name - might be able to identify the substance by searching for CAS no. 117-82-7 at https://www.cas.org/content/chemical-substances]*
Diesel
Diethanolamine (2,2-iminodiethanol)
Dimethyl formamide
Ethylbenzene
Ethylene glycol
Ethylene oxide
Formaldehyde
Hydrogen chloride [hydrochloric acid]
Hydrogen fluoride (hydrofluoric acid)
Isophorone

Lead
Methanol
Naphthalene
Nitrilotriacetic acid
p- Xylene
Phenol
Phenol
Phthalic anhydride
Propylene oxide
Pyrrole
Sulphuric acid
Thiophene
Thoreau [Thoreau is a chemical company - might be able to identify the substance by searching for CAS no. 62-56-6 at https://www.cas.org/content/chemical-substances]*
Toluene
Vinyl chloride