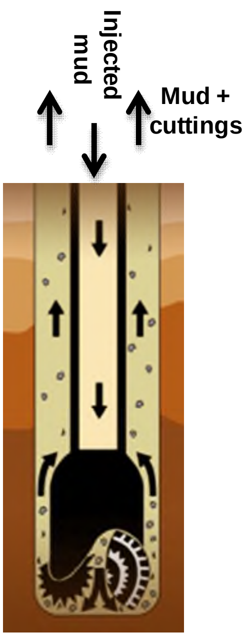
Let us speak about waste management

Like any other industry, oil & gas production generate waste, of which **drilling cuttings** and **produced water** are generated in the largest quantities. Until the mid-eighties, common practice was to discharge them directly at sea or dispose of them on land without actually worrying about the consequences on the flora, fauna and more generally, on the surrounding environment. The environmental awareness which emerged at the end of the 1980s, profoundly changed mentalities. Local and international regulations have become increasingly stringent, requesting oil companies to evolve progressively towards a "*zero discharge*" policy imposing full transparency of environmental performance through the regular publication of Key Performances Indicators now considered by international agencies as being on an equal footing with business performances.

Drilling cuttings

The drilling fluid flowing into the well in a closed loop (**Figure 1)** has many functions such as cooling the drilling bit, lifting the cuttings or maintaining borehole stability. To ensure all of its functions, it is first necessary to adjust physical properties such as density (to maintain borehole stability) and viscosity (to carry the cuttings properly). But the drilling fluid is also required to minimize pressure loss, to reduce friction between the drill string and the borehole and to prevent any unwanted chemical reactions with sensitive formations such as clays. Although most of the additives used in the composition of drilling fluids are not harmful, certain elements in low proportions are not environmentally friendly (**Figure 1**). Before being disposed and to comply with environmental criteria, drilling cuttings impregnated by mud need to be either encapsulated in an inert matrix (generally cement), heated in order to release the organic pollutants or biodegraded by micro-organisms which transform the oily cuttings into non-toxic residues. Another method called CRI (Cuttings Re-Injection) consists in re-injecting the oil-contaminated, crushed and slurrified cuttings into a dedicated formation of the overburden by hydraulic fracturing. Given the number of wells to be drilled, drilling waste disposal is a particularly significant environmental challenge when developing shale gas plays.



Chemical product	Role	% in weight	Environment friendly
Fresh water	Fluid support	70-90	Yes
Bentonite	Solid support	3	Yes
Calcium carbonate	Lost Circulation Material	I	Yes
Barium sulfate	Weighting agent	10-20	Heavy metals
Xanthan gum, glycol	Viscosifier	1	Yes
Guar gum			
CarboxyMethylCellulose	Fluid loss reducer	1	Yes
PolyAnionic Cellulose			
Sodium Polyacrylates	Deflocculants	1	Yes
Lignosulfonates			No
Glycol or surfactant	Lubricant	1-5	No
Potassium chloride	Shale inhibitors	5-10	No
Na or K formate			Yes
Potassium silicate		1-3	Yes
Graphite	Wellbore strenghtening	1-3	Yes
Asphalt derivate			No

Figure 1 – Typical composition of water base mud used for a shale gas well

Water management

The oil industry is "*a water industry which delivers oil and gas as by products*". The worldwide production of each barrel of oil is associated with an average of three barrels of water. For mature regions like US conventional onshore, eight barrels of water are brought to the surface for every barrel of oil representing a global volume of 25Gbbls. According to Global Water Intelligence[1], by 2025, as a result of ageing wells, this Water Oil Ratio is expected to reach an average of 12 for onshore crude oil resources.

In most producing countries, local regulations now impose an OIW (Oil In Water) of less than 30 mg/l. In some environmentally sensitive areas (onshore with discharges in rivers, or very near the coast) a 10 mg/l target can be imposed.

The physical separation of a light fluid (i.e. oil droplets) dispersed in a heavier carrying fluid (i.e. water) is governed by Stoke's law. The higher the density contrast, the bigger the oil droplets and the lower the viscosity of the carrying fluid, the better the separation. After being separated from oil in conventional static "*gravitational separators*" (**Figure 2)**, produced water still contains hydrocarbons in the range of between 500 mg/l and 1g/l. In such proportions, it is a hazardous waste that requires a most sophisticated treatment for safe disposal.

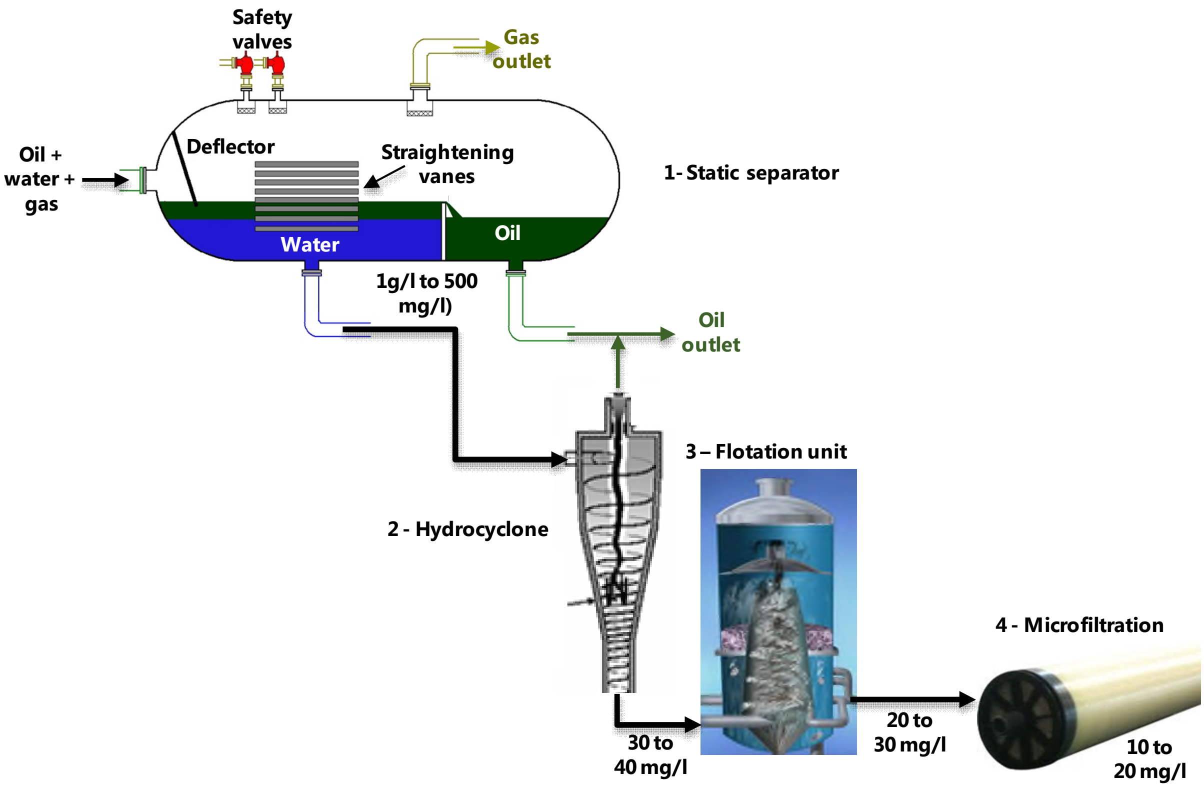


Figure 2 – Successive oil and water separation phases

The 30 mg/l target can be achieved by using hydro-cyclones, a device in which the flow is subjected to a huge parabolic acceleration. The oily water is introduced laterally and begins to flow downwards. Under the effect of the acceleration field, a core of oil turns back and moves upwards to the oil outlet whereas the dense phase moves downwards to the water outlet.

[1] http://www.globalwaterintel.com/archive/12/3/market-profile/waters-growing-role-oil-and-gas.html

To systematically reach an OIW value below 30g/l, the oil industry has turned to other technologies such as floatation[2] which routinely obtains an OIW around20 mg/l.

It consists of injecting gas into the oily water. Aided by flocculating chemicals, the oil is extracted from the water by the rising gas bubbles.

However, in highly sensitive onshore areas where OIW below 20mg/l is requested, other methods[3] such as biological (use of selective bacteria fed with the OIW), chemical (oxidation of the organic matter) or physical treatments based on micro-filtering through washable ceramic membranes are implemented more and more frequently. The sophistication of the processing chain can significantly increase operational costs especially when the amounts of water to be treated become prohibitive.

To accommodate the large volumes to be treated and the increasingly severe regulations with acceptable production costs, host countries encourage operators to re-inject untreated produced water into a dedicated disposal zone such as an aquifer, a depleted reservoir or a formation of the overburden. However, produced water which contains oil and solid particles can quickly plug the rock matrix and makes injection impossible under the matrix regime. Except in highly permeable or naturally fractured formations the PWRI[4] will therefore be performed under a hydraulic fracturing regime.

Finally, over the last ten years the DOWS (Down-hole Oil Water Separation) concept has emerged, a technique which consists in separating oil and water down hole, producing oil with a reduced amount of water and re-injecting most of the water, which is almost oil-free, into a disposal zone of the same well.

The flowback effluents following the bleeding of a multi-fractured well can be considered as specific produced water. Apart from formation water, hydrocarbons (dissolved oil or gas) and minerals (some of which are radio-elements[5]) extracted from reservoir also contain large amounts of the injected water and chemicals[6]. Experience from shale gas shows that 30% to 50% of the injected fluid flows back during the clean-up of the well. A large quantity remains adsorbed in clay minerals and the rest is produced progressively during the lifetime of the well.

Flowback effluents, which are usually stored in ponds (including barriers to protect wildlife) or sealed steel tanks can be either disposed in specific wells (PWRI) or recycled after a multi-step process. It includes de-oiling, oxygenation to remove iron, killing bacteria, breaking polymers, flocculating and precipitating solids, and then desalting if needed. Filtration and distillation are the two main methods used. After treatment, solids and liquid waste (some can be harmful in high concentrations) are temporarily stored in sealed containers and then sent to licensed facilities for final treatment and disposal according to permit procedures and applicable regulations.

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[2] The Vorsep Compact Flotation System (Siemens) incorporates several unique methods for removing oil from produced and wastewater streams before they are discharged, reused, or injected.

http://www.water.siemens.com/en/products/separation_clarification/flotation_equipment/Pages/vorsep_compact_flotation_system.aspx?stc=wwiis211000

[3] These methods are widely used for domestic water treatment

[4] PWRI = Produced Water Re-Injection

[5] Compared to reservoirs, source rocks naturally contain higher levels of radioactive minerals mainly located in the organic part of the rock. However, they present very low risks.

[6] Each chemical serves a specific purpose such as reducing friction, preventing corrosion or the growth of micro-organisms. Many of them are commonly used in regular household products, cosmetics and foods. Even if the concentration of chemical additives in fracturing fluids is extremely low, some can however be toxic in higher concentrations. Fracturing fluid suppliers are working proactively to find “green” non-toxic alternatives to the chemicals currently used.

As for any other environmental or societal issue, before any operation starts a clear baseline of the chemical status of all water sources in the immediate vicinity of the planned activities will be carried out. All the information (types of chemicals and quantity used) about fracturing fluids[7] with no prejudice to intellectual property rights is openly disclosed to local authorities and local communities. In the US, several states have even established mandatory disclosure of chemicals. Such severe regulations are also in place in The European Community[8].

[7] A specific website www.fracfocus.org has been created to facilitate exchanges between companies and stakeholders

[8] In Europe, the chemical additives used are pre-registered and regulated through the European Commission legislative framework REACH including basic information on the substance, a risk assessment for given applications, and guidelines for safe use.