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Gulf of Mexiko Oil Spill - How does oil and gas behave when released in deepwater

Hydrolink

How does oil and gas behave

An impromptu meeting was held during the recent IAHR Symposium 6th ISEH – International Symposium on Environmental Hydraulics - to discuss the recent disaster in the Gulf of Mexico

From time to time there have been major oil spills that brought a lot of media and public attention to the environmental problems caused by them. However, underwater oil spills have been much less common. The only other oil and gas release from underwater is the IXTOC well blow out in 1979. In IXTOC incident oil was released from a water depth of 50m. The recent Horizon spill in the Gulf of Mexico has generated wide scale awareness to issues related to deepwater oil spills. The fact that Horizon spill originates from a water depth of 1500 m has confounded many problems on understanding the behavior of oil and how to deal with it.

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Contrary to reports that no one has ever anticipated any accidental release of oil and gas from deepwater, there has been at least some preparation for such an event. About 15 years ago, a project was initiated by the US Minerals Management Services and the oil industry to develop a computer model to simulate the transport and fate of oil and gas when released in deepwater. Prof. Poojitha D. Yapa at Clarkson University, US was assigned the task of developing this model, which evolved as CDOG (Zheng, Yapa, Chen, 2003; and Chen and Yapa 2003 b). At about the same time, a similar model was developed at SINTEF, Norway, which evolved as DEEPBLOW (Johansen 2000). The computer model development was supported by some laboratory experiments and large scale field experiments, Deepspill, conducted off shore Norway in 2000. The field experiments were sponsored by the US Minerals Management Services and the oil industry. One of the objectives of the large scale field experiments was to provide data to test the computer models being developed.

Description of how an underwater oil and gas release behaves

The description here explains how oil and gas behave in general terms when they are released in deep water and unrelated to a specific event. These descriptions are based on principles of fluid mechanics, years of modeling experience, and the experience from observations of data from Deepspill (i.e large scale field experiments).

In general, when oil and gas are released from a deep water location, they are expected to breakup into bubbles or droplets of various sizes. These sizes can vary widely. The bubble sizes measured during Deepspill were generally between 1 mm and 10 mm. However, they can be much smaller or larger under different release conditions. Let's consider oil. The larger droplets are going to move faster towards the surface

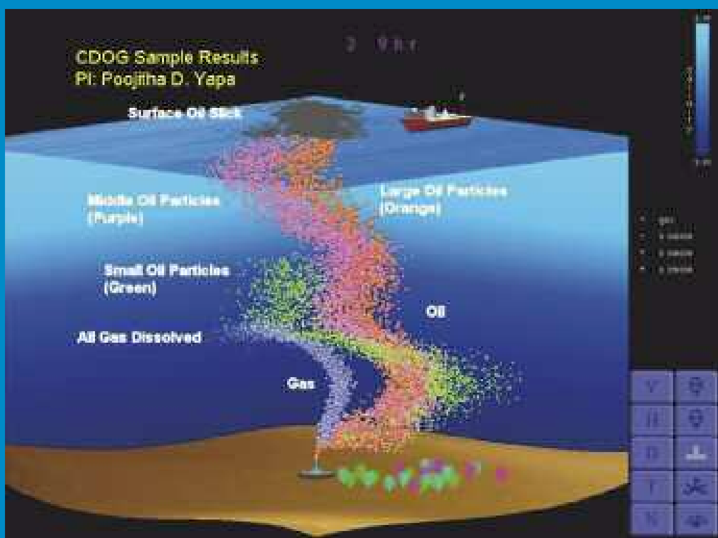

Figure 1: A Schematic representation of oil and gas behaviour when released underwater (Figure by Yapa and Xie)

when released in deepwater

while the smaller droplets move more slowly. Bubbles are subjected to cross currents which will move them laterally while they are moving upwards. Therefore, the larger droplets and the smaller droplets may not come to the surface at the same location, but quite a distance apart. Also they may reach the surface at different times. If there are droplets of very fine scale, like 100 microns or 500 microns they may take weeks or even months to reach the surface - assuming that the ambient water current doesn't have any downward component. If it has even a slight downward velocity, then that may negate the buoyant velocity of the smaller bubbles and they may stay under water for a very long time. Gas also breaks up into bubbles of many sizes. In many deepwater releases large amounts of gas bubbles will dissolve and may never make it to the surface (see Zheng and Yapa, 2002). Gas bubbles move faster than oil bubbles for the same size. Because of this, gases can separate from the main plume and move in a slightly different direction (Chen and Yapa 2004 a) as can also be seen in Figure 1. Although in reality many bubble sizes exist in a continuous distribution, for clarity this schematic uses only three oil bubble sizes and one gas bubble size. Gas bubbles are in purple color and oil bubbles are in orange, pink, and green. Orange are the largest size and come to the surface fastest, green are the slowest because they are the smallest bubbles. Gas bubbles, shown in purple color, in this case dissolve before they reach the surface. Gases when released in deep water also have the potential to be converted to hydrates. Methane has a level of hydrate dissociation generally around 550 m of water depth as shown in Figure 2. But this is not a fixed value. It depends on parameters like water temperature and gas type. Natural gas can be converted to hydrates at a much higher level. Therefore, in general, gases can be converted into hydrates upon release, and as they travel towards the water surface, (because of their buoyant nature). It should be noted that no hydrates were observed during the Deepspill experiments.

As hydrates travel towards the water surface they can be reconverted back into gas when they reach the lower pressure of the shallower regions. Figure 2 below, shows the thermodynamic equilibrium curve and the water temperature. This is for a location in the Gulf of Mexico. Figure 3 shows schematically how the gases (shown in yellow) are converted into hydrates (shown in blue).

In summary, it is important to understand that what has been described here is the general behavior of oil and gas, when it is spilled in deep water and each individual spill may have different conditions depending on the environmental factors, ambient factors like water temperature, salinity and the depth at which it was released, the type of oil.

REFERENCES

Chen, F.H. and Yapa, P.D. (2003a). "Three-Dimensional Visualization of multi-phase (oil/gas/hydrate) plumes," *Journal of Environmental Modelling and Software*, Elsevier, the United Kingdom, 19 (2004), 751-760.

Chen, F.H. and Yapa, P.D. (2004 a). "Modeling Gas Separation From a Bent Deepwater Oil and Gas Jet/Plume," *Journal of Marine Systems*, Elsevier, the Netherlands, Vol 45 (3-4), 189-203

Chen, F.H. and Yapa, P.D. (2003b). "A Model for Simulating Deepwater Oil and Gas Blowouts - Part II : Comparison of Numerical Simulations with "Deepspill" Field Experiments", *Journal of Hydraulic Research, IAHR*, August, 41(4), 353-365

Johansen, O. (2000). DeepBlow: A Lagrangian plume model for deep water blowouts. *Spill Science & Technology Bull. 6*, 103-111.

Zheng, L. and Yapa, P.D. (2002). "Modeling Gas Dissolution in Deepwater Oil/Gas Spills," *Journal of Marine Systems*, Elsevier, the Netherlands, March, 299-309.

Zheng, L., Yapa, P. D., and Chen, F.H. (2003). "A Model for Simulating Deepwater Oil and Gas Blowouts - Part I: Theory and Model Formulation" *Journal of Hydraulic Research, IAHR*, August, 41(4), 339-351

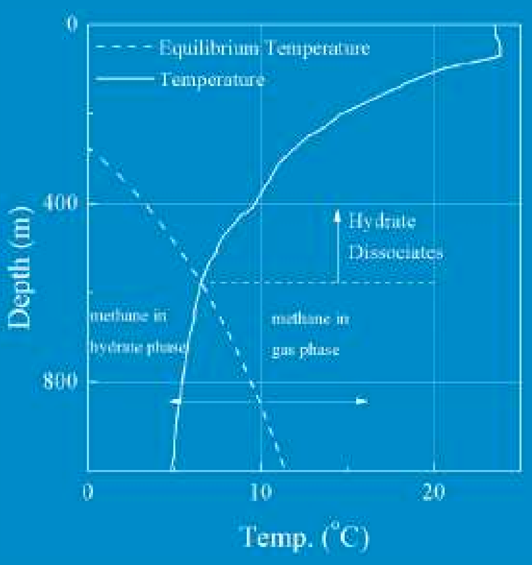

Figure 2: A typical ambient temperature and thermodynamic equilibrium curve for Methane (Yapa and Chen 2004)

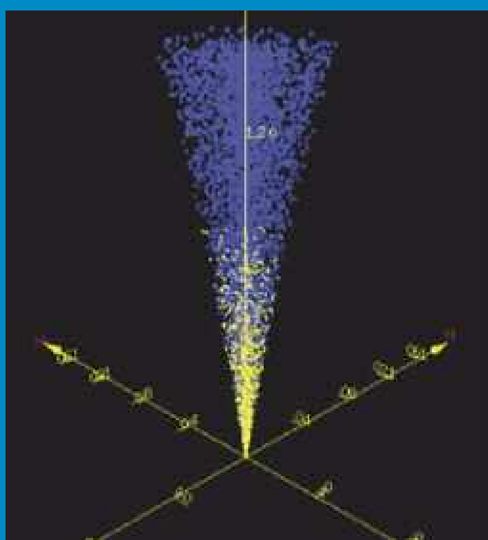

Figure 3: Schematic representation of gas (yellow) converting to hydrates (blue) as they travel upwards. Ambient current = 0 (Chen and Yapa, 2003)