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Advances in oil spill modelling

Hydrolink

ADVANCES IN OIL SPILL MODELLING

BY POOJITHA D. YAPA

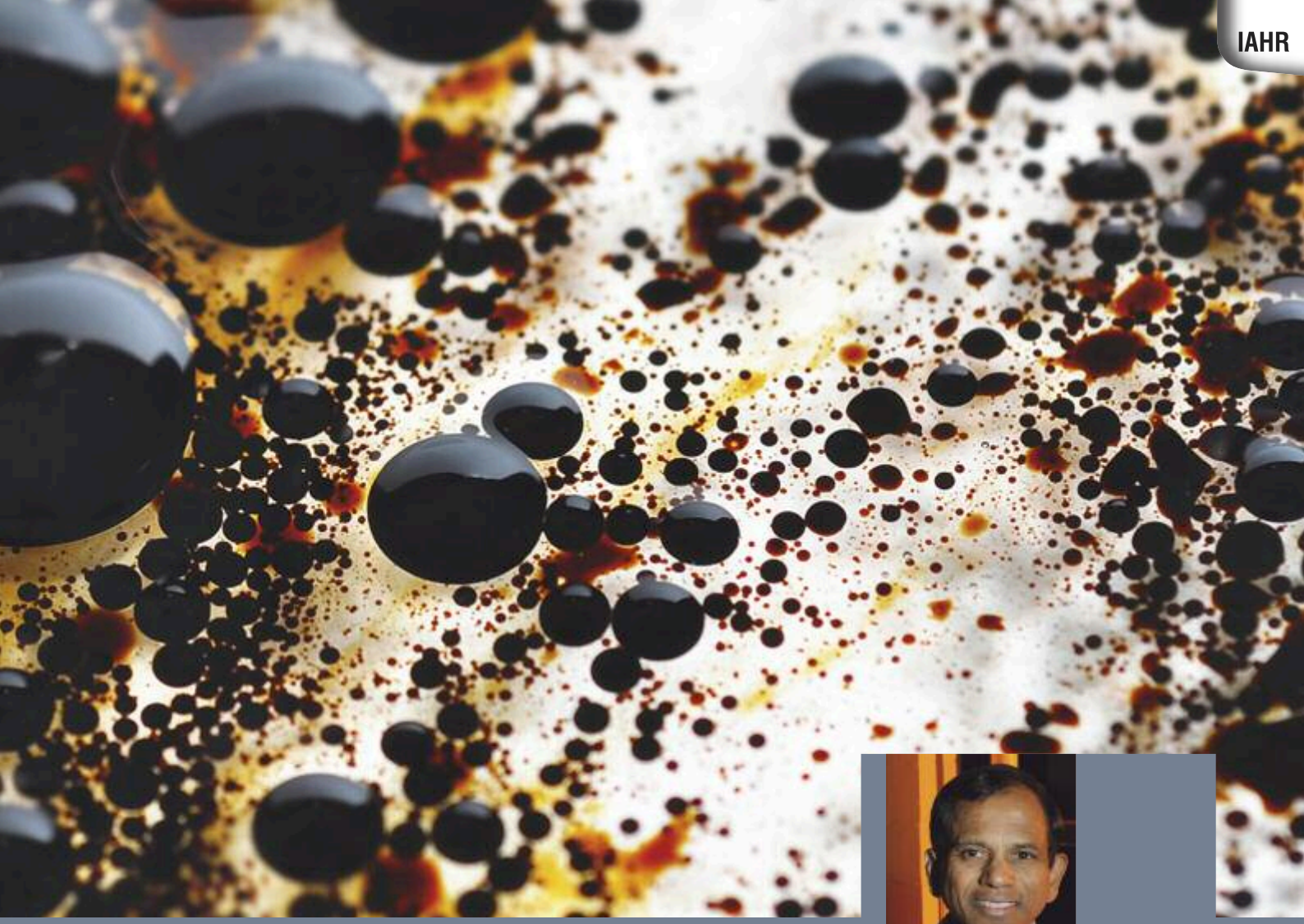
Conference Report on IAHR Kuwait International Summit on Advances in Oil Spill Modelling (November 8-9th, 2011)

A workshop was held in November 2011 under the sponsorship of Kuwait Oil Company and the Kuwait Institute for Scientific Research (KISR), Kuwait and was held at the latter location. It was a two-day workshop (open to the public), bringing together an international panel of leading experts on oil spill modelling to give presentations sharing their many years of experience on the topic and aimed at achieving a common viewpoint on where oil spill modelling stands. Expertise of the panel members covered a broad range of topics related to oil spill modeling that included areas of fluid mechanics and hydraulics, chemical engineering and chemistry, environmental engineering, and biology.

The purpose of the workshop was to present and discuss the state-of–the-art in modelling of oil spills and identify key needs for future research from a multi-disciplinary standpoint to satisfy the requirements of the oil industry and governmental organizations in preparing adequate emergency oil spill contingency plans. The Workshop was to serve as the "kickoff meeting" for the interdisciplinary Working Group (WG) with clear outputs which will constitute a roadmap for the Oil Spill Modelling WG.

The workshop was opened with the remarks from Dr. Naji Al-Mutairi, Director General of KISR, Dr. Christopher George, IAHR Executive Director, Prof. Poojitha Yapa, Chair IAHR Working Group on Oil Spill Modeling, and Dr. Khaled Al-Banaa, Vice-Chair IAHR Working Group on Oil Spill Modeling.
The following presentations were given:

- Overview of Current state of the art in oil spill modeling
  Prof. Poojitha Yapa (Chair, IAHR Working Group on Oil Spill Modelling, Professor of Civil and Envir. Engrg.,Clarkson University, USA)
- Modeling ocean/coastal hydrodynamics for oil spill simulations.
  Prof. Peter Sheng (Professor, Department of Civil and Coastal Engineering, University of Florida)
- The effects of oil weathering on the properties and behavior of oil
  Dr. Bruce Hollebone (Oil Research Laboratory, Emergencies Science and Technology Section of Environment Canada.)
- Using marine environmental risk concepts to evaluate alternative spill response strategies
  Dr. Mark Reed (Senior Scientist, SINTEF, Trondheim, Norway)
- Oil spill modeling and risk management systems in the Atlantic
  Mr. Rodrigo Fernandes (Researcher, MARETEC - Institute Superior Técnico Lisboa – Portugal)
- Computational-based decision support systems for risk assessment and management of sea oil spills
  Dr. Augusto Maidana (Scientist, International Center for Numerical Methods in Engineering (CIMNE), UPC, Spain)
- Model uses during oil spill emergency response
  Dr. Bill Lehr (Senior Scientist, Office of Response and Restoration, National Oceanic and Atmospheric Administration (NOAA), USA)
- An application of oil spill modeling on smart



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Dr. Khaled Al-Banaa (Vice Chair, IAHR Working Group on Oil Spill Modelling, Research Scientist, KISR, Kuwait)

- Oil spill modeling activities in Japan
  Mr. Hiroshi Yamada (Chief Consultant, Environment and Energy Division 1, Mizuho Information and Research Institute, Inc., Tokyo, Japan
- Oil shoreline interactions
  Dr. Eric Gundlach (ETech International, USA) Recorder: Bassam Shuhaibar Researcher, KISR, Kuwait

Collectively the presentations made by the distinguished speakers discussed the importance of water hydrodynamics, processes that oil undergo when spilled on or near the water surface, and oil spill modeling for emergency management as well as risk management in contingency planning.
All important physico-chemical processes that oil undergo (called oil spill processes hereinafter) after an oil spill that are needed to be included in an oil spill model and their relative importance in different time scales were identified. These processes are Advection, Mechanical spreading, Turbulent diffusion, Evaporation, Dissolution, Vertical mixing, Oil shoreline interaction, Emulsification, Bio-degradation, Photo-chemical reactions, Oil Sediment Interaction. In addition to identifying the processes, these talks covered how these different processes would play roles in affecting each other. For example evaporation may affect dissolution as well emulsification. Emulsification may affect the oil transport as well as further evaporation. Oil sediment interaction may affect the transport of oil as well as sediments. This may also lead to oil sedimentation as well. Regarding the hydrodynamics the presenters were of the view that in the past it has not received the attention it deserves and only the water velocity has been taken into account. For example, how a massive amount of oil in the water affects the water transport has not been modeled. The need for models to forecast under extreme weather conditions like hurricane conditions was also stressed. Langmuir circulation may also affect the oil transport and

***Poojitha D. Yapa,* a Professor of Civil and Environmental Engineering at Clarkson University, Potsdam, NY, USA has B.Sc (Honors) in Civil Engineering and M.Sc in Hydraulic engineering. He received his Ph.D. in Civil and Environmental Engineering from Clarkson University in 1983. His research has focused on "environmental hydraulics problems". For over 25 years his research has been focused on oil spill modeling. This includes not only trajectory modeling, but modeling physico-chemical processes oil undergo when spilled in the ocean or rivers. In the last 15 years his modeling has been on deepwater oil, gas, and hydrates, studying the complex processes they undergo during the travel from deepwater to the surface. Prof. Yapa and his students developed computer models such as CDOG, MEGADEEP, and ADMS for modeling the behavior of oil and gas when released in deepwater. The work has been published in leading journals.**

needs to be included in the models in a more comprehensive way. Presentations also discussed how water velocity and turbulence affect not only the horizontal and vertical transport of oil but also the emulsification process. The water turbulence (including that induced by the winds) need to be included in models to simulate oil break up and coalescence, and vertical mixing,

On the model application side the presentations included past cases of simulating actual major spills, how models were used during emergencies as well as for risk management. Model capabilities are addressed later in this article in tabular form.

On the second day there were two extensive panel discussions on "modeling needs and data availability" and "what needs to be done to improve our current practices?" The two panel discussions were moderated by Prof. Poojitha Yapa and Dr. Bruce Hollebone respectively. During the panel discussions needs for models, model use, and data requirements and availability were identified. The tables below present a summary of the panel discussions.

For more information on the IAHR Working Group on Oil Spill modeling visit www.iahr.org

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Table 1: Physical properties of crude oils determined by composition

Property	Relevance	Predictability*
Density	Physical transport	Good
Viscosity	• Increases surface slick lifetime • Potential for injury to birds, marine mammals and shorelines • Affects "windows of opportunity" for different response actions	Poor without empirical data
Pour Point	• Spreading • As for viscosity	Poor without empirical data
Evaporation potential	Mass balance, density, emulsion stability	Good
Interfacial tension	Spreading dispersion & droplet sizes	Poor

* Predictability based on oil properties alone

Table 2: Weathering processes affecting oil spills

Natural weathering processes	Predictive ability
Evaporation	Very good
Water-in-oil (w/o) emulsification and viscosity	Fair-to-poor without empirical data
Oil-in-water (o/w) dispersion	Fair for fresh oils, poor for emulsions
Oil droplet formation and size distribution	Poor
Dissolution of oil components into water	Fair-to-good
Photo-oxidation	Poor
Biodegradation	Good for dissolved, poor for droplets/tar-balls

Table 3: Physical processes affecting oil spills

Physical processes	Predictive ability
Advection	Very good
Oil stranding	Fair
Remobilization from shoreline	Poor
Re-suspension	Poor-to-fair
Surface spreading	Fair
Langmuir circulation	Poor
Turbulent mixing (vertical & horizontal)	Poor (with LC)-to-good (without LC)
Oil-SPM	Poor
Interaction with Bottom Sediments	Poor
Current-wave interaction	Fair-to-good
Oil effects on hydrodynamics	Poor

Table 4: Response Actions

Response Actions	Modelling Capability
Surface application of dispersants	Fair
Injection of dispersants at source	Poor
Mechanical response	Fair-to-good
Controlled burn	Fair-to-good
Booming & containment	Good
New techniques (solidifiers; herders; etc.)	N/A

Oil swirls in the Gulf of Mexico currents May 6 AP. Photo: Dave Martin