Module 7

Navigation in Muddy Areas and Environmental Issues

R Kirby BSc, PhD, Dist D. NE

Ravensrodd Consultants Ltd

Ports and Maritime Organization of Iran
And PIANC-Iran
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Navigation issues:-

Ship model studies, theoretical investigations, full scale prototype tests
Insurance implications
Pilotage training

Environmental consequences

Passive Nautical Depth (PND)
Active Nautical Depth
AND v WID? Both involve fluidisation
Far-field
Near-field

Navigation Issues

Dutch government followed a twin-track approach in 1975-6.

1. Physical model tests in the ship research tank at Waageningen used paraffin wax to simulate fluid mud. Sailed model at various heights above and within the layer.
2. Full scale test with the Shell supertanker ‘Lepton’. Vessel coming to Rotterdam for dry docking. Sailed two axial tracks first close to water/fluid mud interface, then ballasted with sea water, and returned with keel trailing in fluid mud. Then dry-docked and inspected. No consequences noted.

Changes in vessel behaviour:- more power needed, less squat, stops more quickly, turns more tightly (smaller rudder angle) etc.

These prototype trials repeated in 1980’s in Zeebrugge, Belgium using the trailer suction hopper dredger Vlaanderen XVIII ballasted with sea water and sailing at various heights above and within fluid mud; also at varying speeds.

These trials supported by the theoretical work of Prof. Marc Vantorre at University Ghent.

Work with ship insurers, Lloyds of London etc.:-
Once 1970's trials complete insurers were advised and routine operations then permitted.

In the USA a very extensive list of those from whom permission must be sought has been drawn up. Usually Americans ask "What did you do?" (in Europe) US has still, after 40 years, never made any sensible progress.

Authorisation from IMO
PIANC and the IMO has revisited the issue of sailing vessels in mud based on these European experiences twice and verified the method for world wide use.
(First paper Nederlof and van Bochove 1982)

PIANC 1997 'Approach channels, a guide for design' Supplement to Bulletin No. 95 World Association for Waterborne Transport Infrastructure, (PIANC) Brussels, Belgium.
PIANC 2014 'Harbour approach channels, design guidelines. MarCom Working Group. Report 121 World Association for Waterborne Transport Infrastructure (PIANC) Brussels, Belgium.
(PIANC 2008. Minimising Harbour Siltation. Chairman R Kirby Report No 102 Mar Com working group43. World Association for Waterborne Transport Infrastructure (PIANC) Brussels, Belgium).

Pilots Handbook?
Understood at various times that this exists in Rotterdam. If so not seen it.

Environmental Consequences

PND major environmental benefit arises from ignoring the shallowest echo sounder reflector and only working to lower elevation of denser mud horizons beneath. There is no consequence at dredging site as natural fluid mud is anaerobic and barren. Benefit confined to disposal site.

AND Water Injection involves high energy input which fluidises firm bed muds and natural fluid muds, both of which are anaerobic and contain high volumes of anoxic pore water. Anoxic pore water is released, with detrimental impact on BOD of water body. Mud is dispersed >widely and readily settles on reefs, shellfish beds and fish spawning areas.

Conditioning involves slow, low energy input involving a small submerged mud pump aimed at raising dense fluid mud in the operational area, destroying inter-particle bonds and oxygenating the mud cloud, which is gently placed a few metres down onto the bed. The object is to retain conditioned mud, not disperse it. These are contrasted mechanisms with contrasted consequences.

Far-field (BOTH engineering and environmental consequences)

1. Method (AND) can be applied to fairways as well as entrances and fairways.
2. Thus: - could be applied to permit over-deepened, destabilised estuaries (and coasts) to return to 'regime' (ref Ems, Loire etc.) whilst maintaining deep-draughted vessel working.
3. Such application would reduce tidal flat erosion rate.
4. Scheldt estuary (NL and B) has suffered 'winnowing' of mud from its mixed muddy sand bed leading to coarsening and increased channel instability. Shifting to AND <u>might</u> return the mud population.
5. Estuaries/coasts have a 'sediment budget' (sources and sinks) to which port dredging often makes a large, undesirable contribution. This disappears.
6. Concept called 'Environmental Windows' in which dredging and fish spawning/migration are separated by statute becomes irrelevant. Either conditioning can continue or conditioning operations can be timed to avoid environmentally sensitive spells.
7. Certain zones of oceans, for example Baltic Sea, Gulf of Mexico have such poor DOx status that disposal of muddy dredge material, which has a high BOD, can trigger anaerobiosis and mass 'wipe-outs'/is forbidden-to detriment of port management. AND involves oxygenation but also avoids mud spoil relocation.
8. Recognition of coastal sediment circulation cells helps understand why both disposal within a cell, leading to repetitive return, plus why disposal beyond such cells, accentuating sediment loss, are undesirable. AND and conditioning retains fine sediment in coastal zones.
9. Many attributes (above) exaggerated in warm water regions. (DO carrying capacity reduces as temperature rises)

Near-field environmental consequences.

1. Naturally-occurring fluid mud is in all respects ‘bad’. Combination of its low strength and anaerobic (anoxic) nature renders it incapable of hosting macroscopic organisms. Thus barren. They dewater and in doing so expel high volumes of anaerobic pore water rendering near bed zones of water body inhospitable, too.

   Products of WID behave comparably
2. When a deep-draughted vessel sails close to or within such a layer the internal wave at its bow (if it breaks), the hull and propeller disturbance, all entrain anaerobic flocs and de-oxygenated water. In all respects ‘bad’ too. Thus ship traffic imposes a high BOD on water bodies with often limited Dissolved Oxygen.
3. In direct contrast, engineered fluid mud clouds are aerobic and form a stable, non-settling emulsion. It doesn’t dewater. Passage of a vessel over or through such material creates comparable entrainment to 2 (above), though the flocs and pore water will be aerobic. (Oxygenated).

   i.e. A mechanism having undesirable implications for natural fluid mud is neutral or beneficial in respect of conditioned mud.
4. Density, shear strength and viscosity contrast between conditioned mud and the water body prevents recirculation onto marginal shoals.
5. Reefs, fish, manatees, dugongs, turtles etc., can’t be damaged physically.
6. Anaerobic bacteria are disabled. Thus ammonia, methane and hydrogen sulphide gases never generated or expelled.

7. Unexpected phenomenon of induced self-cleansing by bacteria in aerobic mud

Table of TBT reduction

	Date	No. of samples	Top of mud	Mud basal zone
			Mean TBT, µg Sn/kg Dried Mud	
Emden entrance	**Oct. 1992**	**9**	**283**	
	Feb. 1993	**2**		**1560**
Storage site	**Dec. 1998**	**10**	**64**	**159**
	Sept. 2000	**10/8**	**16**	**29**

Aerobic bacteria break down and destroy the active biocide TBT in former anti-fouling paint 'Natural self-cleaning' of other anthropogenic contaminants 226 Ra, heavy metals etc. has also been reported due to cycling mud between aerobic and anaerobic phases.

We believe the heavy metal mercury (Hg) can be converted into a gaseous phase. PCB's?

General Conclusions

1. Efficient port operations require modern vessels, ‘landside’ and ‘waterside’ management. With recent growth in vessel size, traditional mud management by dredging has been found wanting.
2. We are becoming acquainted with damaging consequences of gross-scale overdevelopment, for example of major estuaries aimed at accommodating deep-draughted vessels. We must learn how to reverse these and find other means of trading (move ports to mouths of estuaries, but needs more)
3. Sustainable soft sediment engineering methods are cheaper and more desirable than hard engineered solutions.
4. Unlike with vessel and port refinements, there is strong opposition from certain quarters wishing to stick with traditional methods.
5. Some modern methods have emerged from hydraulics (CDW), others from application of scientific instruments designed for a different purpose (PND), finally our best solutions are emerging from the broad field of the ocean sciences (auto-flushing from mud rheology, AND and conditioning from physics, chemistry and micro-biology). These latter represent pinnacle, being total solutions.
6. What lessons might governments learn? What commercial opportunities do these technologies afford? Nationally/internationally?
7. Highlight fundamental differences between naturally-occurring fluid mud, which is invariably anaerobic and damaging, compared to engineered, aerobic fluid mud which is beneficial.
8. Costs? Modern methods are universally less expensive but benefits can be extremely large.

9. Operations: - Need familiarity with IMO certifications and agreement from insurers. Need to understand and account for contrasts in vessel behaviour. Need training and experience for harbour pilots. Need to routinely, reliably produce nautical depth charts. Need one or a number of dedicated 'Conditioning' vessels. Forty + years experience in NW Europe. Need to evaluate, from experience at Emden/Delfzijl etc., how conditioned mud 'matures' with time. Need same experience to fine tune/optimise operations to take account of local idiosyncrasies.
10. Explore new field opened up by application of aerobic mud bacteria for 'self-cleansing' of contaminants.
11. My journey. The team.
12. Research

    Design CDW's, if progressed, by computer, not in physical models.

    Need international scale of effort in chemical oceanography to explore prospects for 'self-cleansing'.

    Need to better understand aerobic micro-biological processes and how these destroy/liberate organic/inorganic contaminants.
13. Will AND work in muddy/Iranian coastal zone and ports? Best guess is that it will work better than in NW Europe.