Maritime & Coastguard Agency

# Fate and Behaviour of Oil

Safer Lives, Safer Ships, Cleaner Seas

1

Maritime & Coastguard Agency

# Composition of crude oils

- Crude oils are mixtures of many thousands of different hydrocarbons
- Different crude oils have different proportions and therefore different properties
- These range from propane to bitumen
- Other components may include substances such as:
  - Polycyclic Aromatic Hydrocarbons (PAHs);
  - BETX (Benzene, Ethylene, Toluene, Xylene);
  - Heavy metals;
  - Sulphur compounds

Safer Lives, Safer Ships, Cleaner Seas

2

Maritime & Coastguard Agency

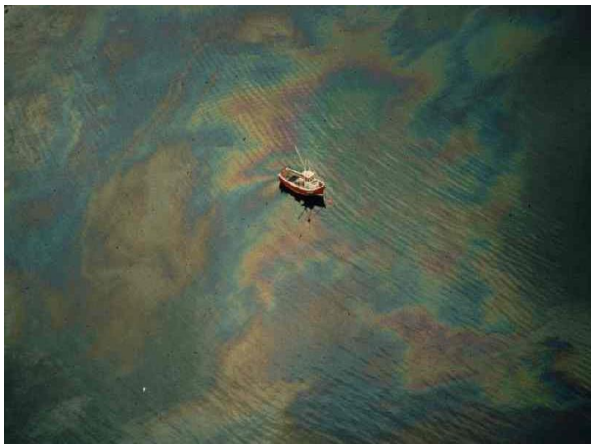
# Relevant oil properties

CRUDE OIL ASSAY OR DATA SHEETS

- Density, Specific Gravity, API Gravity
- Volatility - related to boiling point
- Viscosity
- Pour point
- Wax content
- Asphaltene content

Safer Lives, Safer Ships, Cleaner Seas

3



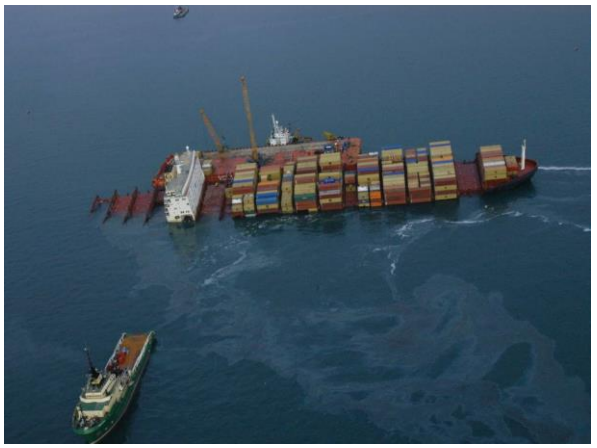
4

Maritime & Coastguard Agency

| Code | Description Appearance | Layer Thickness Interval (µm) | Litres per km² |
|---|---|---|---|
| 1 | Sheen (silvery/grey) | 0.04 to 0.30 | 40 – 300 |
| 2 | Rainbow | 0.30 to 5.0 | 300 – 5000 |
| 3 | Metallic | 5.0 to 50 | 5000 – 50,000 |
| 4 | Discontinuous True Oil Colour | 50 to 200 | 50,000 – 200,000 |
| 5 | Continuous True Oil Colour | 200 to More than 200 | 200,000 - More than 200,000 |

Safer Lives, Safer Ships, Cleaner Seas

5



6

7

9

10

11

12

14

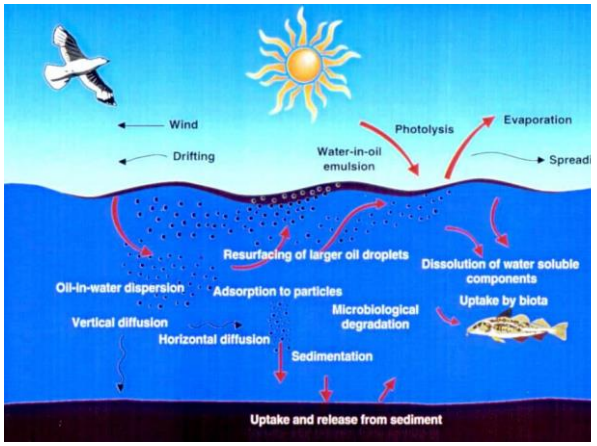
Maritime & Coastguard Agency

## Fate of spilled oil - Weathering

- Major processes
  - Spreading
  - Evaporation
  - Emulsion formation
  - Natural dispersion
- Other processes
  - Dissolution
  - Oxidation
  - Sedimentation
  - Biodegradation

Safer Lives, Safer Ships, Cleaner Seas

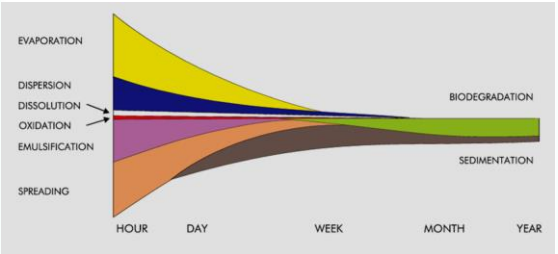
15




16

Maritime & Coastguard Agency

## Process with time




Source: *ITOPF*

Safer Lives, Safer Ships, Cleaner Seas

17

Maritime & Coastguard Agency

## Spreading of spilled oil

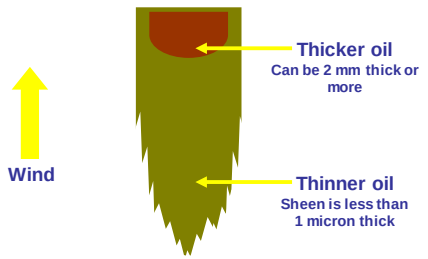
- Spilled oil floats and spreads out to form an 'oil slick'
  - Very variable thickness from very thin to thick
  - Sheen that is less than 0.1 microns thick
  - Approximate average of 0.1 mm
- 1 tonne of spilled oil will rapidly spread out to a slick with an area of about 10,000 $m^2$

Safer Lives, Safer Ships, Cleaner Seas

18

Maritime & Coastguard Agency

## Typical oil slick




Safer Lives, Safer Ships, Cleaner Seas

19

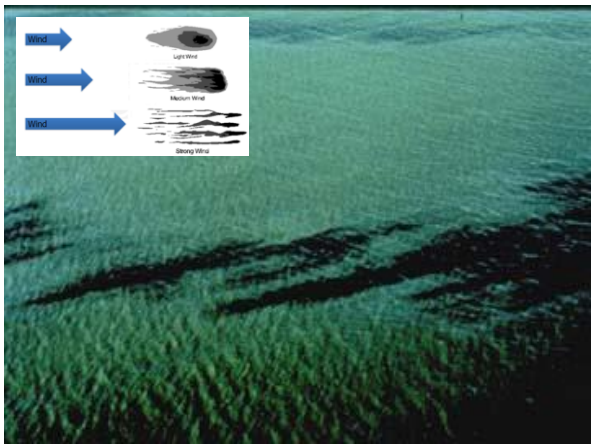
Maritime & Coastguard Agency

## Spreading

- Rate of spreading depends on viscosity
- Waxy oils break into pieces, rather than spread
- Slicks broken up by wind and currents
- Form 'windrows' parallel to wind direction

Safer Lives, Safer Ships, Cleaner Seas

20

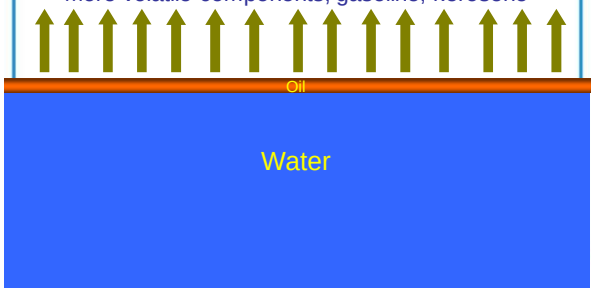



21

## Evaporation of volatile oil components

Maritime & Coastguard Agency

More volatile components; gasoline, kerosene




22

## Evaporation

Maritime & Coastguard Agency

- Volume of oil on the sea surface decreases depending on:
  - Oil composition
  - Temperature
  - Wind speed

Safer Lives, Safer Ships, Cleaner Seas

23

Maritime & Coastguard Agency

## Consequences of evaporation

- As the gasoline evaporates the residue contains more of the high viscosity components
- The viscosity of what is left behind increases
- The oil becomes thicker and more sticky

Safer Lives, Safer Ships, Cleaner Seas

24

Maritime & Coastguard Agency

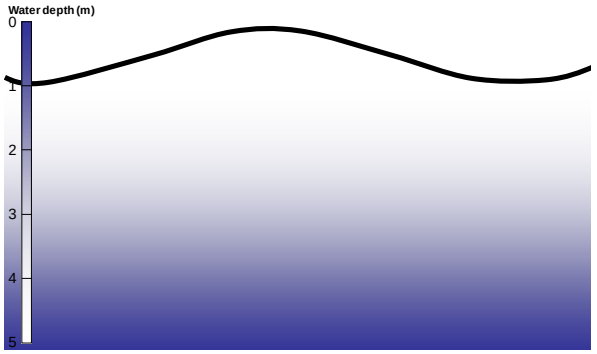
## Natural dispersion

- Natural dispersion requires breaking waves
  - Not a significant process in calm seas
  - Proceeds more rapidly in rough seas
- If natural dispersion continued to completion all the spilled oil would eventually be naturally dispersed and there would be no need for oil spill response

Safer Lives, Safer Ships, Cleaner Seas

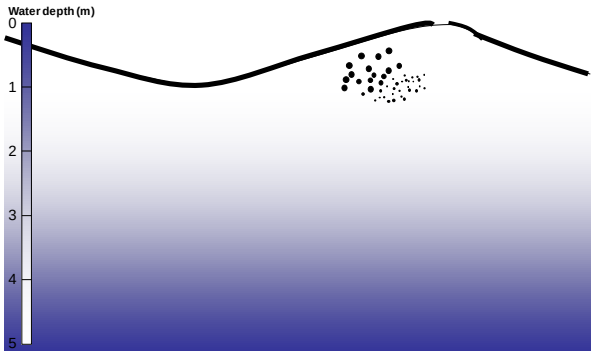
25

## Natural dispersion



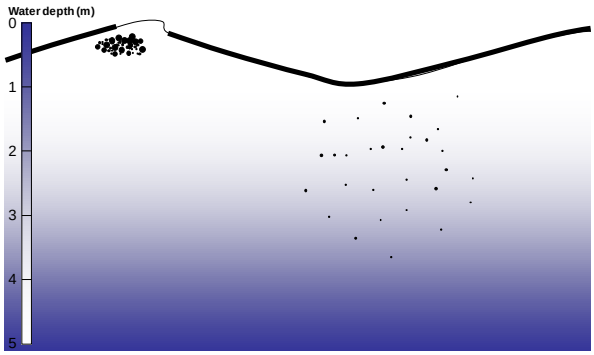

26

## Natural dispersion



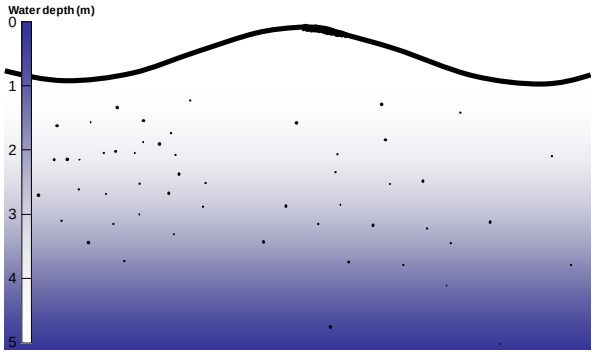

27

## Natural dispersion




28

## Natural dispersion




29

Maritime & Coastguard Agency

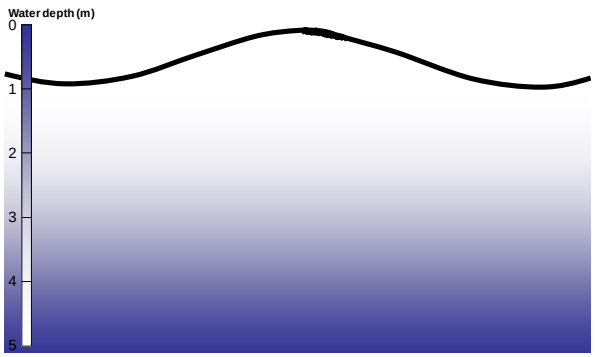
## Water-in-oil emulsification

- Water droplets can become incorporated in the body of oil
- Asphaltenes help this emulsification process

Safer Lives, Safer Ships, Cleaner Seas

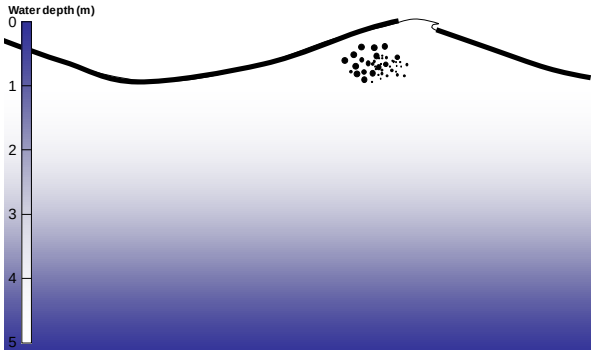
30

## Water-in-oil emulsification

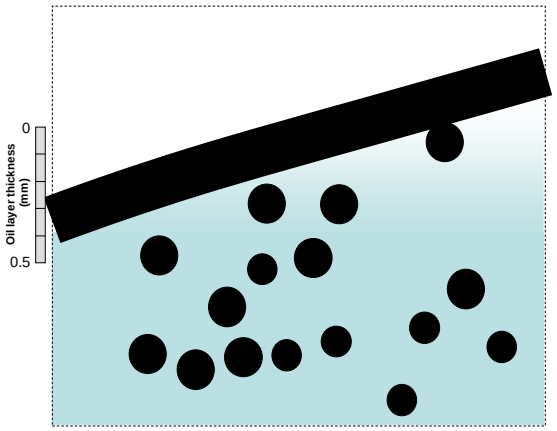



31

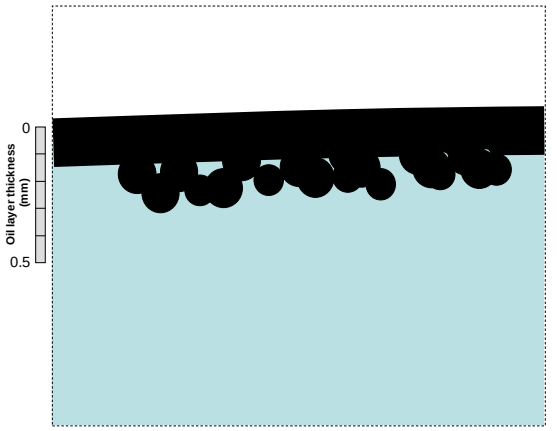
## Water-in-oil emulsification



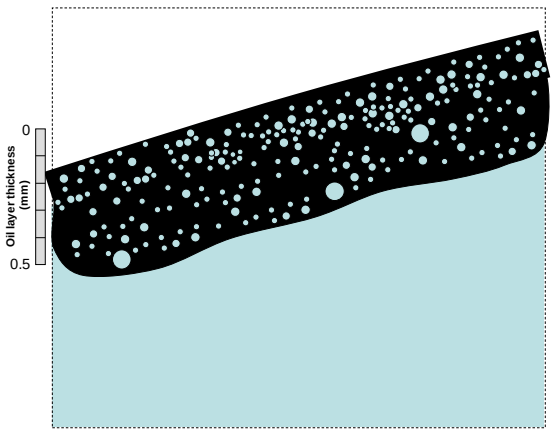

32


0
Oil layer thickness (mm)
0.5

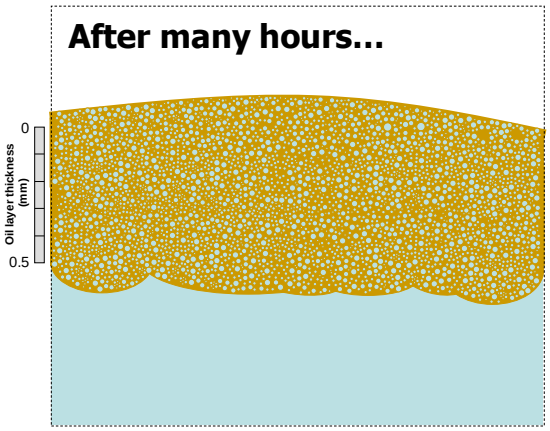
33


0
Oil layer thickness (mm)
0.5

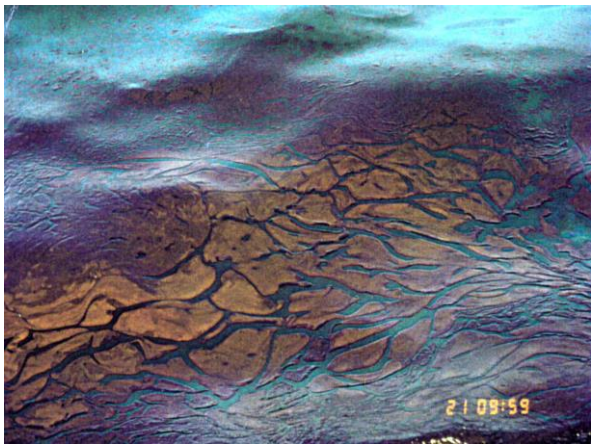
34


0
Oil layer thickness (mm)
0.5

35




36




37

Maritime & Coastguard Agency

## Consequences of emulsification

- Up to 75% volume of water
- Volume of the emulsified oil is 4 times that of residue left after evaporation
- Emulsified oil is much thicker (higher viscosity) than that of oil that was spilled

Safer Lives, Safer Ships, Cleaner Seas

38

Maritime & Coastguard Agency

## An example

- 1,000 tonnes of a light crude oil spilled
  - Spreads out into a slick with an area of approximately 10 $km^2$ (10,000,000 $m^2$).
  - Approximately 30% (300 tonnes) will evaporate in 24 hours leaving 700 tonnes
  - Remaining oil will incorporate water to produce 2,800 tonnes of emulsified oil
- 1,000 tonnes spilled, 2,800 tonnes formed

Safer Lives, Safer Ships, Cleaner Seas

39

Maritime & Coastguard Agency

## Other processes

- Dissolution
  - A few oil components dissolve in water
- Oxidation
  - Sunlight and air cause oil to change
- Biodegradation
  - Micro-organisms 'eat' oil if it is dispersed
- Sedimentation
  - If there is suspended sediment

Safer Lives, Safer Ships, Cleaner Seas

40

Maritime & Coastguard Agency

## Spilled oil movement

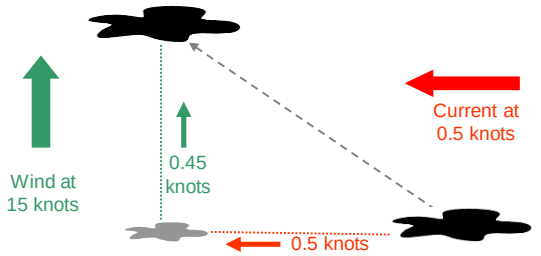
- Oils slicks drift
  - With the current at the speed of the current
  - In the direction of the wind at 3% of wind speed

Safer Lives, Safer Ships, Cleaner Seas

41

Maritime & Coastguard Agency

## Effect of current and wind




Safer Lives, Safer Ships, Cleaner Seas

42

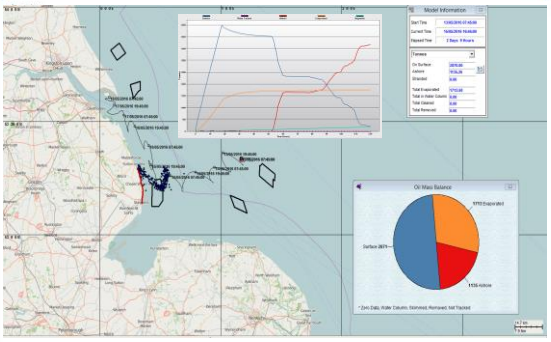
Maritime & Coastguard Agency

## Computer models predict:

- Oil spill movement:
  - Tidal databases and wind direction and speed input
  - Slick trajectory output
- Oil 'weathering' properties:
  - Oil specific inputs
  - Increase in emulsified oil viscosity output
  - Increase in emulsified oil volume output

Safer Lives, Safer Ships, Cleaner Seas

43



Safer Lives, Safer Ships, Cleaner Seas

44

Maritime & Coastguard Agency

## Oil that comes ashore

- Oil that comes ashore becomes mixed up with seaweed, sand etc.
- Great care is needed to prevent picking up a lot of beach material with the oil
  - Best practice will mean oily material contains 25% - 30% oil
  - Bad practice can results in 10% or less oil picked up

Safer Lives, Safer Ships, Cleaner Seas

45

Maritime & Coastguard Agency

## Shoreline clean-up volumes

- 1,000 tonnes of a light crude oil spilled
- 2,800 tonnes emulsified oil comes ashore
- Amount of oil to be disposed of varies:
  - 10,000 tonnes of oily material recovered with best practice
  - 30,000 tonnes of oily material recovered with poor practice

Safer Lives, Safer Ships, Cleaner Seas

46

47