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COMPARISON AND ASSESSMENT OF WASTE GENERATED DURING OIL SPILLS

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1 ABSTRACT 300178:

Experience has shown that the most time-consuming and costly component of a response to an oil spill is often the treatment or disposal of collected waste. The amount of waste generated is dependent on many factors, some which may be controlled more readily during the response.

This paper analyses a number of important incidents as a result of which spilled oil affected shoreline resources with significant resultant clean-up effort. Spills of crude oil and of heavy fuel oil carried as cargo in tankers are reviewed to determine the types and volumes of waste generated and the clean-up methods undertaken to generate that waste. A comparison of the incidents will allow the most effective response methods to be determined, to show the techniques that generated the least volumes of waste. Data from DEEPWATER HORIZON is included to allow a discussion of the associated response.

To achieve a practical comparison, the amount of waste is balanced against the amount of oil spilled to determine the oil:waste ratio. This ratio has evolved over many years into a long held guideline, used often for the purpose of contingency planning, that the amount of waste generated during an incident is approximately ten times the amount of oil spilled. This paper shows that with appropriate response actions, the guideline can be upheld.

2 INTRODUCTION:

Information from 18 marine incidents has been compared. The thread common to these incidents is a release of a significant amount of oil that resulted in a correspondingly significant amount of waste, generated primarily from shoreline clean-up. Incidents in which oil was consumed by uncontained fire are not considered, since an accurate estimation of the amount of floating oil remaining and affecting shorelines is rarely possible. The incidents are summarised in table 1, grouped according to whether a crude oil or a fuel oil was spilled.

For the purposes of this paper, waste is defined as material collected from the sea or shoreline transported for treatment or disposal elsewhere. Material collected but treated in-situ, and not removed from the immediate area, is excluded from this definition. Where identified explicitly in the references, waste derived from the removal of fisheries infrastructure (e.g. nets or traps) and the destruction of stock is excluded also.

3 COMPARISON OF INCIDENTS:

Year	Incident name	Oil spilled (tonnes)	Liquid waste (tonnes)	Solid waste (tonnes)	Total waste (tonnes)	Ratio - waste:spilled oil (=1)
Crude Oil Spills						
1978	AMOCO CADIZ	227,000	100,000	100,000	200,000	0.9
1989	EXXON VALDEZ	37,000	97,500	38,800	136,300	3.7
1995	SEA PRINCE	5,500	2,000	5,100	7,100	1.3
1993	BRAER	86,200		2,000	2,000	0.02
1996	SEA EMPRESS	72,370	25,000	11,000	36,000	0.5
2004	ATHOS 1	900	200	6,700	6,900	7.7
2007	HEBEI SPIRIT	10,900	2,610	37,610	40,220	3.7
2010	DEEPWATER HORIZON	780,000	162,260	89,200	251,460	0.3
					Average ratio for crude oil spills:	2.3
Fuel Oil Spills						
1980	TANIO	13,500		28,000	28,000	2.1
1988	AMAZZONE	2,100		13,000	13,000	6.2
1997	NAKHODKA	6,200		50,000*	50,000	8.1
1997	NISSOS AMORGOS	3,600		40,000*	40,000	11.1
1999	VOLGONEFT 248	1,280		4,500	4,500	3.5
1999	ERIKA	19,800	1,100	200,000**	201,100	10.2
2001	BALTIC CARRIER	2,550	965	10,750	11,715	4.6
2002	PRESTIGE	63,000	50,000	159,300	209,300	3.3
2006	SOLAR 1	2,080		5,010	5,010	2.4
2007	VOLGONEFT 139	2,000	200	79,740	79,940	40.0
					Average ratio for fuel oil spills:	9.1
					Average ratio for all oil spills:	6.1

Table 1: Waste amounts generated from significant marine pollution incidents.

* for NAKHODKA and NISSOS AMORGOS, the liquid and solid waste was consolidated, and separate figures for the amounts of liquid and solid material generated are not available. However, it is understood for both incidents that the amount of liquid collected at sea was low in relation to the amount of solid material collected on the shorelines.

** excludes waste generated from temporary storage of the waste.

Figures 1 to 3 illustrate the primary statistics from the table.

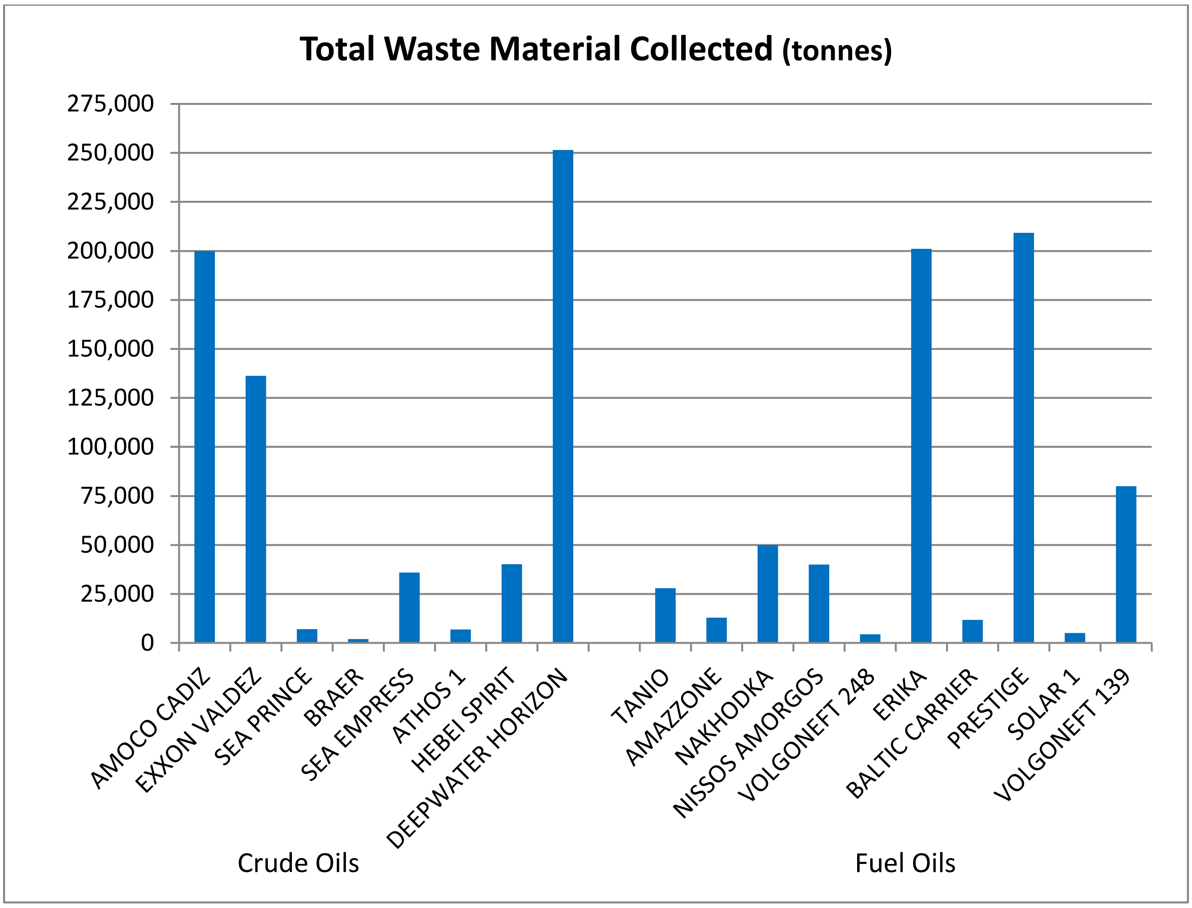

Figure 1: Total amount of waste collected at sea and on shorelines for 18 incidents.

The amount of total waste collected from the sea surface and from the shorelines during each response is illustrated, showing that six incidents of those reviewed resulted in very large amounts of waste, i.e. greater than 50,000 tonnes. A further five incidents resulted in waste amounts between 25- and 50,000 tonnes. The remaining seven incidents resulted in amounts of waste less than 25,000 tonnes.

Liquid waste, recovered from the sea-surface, and from the shoreline in some incidents, was recorded in eleven of the incidents. The amounts of liquid waste collected in five incidents; AMOCO CADIZ, DEEPWATER HORIZON, EXXON VALDEZ, PRESTIGE and SEA EMPRESS was significant, affecting markedly the total amounts of waste recorded. As a result, deducting the liquid waste from the total figures causes the picture to change. In particular, the amounts of solid waste collected was very large (i.e. >50,000 tonnes) in five incidents.

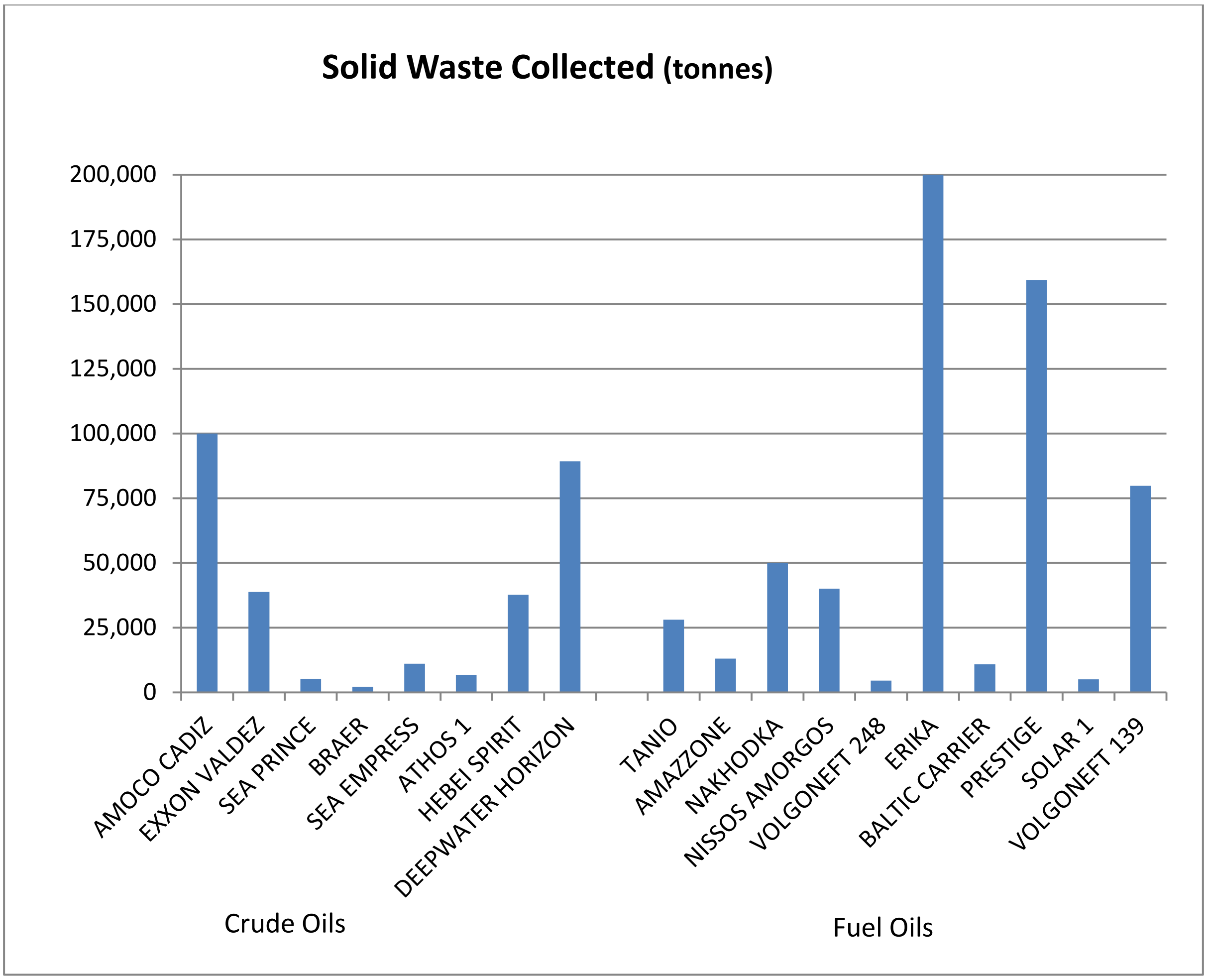

Figure 2: Amount of solid waste collected from 18 incidents'

It is clear from the table, and from figures 1 and 2, that the amount of waste material generated during an incident varies widely. Also notable from table 1 is the variation in the volumes of oil recorded as spilled in the 18 incidents, from 900 tonnes (ATHOS 1) to over 780,000 tonnes (DEEPWATER HORIZON), some 860 times greater. Comparing the amount of waste collected against the amount of oil spilled derives the ratios listed in the final column of table 1, and in figure 3, and shows a dramatic change in the relationships between the incidents.

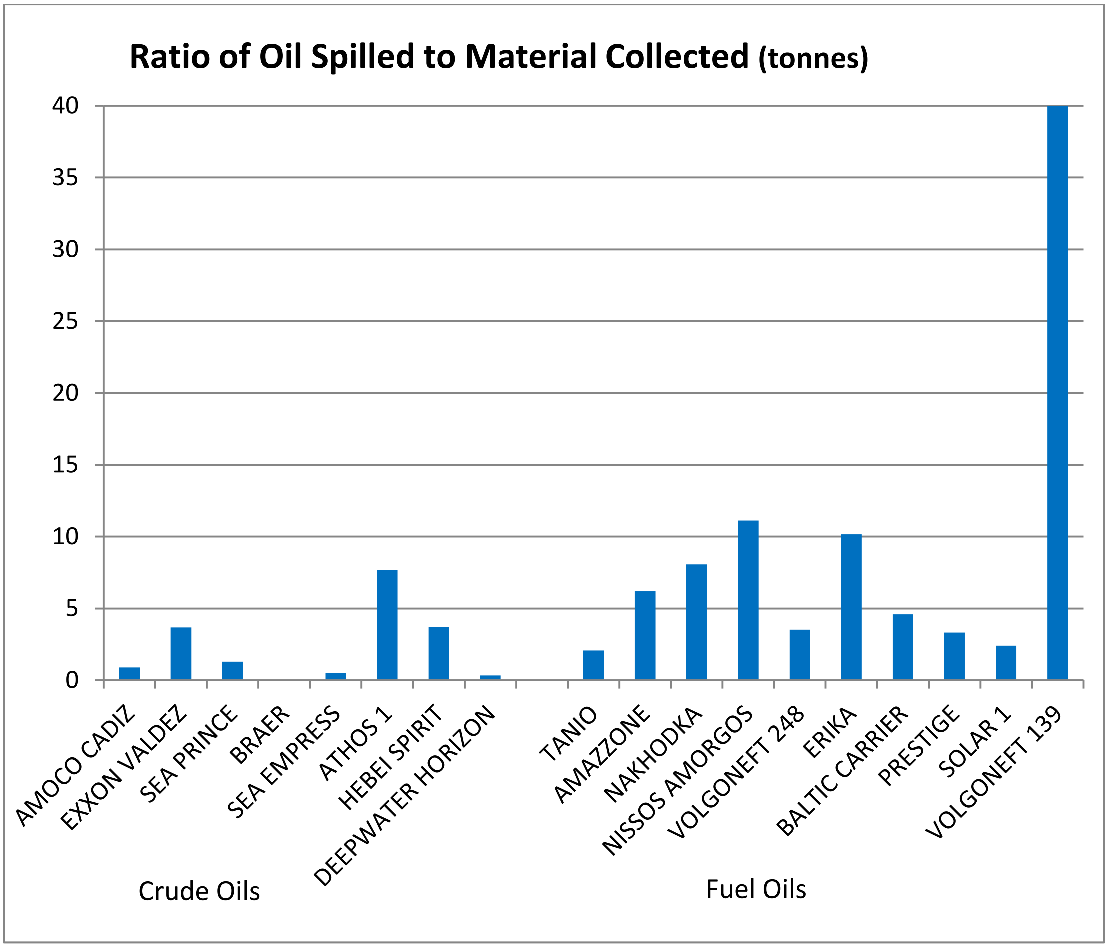

Figure 3: Ratio of waste material collected to volume of oil spilled

This ratio varies from less than one, for AMOCO CADIZ, BRAER, DEEPWATER HORIZON and SEA EMPRESS, to 40 for VOLGONEFT 139. The ratio for two incidents is calculated to be greater than 10:1 (NISSOS AMORGOS and VOLGONEFT 139), the figure for ERIKA being close to this ratio and the remaining 15 incidents exhibiting ratios lower than 10:1. The remainder of this paper provides an overview of the reasons for these marked differences in the absolute and comparative amounts of waste collected.

4 ANALYSIS AND DISCUSSION:

The table and figures show that the amount of waste material generated during an incident is not in direct proportion to the amount of oil spilled. Every incident has a unique combination of factors affecting the amount of material collected from the sea and from shorelines, including the quantity of oil spilled, the oil's initial physical and chemical characteristics, the prevailing climatic and sea conditions, whether the oil remains at sea or is washed ashore, the shoreline types impacted and the methods employed to respond to and recover the spilled oil and oiled material.

4.1 OIL AMOUNT AND TYPE

The amount of oil spilled has an important bearing on the amount of waste material collected subsequently. However, the unique circumstances of every incident mean this factor alone cannot be a reliable indicator of the amount of waste generated.

Separating the incidents by generic oil type shows a clear difference in the associated waste amounts. Once spilled, crude oils, comprising a complex mixture of hydrocarbons of a wide range of molecular weights, behave differently to fuel oils, comprising the heavy molecular-weight hydrocarbons remaining after distillation and diluted often with a lighter oil to meet the required viscosity specification. Once spilled, evaporation of the lighter molecular weight hydrocarbons can cause the volume of a crude oil to reduce significantly, the exact percentage varying for each crude oil and dependent upon the ambient conditions. For example, in SEA EMPRESS, 40% of the spilled oil was calculated to have dispersed. Other weathering processes, such as natural dispersion and dissolution, may serve also to reduce the amount of a crude oil affecting nearby shorelines, and in DEEPWATER HORIZON 37% of the released oil was estimated to have evaporated, dissolved or dispersed naturally.

For a spill of a fuel oil, a minor percentage of the oil, dependent to an extent upon the dilutant, could be expected to evaporate or disperse. As a consequence of generally greater persistence, a greater proportion of a spilled fuel oil might be expected to affect nearby shorelines than the equivalent volume of a crude oil spilled in the same circumstances, and this is reflected in the figures. Crude oils display an average ratio of waste to spilled oil of 2.3:1 whereas the average ratio of 9.1:1 is calculated for fuel oils. Excluding the incident displaying the highest ratio for each group of oil type (ATHOS 1 and VOLGONEFT 139), reduces the averages to 1.5:1 and 5.7:1 respectively, showing the effect of a single incident on each group of figures.

Fuel oils and crude oils floating at sea for extensive periods can undergo significant emulsification, whereby the water-in-oil emulsion formed can increase the amount of remaining pollutant by up to five times. For a given amount of oil spilled, the volume of emulsion generated is expected to be greater for a fuel oil due to the greater amount of oil remaining on the sea surface. AMAZZONE, ERIKA and PRESTIGE, incidents in which heavy fuel oil remained at sea for days and weeks prior to stranding, exhibited high amounts of emulsion. Significant amounts of emulsion were noted also during AMOCO CADIZ, SEA EMPRESS and DEEPWATER HORIZON and two of these crude oil spills are notable for the amounts of waste collected.

Conversely the release of oil from BRAER, provides a very good example of the effect of the oil properties to minimise waste. Approximately 86,000 tonnes of oil was spilled from BRAER, the great majority of which dispersed naturally as a result of its low viscosity and low asphaltene content, and of the prevalent storm conditions, the latter which also prevented recovery of oil at sea. The extent of shoreline oiling was relatively low with approximately 2,000 tonnes of material collected, some of this debris from the casualty.

Crude oils are generally more amenable to chemical dispersion than fuel oils, allowing further reduction of the former. For example, 445 tonnes of dispersant applied in response to SEA EMPRESS was calculated to have removed between 18,000 and 29,000 tonnes of oil from the sea surface. In DEEPWATER HORIZON approximately 7,000m3 of dispersant was applied to disperse an estimated 16% of the amount of oil released. Approximately 60% of this dispersant was applied to the sea surface. Also in DEEPWATER HORIZON, the large number of controlled burns is suggested to have contributed further to a reduction in oil reaching the shoreline.

Conversely, the generally higher viscosity of the fuel oils spilled has negated the effective use of dispersants and burning, with response at sea focussed on mechanical containment and recovery, with consequent generation of waste. Nevertheless, it is notable that the amounts of liquid waste collected were comparatively lower for fuel oil spills than for crude oil spills. This is due more to factors such as the incident location, weather conditions, notification of the incident, availability of response resources etc. However, the generally greater viscosity of the fuel oils limited the effectiveness of recovery resources.

4.2 LOCATION AND DURATION OF THE SPILL

The majority of incidents studied occurred close to shore, often preventing the large scale recovery of floating oil prior to stranding on the shoreline, even if the resources necessary for such recovery had been available. AMOCO CADIZ, in particular, grounded on the coast and large volumes of emulsified oil were collected from the shore.

However, if time allows, response at sea can be successful. PRESTIGE occurred some 250 kilometres off the Spanish coast, allowing a large flotilla of specialised response vessels to mobilise, and, together with over a thousand fishing vessels, collected approximately 50,000 tonnes of floating pollutant. Nevertheless, the response was hampered by severe weather and did not prevent extensive coastal contamination.

Similarly a protracted release can allow recovery of significant amounts of floating oil. SEA EMPRESS grounded at the entrance to an estuary in Wales and released 72,000 tonnes of oil over the following week. A prompt response by a variety of vessels allowed a total of 25,000 tonnes of oil emulsion and oily water to be recovered, estimated to have contained 3,000 tonnes of pure oil.

The location of the DEEPWATER HORIZON blowout approximately 60km offshore, and the protracted release over 87 days, allowed a concerted response to be developed at-sea. In addition to spraying and burning, a large flotilla of response vessels was utilised, that contributed to the amount of liquid waste recorded.

Although TANIO occurred some distance off the French coast, storm conditions prevented the deployment of resources for containment and recovery. Similarly in ERIKA, the large scale recovery of floating oil was prevented by storm conditions. In both instances, large amounts of oil stranded on the coast.

From a different perspective, the remote location of EXXON VALDEZ in Alaska necessitated construction and maintenance of considerable supporting infrastructure. Dismantling these structures added to the waste. Furthermore significant volumes of waste water were collected from the bilges of the large number of response vessels required, in part, to access the remote shorelines, from cleaning those vessels and other equipment, and well as contaminated rainwater from temporary storage sites.

4.3 SHORELINE TYPES AND CLEAN-UP TECHNIQUES

A wide variety of shoreline types were affected to varying extents in the spills analysed, including sand beaches, marsh, rock, mangroves etc. The clean-up of these shorelines necessitated various techniques, including the use of both manual and mechanical resources.

In some instances, the appropriate response method may be to leave an area affected to clean naturally. For example, a part of the oil released from SOLAR 1 affected approximately 500 hectares of mangroves and this area was not cleaned actively, so as to avoid damage from clean-up actions.

Where pro-active clean-up was undertaken, it is clear that some techniques employed served to minimise the amount of waste requiring removal from site. The use of dispersants at sea is a primary example discussed earlier, and the use of cleaning agents on the shoreline reduced the removal of additional material, notably in TANIO and SEA EMPRESS. Other response techniques served a similar purpose, such that in AMOCO CADIZ, SEA EMPRESS and HEBEI SPIRIT oiled shoreline substrate (sand, pebbles and cobbles) was cleaned by surf washing, whereby contaminated material was placed close to the water’s edge to be washed by wave action, and by flushing, whereby large amounts of clean water were pumped into the substrate to flush out the oil. Flushing was used also in DEEPWATER HORIZON to minimise removal of marsh material.

Where recovery of oil and oiled material from the shoreline is necessary, the use of manual labour has been shown to limit the generation of waste. During the response to VOLGONEFT 248 in the Sea of Marmara, every effort was made to minimise the amount of oily waste collected by clean-up workers, since it was clear from the outset that the disposal costs would be very high. For this reason, no attempt was made to collect oil from beaches using heavy machinery, use of which was limited to assist with the selective recovery of heavily contaminated pebbles. Also in VOLGONEFT 248, and to support the management of the recovery of sunken oil from the sea-bed, contractors were paid an agreed rate for the amount of oil collected, thereby discouraging the collection of other materials. An emphasis on manual shoreline clean-up was central to the relatively limited waste generated in several of the incidents reviewed, including SEA PRINCE.

In a number of incidents, including ERIKA, HEBEI SPIRIT, NISSOS AMORGOS, PRESTIGE and SEA EMPRESS, oil became buried in the shoreline due to successive tides or storms. In some incidents, heavy machinery was used to recover this buried oil. In some incidents sieving of the recovered oily sand was employed to separate clean from oiled material on the beach. Large scale sieving of sand in DEEPWATER HORIZON, VOLGONEFT 248 and other incidents served also to recover tarballs selectively. While time consuming, sieving was instrumental in minimising removal of uncontaminated material.

Conversely, the relatively high oil to waste ratios of NISSOS AMORGOS and VOLGONEFT 139 resulted in part from the indiscriminate collection of oiled shoreline substrate (sand and soil primarily) using heavy machinery. Furthermore, in the latter incident, the casualty could not be confirmed as the source of all the waste collected, with the large scale removal of the all shoreline material found to contain oil. Collection of relatively large amounts of sand and other shoreline substrates contributed to the waste generated during AMOCO CADIZ, ERIKA, NAKHODKA, SOLAR 1 and TANIO. In BALTIC CARRIER, use of heavy machinery to collect stranded oil and oiled shoreline substrate was decided upon in order to minimise the remobilisation of stranded oil. A part of the collected material, taken offsite, was cleaned and returned at a later date.

Material on affected shorelines was a further significant factor in the amount of waste. For example. the waste from AMAZZONE, AMOCO CADIZ, ERIKA and VOLGONEFT 139 is notable for the amounts of seaweed and other algae, sea-grass, reeds and other marine plants collected, caused in part by the difficulty of selectively recovering oil mixed with these organisms. In a similar vein, the complicated topography of the Delaware River affected by oil from ATHOS 1, comprised numerous natural creeks, industrial features and islands with extensive amounts of driftwood and flotsam. Recovery of this debris contributed significantly to the high ratio of waste.

Finally, the resources used in the response contributed greatly to the amount of waste for a number of incidents. For example, the response to DEEPWATER HORIZON involved the deployment of over 1.3 million metres of containment boom and 2.8 million metres of sorbent boom. Much of this boom was sent for disposal after use, and although oiled lightly in general, contributed greatly to the total volume of solid waste. Significant amounts of sorbent products and other response resources, including personal protective equipment, were disposed of in ATHOS 1, EXXON VALDEZ and HEBEI SPIRIT.

5 CONCLUSION:

The response to a spill of crude or fuel oil will, in most instances, generate waste requiring disposal. A number of the factors affecting the amount of waste are beyond the control of the authorities responding. In particular, the type of oil spilled, the location of the incident and the types of shoreline impacted can have a bearing on the potential amount of waste. These uncontrollable factors determine available response techniques. Instead, with careful thought, the response actions chosen, both at sea and on the shoreline, can serve directly to influence the amount of waste generated. The use of dispersants, where possible, on floating oil and methods to clean oiled shoreline material in-situ, are notable in this regard. Where the decision is made to remove oiled material from an area, the use and careful management of selective techniques can be advantageous. The functional use of sorbent products and personal protective clothing and the sensible deployment of containment boom, can also serve to keep waste to a minimum. The use of such resources is perhaps one of the factors contributing to the amounts of waste that can be controlled in a relatively straightforward manner during a response. In certain circumstances, incentives to focus recovery efforts on the oil, rather than other material, can contribute to a reduction in waste.

With careful management of appropriate response techniques, previous experience has shown that the amount of waste generated during a response can be kept to a figure that is up to 10 times the amount of oil spilled.

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