HAZARDOUS GOODS
AND THEIR ENVIRONMENTAL IMPACT

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The paper reviews the problems generated by transportation, handling and storing of hazardous goods in harbours and their surroundings. It expands on the heretofore narrow topic of direct dangers and consequences for the environment and examines secondary effects and potential remedies.

Keywords: In situ bio-remediation; Cargo; Explosives; Belgium; Morocco

0. INTRODUCTION

Dangerous goods have been transported by sea and handled in ports since earliest times. The mariner’s experience in treating such cargoes will not do any longer, as their nature, amounts and shipment methods are steadily diversifying and increasing in number. The new “scene” has created a need for stringent safety measures as well as for impact minimization.

In port design, whether for a new facility or adaptation of an existing one, consideration must be given to shipping lanes, ships’ berths, storage and processing facilities and off-terminal road, rail, inland water, and even air transport. Primarily all endeavours must aim at safety with environmental considerations a close second. Safety discussed in a report from PIANC, a document, nearly ten years old, does not face up to environmental consequences.

In the studies conducted for several Moroccan ports, for instance, it has become apparent that while handling of dangerous substances
ranging from hydrocarbons to sulfuric acid and others, water, and air become polluted at intolerable rates; impact assessments, let alone statements, have not been made, though the contamination is well known, and has been for a long time.

Standards, rules, precautionary, but also abatement measures are necessary, if safety and cleanliness are to be the rule.

1. DANGEROUS GOODS IN PORTS

1.1. Scope of the Problem

Statistics show that over 50% of the shipped goods today fall within one of the 9 classes of the IMDG-code [1], and 10 to 15% of containerized cargo is currently IMDG-cargo with an upward trend.

Ships and operations involved are mostly covered by legislation, as shown by the comprehensive work of IMO, but ports of individual nations, with their own legislation, are simultaneously covered by internationally accepted codes [2].

The ever increasing number of chemical substances, a growing concern for the environment, and the advent of massive bulk transportation has significantly altered the scene of maritime transport. As storage and distribution centers, ports became buffers between large scale sea transport and land transport. Not so much the loss of lives, vessel and cargo but other risks and larger consequences make safety preoccupation a basic issue for both port planners and port operators. Responsibility of the terminal and port authority increased, but specialized knowledge of dangerous goods handling and of risks hasn't grown equally.

1.2. Safety in Ports

Transport by sea and by land have different aims and standards, safety consciousness and discipline. Because of the multitude of functions carried out by people with different training, human error or negligence caused accidents to occur more often. Engineering modifications may eliminate some of the worst consequences of human error. But each port is a unique case, and not uniform regulations but general recommendations are advisable.
1.3. The Shipping Lane

Most accidents occur in, near, or approaching ports. Setting aside onboard ship mishaps, collision and grounding are main worries for the port designer. Designation of an access channel for ships carrying dangerous cargo can reduce the risk of a major mishap. The Vessel Traffic Service (VTS) has been shown to be useful, complemented by obligatory piloting, priority status, day-light only operations, movements, weather condition and restrictions, warning system and others. A port control center should be the center for information, communication, observation and contingency control in the harbour.

1.4. At Berth

Berth Sitting As the siting of the berths where dangerous goods are handled determines virtually all subsequent actions, some guidelines are in order. Concepts handling for new ports or extensions of existing harbours should observe the zoning principle; while maintaining appropriate spacing to avoid a domino effect, all dangerous cargoes terminals or berths should be grouped, in a zone as near as possible to the harbour entrance, isolated, and far from residential areas, passenger terminals, and storing facilities for other goods. Spacing precludes a domino effect; restricted access is advisable, as is that of the terminal’s own security services. For existing harbours, the site is prefixed. Shortage of space and the ensuing lower level of safety should then be compensated through constructional features and operational procedures. Where no acceptable solution can be worked out, a prohibition to handle those goods there should be seriously considered.

For port planning purposes the Maximum Credible Accident (M.C.A.) - approach, based on risk analysis techniques, may prove beneficial. It assumes that a project (e.g., a LNG-import facility) is designed according to the relevant standards and good engineering practice, then critically assessed, using risk analysis techniques, to determine the possible major accidents and their consequences are selected and site conditions are altered to physically prevent those accidents from occurring; the M.C.A. will subsequently determine the design and operation philosophy of the installation. Example: one full LNG-tank on fire.
This subjective approach allows to define exactly for what major accident(s) the terminal is designed and to offer a clear understanding of the underlying safety philosophy and prompt initiatives for contingency plans in the worst credible situations.

1.5. Dangerous Cargo in Bulk

Bulk transport handles large volumes. A manoeuvring ship, especially with liquid cargo, is the potentially most dangerous element.

Most frequently encountered major accidents are e.g., the grounding or collision of the ship, breaking off of the ship–shore connection with a delay in emergency response. Offshore operations are safer but possible only for some dangerous bulk cargoes and limited by economic constraints.

Factors governing birth siting are, besides accessibility and transshipment safety, wind, currents, waves, and available stopping length and manoeuvring space. Hazards encompass explosion, fire and toxicity. Expert knowledge is necessary where the product and the physical aspects of the hazards are concerned.

Storage and Processing A general safety rule with regard to dangerous goods is to expose the minimum people – and expensive infrastructure – to the minimum amount of risk during the minimum time span. It leads to port regulations defining maximum storage time, even storage prohibition (e.g., for explosives). Highly dangerous goods should in general not be temporarily stored within the port confines. While for other dangerous goods, depending on the hazard involved, a temporary storage should be organized.

A study on handling of packaged goods was done for the port of Rotterdam as shown in Tables I, II and III. These results serve only as an illustration of the principles.

Off-terminal Transport Off-terminal transport is generally regulated in most cases by separate legislation. It may affect port design only in specific areas such as installation of compulsory routing and prohibition of use of tunnels.

Safety studies being expensive, they are only carried out for large projects. Occurrences are unlikely, but consequences are vast.
<table>
<thead>
<tr>
<th>Product</th>
<th>Type of package</th>
<th>Mass of contents (kg)</th>
<th>Distances (m) to LC</th>
<th>Lowest &gt; 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>acrylonitrile</td>
<td>drum</td>
<td>178</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>bromine</td>
<td>tank-container</td>
<td>13.500</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>hydrazine</td>
<td>drum</td>
<td>220</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>hydrogen - fluoride</td>
<td>tank-container</td>
<td>10.000</td>
<td>x (4000)</td>
<td></td>
</tr>
<tr>
<td>hydrogen - fluoride</td>
<td>cylinder</td>
<td>50</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

(catastrophic damage to containment resulting in evaporating liquid pool).
### TABLE II  Toxic gases

<table>
<thead>
<tr>
<th>Product</th>
<th>Type of package</th>
<th>Mass of contents (kg)</th>
<th>Distances (m) to LC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 100</td>
<td>100 – 300</td>
</tr>
<tr>
<td>ammonia</td>
<td>cylinder</td>
<td>860</td>
<td>0</td>
</tr>
<tr>
<td>vinyl-chloride</td>
<td>tank-container</td>
<td>16.000</td>
<td>0</td>
</tr>
<tr>
<td>methyl-bromide</td>
<td>tank-container</td>
<td>14.500</td>
<td>0</td>
</tr>
<tr>
<td>hydrogen-chloride</td>
<td>cylinder</td>
<td>82</td>
<td>0 + (*)</td>
</tr>
<tr>
<td>chlorine</td>
<td>cylinder</td>
<td>360</td>
<td>0</td>
</tr>
</tbody>
</table>

0: due to a leak of 10 cm².
+ : due to catastrophic failure.
(*) : containment is emptied so fast when damaged that a leak of 10 cm² causes an instantaneous spill.
<table>
<thead>
<tr>
<th>Product</th>
<th>Type of package</th>
<th>contents (kg)</th>
<th>Mass of</th>
<th>Distances (m) to LC</th>
</tr>
</thead>
<tbody>
<tr>
<td>propane</td>
<td>tank-container</td>
<td>8.000</td>
<td>&lt; 100</td>
<td>0</td>
</tr>
<tr>
<td>vinyl-chloride</td>
<td>tank-container</td>
<td>16.000</td>
<td>100 – 300</td>
<td>0 + (565)</td>
</tr>
</tbody>
</table>

0: due to a leak of 10 cm$^2$.
+: due to catastrophic failure.
Risk analysis is not very reliable where new technologies or products are involved. Safety levels can be set so high that investment is out of proportion with a project's economic dimensions. As most accidents are due to human error or negligence, the design must be matched by safe operation.

An overextended reliance on the calculation results may create an illusion of safety, underestimating channels of human error or negligence. A well conceived design not matched by well-conceived and safety orientated operation, will be fruitless.

The arguments against such calculation include the safety record, the lack of experimental data. Offshore operations are safer but are possible only for some dangerous bulk cargoes and are further limited by economic constraints.

Factors governing birth siting are, besides accessibility and transshipment safety, wind, currents, waves, and available stopping length and manoeuvring space. Hazards encompass explosion, fire and toxicity. Expert knowledge is necessary where the product and the physical aspects of the hazards are concerned.

1.6. Packaged Dangerous Goods

The main characteristic of packaged dangerous goods is the wide variety of packaging in use. Containerization introduced the portable tanks which significantly increased volumes. But a tank container has significant safety advantages as it offers additional protection and simplified handling procedures.

The increasing flow of dangerous goods in larger individual packages through conventional general cargo terminals poses an acutely felt problem when a port is renovated. Preference goes towards shore-based handling of packaged dangerous goods, though risks exists when such handling occurs close to populated areas.

1.7. Explosives

Explosives when detonating will generate a strong air blast wave well beyond the terminal's premises coupled with the ejection of fragments of casing and contaminant over similar distances. The effects of the underground shock wave and the water wave due to an explosion can
be serious. Direct delivery is to be the rule while handling and storage requirements are to be very stringent. Distance is the only safety feature.

For explosions, as few bulk cargo layout and handling should heed the rule “expose the minimum people, and infrastructure, to the minimum risk during a minimum of time”.

1.8. Hidden Dangers

Innocuous goods may turn out to be a source of dangers. The storage of grain in silos may lead to effects comparable to those of explosives when uncontrolled fermentation processes take place. One of the largest grain export terminals in the world located at Balira Blomu in Argentina, has been severely damaged by a silo explosion, yet grain is not considered a hazardous good. Similarly linen when getting wet starts fermenting and will ignite by auto-combustion even after being submerged for two weeks.

1.9. Conclusion

Port operations carry hazards which cannot be totally eradicated. Beyond dangerous goods of all types, other insidious dangers threaten the portuary environment. Transshipment and storage of goods as well as placing of infrastructure elements are sources of pollution and contamination, as are portlinked industries. Redressment and safety measures must be foreseen to minimize their impact.

2. PORTS AND ENVIRONMENTAL IMPACT

Hazard assessment involves thus risk analysis, but contemporary concerns go beyond the problems of handling dangerous cargo and potential accidents. Environmental protection has been for too long, ignored. Multinational agreements and conventions are currently on the books. Discharges from not at the onset dangerous goods result also in pollution: presence of large quantities of nutrients generate algal growth with subsequent eutrophication. The matter can be illustrated by some concrete cases.
2.1. Belgian Coast

An impact evaluation has been carried out for pipelaying, trenching and disposing of trenched material on the Belgian Continental Shelf. Such evaluations take into account for the territorial sea Belgian Coastal regulations and for the shelf the 1885 Convention of Paris. Impacts cover contamination by ships, aircrafts, engineering works and common usage; by disposal of wastes from ships and aircrafts, and incineration at sea; by terrestrial and atmospheric activities and sources. Pipeline operations will have impacts falling in the first two groups. Several EC directives have to be abided by, while additional ones are pending, and a variety of permits, it be for at-sea, it be for on-land operations, must be obtained prior to the start of any activity.

On a European scope, the North Sea Conference aims at reducing excessive contaminants, contents in dumping material, eventually to preclude their inclusion. A first step requires their load to be cut in half by 1995, a path that is to lead to the U.S. and Canadian evocations of zero waste, or total recycling. Though Environmental Impact reports as advised by E.C. directives are required for pipeline laying on land, no such rule is in force for offshore projects, nor does a general regulation exist to conduct physico-chemical sediments analyses. For dump-material such analysis should cover amount, composition, form, properties, toxicity, persistance, accumulation, biotransformation, susceptibility to change and reaction. Some substances make up a "black list", others a "grey list"; most of them are also of concern to port authorities as they readily accumulate in basins. Tests exist to evaluate contaminant mobility.

In short when a proposal was made to lay a pipeline on the Belgian Continental Shelf EIA and EIS were made and they covered as well dumping activities and dumping site identification. The EIA considered biota and abiota, social, economic, access consequences, and outfall upon fisheries, recreation and land use.

2.2. Morocco

The harbours of Casablanca, Jorf Lasfar, Agadir and Tan–Tan have been areas of severe accidental and continued pollutions. Transport, manipulation and storing of dangerous and toxic goods
in Casablanca have exacted a toll; the normal port activities, and industrial, municipal, touristic operations and agriculture are continuous sources of pollution. Air and water are polluted in a variety of ways ranging from phosphatic dusts to petroleum. Dredging and subsequent offshore dumping contribute to existing problems.

Air is polluted by ores and fertilizers at Jorf Lasfar. While there is no direct discharge of sewerage, sulfur precipitates and phosphorus may impair water quality. No impact assessment was ever carried out. Agadir, a vaunted shore resort, is not much better off. Cement and fish-products factories foul the air from inland, and right in the commercial harbour dusts are produced by coal, ores, fertilizers; butane, ammonium nitrate and sulfuric acid contribute their share of pollutants. Water quality is impaired by unauthorized petroleum products discharges by fishing vessels (close to 550 units), and the used municipal and port industries waters are led to the ocean by the major sewer between the old and new ports. Solutions have been proposed but they still involve draining into the ocean and meanwhile waste products accumulate at the rate of 1,200 m³/year in the former pleasure craft harbour and sediment at 50 cm/year in the fishing harbour.

Air pollution in Tan–Tan is caused by the bad odour of fish processing plants’ activities. Water pollution results from waste products from sardine boats and factories, petroleum wastes and used waters.

Briefly put, there exists an urgent need for an impact assessment that embodies air and water quality, measurements, human aspects.

3. BIOREMEDIATION

A situation that has reached the level of that observed in the Moroccan ports – and persists – deserves a multipronged approach. Open sewers that discharge into harbour basins or the sea, and dredgings that are dumped offshore are blatant contradictions with any program of environmental concern. In some cases, as treated by HAECON Inc., a bioremediation approach is conceivable. ABR–CIS covers in depth identification of the contaminated area, laboratory microbiological study, definition of an appropriate formula, and
naturally management and monitoring. Effects of the treatment include sludge volume reduction, contaminants degradation in water and sludges, biological oxygen demand and elimination of bad odours.

Advantages of this approach, where applicable, are in-situ treatment and volume reduction, elimination of disposal sites, an environmentally favorable technology.

Organic-rich sediments and sediments contaminated with organic compounds can effectively be treated in-situ by the ABR–CIS system (Augmented Bio Reclamation – Conditioning In-Situ). ABR–CIS has been applied on full industrial scale on 5 different projects in Belgium and The Netherlands; it was shown that the sludge-volume can be reduced and that contaminants can be degraded by stimulated and restored natural microbiological activity.

3.1. A Natural Approach

Dredging is a costly and recurrent operation. Mud deposits in aqua-systems may promote accumulation of organic micro-pollutants; large nitrogen and phosphorous run-offs into streams, rivers and, eventually, seas and their bays are at the origin of eutrophication and blooms, e.g., the green tides. Likewise heavy metals often concentrate in dock- and harbour basins sediments.

Cleaning of dredging materials, prior to acceptable disposal, is costly, not entirely efficient, time-consuming, and causes bad smells; handling and immobilisation techniques, rather than to solve the problem, transpose it.

Appropriate conditioning in-situ (CIS) using natural oxygen-supplying products may, in specific instances, reactivate aerobic mineralization of organic matter, even some organic micro-pollutants. The potential value of CIS encompasses thus micro-biological dredging and treatment in-situ.

Mud habitats are home to decaying biomass, adsorbed organic compounds, various nutrients and anthropogenic contributed contaminants. In the water column and the underlying sediment, bacteria play a major role in organic matter mineralization.

Bacteria show remarkable adaptability to sediment texture, temperature, oxygen content, contaminants adsorbed by mineral or
organic mud particles and/or bacteria aimed toxicity, and, to other seasonally cycled organisms.

Oxygen supply in muds decreases with sediment thickness, and where aerobic species cannot thrive any longer, respiration is anaerobic or fermentative processes come into line. Anaerobic mineralization processes are slow and low efficiency results in a slow biodegradation. Aerobic processes however are fast and CIS provides bio-available oxygen disseminated in the sediment stimulating the fast aerobic biodegradation processes.

3.2. Augmented Bio-Reclamation

ABR accelerates the natural processes and aim-directs them by adding all the necessary microbiological families simultaneously; the break-up occurs then without interruptions. The technique was recently utilized to clean-up the Exxon Valdez spill in Alaska.

The sediment is conditioned on site by furnishing the oxygen that will reactivate and stimulate the aerobic microbiological activity leading to the microbiological mineralization of the organic components. This is done by injecting a mixture of water, ABR-bacteria and conditioner, a carefully prepared blend of natural minerals containing mainly oxydes and/or carbonates. Oxygen present in the minerals can be released rather fast because of the special chemical composition and the large contact surface. The sediment’s characteristics, the selected handling and the physico-chemical condition of the waterway determine the CIS dosage.

ABR-blends which are injected simultaneously with the CIS are carefully selected based upon the indigenous bacterial populations and the micropollutants aimed to be biodegraded.

The CIS product comes in powder form and is injected into water and/or bottom as a suspension. Mixing is with the water of the waterway itself. Specially adapted equipment is used for the injection.

3.3. Savings

Considerable savings can be realized with the ABR-CIS approach because dredging becomes unnecessary or at least its frequency is
greatly reduced. The problems of storage and/or incineration are cancelled. The foul smell concomitant with the removal of the "mud" are eliminated. And the method is environment-friendly in as much as "nature's way" is applied, scourges such as eutrophication and algal blooms disappear or decrease and restoration of fauna and flora follows.

Sedimentation occurs in harbours, canals, rivers and coastal zones, often in areas with slow water renewal.

To maintain the navigability of waterways, to prevent flooding at times of spate or heavy rains, they must be dredged. Ocean dumping is severely frowned upon nowadays and land disposal costs as much as U.S. Dollars 50/m³. Industrial treatment is likewise quite expensive.

In less industrialized but densely populated countries the discomfort, viz. foul smell, brought about by dredging operations generates strong opposition. Yet, the sediment in place may constitute a health hazard.

Randomly taken sediment-samples from canals in Ghent harbour (Belgium) showed in all cases bacterial growth with breakdown of the contaminants; after approximately 14 days 90% digestion was reached. The treatment was also used in Zeebrugge (Belgium), where the fishing port was heavily polluted with o.a. hydrocarbons and TBT, and in the Bakhuistervaart (Gaasterlaan-Sleat, The Netherlands), a waterway polluted by hydrocarbons.

4. CONCLUSION

Contemporary constraints in harbours have compounding effects. No longer can potential or occurring consequences be ignored on convenience and/or economic bases. Safety and ecological considerations are at the forefront of concerns when building, and siting, new portuary facilities, and when expanding existing ones. Times are bygone when experience directed dangerous goods handling – including but not limited to nuclear products – was an acceptable approach. Nor can new, or further, pollution from a harbour area be tolerated, or the relationship shore-land be ignored; even less when basins are the topic.
HAZARDOUS GOODS

References & Notes

[1] The International Maritime Dangerous Goods Code or IMDG-code is a five volume book issued in 1977 with amendments. All dangerous goods acceptable in maritime trade are listed in one of the nine classes:
Class 1  -  Explosives
Class 2  -  Gases: compressed, liquefied or dissolved under pressure
Class 3  -  Flammable liquids
Class 4.1  -  Flammable solids
Class 4.2  -  Flammable solids, or substances, liable to spontaneous combustion
Class 4.3  -  Flammable solids, or substances, which in contact with water emit inflammable gases
Class 5.1  -  Oxidizing substances
Class 5.2  -  Organic peroxides
Class 6.1  -  Poisonous (toxic) substances
Class 6.2  -  Infectious substances
Class 7  -  Radioactive substances
Class 8  -  Corrosives
Class 9  -  Miscellaneous dangerous substances.