Blending and bunkering

Admixture of hazardous materials to bunker fuels for maritime shipping — **risks and strategies**

CE Delft
Committed to the Environment

Introduction

Worldwide, around 100 incidents with ocean-going vessels triggered by fuel oil contaminated with hazardous (waste) materials have been reported since 2003. Because incidents are only reported if there is serious damage to ship's engines, it seems likely that admixture of harmful components is a more frequent occurrence than these figures suggest. This will lead to further material damage as time progresses and to emissions of noxious combustion products, with attendant risks to crews, the environment and ship's engines.

This brochure discusses the composition of fuel oil and analyses the supply chain, the magnitude of the streams involved, the market players and above all the risk of admixture of hazardous (waste) materials and what steps can be taken to avoid such practices. This brochure is concerned mainly with the impacts of potential admixture of hazardous substances to shipping fuels, in terms of both environmental and health risks and risks for the functioning of ship's engines. Figure 1 provides a summary of the substances involved.

	Environment/Health	Engine operation/ Ship safety
'Naturally' present in refinery residues	Sulphur PAH Metals PM (combustion emissions) H_2S *ISO 8217/Marpol VI*	Vanadium Nickel Ash residues Silicon Aluminium Water (and others) *ISO 8217*
Risks due to admixture of (waste) materials	Organohalogens (EOX) Phenol Styrene monomer Naphthalene Metals Solvents/VOC	Styrene monomer, Polystyrene, Polypropylene Organic acids (TAN, SAN) Zinc, Phosphorus, Calcium, Magnesium

Figure 1 Spectrum of hazardous substances and risk aspects

Worldwide, the bulk of bunker fuel trading occurs in four ports: Fujairah, Houston, Rotterdam and Singapore. In the Netherlands, Rotterdam is by far the major trading location, the source of around 88% of all bunker fuel. All in all, over 22,000 vessels are bunkered in the Netherlands annually, together taking in around 13 million tonnes (Mt) of fuel. To a large extent the constituents of this fuel derive from imported materials. In recent years this import volume has risen significantly, particularly from Russia and the Baltic states, and now stands at 26.8 Mt. At the same time, there are very substantial exports of 21.5 Mt, particularly to Singapore.

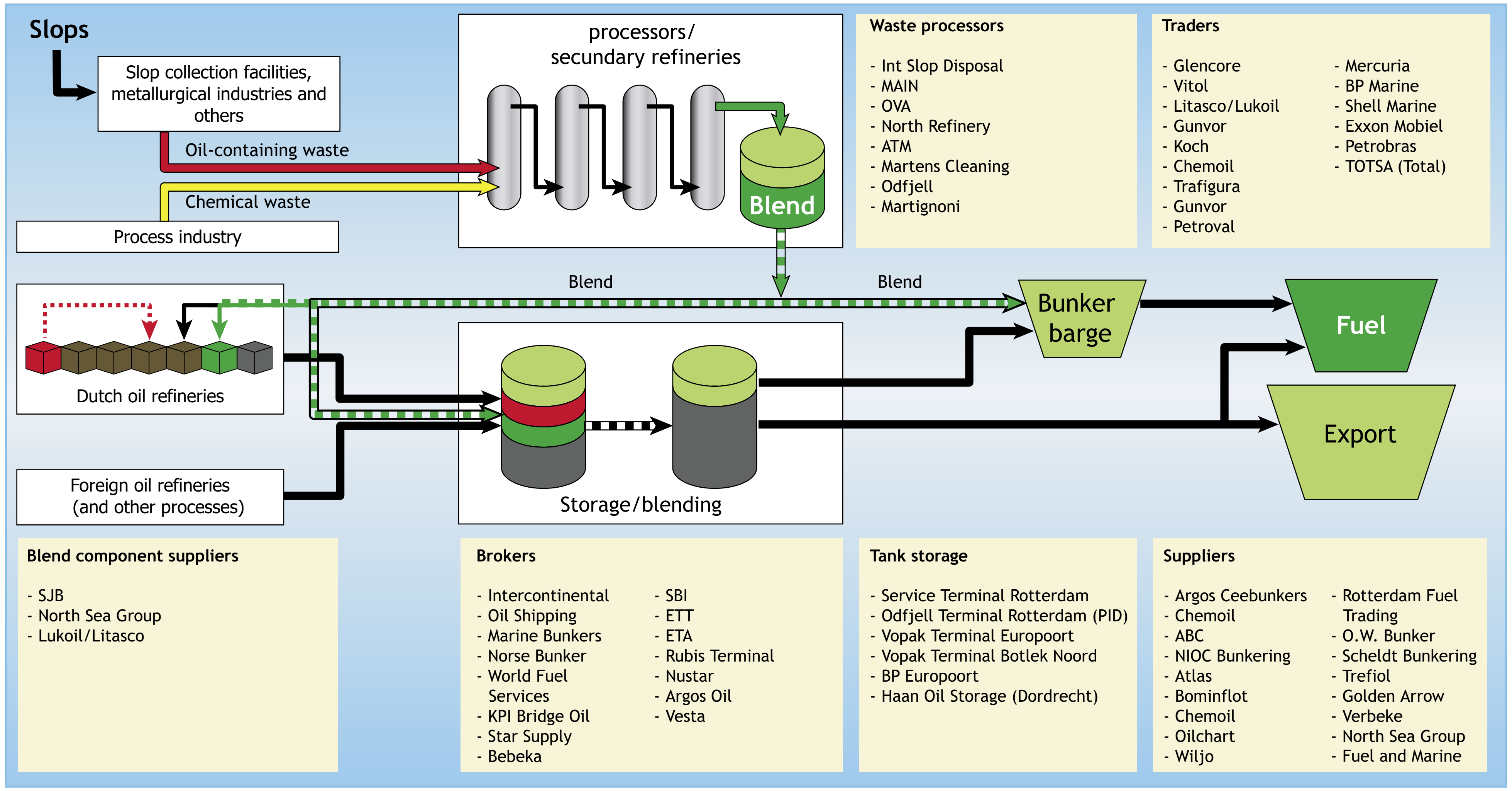


Figure 2 Companies in the Dutch bunker fuel supply chain, including waste processors. Solid lines represent 'regular' product streams, dashed lines potential streams

Bunker fuel market

The main links in the bunker fuel supply chain are trading (trade, storage and transit, including blending) and supply (physical delivery of bunker fuel). Some companies are active on all fronts.

The main market players in North-West Europe are the independent oil traders (particularly Vitol, Glencore, Gunvor, Chemoil, Koch, Trafigura and Litasco), the big oil companies (Shell, BP, Exxon Mobil, Total and others), the tank storage and transit companies (Vopak, ETT, Argos, STR and others) and the suppliers (Argos Ceebunkers, OW Bunkers, Wiljo/NIOC, Verbeke and others). Trading is carried out by the big oil companies (the 'majors') as well as by independent oil traders. These are companies with serious financial clout. The annual turnover of oil trader Vitol is almost € 200 billion, for example. Storage and transit takes place at a limited number of storage terminals, most of which are owned by independent storage and transit companies. The remainder are owned by traders and majors.

The market is very untransparent and highly dynamic, involving an ever-changing array of players, regular take-overs and intense price competition. Figure 2 shows the companies currently involved in the Dutch bunker fuel supply chain.

Bunker fuel analysed

The fuels used by shipping vessels are referred to as 'bunker fuels'. In the case of maritime shipping this is mainly fuel oil.
The bunker fuels on the market vary widely in composition. To produce fuel meeting the required specifications many different components are blended, sometimes ten or more. The main stream consists of residues from oil refining processes: the heavy residues remaining after the lighter products like kerosene, gasoil and petrol have been separated off. Older refineries, known as 'straight-run refineries', yield a relatively large volume of such residues. Modern refineries use more advanced production plant to separate off the lighter products, leaving behind less residues. This residual oil is heavier than that from a straight run-refinery and generally contains more metals (aluminium and various silicates). The composition of the residual oil thus varies depending on the type of refinery and the type of crude oil being processed. Because of its very high viscosity, residual oil must be heated prior to use. This means it can only be used in heavy plant like industrial installations and ocean-going vessels. Over the past few decades its use in power stations and refineries has been largely discontinued as a result of environmental legislation on acidifying emissions.

Blend component	Potential constituents	Issues/properties
Resin residues (residues from synthetic resin production)	Aromatics, Terpenes, Naphthalene, Phenolic compounds	Low flash point
Ethylene cracker residue	Higher naphthalenes	Poor miscibility
Ethylene cracker side-stream	Styrene monomeer, Naphthalenes, Cresols, Dicyclo-pentadiene	Polystyrene formation, Stench
Shale oil	Phenol, Higher phenols, Arsenic	Poor miscibility
Coal tar, Lignite tar	PAH, Phenol, Higher phenols	Poor miscibility
Carbon black feedstock	Cresols	
Waste oil	Phosphorus, Zinc, Calcium, Magnesium	
Biodiesel residues	Organic acids	

Figure 3 Blend components of bunker fuel

Cutter stock

The hydrocarbons added to bring the fuel oil up to specification are known as 'cutter stocks', 'blend components' or 'light cycle oils'. These also come from oil refineries or are waste streams from other industrial processes, such as ethylene crackers and resin plants.

Hazardous substances

Fuel oil 'naturally' contains a variety of hazardous substances in high concentrations. These are substances present in the crude oil feedstock from which the fuel oil derives and that end up in concentrated form in the residue during the refining process. Key classes of hazardous substances include heavy metals, particularly vanadium, polyaromatic hydrocarbons (PAH) and hydrogen sulphide (H_2S). During on-board combustion in ship's engines there are also considerable emissions of particulate matter (PM), with substantial health impacts. Research published in 2007 suggests that air pollution from bunker fuel combustion leads to around 60,000 deaths worldwide annually.

Another risk is that the residual oil from modern refineries can contain high levels of aluminium and silicon, which can lead to wear and tear of ship's engines, as well as asphaltenes, which are often mixed with high-aromatic streams in order to dissolve them. Together these may pose a serious threat for the reliable functioning of engines. Engine damage and failure can lead to shipping accidents, with attendant risks of serious material, human and environmental damage.

Figure 3 shows the streams most frequently used as blend components in today's market, with an indication of their potential undesirable properties and the constituents they may contain.

Quality control and sampling

When it comes to environmental care and fuel quality, most companies operate according to their own standards. The situation at the independent oil traders is unclear; these companies are the least transparent of all.

The International Maritime Organisation (IMO) has laid down standards for bunker fuel in Marpol Annex VI. These standards are in force across the world and set maximum limits on fuel sulphur content (45,000 ppm in the open seas and, from 2012, 35,000 ppm). The standard is to be tightened further in 2020 to 5,000 ppm (or possibly in 2025, pending a review in 2018).

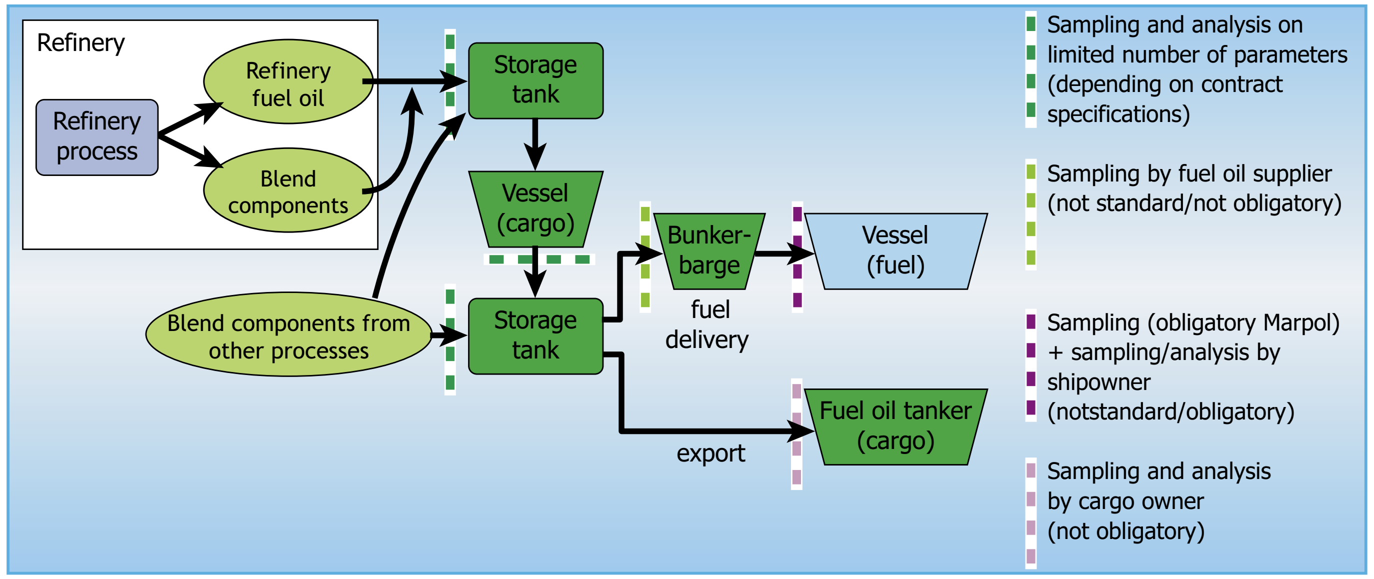
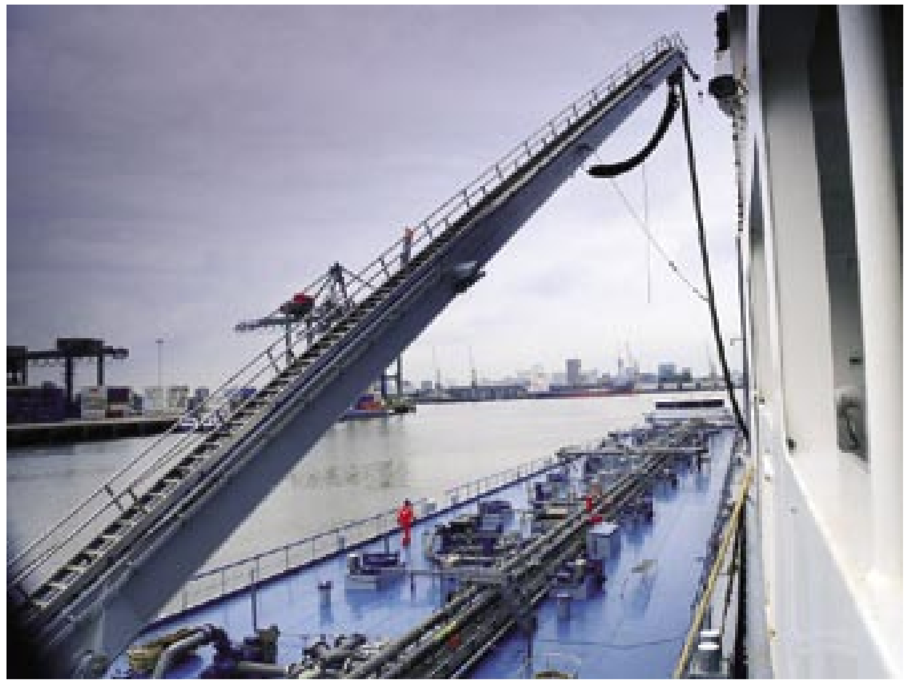


Figure 4 Bunker fuel supply chain, showing points at which product samples are or may be taken

On a voluntary basis the market has also adopted the ISO 8217 product standard, which sets criteria for bunker fuel geared mainly to guaranteeing proper functioning of ship's engines. With a view to protecting crew health, limits on H_2S (hydrogen sulphide) content were recently added.

Sampling

Sampling takes place at various places along the bunker fuel production and trading chain. As standard practice, when a vessel takes bunker fuel on board a sample is taken under the terms of Marpol Annex VI. In addition, a sample is regularly taken to analyse the ISO 8217 parameters. Earlier in the chain, blend components are also sampled and analysed, but this is generally only on a limited number of parameters, to determine whether the component is suitable for blending. There are no systematic checks on undesirable contaminants or hazardous substances in the blend components or in the fuel oil ultimately produced.
Shipowners state that they are generally unaware of the composition of the bunker fuel taken on board. While tank storage and transit companies have a rough idea of the source and composition of stored fuel batches, detailed information is usually lacking.



An additional issue of concern is that demand for blend components is set to rise even further in the coming years. This is because today's more advanced refineries are able to extract more light fractions from crude oil than older plant, which means the residue is heavier than it used to be. A relatively higher proportion of more expensive blend components is consequently required, increasing still further the cited incentive for admixture.

Risk of admixture

As stated, fuel oil production involves the admixture of blend components to bring the product up to the required specifications. As the cost price of pure blend components is relatively high, there is an incentive to minimise the amounts used as well as the price paid for them.

Sometimes waste products from other refinery processes or other chemical industries may be used as blend components. Since waste streams can contain hazardous substances, these must be processed at specialised companies before they may be processed in bunker fuel. However, given the financial benefits of direct admixture of such materials, there is no guarantee of waste streams only being added post-processing. The cost of responsible processing (or destruction) is high and can be avoided by direct admixture to fuel oil. At the same time, admixture saves out on the costs of other 'cutter stocks'. In addition, the physicochemical properties of fuel oil (black, highly viscous) make it relatively easy to add other components without them being able to be detected. Finally, given the current situation with regard to monitoring down the supply chain, there is little chance of detection (of the substances themselves, and of parties involved in such practices). Given all these factors, it is very tempting to 'mix away' hazardous (waste) materials in fuel oil.

Does admixture occur?

As mentioned at the outset, there are regular reports of serious damage to the engines of ocean-going vessels occurring as a result of contaminants in bunker fuel deriving from the admixture of hazardous (waste) materials. Further evidence of undesirable components being present in bunker fuel is provided by the practice of 'debunkering', occurring if the product taken on board proves to be off-spec. The fuel batch is then returned to the supplier. Data from the Port of Rotterdam shows that over the past few years debunkering has taken place around ten times a year. Debunkering is associated with substantial delays and financial damage, costing from around € 100,000 up to over € 1,000,000 per debunkering operation.

Contamination of bunker fuel with hazardous waste is certainly also a real risk with import streams, the size of which is immense and the physicochemical properties of which provide plenty of scope for 'mixing away'. An additional problem are the major volumes of hazardous waste arising in East European countries and Russia, such as PCBs from dismantled transformers. Admixture of these kind of streams to fuel oil is financially a far more attractive course of action than responsible disposal.
A compounding issue is that in the cited countries the processing infrastructure as well as enforcement of responsible processing methods are less well developed. Given current sampling and analysis practice in the bunker fuel trading and supply chain, admixture of hazardous waste will in many cases simply not be detected.

Figure 5 Damage to a ship's engine due to polystyrene deposits in the filter system

Policy suggestions

Based on the above considerations, CE Delft advises that the following issues be taken to hand within an international framework (IMO and ISO):

1. There should be tighter selection of blend components deemed suitable for addition to bunker fuel, with this being explicitly laid down for those involved in the supply chain.
   We advise the Member States of IMO to state in Marpol Annex VI which blend components are acceptable. Paragraph 3.1 of Regulation 18 already lays down that fuel oil must consist of hydrocarbons from petroleum refining, but further specification is desirable, specifically stating which cutter stocks are suitable and setting criteria for the maximum levels of hazardous substances they may contain (typically: phenol, naphthalene, EOX, styrene monomer, arsenic). Analogous criteria should be included in ISO 8217, Paragraphs 5.2 to 5.5.
2. There should be an obligation for parties in the supply chain to keep a record of the origin and composition of blend components and fuels delivered, enabling a chain of responsibility to be established in the event of an incident.
   We advise the Member States of IMO to extend the cited paragraph of Marpol Annex VI to include a provision that delivery of bunker fuel should be accompanied by a specification of the blend components it contains. Analogous criteria should be included in ISO 8217.
3. A sealed sample should be taken of delivered blend components, applying both to imports and to domestic transit. Such arrangements could be combined with the sampling already being undertaken. The sampling method is important here (drip sampling). We advise specifically to also take a representative sample, as standard practice, during the filling up of bunker barges. Although this is already often done by market parties, from a quality control perspective it would be wise to make this standard practice.
   We advise including provisions to this effect in ISO 8217.
4. The quality standards for marine fuels (ISO 8217) should be extended to include environmental and health standards. At present these are concerned with 'technical' issues, geared to proper functioning of ship's engines, but it is desirable that limits also be set for hazardous substances like phenol, styrene monomer, naphthalene, arsenic and EOX.
   In addition, standards are also required for the hazardous substances occurring 'naturally' in bunker fuel, such as PAH, nickel and VOC.
5. Port authorities should keep a record of the motives cited for debunkering, so that problems with marine fuel quality can be analysed more efficiently and rapidly, and the underlying causes addressed.
   We advise the International Association of Ports and Harbours to appeal to the affiliated ports and harbours to take due measures to this end.
6. In each IMO-Member State an agency should be set up where parties can report inferior fuel batches anonymously. This would allow testing stations and labs to send out a rapid alert that particular batches are contaminated.
   We advise the Member States of IMO to establish such an agency and inform market parties accordingly.

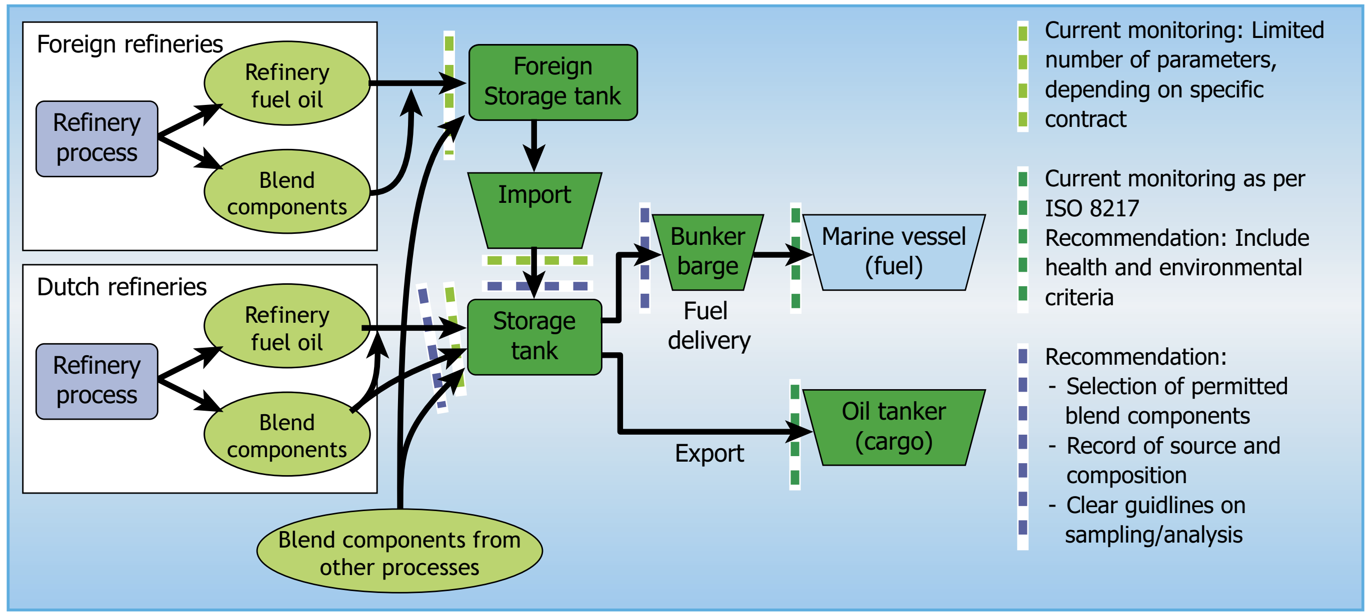


Figure 6 Points in the bunker fuel supply chain where additional monitoring is suggested

More information:

Ab de Buck
Tel.: +31 (0) 15 2150150
E-mail: buck@ce.nl

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This brochure is an extended summary of the Dutch report "Blends in beeld; een analyse van de bunkerolieketen" (Blending and bunkering – an analysis of the bunker fuel supply chain) written by CE Delft in spring 2011. The full report can be downloaded from the CE Delft website: www.ce.nl