EMISSIONS REGULATIONS ARE STRICTER but are they better? Three views from dredgers, policymakers and shipbuilders
COVER
A bucket dredger working in the Baltic Sea near Riga, Latvia.
Both the Baltic Sea and the North Sea are SOx Emission Control Areas (SECAs). Dredging vessels in SECAs will have to comply with stricter fuel emissions standards as of January 1, 2015 (see page 14).
EDITORIAL  

SMART, SUSTAINABLE: A LIFE CYCLE APPROACH TO FUEL ECONOMY AS APPLIED TO DREDGING VESSELS  
JEAN-BAPTISTE DE CUYPER, BERT ANSOMS AND BART VERBOOMEN  

No time to wait for policymakers. Dredging contractors need to act now and consider energy efficiency from beginning to end: from ship design to operations to decommissioning.

EuDA INFORMATION PAPER: REDUCTION OF SO₂ EMISSIONS FOR DREDGING VESSELS  
PARIS SANSOGLOU  

New IMO emissions regulations are being adopted each year. But dredging vessels are more than ships. They are work-boats and legislators must keep that in mind.

APPROACHING EMISSIONS IN DREDGING  
B. GONÇALVES CASTRO, S. OOIJENS AND L. W. VAN INGEN  

Since dredging equipment is the source of emissions, shipbuilders and equipment manufacturers must help develop clean technologies that address total energy consumption.

NEW IADC SAFETY COMMITTEE & CHARTER  
P. BOS, W. HAAIJER, R. KOLMAN, C. LEROY AND T. VAN DE MINKELIS  

Safety awareness in the dredging industry has taken a leap forward. The efforts of the IADC are part of the new safety strategy to reduce accidents and incidents to zero.

BOOKS/PERIODICALS REVIEWED  


SEMINARS/CONFERENCES/EVENTS  

Upcoming in 2015: Conference in Moscow in February, WEDA’s Summit & Expo in June, PIANC USA/COPRI/ASCE Conference in October and CEDA Dredging Days in November.
2015 is just around the corner and with the New Year new regulations are coming. Specifically in the realm of fuel emissions. The interaction of dredging and environment has long been on the radar of the dredging contractors, port authorities and other clients, as well as a broad range of stakeholders from environmentalists to average citizens.

If people were not aware of the growing concerns about the relationship of industry and environment, then the Intergovernmental Panel on Climate Change (IPCC) reports brought the message home in no uncertain terms. The IPCC, a United Nations scientific intergovernmental body, was established 25 years ago and has been reporting on climate change ever since. Its studies have consistently indicated that climate change is brought on by human activity and is heating up the planet at an untenable rate. The latest report in 2013 stated that “warming of the climate system is unequivocal” and “it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century”.

One of these “human influences” is the use of fossil fuels and their emissions. Attention to the first two E’s of economy and environment have now given way to the next big E: Emissions. While discussions go on about the CO₂ footprint within the borders of particular countries, emissions from international shipping are not bound to one country. Ships move across vast bodies of water. With this in mind, the International Maritime Organization, also an UN agency, has developed legislation addressing the reduction of greenhouse gases caused by fuel emissions. This is more complex than it may seem: Emissions vary from one type of ship to another. Freight ships differ from dredging vessels even if some dredgers are self-propelled and sea-going. But dredgers are also work-boats. Standing still while at work, they are still expelling emissions.

The question of how best to regulate dredging vessels has absorbed the industry and the lawmakers for quite a while. Globally, a progressive reduction in emissions of SOₓ, NOₓ and Particulate Matter and the introduction of Emission Control Areas (ECAs) have been gradually enacted. Now a new deadline is approaching: As of January 1, 2015, new limitations on SOₓ will be put in place for parts of the North Sea and the California coast. Given the importance of energy efficiency and reducing emissions, from both an environmental as well as an economic standpoint, how these emissions regulations proceed will have significant consequences.

This issue of Terra et Aqua is devoted to an update on “the state of the art” of emissions and what is happening from the perspective of three interested parties: The dredging contractors, the European Dredging Association (EuDA) representing European dredgers in Brussels and the shipbuilders that design and develop dredging vessels with innovative technologies to meet fuel emissions demands. Each group has its own perspective and proficiencies. The insights of each will contribute to finding successful solutions to the “great Emissions debate”.

Also, as a final word: another crucial topic – safety – is addressed in this issue. IADC member companies continue to look for new ways to maintain high safety standards across all lines, for all customers and all main and subcontractors. It is a daily responsibility that is being tackled by a newly launched Safety Committee.

In the modern dredging industry, these challenges – and others – will continue to arise. And the talented dredging engineers and researchers will continue to make exceptional discoveries that lead us into a productive, sustainable future.
ABSTRACT
In times when energy is scarce, fuel prices are rocketing and global warming awareness is high, finding efficiencies in fuel consumption are in everyone’s interest. The International Maritime Organization (IMO) states that although international shipping is the most energy efficient mode of mass transport and only a modest contributor to overall carbon dioxide (CO2) emissions, a global approach to further improve its energy efficiency and effective emission control is needed as sea transport will continue growing apace with world trade.

This article offers a comprehensive overview of how one of the major dredging contractors applied methods of sustainable fuel efficiency to their trailing suction hopper dredgers (TSHDs), while taking a life cycle view. After indicating the specific limiting conditions for dredging vessels as compared to other types of shipping, the challenges and opportunities are discussed in each phase of a dredging vessel’s life cycle: from its design, during its operational life, until decommissioning. This is illustrated with results from pilot projects and studies.

The article is based on a paper and presentation at the 33rd PIANC World Congress, San Francisco, California, USA in June 2014 and is reprinted here in a revised form with permission.

INTRODUCTION
"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century”. This infamous quote from the latest IPCC report on Climate Change (IPCC, 2013) summarises and confirms speculations that have dominated the debate on climate change for decades.

Because of the very nature of waterborne transport, the dredging industry is already contributing to more sustainable transport solutions, particularly when compared to road transport (which is usually the only other suitable alternative). Fuel usage per tonne transported over road is a multiple of the equivalent over water. CO2 contributions from road transport have risen sharply over the last 80 years (see Figure 1). Where possible, a shift from road transport to marine transport is the way forward in controlling CO2 emissions.

With more than 1,100 dredging vessels worldwide, of which about half are trailing suction hopper dredgers, DEME believes that dredging companies can contribute to the call of the International Maritime Organization (IMO) for improvements in energy efficiency.

The industry should not wait for policies and regulations to rethink the fuel efficiency performance of their dredging vessels, but should achieve sustainable growth by improving energy efficiency with regard to carbon emissions.

Energy objectives at DEME are quantified through an increase in efficiency of 7% by 2022 compared to 2011. To achieve its emission objectives, the company implemented a group-wide Greenhouse Gas and Energy Management system, conform the ISO 14064 (Greenhouse Gases standard) and based on the ISO 50001 (Energy Management Systems standard). The measures set forth include efficiency actions at office, vessel and project level.
Regulatory context
The regulatory context is changing as well. IMO’s MARPOL Annex VI Regulations for the Prevention of Air Pollution from Ships, in force globally since July 2010, established general fuel oil sulphur limits as well as more stringent restrictions on sulphur emissions in certain protected areas: the SOX Emission Control Areas (SECAs). The progressive reductions are soon reaching their final stage inside the SECAs, where the limit of sulphur content in bunker fuels will be set at 0.10%.

To date, the most realistic (technical and economic) solution for the dredgers operating in a SECA with regard to primary methods of SOX compliance (0.10%), would be to run on Marine Diesel Oil (MDO) (EuDA, 2013). Considering that MDO is about 40% more expensive than LS380 (1% sulphur) or even 50% more expensive than regular IFO380 grade fuels, the financial impact of such restrictions is very considerable, incentivising the search for fuel economy even more.

DREDGING FLEET SPECIFICS
Although the size of the dredging fleet is marginal as compared to the global shipping numbers, the differences in the types of operations are substantial. Therefore, general fuel economy principles for freight shipping should not be applied to dredging vessels. Freight shipping generally moves cargo from one port to another and has a well-defined project cost, any savings on fuel consumption has an immediate positive effect on the competitiveness of dredging rates.

Life Cycle Analysis
In a Life Cycle Analysis (LCA), the environmental impact of a product is measured throughout all phases of its life cycle, namely construction, operation and disposal. When applied to trailing suction hopper dredgers (TSHDs), the LCA of a middle-sized TSHD stresses the clearly dominant contribution of the operational phase (Figure 2).

Furthermore, the use of fossil fuels and the environmental burden related to its emissions are dominant in all life cycle phases (CEDA, 2011). This demonstrates the required focus on fuel efficiency when searching for improvements to lower the environmental impact of a TSHD.

Apart from the obvious environmental benefits of fuel efficiency, the economic benefits are as important, particularly in today’s competitive globalised economy. Fuel prices have risen over the last decade, at a far greater pace than general inflation. Since 2004, the fuel index as assessed by BCIS (Building Cost Information Service, UK) has increased 4 times faster than the labour and supervision price index (Figure 3).

Because the operational fuel costs for TSHD dredging can be as high as 20% of the total project cost, any savings on fuel consumption has an immediate positive effect on the competitiveness of dredging rates.
JEAN-BAPTISTE DE CUYPER
obtained an MSc in Civil Engineering, University of Gent, Belgium and has been involved with a variety of complex port developments, marine and waterway engineering and strategic flood protection schemes, reaching from Australia and Far East Russia to the Middle East and Europe. For the last 5 years he has worked in the UK and Ireland as Deputy Area Manager, tendering and following up marine infrastructure works for Dredging International (DI), part of the DEME Group.

BERT ANSOMS
has been working at DEME headquarters in Belgium and on projects abroad since 2008 as a Project Engineer. He received his Masters in Applied Economic Sciences - Commercial Engineering from the University of Antwerp, Belgium. He is involved in DEME’s drive for Operational Excellence and gained experience in the field of Carbon Emissions and Fuel Efficiency while setting up DEME’s Greenhouse Gas and Energy Management System conform ISO14064 and based on ISO50001.

BART VERBOOMEN
graduated as an electromechanical engineer in 1993. After several years as a project engineer and project manager for large dredging and marine related projects worldwide, off-shore works and cleaning of wrecked ships for DEME (Dredging Environmental Marine Engineering), he became General Manager of NV Baggerwerken Decloedt en Zoon, a subsidiary of DEME with headquarters in Oostende, and is Managing Director of all technical departments of the DEME group.

A TSHD is a work-boat and not merely a transport vessel. Its purpose is to perform works in a unique project environment, working under a regime characterised by variation on an hourly basis. This can be variation in sailing speed (full speed, trailing speed, positioning), cargo (empty, full), draught, type of activity (trailing, pumping ashore, bottom-door disposal) and so on. Furthermore, the area of operation is not pre-defined and can range from Arctic seas to Caribbean waters. A dredging vessel can be operational in a small area (e.g., North Sea) for years, but could easily be sailing all oceans when repetitively mobilising from one project to the other.

Flexibility is a key word: Globally operating dredging companies look for dredging vessels that can be deployed for many types of activities, in many types of conditions, in order to increase their annual usage percentage. This flexibility and versatility of operations are the major challenges in defining fuel economy programmes for dredging vessels.

**INTRODUCTION TO LIFE CYCLE**

The concept of Life Cycle Analysis (as introduced above) is used as a roadmap to discuss opportunities for fuel economy for TSHDs. The following 3 stages in the life cycle of a TSHD play a vital role in fuel economy:

1. **Conceptual Design**
2. **Operational Life**
3. **Decommissioning**

**STAGE 1: DESIGN**

**Concept of a dredging vessel**

A fuel-efficient TSHD requires a clever design that makes the adequate considerations on fuel economy during the conceptual stage. The requirement for versatility is the biggest challenge for TSHD designers to make an optimal selection of engine setup.

Firstly, there is the question of total engine power. The main engines distribute their energy over various processes, which do not necessarily run simultaneously. Driving pumps and driving propulsion are the main processes. When trailering, the engine power is distributed over both propulsion and pumping. When sailing full, all power is available for propulsion. When pumping ashore, little to no propulsion power is required and all power is available for driving the inboard pumps. In all these phases, the engines ideally run at their optimum power output. In any case, the designer should avoid installing latent engine power, which would only be used in rare occasions.

This is inefficient both in investment costs as well as in operational fuel consumption. Good planning and discussions need to be held between the design team and the operational team to understand what types of operations are targeted and need to be designed for. Questions that need to be considered are:

- What kinds of soil will be dredged?
- How far would these soils need to be hydraulically pumped?
- What would be the typical sailing distance between the dredge area and the disposal area?
- Will the vessel be regularly mobilised over great distances (trans-ocean)?

The operational team would want full flexibility, while the designer would ideally want a small, pre-defined power demand range. Clearly concessions will need to be made. To illustrate the difficulty in optimising engine selection during the design stage, take the example “mega-trailers”.

Mega-trailers are the largest types of TSHDs, typically with a hopper capacity beyond 30,000 m³. Such mega-trailers are typically deployed where economy of scale is to their advantage. Project conditions would then be characterised by large sailing distances between dredging site and disposal or pumping site. In such conditions, engine design would focus on sailing (high sailing speed). On the other hand, these mega-trailers are regularly deployed for dredging down to the deepest seabed relying on their long suction pipe (in combination with an underwater pump). Such operations are usually characterised by precision dredging with manoeuvring and positioning being the governing activity (e.g., the dredging of trenches for the oil & gas industry). These two types of operations demand very different loads of the main engines.

The multi-disciplinary deployment of the global dredging fleet today amplifies this difficulty. Vessels are now used in the renewables sector, working under very different conditions compared to what was anticipated at the time of their design and construction.

Secondly, there is the optimal working range of the main engines, where fuel consumption
per unit of energy is the lowest (most efficient combustion). Vessel speed sailing, vessel speed dredging, suction power and pumping power. All of these power demands need to be aligned as engines will run most efficiently at their optimum load (Figure 4).

In order to measure the energy performance of a new vessel and facilitate decision making, the IMO have launched the concept of an Energy Efficiency Design Index (EEDI) (MEPC, 2011). The EEDI for new ships is an important technical measure and it aims at promoting the use of more energy-efficient (less polluting) equipment and engines. The EEDI requires a minimum energy efficiency level per capacity mile (e.g., tonne mile) for different ship types and size segments. However, given the complexity of the engine setup and energy demands for dredging vessels, as described above, the dredging industry has for the time being been exempted from these requirements.

**Fuel-efficient engine design**

As identified by the European Dredging Association (EuDA), fuel efficiency would be an appropriate starting point in the reduction of emissions of pollutants. Over the last decades, intrinsic improvements in the design of TSHDs have already led to a 7.5% reduction in CO₂ emission per m³ loaded.

Apart from the technological progress in the design of fuel-efficient engines, the scale increase of TSHDs also contributes to better fuel economy. Namely, with the increase of hopper capacity and engine size comes more efficient energy use because of the economy of scale when sailing over longer distances and the more efficient transport energy demand. The latter is demonstrated in Figure 5: for the largest TSHDs, one volume unit can be transported at a certain speed with the lowest energy demand. One needs to be careful when such mega-trailers are deployed in other types of dredging cycles (e.g., short sailing distances). Fuel efficiencies can be lost rapidly when conditions are unfavorable.

**Methods during design**

Important gains in fuel efficiency have over the recent years been achieved in the design stage by improvements, developments and considerations on the following aspects:

- 3D design technology has simplified studying the effect of streamlining and curving a vessel’s hull in the right places while trying to maximise its carrying capacity. Such studies define, amongst other things, the optimum block coefficient.
- Use of different materials, optimise space for accommodation units and stores, management of spares, use of high tensile steels and reduced steel usage through the creation of 3D complex forms all aim at reducing lightweight ship.
- Developments in the type of drive system: electric versus diesel direct. While electric has clear advantages in terms of flexibility, one should be aware of every conversion of energy from diesel engine to generator and generator to electric motor. Each conversion causes a loss of energy efficiency of up to a few percentages. For direct drive systems with gearbox this conversion loss only needs to be accounted for once. Furthermore, one should allow for the energy efficiency of a generator and electric motor.
- Thorough understanding in every aspect of the energy household. The size of the engine (installed power) is governed by the most demanding cycle status (trailing, sailing, pumping). The vessel’s power is balanced out in any phase of operation minimising any latent engine power.

**STAGE 2: OPERATIONAL LIFE**

While the design phase of a vessel is very short in comparison to its operational life, unmistakably, a fundamental misconception in the design phase will drastically impact the total fuel cost (and thus operational cost). Nevertheless, once the TSHD has been built, there are several opportunities to improve fuel efficiency during the operational life.

**Methods**

Fuel economy initiatives during the operational life either focus on 1) reducing the energy demand (preventive) or 2) increasing the fuel combustion efficiency (reactive). The preventive approach is clearly the more sustainable one. For every method,
the cost versus the benefit should be investigated when making a decision to proceed.

Creating awareness
Bringing awareness (to the operators, engineers, technical superintendents, planners, and others) means improving the understanding of the operational processes consuming fuel. Creating awareness goes hand in hand with fuel consumption measurement and reporting.

These two aspects are fundamental to increasing understanding of fuel consumption on a TSHD and support fuel efficiency decisions. Fuel consumption measurement requires fuel counters, which are generally implemented as flow meters installed at the heart of the engine room, between the fuel tanks and the engines. Such new fuel measurement techniques are gaining in importance over the more traditional measurement techniques such as manual sounding or the use of pingers. These traditional measurement techniques deliver less accurate data, which are prone to errors owing to non-standardisation (different persons performing sounding at different times of the day or week). Reporting of manual soundings is useful for understanding average trends, but cannot provide for real-time data.

To understand the impact of certain actions on fuel consumption, fuel counters should have digital output which can be added to the dredging console display on the vessel’s bridge (Figure 6), integrated in the SCADA system (supervisory control and data acquisition). An example of such digital visualisation is shown in Figure 7.

Controlling the energy demand
From an operational point of view, fuel efficiency can be achieved by maximising payload while minimising fuel consumption. Firstly, focussing on payload, the principle is straightforward: Don’t move around non-paid load at the expense of burning precious fuel. Some typical actions that can be taken are:
- Avoid water trapped on top of dredged materials in the hopper
- Spares: leave parts on the shore when not needed
- Optimise bunker volumes (don’t take full bunkers if not required).

In addition to this, the vessel’s Lightweight Tonnage (LWT) needs to be monitored frequently and considerable differences with the design LWT need to be investigated. Usually such differences arise from ad hoc adaptations and maintenance over the years.

Secondly, savings in fuel demand have an immediate contribution to fuel efficiency. Such savings can be achieved on multiple fronts. Some typical processes where fuel demand can be controlled are listed here:
- Rely on shore power when the TSHD is alongside a quay. Whether this is during a planned event (maintenance, bunkering, working schedule, and so on) or unplanned (weather downtime), the use of (green) shore power can be a sustainable alternative to burning carbon fuels. This requires suitable connections on the quayside.
- Idle ship power management: monitor what engines and power users need to remain switched on and which ones can be switched off when the ship is idle.
- Lower sailing speed when downtime is anticipated (tides, locks, bad weather and
such), both during voyage (Panama Canal, Suez) as well as during project execution.

- Reduce resistance in the water: perform regular hull maintenance by removing fouling and applying coatings.
- Polish propellers to increase propulsion efficiency.
- Reduce draghead resistance without giving in on dredging production.

The observation made so far by DEME is that operational fuel economy opportunities are present in a multiple of smaller aspects, owing to the complexity and diversity of operational activities of dredging vessels. There is no golden egg and efforts need to be made in all of these smaller initiatives to achieve an overall distinctive saving.

**Fuel combustion efficiency**

A popular fuel saving option is the use of fuel additives, which is becoming a market on its own. Several dredging companies are testing different kinds of products. The effectiveness of such products is under review.

**Testing**

The effectiveness of many of these initiatives is difficult to predict or calculate and can usually only be assessed empirically. When performing such tests, the challenge is to create exact conditions to distillate the effect of a certain factor. As an illustration, DEME is running a test programme where the effectiveness of an anti-fouling system is investigated by the comparison of two sister vessels, operated on the same site: one vessel with the system, the other one without (Figure 8). Such test setups enable correct assumptions about the overall benefit of a fuel economy option.

**Standardised approach**

The initiatives presented above are at company level, and can therefore be managed centrally. For initiatives at individual project level, a standardised approach is recommended.

Operational fuel improvement exercises consist of five short stages:
1. Identification of opportunities (from the early stage: kick-off meetings)
2. Preparation of operational key performance indicators (KPIs)
3. Launch and mobilisation of involved parties through a detailed action plan
4. Progress follow-up and evaluation
5. Close-out stage

This follows the DMAIC project methodology: Define, Measure, Analyze, Improve and Control.

**CASE STUDY: LINCShore BEACH RE Norrisment PROJECT 2010-2015**

The Lincshore Beach Renourishment 2010-2015 scheme provides for the protection of about 11,000 homes against the flood risk on the English East Coast. Its annual scope of works includes the renourishment of beaches with about 500,000 m³ of sand. These sands are dredged from offshore licensed borrow areas and are pumped hydraulically onto the beaches (Figure 9).

Because of the shallow nature of the Lincshore coast, the dredging vessel can only approach the coast and discharge its load at high water. The dredging vessel’s cycle is therefore determined by the tidal cycle, which is one high tide every 12 hours. Since the sand borrow areas are close by, the vessel can sail at less than full speed to and from the dredging location, as the ship would need to go on standby anyhow while waiting for the tide to rise.

Before the start of the 2013 campaign, specific preparations were taken to evaluate optimal fuel usage under these circumstances. A simple and effective Key Performance Indicator (KPI) was set, namely, fuel usage per m³ of loaded sand in the hopper.
Measurement
A flow meter, part of the booster unit of the fuel oil system, was used as a fuel counter and was linked to the PLC (programmable logic controller). The flow meter is located between the daily service tanks (both marine gasoil and heavy fuel oil) and the mixing tank. This indicates that the flow to the engines and their corresponding fuel consumption was not measured directly.

Furthermore, allowance had to be made for return fuel from the engines, which is not consumed. This was achieved by continuous gauging of the mixing tank level and by maintaining a constant level with the feeder pumps, considering the amount of fuel requested by the engines via the circulation pumps. With this setup, it could be assumed that the measured fuel flow was equal to the fuel consumption by the engines.

These measurements were compared and benchmarked with the daily soundings of the bunker tanks, which is regular practice on board of dredging vessels. Applying the correct temperature coefficient to allow for the density variation of up to 7% owing to the temperate difference of about 50°C to 60°C between bunker tanks and flow meter was important.

Method
Figure 10 shows the fuel consumption at various loads of the main engines. Several trials were done with changing loads of the main engine during sailing, and overall fuel consumption per cycle was evaluated. These were compared to identify an optimal working method.

Trials
To properly evaluate the effectiveness of a certain fuel economy setup, trials had to be executed over several days up to a week. This allowed for balancing out the changing environmental conditions such as sea-state, different borrow areas, different sand characteristics and different pumping distances. This variability of the background conditions is a general concern for fuel consumption evaluation during dredging operations as compared to more “industrial” activities such as freight shipping (sailing at constant load).

Pitch reduction during sailing empty or loaded
First trials were done with reduced pitch of both propellers, done in incremental steps of 5%. Engine load and sailing speed dropped accordingly, resulting in lower fuel consumption. However, to ensure the vessel remains steerable and its sailing direction is in line with its heading, a minimum speed is required. When sailing at death slow speed, the impact of wind and current on the sailing direction requires a compensating large steering angle of the rudders. The vessel will continue its desired sailing direction, but with its heading under a different angle. This causes unnecessarily high resistance and should be avoided. As a result of these first trials, it was assessed that a 55% pitch was optimal (see Figure 11, “Stage 1 Improvements”).

However, two aspects had a negative effect on fuel consumption at reduced pitch:
- Engine load dropped below the optimum (see Figure 10) and less time was spent at the anchorage where the vessel waits on the high tide and where fuel consumption is minimal.
- Furthermore, low engine loads result in faster contamination (decreasing fuel efficiency), requiring a frequent turbo-wash (which is also energy consuming).

Therefore, during a second trial phase (see Figure 11, “Stage 2 Improvements”), the assessments done with regard to optimal pitch were further refined, considering engine load versus fuel consumption characteristics.
Engine loads between 75% and 85% were targeted. This resulted in a higher sailing speed, offering greater steering control. Owing to the larger sailing speed (and higher fuel consumption), more hours were spent at the anchorage, where fuel consumption on standby is an absolute minimum. Fuel saved during standby time should compensate for the extra fuel burnt to deliver more power and higher sailing speed.

This can be evaluated by the following equation:

\[ \text{Fuel consumption} \ [g] = \text{specific fuel consumption} \ [g/kWh] \times \text{time} \ [h] \times \text{power} \ [kW] \]

Weather permitting, these set-ups can be applied while one main engine is shut down, further reducing the overall fuel consumption.

In addition to trials during sailing empty and loaded, fuel economy initiatives were also done during pumping and dredging. Automated control of the pumping and
dredging process keeps the load on the dredging engine lower than when done manually. During the 2013 campaign, a reduction of over 100 tonnes of fuel (equivalent to over 300 tonnes of CO₂) was achieved. Figure 11 shows the realised improvements, referenced to standard fuel consumption of the TSHD.

STAGE 3: DECOMMISSIONING

Technical innovation is key in the newest generation of dredging vessels. This is embedded in the design process. TSHDs have moved from mechanical devices towards hi-tech working tools, where information technology and automated processes form a central nervous system. As a result of technological progress, with time, a vessel’s design basis has a higher risk of being labelled old-fashioned and will be outperformed by newer, more efficient vessels. Nonetheless, savings that can be achieved by implementing newer technology need to be weighed against the required investments, following the BATNEEC principle (Best Available Technology not Entailing Excessive Costs) (CEC, 1984).

This analysis is done by the vessel’s designers when they make a projection of the anticipated decommissioning date, while accounting for re-fit options during its lifetime (Figure 12).

On the background of this uncertainty caused by regulatory changes, the decommissioning aspect of a TSHD comes in the spotlight. The main question is: When is the right time to decommission an old TSHD and have it replaced with an efficient new TSHD? It is no exception that the actual lifetime of a dredging vessel is well above 30 years, with several operators extending the life of their vessels by performing a thorough retro-fit. Obviously, no 30-year-old design has allowed for the current dredging market reality and regulatory framework and, back then, nobody

introduced after its keel-laying. With this particular regulation, it will need to be complied with on all operational technology and thus has retroactive effects on older dredgers.

Ship owners operating in these SOx emission control areas (SECAs) have only a few options. First of all, operators could shift to SECA-compliant fuel on their vessels, which however would ask for a retro-fit of the engines that are designed to run on heavy fuel oil, mainly because of the differences in caloric values. Furthermore, the price per tonne and the availability of such fuels are issues. The other option lies in the removal of pollutants from the exhaust gases. This requires retro-fitting the vessels with scrubber installations. For existing dredging vessels, this latter option is not straightforward because of lack of space and issues with payload and stability.

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had access to the technology that exists now. With that in mind, why not shorten the design life of a TSHD?

A long design life translates into tough (read: heavy) vessels that last longer. With a shortened design life, vessels would progress towards light-weight, economic TSHDs, standardised and suited for its limited purposes. Instead of continuing to use vessels into ages where younger vessels easily outperform their older sisters (on all aspects, but particularly on fuel efficiency), why not incorporate a shorter life cycle into the original design conception and save on material usage? The technical inferiority of older vessels will be less, fuel efficiencies will be better and expensive retro-fitting programmes can be avoided.

In view of the Life Cycle Analysis, one could object to such an approach, as the environmental burden of the construction and disposal phases will considerably gain in relevance. Indeed, the relative contributions will have to be rebalanced, but given the current marginal contribution of construction and disposal (see Figure 2) it is projected that the gain during operational life will easily outweigh such negative effects.

With that in mind, why not shorten the design life of a TSHD?

A long design life translates into tough (read: heavy) vessels that last longer. With a shortened design life, vessels would progress towards light-weight, economic TSHDs, standardised and suited for its limited purposes. Instead of continuing to use vessels into ages where younger vessels easily outperform their older sisters (on all aspects, but particularly on fuel efficiency), why not incorporate a shorter life cycle into the original design conception and save on material usage? The technical inferiority of older vessels will be less, fuel efficiencies will be better and expensive retro-fitting programmes can be avoided.

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Several recommendations (such as the use of fuel additives, coatings and fuel measurement) are still in the testing phase and their effectiveness needs confirmation. Participation in joint initiatives and partnerships with stakeholders will hopefully take place, with plans to report back on some of its findings within the next months and years.

As a final note, the reality is that dredging companies will always have to allow for economic viability when implementing the best technologies available to protect their clients and their own competitiveness.

### CONCLUSIONS

This article provides a new perspective on fuel efficiency improvements in the dredging industry. The main drivers encouraging application of fuel economy principles are the environmental effects, the economic effect and the regulatory framework. The analysis here has been drafted as guidance to dredging industry members for setting up and implementing fuel efficiency programmes within their organisations. DEME has started working on a series of initiatives, which are described in the document, but this work will have to be continued for a considerable time as there is a long way ahead.

Several recommendations (such as the use of fuel additives, coatings and fuel measurement) are still in the testing phase and their effectiveness needs confirmation. Participation in joint initiatives and partnerships with stakeholders will hopefully take place, with plans to report back on some of its findings within the next months and years.

As a final note, the reality is that dredging companies will always have to allow for economic viability when implementing the best technologies available to protect their clients and their own competitiveness.

### REFERENCES


ABSTRACT

Air pollution from ships causes a cumulative effect that contributes to the overall air quality problems on a local scale, particularly in coastal zones, and most of these airborne pollutants are produced when burning fuel oil. To focus on possible legislative or technical concerns of the European dredging companies with regards to the sulphur legislation and to review potential solutions, a workshop was organised by the European Dredging Association (EuDA) in April 2013. Besides dredging experts, the workshop also gathered industry representatives from the ship owners, engine manufacturers and providers of exhaust gas cleaning solutions as well as from the oil refinery and distribution sector. In this article, EuDA presents a summary of the findings of the workshop – including the legislative background, the technological or methodological options to comply with the legal requirements and finally setting forth on the most realistic option available at present.

INTRODUCTION

Air pollution from ships causes a cumulative effect that contributes to the overall air quality problems on a local scale, particularly in coastal zones in the case of sulphur oxides (SOX), nitrogen oxides (NOX), Particulate Matter (PM), and on a global scale with CO2 emissions contributing to climate change. Most of these airborne pollutants are produced when burning fuel oil.

On April 23, 2013 the European Dredging Association (EuDA) organised a workshop focussing on possible legislative or technical concerns of the European dredging companies regarding the sulphur legislation on special areas worldwide, with a particular focus on European waters, and reviewing the solutions available today.

The workshop gathered a group of industry representatives and experts from the dredgers, the ship owners, engine manufacturers and providers of exhaust gas cleaning solutions as well as from the oil refinery and distribution sector. It attempted to answer to the following questions:
- Are there still pending legal issues for the dredgers (relative to emissions)?
- Are there technical issues with engines and/or scrubbers for SOX compliance?
- How about NOX compliance?
- How about compliant fuel availability?
- Is LNG a realistic option for Dredgers? If so, under what conditions?

This article presents a summary of the findings of the workshop starting with the legislative background, then following with the technological or methodological options to comply with the legal requirements. It concludes with the most realistic option available today.

SOX LEGISLATIVE BACKGROUND

The reference legislative body for the shipping industry is the International Maritime Organization (IMO). Beside navigation and safety issues, the IMO legislation also covers all environmental regulatory aspects linked to shipping, including the emission of airborne pollutants (as confirmed recently by United Nations Framework Convention on Climate Change - UNFCCC). The issue of controlling air pollution from ships was already discussed when adopting the MARPOL Convention in 1973. However, no IMO legislation on reducing sulphur emissions was adopted until decades later (i.e., these are the Protocols to the Convention on Long-range Transboundary Air Pollution in 1985 and 1994).
When MARPOL Annex VI (see box) was adopted in 1997, limits were set for the main air pollutants contained in ships’ exhaust gas, including sulphur oxides (SOx) and nitrous oxides (NOx). It also regulated emissions of ozone-depleting substances, of volatile organic compounds from tankers and shipboard incineration. These limits were to be revised in 2005 and were finally adopted in October 2008 by the Marine Environment Protection Committee (MEPC58). The revised MARPOL Annex VI, in force globally since July 2010, sets a progressive reduction in emissions of SOx, NOx and Particulate Matter (PM) and also introduced Emission Control Areas (ECAs) where stricter limits are implemented for those air pollutants. These fuel oil sulphur limits (expressed in terms of % m/m – by weight) are subject to a series of step changes over the years as described in Figure 1.

As a consequence, most ships sailing both outside and inside these SECAs will need to choose to operate on only SECA-compliant fuel or on different fuel oils complying with the respective limits (in and out of the SECA). Sailing on SECA-compliant fuel at all times is in principle possible but costly: Operators will face an average mark-up of about 30% with regards to non-SECA-compliant fuel (Figure 2).

**REGULATION 14 ON SULPHUR OXIDES (SOx)**

Regulation 14 of the MARPOL Annex VI provides both the limit values and the means to comply. The IMO regulation recognises that besides solely sailing on SECA-compliant fuel, there are other means by which equivalent levels of SOx and PM emission control, both outside and inside SECA, could be achieved. These may be divided into:

- methods termed primary, in which the formation of the pollutant is avoided or
- methods termed secondary, in which the pollutant is formed but subsequently removed to some degree prior to discharge of the exhaust gas stream to the atmosphere.

Therefore, the options within an IMO special area are either to use SECA-compliant fuel or to remove the excess pollutants from the exhaust gases. Outside a SECA, equivalent options (0.5% sulphur content) will also have to be implemented by 2020 (or 2025).

The European Commission is also legislating on the sulphur content of marine fuels but largely follows the IMO rules. Following the revision of the MARPOL Annex VI, the Commission has had to amend accordingly its so-called ‘Sulphur Directive’. However, the European ‘Sulphur Directive’ implements the provisions of IMO Annex VI with:

1) stricter deadlines (latest by 2020) and
2) some additional requirements for passenger ships sailing outside SECA zones (same sulphur limits as inside SECA).

**PRIMARY METHODS FOR SULPHUR EMISSION CONTROL**

When trying to reduce the emission of air pollutants, one usual starting point would be to make more and more efficient use of the fuel oils, and therefore, to use fuel oils with lower sulphur content. But this is not enough: In order to achieve the required levels of emission control, the emissions need to be removed at the end of the process of conversion of fuel into exhaust gases. This is done by using specific emission control systems and technologies.

**MARPOL ANNEX VI - REGULATION 14 ON SULPHUR OXIDES (SOx)**

Annex VI Regulations for the Prevention of Air Pollution from Ships established general fuel oil sulphur limits as well as more stringent restrictions on sulphur emissions in certain protected areas, the SOx Emission Control Areas (ECAs) (see Table 1).

SOx and Particulate Matter emission restrictions apply to all fuel oil, combustion equipment and devices onboard and therefore include both main and all auxiliary engines together with items such boilers and inert gas generators. These restrictions divide between those applicable inside SECA established to limit the emission of SOx and Particulate Matter and those applicable outside SECA. These restrictions are primarily achieved by limiting the maximum sulphur content of the fuel oils as loaded, bunkered, and subsequently used onboard.
Historically in the dredging sector, the operations' efficiency improved on average by 7.5% per decade and in particular for trailing suction hopper dredgers (THSDs) (Figure 3). Nevertheless, additional measures need to be taken to achieve the ambitious targets set by legislators worldwide.

The primary methods – avoiding the formation of the pollutants – as considered by IMO include switching to cleaner fuel oils. These are usually found in the more refined products such as the distillates. Indeed the combustion in the main engines follows the rule that “what comes in must come out”. Therefore, in order to avoid the formation of the pollutant, the main possible solutions include:

- **Permanent switching** to compliant fuel (inside and outside SECA)
  a. more refined marine gasoil (MGO)
  b. marine diesel oil (MDO)
  c. LNG

- **Temporary switching** between different fuel types to comply with the emissions standards (only when inside ECA): This means technology operating on multiple liquid and/or on gaseous fuels, allowing for the seamless switch over from non-SECA fuel (heavy fuel oil, HFO) to SECA-compliant fuel (LNG, MGO or MDO) and vice versa.

### Table I. Annex VI Emission Control Areas

<table>
<thead>
<tr>
<th>Special Areas</th>
<th>adopted #</th>
<th>into Force</th>
<th>in Effect from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Sea area (SOx)</td>
<td>26 Sept 1997</td>
<td>19 May 2005</td>
<td>19 May 2006</td>
</tr>
<tr>
<td>North Sea area (SOx)</td>
<td>22 July 2005</td>
<td>22 Nov 2006</td>
<td>22 Nov 2007</td>
</tr>
<tr>
<td>North American area (SOx, and NOx, and PM)</td>
<td>26 Mar 2010</td>
<td>1 Aug 2011</td>
<td>1 Aug 2012</td>
</tr>
<tr>
<td>United States Caribbean Sea area (SOx, NOx and PM)</td>
<td>26 July 2011</td>
<td>1 Jan 2013</td>
<td>1 Jan 2014</td>
</tr>
</tbody>
</table>

Technological solutions

As far as the engine manufacturers are concerned, the technological solutions for full compliance to the IMO sulphur regulation exist for ships sailing through or working within SECAs. The solutions include the use of compliant fuel or the installation of scrubbers. For the use of compliant fuel, the engines may need some adaptation and the specifications need to be upgraded because (non-ECA compliant) heavy fuel (HFO) has a higher calorific value generating more power per metric volume of fuel than (compliant) medium gasoil or diesel oil (MGO or MDO). These solutions can be applied to both new-builds or existing ships (retrofit).

#### Technical viewpoint

From a technical point of view, the engine manufacturers agreed that owing to the strong variations in power demand for the dredging cycle and the current absence of appropriate regulations (e.g., class rules for portable LNG tanks on deck), LNG or dual fuel engines are probably not the most suitable options for dredgers.

#### Economic viewpoint

From an economic point of view, the decision is much more complicated for the existing fleet than for the new-built ships: the operating time spent in and out of a SECA affects the period needed to recover the investment (payback period) and, together with the age of the vessel and the state of recovery of past investments, this determines the economic feasibility of the considered solution for SECA compliance.

The payback period of the investment for a new-built also depends on the operating time spent inside a SECA (which is a small fraction of their time for most of the internationally operating dredgers). Moreover, the benefit of switching fuel will greatly depend on the highly volatile price differential between cheaper non-SECA fuel and more expensive SECA compliant fuel (at the bunkering sites) and on the general worldwide availability of the different fuel types for which investments have been made.

#### Policy-making viewpoint

From a policy making point of view, the best solution should deal in a holistic manner with
Moreover, according to the ship owners’ own experiences, the level maturity (“proven technology”) is not as high as the manufacturers claim and the size of the equipment to be installed is huge (not compatible with existing installations on dredgers). Their current experience remains limited and problems have been reported with regards to:

- the actual performance of the scrubber itself (raising doubts about actual compliance),
- its negative impact on fuel consumption (increase of fuel consumption owing to the weight of the scrubber and sometimes to its interaction with the engine),
- its high cost (particularly in retrofitting),
- its residues and waste management.

The various issues at stake (SOx, NOx, PM, ...). This is typically the case when LNG would be used: indeed, SOx and PM emissions are quasi nonexistent while NOx emissions are strongly reduced and CO2 emissions are reduced by 20% (see Figure 4).

Through programmes such as the Trans-European Transport Network (TEN-T) and the Connecting Europe Facility (CEF), Europe is stimulating infrastructure development for distribution of LNG in the TEN-T core network of ports. However these initiatives still have to be implemented. As far as the dredging companies are concerned, their technical versatility to cope with projects demand has resulted in vessels’ geographical working areas needing to be as flexible and large as possible, therefore worldwide. This imposes on these dredging companies the prerequisite that the choice of fuel should not become a limiting factor: i.e., internationally operating dredging companies need to use a fuel available worldwide (Figure 5).

Fuel availability will also depend on the investment decisions of the oil refiners and distributors for which about US$ 30 bn have been identified. Even so, to satisfy the current fuel consumption for shipping in the European SECA’s with compliant fuel, an extra US$ 21 bn need to be invested. This is probably never going to happen in a saturated and receding market such as Europe, competing for investments against the BRIC (Brazil, Russia, India, China) countries.

To date, the most realistic (technical and economic) solution for dredgers operating in a SECA, with regards to primary methods of SOx compliance (0.1%), would be to run on Marine Diesel Oil (MDO).

SECONDARY METHODS FOR SULPHUR EMISSION CONTROL

The secondary methods – removing the pollutant from the exhaust gas – as considered by IMO include dry and wet (sea / fresh water) scrubbers. For some of these the IMO Guidelines, Classification Societies rules and certification are already in place.

Technological solutions

As far as the scrubber manufacturers are concerned, the technological solutions for full compliance to the IMO sulphur regulation exist for ships sailing through or working within SECA’s. Scrubbers can be installed on both new-builts or on existing ships (retrofit). However for the dredging vessels, the suppliers anticipated some specific issues, such as quality of intake water, deck and engine room space, height of installations, engine load variations, which would need to be solved in a joint effort with the dredging companies for effective performance of the scrubbers and SECA compliance.

Technical viewpoint

From a technical point of view, these “existing” solutions have NOT yet been developed for all ship types or for large engine load variations: a development period of up to two years can be necessary (Figure 6).

Moreover, according to the ship owners’ own experiences, the level maturity (“proven technology”) is not as high as the manufacturers claim and the size of the equipment to be installed is huge (not compatible with existing installations on dredgers).

Their current experience remains limited and problems have been reported with regards to:

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- its negative impact on fuel consumption (increase of fuel consumption owing to the weight of the scrubber and sometimes to its interaction with the engine),
- its high cost (particularly in retrofitting),
- its residues and waste management.

Figure 4. Air Emissions Reduction, Gas vs Diesel operations. Gas mode offers IMO compliant operation without any additional after treatment technology.

Figure 5. An added factor when considering fuel and emissions is that dredging vessels work all over the world and often 24/7. Refuelling is an important issue.
The payback period for the new-builts and existing ships depends on the operating time spent inside a SECA (which is a small fraction of their time for most of the dredgers).

Moreover, as a consequence of these factual elements, the investors will be reluctant to provide the necessary financing. For the dredging companies, these issues are even more critical as they compete on the global open market, including SECAs, where increase of costs or reduction of productivity can become deciding factors for the tendering project owners.

**NOx emissions reducing technologies**

The possible NOx emissions reducing technologies include Engine adjustments, Exhaust Gas Recirculation-EGR, Humid Air Motors-HAM/ Direct Water Injection-DWI, Selective Catalytic Reduction-SCR. In general, these technologies are not as demanding as their sulphur equivalent and can be combined. However the NOx implementation date appears to be shifting (from 2016 to 2021) and until the IMO delivers a clear message with a clear deadline, investment decisions in such technology are difficult to make and particularly for the existing fleet.

For the dredgers, the retrofitting of such systems can also create new issues such as concerns about the stability of the ship as a result of the size and weight of the equipment to be placed onboard.

**Economic viewpoint**

From an economic point of view, the decision is complicated for the existing fleet by the following facts:
- investments need to be paid back (payback period),
- operational efficiency is negatively affected by increase of weight and loss of cargo space (payload) and tank space (fuel capacity).

**CONCLUSIONS**

The main issues for the dredgers to comply with the stricter sulphur emission limits inside SECA, are linked to their design and use:
- the space and weight of dredging vessels are optimised (including accommodations, equipment and cargo haul);
- their economic added value is measured in tonnes of transported material;
- their engine loads vary widely; and
- their geographical versatility is an absolute must.

When considering the technological options:
- all solutions (scrubbers; LNG engines / dual fuel) require a lot of space and add significant weight to the ship (sometimes causing concerns about stability);
- they require availability of compliant fuel in or near SECAs (dredging equipment must work worldwide);
- current economic evaluation is based on (quasi-)permanent operations in a SECA (for return on investment; payback);
- they ignore payback on previous investment (e.g., in HFO installations);
- the various retrofit options are still too expensive, not fully mature and not yet optimised for dredging vessels (e.g., with regards to engine load variations);
- they also require extra logistics for reagent and waste management which are not available worldwide (i.e., in all areas where dredging vessels operate).

The decision for the dredgers on which technological solutions to choose is rigged with uncertainty as it will depend on decisions by other players:
- which fuel type(s), in which quantities and at what price will the refiners and distributors provide?
- will the technology suppliers produce mature, compact, cheap installations and suitable for large load variations?
- will the dredger companies’ clients agree to pay more for a “greener” service?
- will the countries / contracting parties to the Convention opt for a legislative exemption for dredging?

Two further points: To date, the most realistic (technical and economical) solution for the dredgers operating in a SECA (0.1% of sulphur), would be to run on Marine Diesel Oil (MDO). Though sustainable solutions are the only option, no inexpensive solution exists.
ABSTRACT

The international emission legislation for the shipping industry has become increasingly stringent in recent years and will become even more stringent in the coming years. Growing environmental awareness and social challenges like air quality, climate change and energy scarcity have resulted in the latest emission legislation as set forth in the IMO (International Maritime Organization) and EPA (US Environmental Protection Agency) regulations. This emission legislation also challenges the dredging industry.

It calls for action from both the dredge operators as well as manufacturers of dredging equipment, since dredging equipment is the source of the emissions. Currently two paths can be recognised in the industry: creating balanced emission legislation on one side and continuing to develop new clean technologies on the other side.

Ideally these paths cannot be seen separately. Adjusting technology to new legislation does not by definition always result in a lower energy consumption and environmental impact. A large contribution can be achieved by better focussing, not only on the emissions per installed kW, but on the total energy consumption per dredging project or per cubic metre (m³) or cubic yard (yd³) of dredged material. This contribution is often not regulated despite its significant influence on the actual impact.

These efficiencies in the dredging project can be reached technically by optimising a dredger as well as by proper operation and project management. This article describes the continuous developments being carried out at IHC Merwede and their potential for addressing the challenges of a clean and lean dredging process in the future. The article first appeared in the Proceedings of the PIANC World Congress in June 2014 and is published here in an adapted version with permission.

INTRODUCTION

The international emission legislation for the shipping industry has become increasingly stringent in recent years and will become even more stringent in the coming years. Growing environmental awareness and social challenges like air quality, climate change and energy scarcity have resulted in the latest emission legislation as set forth in the IMO (International Maritime Organization) and EPA (US Environmental Protection Agency) regulations. This emissions legislation also challenges the dredging industry.

It calls for action from both the dredge operators as well as manufacturers of dredging equipment, since the dredging equipment is the source of the emissions. Currently two paths can be recognised in the industry: creating balanced emissions legislation on one side and continuing to develop new clean technologies on the other side.

1. Creating new legislation: In response to the emissions legislation trends, a number of activities have been initiated, specifically the active involvement in the development of an alternative IMO EEDI (Energy Efficiency Design Index) calculation method for dredging vessels (CO₂ index for vessels). This alternative CO₂ index will better translate the function-related CO₂ emissions of dredging equipment.

2. Finding technological solutions to comply with new regulations: From the innovation perspective, research on emissions
reduction technologies and innovative drive technology is being conducted. This includes research on the applicability of after-treatment technologies as required onboard dredging vessels for emissions compliance with, e.g., IMO Tier III in ECAs (Emission Control Areas) and EPA Tier 4 emission limits for marine engines, starting in 2016.

On the other hand alternative energy sources or energy management systems should be investigated to see if they can create a solution. Research on gas power technology is being carried out at various levels, from the fundamental level of engine modelling to the integration of gas-powered ship designs.

With a focus on development of electric drives, IHC Merwede as a leading shipbuilder has been conducting research on innovative and advanced drive systems. In particular, permanent magnet technology and technical components such as frequency drives, variable speed generators and energy management systems. This will contribute to more efficient drive systems, also when they utilise the design of shore-powered electrical driven dredges. These innovative drives are highly integrated and have extended workability coupled with high efficiency and low emissions.

**LEGISLATION FOR SUSTAINABLE SHIPPING**

Growing environmental awareness and social challenges like air quality, climate change, and energy scarcity have resulted in the latest emissions legislation as set forth in the International IMO and US EPA regulations.

Recent legislation covers the emission of NOx (Nitrogen Oxides), SOx (Sulfur Oxides), THC (Total Hydrocarbons) and PM (Particulate Matter) (Figure 1).

**EU, CCNR and EPA Legislation**

Globally the current emissions legislation is not uniform, but it is converging towards commonly established emission levels. Next to the IMO for sea-going vessels, three different sets of legislation exist that apply to dredging vessels, the European Union (EU), CCNR (Central Commission for Navigation on the Rhine) and US EPA legislation. The three regulations are still being discussed for harmonisation. The limits stipulated by these three are expected to become identical soon. Figures 2 and 3 show a few legislation limits, illustrating the developments in legislation towards lower emissions.

**IMO Energy Efficiency Design Index (EEDI)**

Furthermore, IMO also launched legislation aiming at improving the energy efficiency of marine vessels by addressing the CO2 emissions, called IMO EEDI. The basic formula dictates that the CO2 emission (as a function of fuel consumption) is divided by the vessel tonnage and the sailing speed. This legislation covers a number of vessel types and requires newly built vessels to decrease their CO2 emissions in subsequent steps of 10%, 20% and 30% respectively.

The EEDI will cover all vessel types in the near future.
future. At IMO current discussions are about the formulas and corrections to be used to vessel type and specific situations (e.g., an ice-class vessel should not be disadvantaged and requires special correction factors). The dredging industry is actively taking part in these discussions on future emissions legislation in order to define an alternative CO\(_2\) index for dredging equipment, which will be further discussed below.

However, even were there an alternative CO\(_2\) index for dredging vessels, it is questionable if this would ultimately bring the best solution in reducing CO\(_2\) emissions for these types of vessels. Although a dredger is considered a ship, the purpose of a dredger is not only the transport of material but also its excavation – and a significant part of the vessel's energy consumption is related to this separate and specialised excavation process. The efficiency of an excavation installation is a very complex process dependent on the efficiency of the excavation process itself, the hydraulic transport efficiency, the sedimentation efficiency and so on. On top of this comes the integrated interaction between these processes.

Finally, the efficiency of dredging equipment is still enormously influenced by local circumstances as well as the users (both operators and managers) and legislators. These parameters are difficult to be expressed in rules or targets.

Although the essential role of emissions legislation in the development of cleaner technologies is recognised, this legislation must be defined on a sound basis that can truly lead to more sustainable maritime operations in general and dredging in particular. This is not always the case and the main reasons can be summarised as:

- the isolated and local emissions reduction approach and
- the lack of systems-perspective to tackle this complex issue so far.

Systems thinking originated in the 1980s as the development of science and technology and led to the awareness of the need to approach complex systems in a different manner, including the interconnections existing in them (Checkland, 1981). This article describes this in more detail and suggestions are made for a possible pathway to more sustainable equipment, dredging processes and emissions legislation.

LIMITATIONS OF CURRENT LEGISLATION

From an innovation perspective, research on emissions reduction technologies and innovative drive technology is being conducted. This includes research on the applicability of after-treatment technologies as required onboard dredging vessels for emission compliance with e.g., NOx IMO Tier III in ECAs (Emission Control Areas) and EPA Tier 4 emission limits for marine engines starting in 2016. On the other hand the question can be investigated whether alternative energy sources or alternative
energy management systems create a solution. Research on gas power technology is also being carried out at various levels, from the fundamental level of engine modelling to the integration of gas-powered ship designs.

Emissions legislation tends towards future harmonisation. A few examples are: the CCNR emissions legislation, the strictest of all legislation that applies to new-built inland vessels. It is even more stringent than the IMO legislation, already demanding fuels now with very low sulphur content (0.1% S in European Sea Ports and 0.001% in inland shipping areas).

The NOx + THC (Total Hydrocarbon Content) emission limits for inland waterways are currently ±7.2 g/kWh (EU Stage IIIA and CCNR Stage II). The NOx+THC emission limit in the USA is ±5.8 g/kWh (EPA Tier 3). In 2016 the NOx emission limits will drop to 1.8 g/kWh in the inland waterways of the United States (EPA) and to 0.4 g/kWh on the River Rhine (CCNR).

These current legislation developments call for action from both the dredge operators and manufacturers of dredging equipment, since the dredging equipment is the source of the emissions. Figure 4 shows that the operational phase is responsible for the large majority of the environmental impact as a result of fuel use and emissions.

Manufacturers, such as IHC Merwede, strive continuously to offer their customers advanced and cost effective dredge drive systems and equipment for a more sustainable and clean dredging future. Therefore much effort has been put into developing vessels with minimum fuel consumption and thus, minimum emissions. This is one of the key pillars for sustainable equipment design.

As Figure 4 shows, the effort to minimise fuel consumption appears to be the right focus for dredging situations. To mention a few examples, this focus has resulted in the development of a lower resistance hull design for dredging vessels (resulting in a 20% fuel saving), high efficiency dredge pumps (5% fuel saving) and optimal jet systems (10% higher production). Unfortunately these developments in fuel efficiency are doomed to be slowed down by upcoming legislation, namely, the NOx emission legislation and the IMO EEDI.

**Limitations of the NOx legislation**

The NOx emission legislation dictates a low emission from the exhaust pipe of vessels. This emission reduction can only be solved partly by internal engine modifications. As a result of the lower combustion temperatures imposed, the required reductions of emissions to comply with Tier II were attained to the detriment of lower engine efficiency (about 5%). Further reduction as required to comply with Tier III legislation (which is 80% lower than Tier I), requires a post-combustion treatment system. The SCR technology (Selective Catalytic Reduction) seems to be the best established technology by now. However such a system does not run for free on board vessels. Internal feasibility studies indicate that the lower combustion temperature, additional equipment and increased exhaust back-pressure add up to 10% higher fuel consumption compared to Tier I.

A system-perspective based analysis, a so-called “Life Cycle Impact Assessment” (for more information see Goedkoop et al., 2009), shows that this figuratively and literally end-of-pipe solution has no benefit when the

<table>
<thead>
<tr>
<th>Substance</th>
<th>Compartment</th>
<th>Unit</th>
<th>Heavy Fuel Combustion</th>
<th>Heavy Fuel Combustion + SCR (80% Lower NOx)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Water</td>
<td>mg</td>
<td>3.86</td>
<td>3.86</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>Air</td>
<td>g</td>
<td>1.68</td>
<td>0.34</td>
</tr>
<tr>
<td>Nitrogen, organic bound</td>
<td>Water</td>
<td>mg</td>
<td>13.81</td>
<td>13.81</td>
</tr>
</tbody>
</table>
The NOx reduction at the local vessel exhaust is indeed decreased by 80%. However, as Table I shows, the additional 10% fuel consumption leads to extra emissions in the upper chain as a result of amongst other things, additional oil production, fuel refining and transportation. The emission of NOx is apparently lowered at the vessel location, which is the original aim of this legislation. Nevertheless, in a broader perspective, the NOx emission is higher. As a result, the effect of exhaust gas emissions reduction by using after-treatment technology is the same total exhaust emission plus an additional 10% fossil fuel depletion. Besides, the post-combustion treatment system implies significant investment and operational costs.

The NOx legislation only applies to newly built vessels. When owners have a choice it is expected that areas with additional NOx limits will be served with older and less environmentally friendly dredge units.

A similar situation arises for the SOx reduction by use of scrubbers in the exhaust system. It is clear that this legislation will not lead to a more sustainable situation, neither at local nor on a global level. Furthermore, it will increase the CO2 emissions, which goes against the IMO EEDI legislation.

Limitations of the IMO CO2 index

The recent IMO EEDI legislation has been defined and entered into force for some vessel types and the fuel consumption and benefits to the environment are weighted in the form of a CO2 index. However, the formulas used are too general and only reasonably apply to large ocean-crossing freight vessels. The dredging industry is actively taking part in the discussions about future emissions legislation and defining an alternative CO2 index for dredging equipment. In this index the specific type and operational characteristics of dredging vessels and projects are included. In short, the index is defined in terms of CO2 emissions per m3 or yd3 dredged soil, depth, sailing distance and soil type.

These discussions are still taking place and will hopefully lead to a more appropriate formulation of the emissions legislation for dredging vessels. Legislation for sustainable shipping must consider the whole (eco-) system where humans operate in order to push innovations forward in a beneficial pathway. Therefore, a “systems perspective” (Checkland, 1981) is the right focus – or one will definitely miss important interconnections and only reach local benefits at global higher costs. Natural and also industrial systems are complex and phenomena such as emissions cannot be isolated without leaving out important aspects. By adopting a systems perspective for environmental legislation issues, a sustainable balance among People, Planet and Profit can be better pursued.

Furthermore, emissions to water are also important in dredging. Underwater sound legislation is in development now. Companies like IHC Merwede also contribute actively within the CEDA work group, which published a position paper on underwater sound (CEDA 2011). In addition, research has been carried out on turbidity where IHC Merwede participated in the ‘Building with Nature’ programme and is now developing...
internal knowledge and special equipment to reduce or eliminate undesired turbidity and underwater sound.

TECHNOLOGICAL SOLUTIONS
Proper legislation is one way to push innovation towards sustainability. On the other hand, the industry itself develops and applies clean technology solutions. These developments are not always rewarded in terms of legislation and more in general by the efficiency of the operation of the vessel itself. However, they do contribute significantly to the reduction of emissions per yd³ or m³ dredged. A few examples of recent developments show how innovations can boost the overall efficiency as well as reduce emissions.

Hull design
The shape of the hull influences the wave pattern of the ship which finally influences the energy consumption of a vessel at a given sailing speed. This new bulbous bow design, which reduces wave-making resistance, can be seen in Figure 7. In Figure 8 two sister ships are shown. The only difference between both ships is the shape of the hull. As can be seen in the pictures, the ship on the left has a significant higher bow crest. In practice this resulted in a difference of 20% more fuel consumption during sailing than in the ship with the improved hull shape.

Pump design
Over the past years pump designs have evolved significantly. In the late 1990s a first step was made to increase efficiencies from 80% up to 93%. In practice this leads to an enormous reduction in emissions per m³ or yd³ of dredged material. With modern tools such as CFD, pumps can be optimised to have a good balance between efficiency, sphere passage, but also suction properties (making higher densities possible). An example is the cutter special pump shown in Figure 9, combining these properties.

Efficient excavation tools
In recent years new excavation tools for both hopper dredgers (such as the wild dragon head, Figure 10) as well as the cutter dredgers (Lancelot cutter and dredging wheel, see Figure 11) has increased production rates in designated soil types. This resulted in a lower use of energy in m³ or yd³ dredged material. This cannot be found back in legislation.

Efficient drive trains
Besides the efficiency of the dredge pump, research has also been conducted on innovative and advanced drive systems, considering frequency drives, variable speed generators and energy management systems. These drive systems have each their own energy losses, but together they also create the opportunity to optimise the working points of the total system. This contributes to more efficient drive systems. Even more when it is utilised in the design of shore-powered electrical driven dredges. These innovative drives are highly integrated and have extended workability coupled with high efficiency and low emissions.
Automation
With the introduction of modern drive trains, also a wide range of automation and control systems have been introduced over the past years. Control systems have made it possible to perform relatively complex dredge projects. Interesting examples are the Dynamic Positioning and Dynamic Tracking systems which made highly accurate dredging with hopper dredgers possible. These automation systems also introduced possibilities to reduce fuel consumption as such as production optimisation with Automatic Pump Controllers and Automatic Cutter Controllers.

Alternative fuel sources
Alternative fuels and energy sources also contribute to create solutions. Natural Gas is considered to be a short-term viable alternative to oil-based fuels for the shipping industry. It is plentiful and a relatively cleaner fuel. Research on gas power technology is also being carried out, from the fundamental level of engine modelling to the integration of gas-powered designs for dredging. Longer-term alternatives include hydrogen (Figure 12) and bio-based fuels.

Waste heat recovery and energy management
The possibilities of Waste Heat Recovery (WHR) technologies from the exhaust gasses has also been investigated. About 50% of the energy contained in fuels is lost in the exhaust. WHR systems that have been developed can be integrated in the existing drive trains and contribute to a fuel consumption reduction of 5% to 10%.

Together with Energy Management systems, all the above-mentioned technologies such as advanced drivelines, electric drives, cleaner fuels and waste heat recovery, can add up to significant efficiency improvements and more sustainable dredging operations. This research on the integration of post-combustion exhaust gas treatment systems, such as SCRs and scrubbers, offers clients alternative power management systems.

Emissions to water
Emissions to water have also been addressed over the past years. Equipment suppliers have participated in discussions and measurement campaigns and recently published a joint position paper on underwater sound (CEDA, 2011), low spill equipment such as environmental cutter heads, low turbidity equipment, IHC’s environmental valve and alternative overflow system and advanced design of overflow positioning to optimise settling in the hopper and minimise turbidity emissions through the overflow. Also a selection of alternative hydraulic oils and lubricants that are more environmental friendly was published.

Recently the so-called Waterhammer® has also been developed in which the hydraulic fluid is replaced by seawater. It is also
equipped with a Noise Mitigation that considerably reduces noises and eliminates the risk of oil spills and minimises noise disturbance during foundation laying at sea.

The above-mentioned developments are a selection of new technologies that contribute to cleaner and more sustainable dredging and offshore operations. Although these often require additional financial investments, the return-on-investment is relatively shortened as a result of lower fuel costs and emission fees.

Dredging takes place in a global market and it is important that the legislation supports the development of clean technologies in a level-playing global field. Technology suppliers must contribute their part in technology development and innovation and must actively participate in the development of standards and legislation.

**OPERATION AND PROJECT MANAGEMENT**

A dredge vessel is a typical work-boat in which performance is not only defined by the sailing properties, but also by the use of the dredge equipment and systems as installed onboard. This introduces an additional human influence on the performance of the machine itself. This means emissions in practice cannot be defined by a nominal calculated output but, moreover by the use of dredgers in practice. A competent crew will strive to operate efficiently focussing on both production (and uptime) and cost.

**Training**

One way to enable the crew to get the most out of the dredging vessel is by continuous education. In the field production improvements can be reached by proper training of crew and project management. During simulator trainings on a cutter simulator by the Training Institute for Dredging, operators were shown the impact of their behaviour on both production and fuel consumption simultaneously. This awareness leads not only to the optimisation of the control parameters (such as pump speed, step size, and so on), but also to a more fluent and efficient operation.

As a small example: if a dredge operator can improve the stepping forward handlings with a cutter dredger, this in principle does not influence the nominal production settings such as flow, cutting speed and so forth. But when the operator is able to perform the procedure as fluently as possible and thus reduces this “stepping time”, the overall efficiency can be improved significantly. This awareness is important for operators, but also for the shore-based project management that in the end decides where and how a dredge unit is going to be used. This applies not only to the production rates but also to wear and tear and fuel consumption.

**Legislation**

Finally, the emissions of a dredger are not only defined by the dredging installation, local circumstances and the crew, but also by the legislation itself. Legislation to restrict environmental impacts, such as turbidity and noise, is likely to influence efficiency and emissions.

**CONCLUSIONS**

Legislation is a necessity and is essential to push forward further clean technologies. However, adjusting technology to new legislation does not by definition result in a lower energy consumption and environmental impact. When designing legislation, a system-based perspective approach, where the interconnections of all elements in the industrial and natural systems are taken into account, is the right focus. For dredging, a large contribution can be achieved by focussing not only on the emissions per kW, but on the total energy consumption per dredging project or per m³ or yd³ of dredged material. This contribution is often not regulated but has an enormous influence on the actual sustainability of the dredging process.

A higher sustainability in the dredging project can be reached technically by optimising the dredger as well as by proper operation and project management. Shipbuilders such as IHC Merwede are continuously developing cleaner alternatives and more efficient dredging, mining and offshore applications for addressing the challenges of a clean and lean dredging process in the future. They also actively participate in the development of legislation and standards in order to contribute to a global level-playing balance between technology and sustainability that truly benefits nature and humans.

**REFERENCES**


NEW IADC SAFETY COMMITTEE & CHARTER

ABSTRACT

Safety is a concern of every heavy industry. The members of the International Association of Dredging Companies (IADC) have long recognised this and as individual companies have implemented rules and regulations to reduce accidents and incidents. Complying with ISO standards and other international and national legislation has been the norm, but in recent years safety awareness has heightened. New programmes and systems of ensuring safety and health of employees have been adopted with positive results. To extend this effort, the Board of the IADC decided to establish a Safety Committee. The IADC Safety Committee has recently developed a Charter outlining the committee’s goals, which includes inter-company exchanges of knowledge and experiences and developing shared safety measures on specific safety subjects. The ultimate aim is to spur the industry’s safety record towards continued improvements and zero accidents. The five authors are all members of the new committee.

INTRODUCTION

Awareness of the risks when dredging has long been present. Like other major heavy industries, managing such risks are at the forefront of safety policies. National and international agreements and legislation stipulate safety guidelines and requirements. They issue certificates such as the ISO to monitor that safety measures are implemented properly. Compliance with these international and national standards has long been recognised as a crucial component in realising a successful project.

On the other hand, implementing legislation into clear, consistent safety programmes in a hands-on, daily routine has not always been obvious. Experience has demonstrated that effective safety systems require a great deal of thought, planning and effort. The investments of time and money in achieving high-levels of safety, reducing accidents and injuries, is significant as well as imperative. Simply stated: A dredging operation is only as safe as its weakest link. To reduce accidents, all employees must realise that safety is everybody’s business, every day.

GROWTH OF SAFETY AWARENESS

Attention to safety and investments in safe working procedures benefit all stakeholders. Acknowledging this led the Board of the International Association of Dredging Companies (IADC), in its role as the umbrella organisation for the international private dredging contractors, to institute an annual award amongst its membership in 2007. The goal was to increase safety awareness by honouring a member company, individual project or employees who had shown outstanding achievement in the area of safety.

In the early days of dredging, safety was not always the foremost issue for project managers or employees. Personal protective equipment (PPE) such as hard hats, safety boots and life jackets were available but not consistently used. The use of this equipment was not consistently enforced by employees or management. As the dredging industry became more involved with the oil and gas industry, however, the dredgers were required to comply with the very high standards of the offshore industry. Following a period of working within these standards dredging companies recognised fully the benefits of a safe work environment. The results: the importance and benefit of safe working is now paramount in the policies and practices of the dredging industry.
The industry developed its demands along the lines of engineering, systems and behaviour. First they had a look at dredging equipment and organisational systems. How can the design and use of the equipment contribute to safer working methods and less incidents?

Then safety systems were developed and put into place. People were encouraged to learn from their experiences, positive and negative. Risk and hazard identification and management grew to be normal practice. Reporting and monitoring systems were developed and feedback from these systems was discussed amongst employees in a structured way. Information from these monitoring systems was analysed. This gave rise to specific measures which resulted in a further decrease of ‘lost time injuries’ (LTIs).

Over time it became apparent that this effort was a good beginning but that much more could and should be done.

The next step in the safety efforts at the dredging companies was a behavioural approach. Safety had to become embedded in the genes of the employees. Programmes like NINA (No Injuries, No Accidents) of Boskalis and CHILD (Colleagues, Help Injuries to Leave DEME) and Van Oord’s Work Safe have contributed to motivation and a safer working environment as shown in Figure 1.

**TODAY’S SAFETY MANAGEMENT**

Nowadays safety is a primary motivator for the IADC dredging companies. From top management to crewmembers, everybody understands that they are responsible for a safe environment. When an unsafe situations arises, employees are required to report it, irrespective of their position and the level of the employee. No matter how big or small the job, each and every employee – on board vessels or in the office – has the right to expect that their well-being is foremost in the minds of their employers and their colleagues.

The industry has now achieved a position in which the safety policies of the major international dredging contractors are judged as equal to those requested by the client (Figure 2). But safety is a constant vigil and the formation of the IADC Safety Committee and Charter is the next big step in the ongoing efforts to maintain and improve industry safety.

**IADC HEALTH & SAFETY CHARTER**

To further support the members’ efforts regarding safety, the IADC is now focusing its efforts on establishing a more substantive, permanent programme. In November a year ago, the Safety Committee was formed, with recruits from amongst the member companies. This year as a first concrete step, the committee announced a “Health & Safety Charter” that reads as follows:

The IADC is aware of the risk of the activities in the dredging industry and recognises the will of its members to safeguard their employees and involved parties. The IADC therefore has established a safety committee that enables sharing of best practices amongst its members and active communication thereof.

By maintaining a high level of health and safety IADC members commit themselves to:

- Create a safe and healthy working environment for their employees;
- Comply with all applicable safety and occupational health laws, regulation standards, codes of practice in all countries in which they operate;
The above mentioned commitments aim to reduce the number of accidents and incidents to zero.

On behalf of all IADC members, Split, Croatia 19-9-2014.

New initiatives, based on the concepts in the Charter, are being developed, concepts which define “best practices” in safety and will incorporate many of the features presently found in the safety programmes of the member companies (Figures 3 and 4).

Additionally, the committee will meet quarterly and discuss specific issues such as mooring/unmooring, Explosives, Asbestos, Crew transfer and Bogg down equipment. General incidents will be discussed with the aim of defining specific best practice ideas. This exchange of information and learning from each other’s experiences will raise create new opportunities to continue to improve the safety of all personnel and vessels. (Figure 5).

CONCLUSIONS

The Safety Committee comprises individuals responsible for SHE-Q within the major dredging contractors. It will aim to prepare information for regular publication of “best practices” in Terra et Aqua Journal and on the website of the IADC. As dredging companies frequently work in joint ventures, a harmonisation of specific safety instructions is an important goal and will contribute to a safer working environment. Through these efforts, the committee wants to emphasise to all stakeholders that safety is a top priority and can contribute to effective and efficient execution of maritime infrastructure projects.
CROSS CULTURE WORK: PRACTICES OF COLLABORATION IN THE PANAMA CANAL EXPANSION PROGRAM
BY KAREN SMITS


Anyone who has ever worked on a large-scale project ‘abroad’ knows that you can feel as though you are caught in the Tower of Babel. Not only can languages be a barrier, but cultures, priorities and attitudes toward organisational hierarchies differ from country to country. In addition, megaprojects often result in cost overruns, delays and the general dissatisfaction of all parties involved. To manage these differences in “cross culture” enterprises, project managers are expected to communicate in ways that may not be obvious or routine.

The study of how to implement cross-cultural collaboration methodologies – which lead to better understanding and ultimately more successful outcomes – is the focus of Smits’ book. With a background in Human Resources, the author turned her attention to Organisational Anthropology and the book derives from her PhD dissertation. Her premise is that in today’s world we work more and more in projects where cultural diversity is the norm and yet little attention is spent to the challenges of project management in these multi-cultural situations.

The case study she uses involves the Panama Canal Expansion Programme. Her approach was to examine the daily interactions of the employees and to determine how they react to a complicated work environment. To describe the project organisation she coined the word “collabryrinth”, which reflects the complex practices in cross-cultural work environments. Within the collabryrinth she differentiates between ‘manifest’ practices and ‘concealed’ practices.

In evaluating her observations, she also distinguishes three types of practices during collaboration: “diminishers” are practices that hinder the development of a collaborative relationship; “amplifiers” are practices that are aimed at enhancing collaboration; and “chaperoning” is a practice focussed on guiding, teaching, and supervising novices in the world of project management.

Through this analysis, the author arrives at several practical recommendations to achieve successful collaboration. In our ever more complex global economy employers and employees, clients and contractors are more often than not from different parts of the world representing different cultures. This book offers a valuable guide through the maze of potential misunderstandings rooted in cross-cultural working environments. The ideas expressed here will certainly provide useful support to project managers who are working with cross-cultural teams.

ONLINE AND INTERACTIVE: FACTS ABOUT BACKHOE DREDGERS

Thirty years ago a custom-built backhoe was relatively rare. Backhoe dredgers were frequently used but rather small compared to other dredging vessels. But as dredging operations and projects have expanded, the need for larger backhoe excavators has become obvious. This resulted in modern, custom-designed BHDs with hi-tech instrumentation. These made-to-order backhoes can dig at greater depths and have greater total installed power and therefore can be utilised more extensively and cost-effectively for larger projects. In the last few decades in terms of the total fleet, the number of backhoe dredgers available has risen significantly and the backhoe dredger continues to grow in popularity. This newly released Facts About explains how a BHD works and when it is the best choice for a project.

Facts About is a series of concise, easy-to-read leaflets which give an effective overview of essential facts about specific dredging and maritime construction subjects. Each leaflet provides a kind of ‘management summary’ for stakeholders who need a quick understanding of a particular issue. These leaflets are part of IADC’s on-going effort to support clients, consultants and others in understanding the fundamental principles of dredging and maritime construction because providing effective information to all involved parties is an essential element in achieving a successful dredging project.

TO SUBSCRIBE: To receive email notifications about new releases of the IADC’s Facts About, please fill out the form at the website http://www.iadc-dredging.com/en/84/dredging/facts-about/ under ‘Keep me informed’.

The book is co-published by Next Generation Infrastructures Foundation (NGINFRA) and the Vrije Universiteit Amsterdam, the Netherlands. The Next Generation Infrastructures Foundation represents an international consortium of knowledge institutions, market players and governmental bodies, which joined forces to cope with the challenges faced by today’s and tomorrow’s infrastructure systems. With the strong participation of practitioners with social and engineering scientists, the Foundation seeks to ensure utilisation of the research results by infrastructure policymakers, regulators and the infrastructure industries. A webcast on this topic conducted by the author Karen Smits will become available on the website of the IADC (www.iadc-dredging.com) as from mid-January 2015.

For further information:
http://crossculturework.com and www.nginfra.nl
THE DELFT SAND, CLAY & ROCK CUTTING MODEL
BY SAPE A. MIEDEMA

This major publication in dredging technology gives an overview of cutting theories for the cutting of sand, clay and rock as applied in dredging engineering. In dredging, trenching, (deep-sea) mining, drilling, tunnel boring and many other applications, sand, clay or rock must be excavated. These materials are excavated by a variety of equipment including bucket ladder dredgers, cutter suction dredgers, wheel dredgers, trailing suction hopper dredgers, clamshells, backhoes and other devices. The production rates and thus dimensions of these excavating tools vary considerably depending on conditions and soil.

For the design, the operation and the production estimation of excavating equipment, predicting the cutting forces and powers is important. As well, after excavation, the soil is usually transported hydraulically as a slurry over a short (TSHDs) or a long distance (CSDs) or mechanically. Estimating the pressure losses and determining whether or not a bend will occur in the pipeline is of great importance. Fundamental processes of sedimentation, initiation of motion and erosion of the soil particles determine the transport process and the flow regimes.

To present an overview of cutting theories, the book starts with a generic model, which is valid for all types of soil after which the specifics of dry sand, water-saturated sand, clay, atmospheric rock and hyperbaric rock are covered. For each soil type small blade angles and large blade angles, resulting in a wedge in front of the blade, are discussed. The failure mechanism of sand, dry and water saturated, the so-called Shear Type as well as the failure mechanism of clay, the so-called Flow Type, are considered. Rock will usually fail for instance in a brittle way. Under hyperbaric conditions rock may also fail in a more apparent ductile way according to the Flow Type or Crushed Type of failure mechanism, also called cataclastic failure.

For each case considered, the equations/model for the cutting forces, power and specific energy are given. Known as the Delft Sand, Clay & Rock Cutting Model, the models are verified with laboratory research, mainly at the Delft University of Technology, but also with data from literature. Up-to-date information and high resolution graphs and drawings can be found on the website www.dscrcm.com.

After a brief introduction in Chapter 1, in Chapter 2: Basic Soil Mechanics, the book turns to the Mohr circle and active and passive soil failure. Although basic soil mechanics can be found elsewhere, covering it here makes the reader familiar with the use of the many trigonometric equations and derivations as applied in the cutting theories. A generic cutting theory for small blade angles is derived in Chapter 3. The generic cutting theory takes all the possible forces into account and six types of cutting mechanisms are distinguished; Shear, Flow, Curling, Tear, Crushed and Chip.

In Chapter 4 the question of which generic equation is valid for which type of soil is considered. A matrix is given to enable the reader to determine the terms and soil properties of influence. The following chapters give the 2D theory of soil cutting with small blade angles that will enable the user to determine the cutting forces, powers and production in different types of soil. Chapters 5 and 6 cover dry and saturated sand cutting, Chapter 7 covers clay cutting, Chapter 8 rock cutting in atmospheric conditions and Chapter 9 in hyperbaric conditions. Chapters 10 through 15 address the occurrences of wedges, wedges in dry and saturated sand cutting, in clay cutting and in atmospheric and hyperbaric rock cutting. Chapters 16, 17 and 18 comprise a bibliography, figures, tables and numerous appendices.

The author, Dr. S.A. Miedema, is a well known expert in the field who has long been associated with Delft University of Technology (DUT) and other international academic institutions. He is presently Head of Studies of the MSc programme Offshore & Dredging Engineering and Head of Studies of the MSc programme Marine Technology as well as Associate Professor of Dredging Engineering. He also teaches at several universities in China and Vietnam and at various dredging companies in the Netherlands and the USA.


MASTERPLANS FOR THE DEVELOPMENT OF EXISTING PORTS
BY MARCOM WORKING GROUP 158
€ 150. Illustrated. 230 pp. PIANC.

A masterplan is the key to ensuring future growth of existing ports, with two factors being crucial: how will port operations be organised and how will investments be financed. The report provides guidelines for the preparation and application of port masterplans and examines the latest trends in maritime engineering, port operations and handling equipment. The principal objective of port management is to communicate a “vision” for the port to stakeholders; develop the port in accordance with international and national legislation; integrate economic, engineering, environmental and safety considerations; promote the establishment of functional areas for port facilities and operations; and allow the port to respond to changing technology, cargo trends, regulations and legislation and port competition.

The publication is available at www.pianc.org -> publications http://www.pianc.org/technicalreportsbrowseall.php
II INTERNATIONAL FORUM OF DREDGING COMPANIES
FEBRUARY 19, 2015
ST. REGIS MOSCOW NIKOLSKAYA, MOSCOW, RUSSIA

“PortNews” Media-Group with the assistance of the Ministry of Transport of Russian Federation, in partnership with FSUE “ROSMORPORT” and leading dredging companies is organising an industry-focussed event – II International Forum of Dredging Companies. Working languages are Russian and English. The forum will be a Business platform where customers and dredging companies will be able to interact effectively. The main themes of the Forum:

• State-of-the-art technologies of dredging and land reclamation
• Technical novelties for operations in seaports’ water areas and inland water ways
• Evaluation of Russian ports’ demand for dredging and land reclamation
• Inland waterways of Russia: dredging and hydraulic engineering works as measures to ensure guaranteed dimensions of navigable channels

SEMINAR ON DREDGING AND RECLAMATION
JUNE 22-26, 2015
UNESCO-IHE, DELFT, THE NETHERLANDS

Aimed at (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations that have to execute dredging projects, the International Seminar on Dredging and Reclamation has been organised by the International Association of Dredging Companies (IADC) in various locations since 1993.

Often presented in co-operation with local technical universities, the IADC Seminar has provides a week-long Seminar especially developed for professionals in dredging-related industries. These intensive courses have been successfully presented in The Netherlands, Singapore, Dubai, Argentina, Abu Dhabi, Bahrain and Brazil. As is appropriate to a dynamic industry, the Seminar programme is continually updated. In addition to basic dredging methods, new equipment and state-of-the-art techniques are explained. The Seminars reflect IADC’s commitment to education, to encouraging young people to enter the field of dredging, and to improving knowledge about dredging throughout the world.

Highlights of the programme
To optimise the chances of the successful completion of a project, contracting parties should, from the start, fully understand the requirements of a dredging project. This five-day course strives to provide an understanding through lectures by experts in the field and workshops, partly conducted on-site in order to give the “students” hands-on experience. Subjects include:

• overview of the dredging market and the development of new ports and maintenance of existing ports;
• project phasing (identification, investigation, feasibility studies, design, construction, and maintenance);
• descriptions of types of dredging equipment and boundary conditions for their use;
• state-of-the-art dredging and reclamation techniques including environmental measures;
• site and soil investigations, designing and estimating from the contractor’s view;
• costing of projects and types of contracts such as charter, unit rates, lump sum and risk-sharing agreements;
• design and measurement of dredging and reclamation works; and
• early contractor involvement.

An important feature of the Seminars is a trip to visit a dredging project being executed in the given geographical area. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the extent of a dredging operation.

Each participant receives a set of comprehensive proceedings with an extensive reference list of relevant literature and, at the end of the week, a Certificate of Achievement in recognition of the completion of the coursework. The Seminar starts Monday, June 22 at 8:45 hrs and ends Friday, June 26 (date to be confirmed) at 17:30 hrs. Please note that full attendance is required for obtaining the Certificate of Achievement.

Costs
The fee for the week-long seminar is € 3,100.- (inclusive VAT). The fee includes all tuition, seminar proceedings, workshops and a special participants’ dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation can be given.

The IADC Seminar will be held at UNESCO-IHE, Delft, The Netherlands in June. A similar Seminar is planned for October 2015 in Jakarta, Indonesia.

For further information contact:
Mr. Jurgen Dhollander
PR & Project Manager
International Association of Dredging Companies
Email: dhollander@iadc-dredging.com
Tel: + 31 70 352 33 34
• Legislative innovations related to organisation of dredging
• Environmental aspects of dredging and land reclamation

Participants include the Ministry of Transport of Russian Federation, the Ministry of Natural Resources of Russian Federation, FSUE Rosmorport, dredging companies, designers, stevedoring companies, shipbuilders, port authorities, Association of Commercial Sea Ports, International association of dredging companies. The event is supported by Association of Commercial Sea Ports and International Association of Dredging Companies. The general sponsor is Van Oord, and in addition DAMEN and Jan de Nul.

The St. Regis Moscow Nikolskaya offers an accommodation discount provided you register for the Forum before January 26, 2015. A room of superior category can be booked at a special price of RUB 8,500 per day (+18% VAT, breakfast excluded).

For further information to register and book hotel please contact:
Elena Snitko
• Email: snitko@portnews.ru
Tel: +7 812 570 78 03

IAPH HAMBURG 2015
29TH WORLD PORTS CONFERENCE
JUNE 1-5, 2015
CONGRESS CENTER HAMBURG (CCH), GERMANY

The 29th IAPH World Ports Conference will take place under the theme of “smartPORT Hamburg”. The following subjects are being addressed:
- smartPORT logistics: technical innovations, land restructuring, expansion of the transport route network and modern communication paths combined with high data transparency
- smartPORT energy: innovative mobility concepts, renewable energy sources and the interlinking of energy-generating plants and consumer plants to promote the efficient use of resources
- Law and global trade: trends, challenges and the advantages of global technical standardisation vs national legal systems
- Liability in ports: evaluating if the international maritime convention system is sufficient to protect ports in the event of shipping accidents and other maritime incidents and if the currently ratified conventions and the liability sums contained therein provide sufficient coverage
- Port financing and pricing in different countries: between theory and practice, examining public-policy discussions, the role of stakeholders and long-term and project-related financing models
- Cruise Shipping: meeting the challenges of the phenomenal growth of the cruise industry.

For further information:
Mrs Sabine Stüben
Tel: +49 40 42847-2208
• E-mail: sabine.stueben@hpa.hamburg.de

Mr Christian Pieper
Tel: +49 40 42847-2622
• E-mail: christian.pieper@hpa.hamburg.de

WEDA/TAMU DREDGING SUMMIT AND EXPO
JUNE 22-25, 2015
WESTIN GALLERIA HOUSTON, TEXAS

The Western Dredging Association (WEDA) and Texas A & M University will host its 2015 Dredging Summit and Expo June 22-25, 2015 at the Westin Galleria Houston, Texas. This is a chance to visit the Houston Ship Channel – one of the busiest waterways in the United States, in addition to the environmental restoration projects in Galveston Bay.
The theme of this year’s conference, “Dredgers, The Environment and Commerce,” will focus on the people and organisations that make dredging happen as well as the environmental and commercial impacts of dredging. Included in the dredging conversations will be the critical economic need for dredging, the importance of enhancing the marine environment, trends in dredging technology and safety and historical dredging developments.

For additional information, including conference registration, exhibition booths reservations & sponsorships contact:
• Email: info@westerndredging.org
https://westerndredging.org/index.php/events/dredging-summit-expo

CALL FOR PAPERS
9TH INTERNATIONAL SEDNET CONFERENCE
SEPTEMBER 23-26, 2015
KRAKOW, POLAND

This is the First Announcement and Call for Abstracts for the annual SedNet Conference which will be hosted and co-organised by the Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology.

Sediments – unseen or unnoticed most of the time – have a variety of impacts on human activities and vice versa, particularly along rivers. If the river is used for shipping, too much sediment may become an obstacle. The foundations of bridges may become unstable if too little sediment is available, creating a safety risk. After flooding, sediments are distributed over flood plains and with increased construction in natural flood plains these sediments add to the clean-up efforts and may become a health issue if contaminated. Even more dangerous are the mud and debris flows that can occur during larger floods. SedNet is dedicated to solving societal challenges as regards working with sediments. Therefore at the core of the SedNet conference will be the link between sediment and society and the exchange of knowledge and experiences on an international level.
Call for Abstracts
SedNet would be pleased to receive abstracts for oral or poster presentation, addressing one or more of the following topics:
- Sediments and society
- Valuing sediments and their services
- Sediment quality and perception
- Understanding sediment fluxes and budgets on a river basin scale
- Restoring sediment continuity (WFD)
- Best practices in sediment management
- Dredged material management in rivers and lakes
- Building with dredged material
- Sediment management in mountainous regions
- Sediment in historical and recent mining areas
- Sediment issues in Poland

Abstracts on these topics will preferably point out the link between society and sediments and relate to its ecosystem functions. Also process-related studies of sediment transport and budget in rivers are welcome that help to understand the sediment-water-soil system. The meaning of effect-oriented research will be a topic as well as the identification of future challenges and perspectives. Abstracts will be selected by the SedNet Steering Group either for platform presentation or for poster presentation. Deadline for submission of abstracts is January 15, 2015.

For the template for submission of abstracts to the SedNet Secretariat please see: www.sednet.org

For further information contact:
Marjan Euser
• Email: marjan.euser@deltares.nl

PIANC USA/COPRI/ASCE DREDGING 2015
OCTOBER 19-22, 2015
HYATT REGENCY, SAVANNAH, GEORGIA

The PIANC USA and the Coasts, Oceans, Ports & Rivers Institute (COPRI / ASCE) Dredging 2015 Conference with the theme “Moving and Managing Sediments” will take place on the riverfront in Savannah, Georgia, October 19-22, 2015, in the Downtown Historic District. The format will include plenary sessions, concurrent technical sessions, short courses, tours, and a large industry exhibit hall.

Abstracts should be submitted in January 2015.

For further information:
Ms. Kelly J. Barnes
PIANC USA Deputy Secretary
USACE, Institute for Water Resources
• Email: Kelly.J.Barnes@usace.army.mil
Tel: +1 703 428-9090
LinkedIn Profile: http://www.linkedin.com/in/kellyjbarnes
http://goo.gl/Z8wlc "Securing the Nation’s Future through Water"
www.pianc.us

CEDA DREDGING DAYS 2015
NOVEMBER 5-6 2015
AHOY ROTTERDAM, THE NETHERLANDS,

CEDA Dredging Days 2015, once again to be held in conjunction with Europort 2015, will address ”Innovative Dredging Solutions for Ports. The organisers are now inviting abstract submissions on this theme from experts in the field. Dredging and the management of sediments are key elements in the sustainable development and operation of most ports. A growing call for ports to become greener, more environmentally aware and more responsible with regard to operations has resulted in the demand for more innovative and cost-effective solutions that meet environmental objectives and offer opportunities for enhancing or creating natural ecosystems around the port. Achieving this will need advanced dredging technology and a thorough understanding of the natural processes around ports including the effects of climate change.

The necessity for more sustainable processes has led to the event’s focus on innovative dredging solutions for ports where the latest technical and scientific developments will be presented. In addition, CEDA Dredging Days 2015 will cover best practices relating to maintenance and capital dredging in ports and access channels, and the management of sediments including the sediment balance of the broader port environment.

CEDA Dredging Days 2015 will include a special Academic Session designed to give young dredging professionals the opportunity to present papers on any dredging subject. In addition, the International Association of Dredging Companies (IADC) will grant its Best Paper Award for a Young Author 35 years of age or under.

Experts working in port authorities, institutions, universities, engineering consultants, government agencies, dredging contractors and manufacturers are invited to submit abstracts by January 7, 2015. The Technical Papers and Programme Committee is particularly interested in papers presenting novel solutions and approaches leading to and/or demonstrating win-win solutions that meet the objectives of the port developer/operator and environmental stakeholders.

All papers will be peer-reviewed and published in the conference proceedings. Details on conference topics and how to submit an abstract are available on the conference website.

For further information:
• http://www.cedaconferences.org/dredgingdays2015
### AFRICA
- **BKI Egypt** for Marine Contracting Works S.A.E., Cairo, Egypt
- **Dredging and Reclamation Jan De Nul Ltd.**, Lagos, Nigeria
- **Dredging International Services Nigeria Ltd.**, Ikoyi Lagos, Nigeria
- **Nigerian Westminster Dredging and Marine Ltd.**, Lagos, Nigeria
- **Van Oord Nigeria Ltd.**, Victoria Island, Nigeria
- **Van Oord (Shanghai) Dredging Co. Ltd.**, Shanghai, PR China
- **Van Oord (Malaysia) Sdn Bhd**, Selangor, Malaysia
- **PT Van Oord Indonesia**, Jakarta, Indonesia
- **P.T. Boskalis International Indonesia**, Jakarta, Indonesia
- **Jan De Nul Dredging India Pvt. Ltd.**, India
- **Jan De Nul Dredging India Pvt. Ltd.**, Singapore
- **Jan De Nul Singapore Pte. Ltd.**, Singapore
- **P.T. Boskalis International Indonesia**, Jakarta, Indonesia
- **Toa Corporation**, Tokyo, Japan
- **Van Oord (Malaysia) Sdn Bhd**, Selangor, Malaysia
- **Van Oord (Shanghai) Dredging Co. Ltd.**, Shanghai, PR China
- **Van Oord Dredging and Marine Contractors bv Hong Kong Branch**, Hong Kong, PR China
- **Van Oord Dredging and Marine Contractors bv Korea Branch**, Busan, Republic of Korea
- **Van Oord Dredging and Marine Contractors by Philippines Branch**, Manila, Philippines
- **Van Oord Dredging and Marine Contractors bv Singapore Branch**, Singapore
- **Van Oord India Pte Ltd.**, Mumbai, India
- **Van Oord Thai Ltd.**, Bangkok, Thailand
- **Zinkcon Marine Singapore Pte. Ltd.**, Singapore

### AUSTRALIA + NEW ZEALAND
- **Boskalis Australia Pty. Ltd.**, Sydney, Australia
- **Dredging International (Australia) Pty. Ltd.**, Brisbane, QLD, Australia
- **Jan De Nul Australia Ltd.**, Australia
- **NZ Dredging & General Contracting Ltd.**, Maunganui, New Zealand
- **Van Oord Australia Pty. Ltd.**, Brisbane, QLD, Australia
- **WA Shell Sands Pty Ltd.**, Perth, Australia

### EUROPE
- **Atlantique Dragage Sarl**, St. Germain en Laye, France
- **Baggermaatschappij Boskalis B.V.**, Papendrecht, Netherlands
- **Baggerwerken Decloedt & Zoon NV**, Oostende, Belgium
- **Ballast Ham Dredging**, St. Petersburg, Russia
- **Baltic Marine Contractors SIA**, Riga, Latvia
- **BSKW Dredging & Contracting Ltd.**, Cyprus
- **Boskalis International B.V.**, Papendrecht, Netherlands
- **Boskalis Italia Srl.**, Rome, Italy
- **Boskalis Nederland B.V.**, Rotterdam, Netherlands
- **Boskalis Offshore Subsea Contracting B.V.**, Papendrecht, Netherlands
- **Boskalis Sweden AB**, Gothenburg, Sweden
- **Boskalis Westminster Ltd.**, Fareham, UK
- **Boskalis Westminster Middle East Ltd.**, Limassol, Cyprus
- **Boskalis Westminster Shipping BV**, Papendrecht, Netherlands
- **BW Marine (Cyprus) Ltd.**, Limassol, Cyprus
- **DEME Building Materials NV (DBM)**, Zwijndrecht, Belgium
- **Dragapor Dragagens de Portugal S.A.**, Alcochete, Portugal
- **Dravo SA**, Italia, Amelia (TR), Italy
- **Dravo SA**, Lisbon, Portugal
- **Dravo SA**, Madrid, Spain
- **Dredging and Contracting Rotterdam b.v.**, Bergen op Zoom, Netherlands
- **Dredging and Maritime Management sa**, Steinfort, Luxembourg
- **Dredging International (Luxembourg) SA**, Luxembourg, Luxembourg
- **Dredging International (UK) Ltd.**, East Grinstead, UK
- **Dredging International N.V.**, Zwijndrecht, Belgium
- **Heinrich Hirdes G.m.b.H.**, Hamburg, Germany
- **Irish Dredging Company Ltd.**, Cork, Ireland
- **Jan De Nul (UK) Ltd.**, Ascot, UK
- **Jan De Nul n.v.**, Hofstade/Aalst, Belgium
- **Mijnster Zand- en Grinthenbal bv**, Gorinchem, Netherlands
- **Nordsee Nassbagger-und Tiefbau GmbH**, Bremen, Germany
- **Paans Van Oord B.V.**, Gorinchem, Netherlands
- **Rock Fall Company Ltd.**, Aberdeen, UK
- **Rohde Nielsen**, Copenhagen, Denmark
- **Sociedad Espanola de Dragados S.A.**, Madrid, Spain
- **Société de Dragage International 'SIDA' SA**, Lambersart, France
- **Sodraco International S.A.S.**, Lille, France
- **Sodranord S.A.R.L.**, Le Blanc-Mesnil Cédex, France
- **Terramare Esti OÜ**, Tallinn, Estonia
- **Terramare Oy**, Helsinki, Finland
- **Tideway B.V.**, Breda, Netherlands
- **TOA (LUX) S.A.**, Luxembourg, Luxembourg
- **Van Oord (Gibraltar) Ltd.**, Gibraltar
- **Van Oord ACZ Marine Contractors bv, Rotterdam, Netherlands**
- **Van Oord Deutschland GmbH**, Bremen, Germany
- **Van Oord Ireland Ltd.**, Dublin, Ireland
- **Van Oord Middle East Ltd.**, Nicosia, Cyprus
- **Van Oord Nederland bv, Gorinchem, Netherlands**
- **Van Oord nv, Rotterdam, Netherlands**
- **Van Oord Offshore bv, Gorinchem, Netherlands**
- **Van Oord UK Ltd.**, Newbury, UK

### MIDDLE EAST
- **Boskalis Westminster (Oman) LLC**, Muscat, Oman
- **Boskalis Westminster Al Rusaid Co. Ltd.**, Al Khobar, Saudi Arabia
- **Boskalis Westminster Middle East Ltd.**, Manama, Bahrain
- **Gulf Cobia (Limited Liability Company)**, Dubai, UAE
- **Jan De Nul Dredging Ltd. (Dubai Branch)**, Dubai, UAE
- **Middle East Dredging Company (MEXCO)**, Doha, Qatar
- **National Marine Dredging Company**, Abu Dhabi, UAE
- **Van Oord Gulf FZE**, Dubai, UAE

### THE AMERICAS
- **Boskalis International bv Suncor Argentina**, Buenos Aires, Argentina
- **Boskalis International Uruguay S.A.**, Montevideo, Uruguay
- **Boskalis Panama SA**, Panama City, Panama
- **Compania Sud Americana de Dragados S.A.**, Buenos Aires, Argentina
- **Dragabras Servicos de Dragagem Ltda.**, Brazil
- **Drimagex SA de CV**, Mexico City, Mexico
- **Dravensa C.A.**, Caracas, Venezuela
- **Dredging International de Panama SA**, Panama
- **Dredging International Mexico SA de CV, Veracruz, Mexico**
- **Jan De Nul do Brasil Dragagem Ltda.**, Brazil
- **Mexicana de Dragados S.A. de C.V.**, Mexico City, Mexico
- **Stuyvesant Dredging Company**, Louisiana, USA
- **Van Oord Colombia S.A.S.**, Bogota, Colombia
- **Van Oord Curaçao n.v., Willemstad, Curaçao**
- **Van Oord de Mexico, S.A. de C.V.**, Mexico City, Mexico
- **Van Oord Dragagens do Brasil Ltd., Rio de Janeiro, Brazil**
- **Van Oord Marine Contractors Canada Ltd.**, Ontario, Canada
- **Westminster Dredging (Overseas) Ltd.**, Trinidad

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