Dry Bulk Cargoes and the Impact on Air Pollution in Ports

A PEMA Information Paper

The purpose of this information paper is to assist readers to understand the issues associated with the handling of dry bulk materials in port environments in terms of the pollution generated and what technologies and solutions are available to port operators to reduce the pollution impact.

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1. EXECUTIVE SUMMARY

The purpose of this article is to help readers understand the issues associated with the handling of dry bulk materials in port environments in terms of the pollution generated and to inform them of what technologies and solutions are available to port operators to improve the situation.

Many dry bulk commodities are prone to spillage and can generate dust pollution, posing issues for ports that will become more and more prevalent due to the ever-tightening of pollution guidelines, regulations, and laws. This is particularly of concern for low volume operators that work infrequently or seasonally and who will not readily be able to invest in significant infrastructure like those operators and ports that have a continual throughput.

Ports handling dry bulk need to consider the vast differences between handling containers and the issues faced with dry bulk goods.

2. INTRODUCTION

2.1 THE ISSUE

Pollution in port environments comes in many forms and from many sources. The focus of this article is the pollution generated by the import and export of dry bulk cargoes in port environments.

At the outset, however, it must be highlighted that the main pollution generated as a result of port/cargo operations is through the combustion of fuels to power ships, port vehicles, and from the generation of port power.

Shipping vessels engines run on heavy fuel oil. Heavy fuel oil is much cheaper than the petrol/diesel used for inland transportation but has a higher polluting impact. As an example, the Sulphur Dioxide content of Heavy Fuel Oil is 2700 times higher than that of road fuel. In addition to ships, ports operate a vast array of diesel-powered machinery: RTGs, Straddle carriers, Terminal tractors, Reach-stackers, Mobile cranes, etc. Diesel-powered engines result in elevated emissions of various pollutants. Added to the shipping emissions this makes port activities a significant net contributor to pollution in the vicinity of ports globally.

The various Nitrous Oxides (NOx), Sulphur Oxides (SOx), and Volatile Organic Compounds (VOC) released by internal combustion engines or through power generation are addressed in great detail in various articles and have been the subject of many studies. Furthermore, diesel engines are noisy this being another form of environmental pollution.

The International Maritime Organisation (IMO) is working continuously on countermeasures to mitigate the air pollutants emitted from ships in terms of exhaust emissions mentioned above with these measures being applied globally and having a positive effect.

The focus of this article is on the pollution generated by the import and export of dry bulk cargoes in port environments.

Port pollution causes an array of environmental impacts which can seriously affect the health of workers and contributes significantly to regional air and water pollution. Reducing pollution from ships and ports is a top priority for many governments. Such initiatives can however incur significant costs and are often politically challenging. In many cases, ports are located close to large population centres or close to areas of natural beauty/conservation which results in a conflict between industrial activity and the environment.

In addition to causing water and air pollution, the handling of bulk materials in a port setting can also result in cross-contamination between different products within a port. This occurs when the storage and handling systems employed are inadequate, impacting product quality and usability – no one wants cement clinker in their sugar!

2.2 DRY BULK DUST

Typical bulk cargoes in ports include cereals, animal foodstuffs, mineral ores, coal and coke, cement, biomass, phosphate, and other fertilisers. Handling these cargoes can create large quantities of dust. In some cases, e.g. coal and aggregates, the dust is simply small particles of the material itself. In other cases, e.g. grains and pulses, the dust may include contaminants such as bacteria and fungi. Handling materials from the vessel holds through the port to storage and from storage into a ship's hold or trans-shipping from one vessel to another will generate dust. Every change in energy applied to the bulk material will generate dust whether this is via crosswind to exposed material, material falling (from a front-end loader for example), or processing materials. Control of dust generation should therefore be the primary aim when reducing pollution in ports from dry bulk cargo.

Six main parameters influence dust generation when handling bulk materials:

- Falling distance: The vertical distance between the material discharge point and the material pile.
- Loading rate: The speed and quantity of the material being loaded within a given timeframe.
- Environmental considerations: These include rain, wind, and other conditions.
- Type of transport: These include enclosed or open trucks and railcars, barges, and ships.
- Material Properties: Moisture content and particle geometry
- Loading/Unloading technique: Equipment used in the process

Material properties have a large impact on how dusty material is and how polluting it can be. Dry materials have a greater propensity to be dusty (cement for example) whereas some mineral ores or mined products can contain an amount of moisture that inhibits dust generation when handling.

2.3 THE EFFECTS

Different dust types have different adverse effects on health but the most serious effect of dusty cargoes is on the respiratory system of humans (and animals). Some of these dusts (including grain and soya) can be the cause of occupational asthma. Other dust types may cause chronic obstructive pulmonary disease (COPD).

In addition to health implications, dust can also cause environmental issues and damage to the local animal and plant life.

Under certain conditions, the dust associated with some cargoes may form an explosive and/or flammable mixture with air. Examples include sugar, coal, wood, grain, certain metals, many synthetic organic chemicals, and fertiliser products. The latter was highlighted in the port explosion of 2020 in Lebanon.

Ports need to consider controlling dust as far as possible to help future proof themselves against current and forthcoming legislation. Considerations should include:

- Prevention and minimised exposure of port personnel and other port users to dust
- Avoid dust-related environmental harm or environmental nuisance, including contaminating surrounding locales
- Not adversely impacting the visual amenity of third parties
- Not contaminating the products of other port users
- Not restricting operational navigation and shipping visibility in extreme situations
- Not reducing the useful life of buildings, structures, property, and materials
- Compliance with all applicable legal and other local requirements

3. PROBLEMS FACED BY PORTS

3.1 HISTORICAL

Many ports of all sizes around the world are old with antiquated or natural infrastructure rather than purpose-built facilities. These natural features have the potential to make older ports unsuitable for modern logistic practices resulting in the inability to control material handling in a manner deemed necessary for reducing dust pollution. Ports also tend to be situated close to raw material sources where not all such materials are of a commodity value where extensive investment in infrastructure is viable without legislation and political will. Ports typically are close to large population centres and certainly not “out of sight, out of mind” in terms of their visibility. How for example do you hide a Handysize bulk carrier whereby the general population will be able to see pollution activities and feel its effects being so close to the source? In addition to being located near to urban populations, some ports are also located close to tourist resorts with industrial activity and tourism not being good bedfellows for obvious reasons.

3.2 STRUCTURAL AND OPERATIONAL

Many existing ports are limited by way of construction detail and infrastructure as they were designed and built with different usage in mind than is currently the case. Many older quays have a low load capacity limit (equipment weight), are in a poor state of repair, and are typically small in size and inefficient. This situation conflicts with the current practice where berthing fees and demurrage have cost considerations that have to be minimised to make the logistics economically viable. Such a requirement results in the need for quicker loading/unloading where the throughput of the material handling equipment increases. This in turn requires larger handling equipment in terms of space and weight and requires the upgrading of some existing quays/ports if they are to remain viable for such activity.

3.3 ECONOMICS

When considering port operators' economics, there is an increased need for ports to be multi-purpose, multi-product, and flexible in respect of materials handled. Adapting to these logistics requirements is challenging for an existing port with operators reluctant to commit to large infrastructure investments without the backup of long-term contracts to financially support such investment. Mobile equipment suited to handling multiple products has become the preferred solution. The adaptability of such equipment allows ports to invest while retaining a certain amount of flexibility. Being mobile these are assets with a greater potential re-sale value than fixed installations. Financial considerations are typically the driving force behind any decision to invest in or upgrade a port. All operators want a tangible benefit or return on any investment as clearly if there is no economic case to invest then operators will not do so.

3.3.1 EQUIPMENT

The handling of dry bulk materials generates significant amounts of dust where proper control measures are not employed. If dust generation is left unchecked, dust accumulation on equipment has an adverse impact on its performance and increases wear and tear. If equipment is not maintained in the peak condition required for efficient operation this invariably results in greater costs due to component failure, downtime, and longer maintenance periods.

3.3.2 WASTAGE

The absence of dust control also reduces yields, dust results in lost product and lost money. In the author's experience, a loss of 0.5% per day as a percentage of the overall capacity gives a realistic idea of the quantum. (Ref: data from a cement grinding plant importing raw materials using crane grabs). This figure has been used as a method of calculating the return on investment by operators when evaluating technology comparing the benefits of applying dust control versus no dust control measures when loading or unloading vessels. This cost-benefit evaluation does not consider the fact that legislation may require an operator to utilize dust control measures nor the value of the commodity being handled.

3.3.3 FLEXIBILITY

Bulk handling ports also have to be flexible in respect of current and future product demands. The volatile nature of global trade means that operators need to be adaptable and able to handle different products. This adaptability however usually conflicts with the application of efficient environmentally friendly equipment. Most material handling equipment types are typically designed specifically for the application and the material handled. Adaptability for the handling of other products can be expensive and hard to achieve unless planned for.

3.3.4 UPSTREAM/DOWNSTREAM CONSIDERATIONS

A further economic factor to consider is the trend towards the use of biomass materials for power generation. All renewable energy power stations are under increasing pressure in respect of emission monitoring. This will extend back the supply chain to the forestry companies through to bulk ports and to the generating station itself.

Most multi-product ports are typically situated away from the process plant where the material comes from and goes to. This transportation required increases the amount of handling needed thereby increasing the dust generated. Additional transport using inefficient transport methods such as trucks also contributes to fuel-related emissions.

In summary, a holistic view must be taken with a view on upstream and downstream handling with all factors in a project being be considered. This will ensure that the most cost-effective and environmentally friendly transport and shipping methods are applied to maximise overall efficiency.

4. HEALTH AND ENVIRONMENTAL

4.1 DUST POLLUTION

The main consideration for dust pollution reduction is the benefits for health and the environment in the local area and the world in general. There are many examples of pollution originating on one side of the world where the pollutants make their way to the other side of the world via air or sea currents.

The World Health Organisation (WHO) has produced air quality guidelines dealing with pollutants such as Nitrogen Dioxide, Sulphur Dioxide, Ozone, and particulate matter (PM) suspended in the air. A WHO assessment suggests that 2 million people die every year prematurely from air pollution, with over 50% of these deaths occurring in developing countries. These stark figures do not include any quantification of the environmental damage that also occurs due to such pollution.

The risks from pollution to health are well known, many of the diseases associated with pollution involve the respiration of particles and their subsequent entry into the bloodstream.

Ultrafine particles are those with a mean diameter of less than 0.1 microns. This particle size can easily enter the bloodstream of humans (and animals) via the lungs. Fig 1 shows how particles of different sizes are dealt with by the human respiratory system. It should be noted that larger particles are dealt with by the respiratory system's natural defences.

Figure 1

4.2 OTHER POLLUTANTS

There are other forms of pollution that ports produce that can have adverse effects on health and wellbeing. These include noise and light pollution. Many countries have already dealt with these issues through reduced working hours, the reduction of night working, anti-glare lighting, and limiting noise by attenuation. Other health pollution risks are associated with water pollution, runoff, and spillages. Therefore airborne dust is only one factor to consider.

5. REGULATIONS

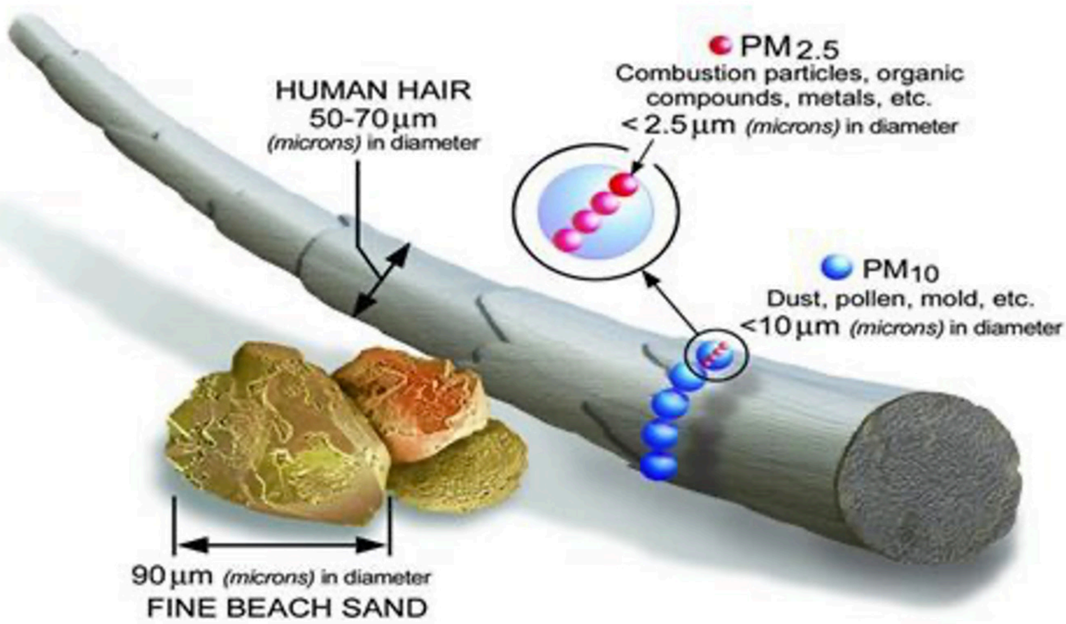
5.1 HARMONISATION

The lack of globally harmonised regulations in respect of air pollution from the movement of dry bulk solids is hampering efforts to reduce pollution in and around ports. While many countries have committed to reducing air pollution and have succeeded to some extent, the lack of a common consensus is holding back efforts on a global basis. Pollution generated in one place can have an effect thousands of miles away. Without political will on both local and international levels, a common consensus, and strictly enforced regulations, this global disparity will continue.

Matters are however improving in this respect with countries around the world looking to draft and implement their own regulations, rules, and financial incentives. Understanding and application of any regulations need to be fully appreciated by all stakeholders. Many governments are applying WHO guidelines without understanding fully how they apply, particularly to ports with bulk handling operations.

5.2 GUIDELINES

Using WHO PM10 as an example, the guidelines suggest that the 24-hour mean concentration of 10 microns (µm) diameter particles, or smaller, is limited to 50µg/m3 (or an annualised mean of 20µg/m3). To provide some context, fine beach sand particles are 90 microns in diameter and a human hair is approx. 50-70 microns in diameter. Suffice to say, any PM particle is not visible to the human eye. PM is also not solely focused on dust or solid particles, liquids and aerosols are also measured. Simple extrapolation of these figures with a view to the bulk product being handled suggests these figures are very low in terms of dust generated. Consideration must be given to the fact that PM measures all particulate matter while a considerable proportion of PM is naturally produced in and around ports, sea sprays, and plant pollen being two big contributors. This PM criterion results in more and more stringent requirements for equipment to meet the regulations. Port operators considering infrastructure changes or new equipment should fully understand what they are trying to achieve and the application in their unique circumstances.



Some good news for port operators in terms of compliance is the fact that many bulk materials have larger dust particles than those of most concern (sub 10 microns). While still a pollutant, a particle of 100-micron diameter can be effectively dealt with by the human bodies' natural defences and expelled rather than getting into the bloodstream. However, these particles are still pollutants and can cause lasting damage to health and the environment.

Many countries are now looking at options to provide financial stimuli to polluters to reduce emissions. These include tax breaks for those whose efforts have provided tangible pollution reduction.

5.3 PARTICULATE MATTER DATA

The common practice of using PM as a measure for pollution control equipment performance is a misnomer as no equipment within a realistic budget is capable of controlling the whole environment to these low levels. Therefore equipment needs to be measured against a known baseline or reference level to accurately quantify its effectiveness.

To help better explain PM and its application data below is taken from a 2020 study of pollution in Busan Port, South Korea. The image Fig. 2 provides a graph showing the total amount of air pollutant emissions in Busan Metropolitan City in 2016 related to port activities. In total, 49,468 tons of NOx were emitted, followed by 40,899 tons of VOCs, 23,388 tons of Carbon Monoxide, 10,777 tons of SOx, 6,903 tons of PM10 classed particulate matter, 2,544 tons of PM2.5 classed matter, and 1,744 tons of ammonia.

The graph clearly illustrates that PM accounts for a low portion, approximately 7%, of the total air pollutants. Although the portion of PM is small, its effects can be great on the weather, health, and the environment with PM likely to include heavy metals and other toxic substances.

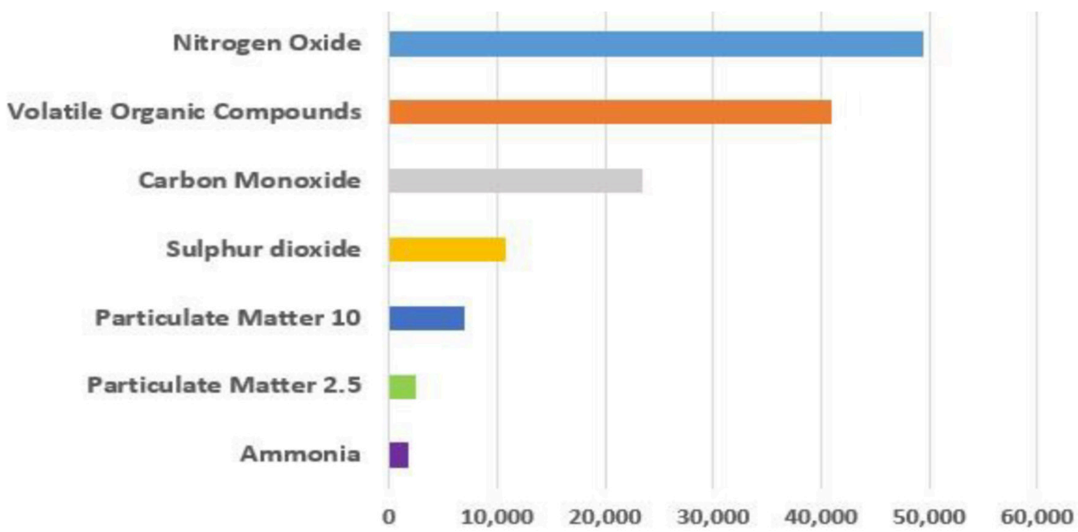


Figure 2

Other studies on port activities relating to pollution suggest handling of cement clinker increases local PM10 concentrations by 23% to 53% when minimal pollution prevention is employed.

The same study at Busan Port, the primary port in South Korea, showed that the port and surrounding industries were designated as one of the global top 10 port areas emitting ultra-fine particles, i.e. those particles with a diameter less than 0.1 micron. The below heat map Fig 3 shows where ultrafine particle concentrations are highest around the world.

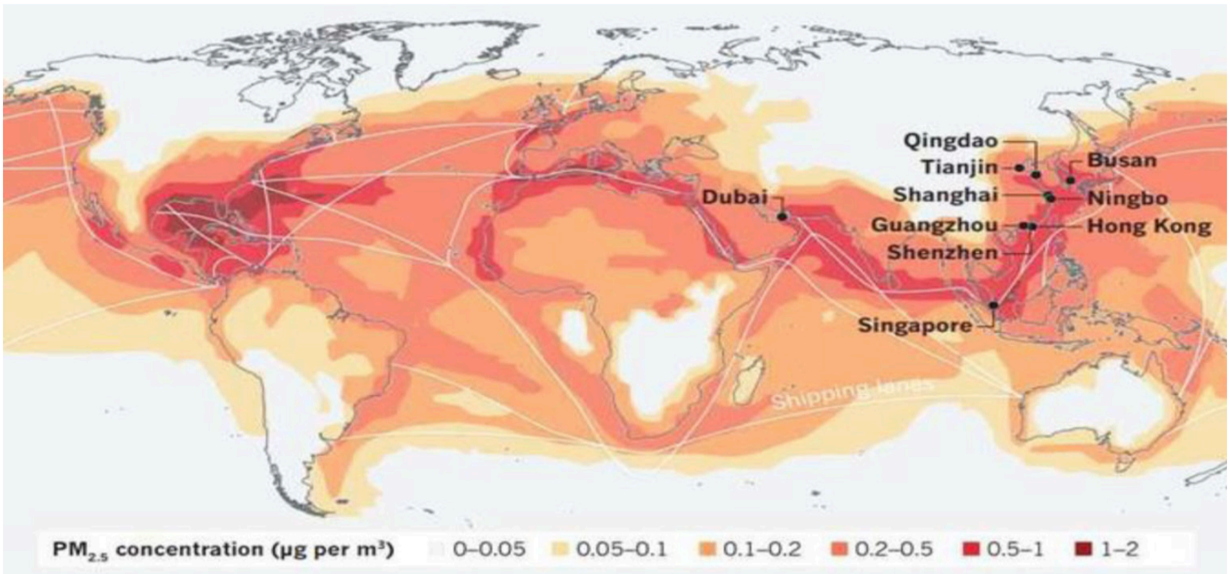
South Korea has recognized the severity of air pollution in port areas and has implemented improvement policies and regulations such as:

- Designated low-speed sailing sea areas,
- Expediting eco-friendly ship purchases,
- Strengthening criteria on air pollutant emissions for unloading equipment,
- Regulating scattering dust,
- Introducing eco-friendly unloading equipment,
- Use of Alternative Maritime Power

The above data Fig 2 shows that emissions from the burning of fuels are a primary source of port pollu- tion generating SOx, NOx, and VOCs. The handling of dry cargo has a lower impact in terms of the pollution generated. Ever-increasing electrification of port equipment and the practice of ships operating with onshore power when in port will significantly reduce pollution in and around ports currently caused by the burning of fuel oils.

One word of caution, pollution as described above is easily transferred from source to other areas due to winds. Upwind onshore processing facilities/factories/power stations could well be the main source of pollution in a port. Therefore pollution must be fully studied and analysed for content in order to detect what are the main contributing factors in any particular area.

Figure 3



6. CURRENT PRACTICES & TECHNOLOGIES

Control of dust in ports can be affected in several ways using various technologies. The main technologies applied are either physical barriers for the material being handled or the use of capture/suppression type technology (filtration or water mist). Both technologies have advantages and disadvantages depending on the material being handled and the required outcomes. Details are provided in the following paragraphs on the available technologies.

6.1 BULK CARGO STORAGE AND HANDLING

Material storage in a port is a notable consideration and can be critical to operations for bulk products and other general cargoes. It is highly unlikely that a port operator unless the port is designated for one commodity will have sufficient onward transport freely available when a vessel arrives to be loaded/unloaded. The sequencing of trucks or rail wagons can be problematic and can lead to untold delays and demurrage fees for ports. The way to resolve this issue is to provide temporary short-term bulk storage close to the operation.

Many ports have historically used open-air stockpiles on the port quays to provide this buffer storage facility. There are several issues associated with open-air storage such as pollution from material leeching into waterways, dust generated by winds, or material degradation issues (rain/moisture is to be avoided when handling dry bulk materials). These stockpiles when used for bulk shipping can number hundreds of thousands of tonnes in size which presents a physical space challenge along with structural issues. Both of these requirements are usually limited in a port environment. A simple remedy to pollution issues for open stockpiles is to provide a retaining/wind wall to provide some protection and the installation of water spray dust suppression technology, commonly seen when handling coal. Water misting is effective but is not suitable for all dry bulk products while the leeching of this mist into the surrounding environment has to be taken into consideration.

Other types of bulk temporary storage include enclosed storage sheds (i.e. Godown), warehouses, traditional steel or concrete silos, and the newer dome-type silos all of which are an improvement on open stockpiles in terms of pollution.

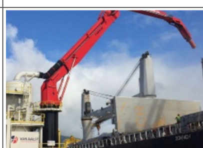
Figure 4

	Open Stock Pile	Walled Stockpile	Storage Shed	Vertical Silo	Dome Silo
Investment	Minimal	Low-Medium	Medium	High	Very High
Operating Costs	Minimal	Low	High	Medium	Medium
Advantages	Low cost for infrequent use	Flexibility and adaptability	Contained with large storage volumes	High product integrity, closed system	Fully contained and automated environment
Dis-Advantages	Rain and wind can interact with the product freely, product yield	Material open to the environment, minimal wind protection from walls	Large area needed, level of fixed infrastructure to support	High capital costs, highly mechanised	Large Surface area needed and very high capital costs
Pollution Impact	Very High	High	Medium to Low	Minimal	Minimal
					

6.2 MATERIAL IMPORT

When bulk material arrives at a port for onward transportation or processing, the material needs to be taken out of the vessel holds and brought on to land. There are many ways to achieve this using different technologies, all with unique features suited to certain products or applications. Table Fig 5, compares the main and commonly utilised technologies and the various technologies and systems used for unloading bulk materials are described below.

Figure 5

	Self-Unloading Ships	Grab and Crane	Pneumatic Conveying	Continuous Mechanical unloaders	Bulk Bag/Dry Bulk Containers
Investment	Low, the unloading equipment is supplied mainly by the vessel	High	Medium to high	Very High	Medium, port (or final recipient) will need an unloading system, the exporter will need a loading system
Operating Costs	Very High Ship Day Rates (Time Charter Rates) compared to normal bulk carriers	Low	High, increased power consumption	Medium, large power user	Medium to low, special containers and liners will be needed to protect the product
Advantages	Contained discharge, lack of quayside infrastructure needed	Flexibility and adaptability – can be configured for various port tasks	Fully contained system with large throughputs	High throughputs, continuous operation	Can be handled by existing port infrastructure (RTG/STS) – no need for a dedicated vessel for part loads/small tonnage, no special storage for products, can be shipped on container vessels with other cargoes.
Dis-Advantages	Material specific and reduced rates, inflexibility – loss of shipping volume. Not designed with effective dust control	Limited throughput rate for dry bulk	High energy usage, dedicated materials only.	Material specific, large supporting infrastructure costs	Low throughput, additional cost to fill/empty container. No dust control.
Pollution Impact	Low	Very low (with dedicated technology)	Low, closed system	Medium	Medium
					

6.2.1 SELF-DISCHARGER

Self-discharging ships feature integrated conveyor systems minimising the need for any port side infrastructure. The ship can transfer the material from the hold to the quay without the need for additional equipment. In addition to the non-requirement of quayside equipment needed to unload this type of vessel, another advantage is the fact the ship's holds are closed during discharge. This means that any material disturbed does not leave the hold and pollute the surrounding environment. Depending on the material handled some sort of reception facility will be needed shoreside to collect the discharged material. Self-discharging ships also typically use an uncovered conveyor to transfer material to the shore.

Disadvantages of self-discharging ships are the lack of flexibility, not being suitable for all material types as well as reduced throughputs. The pros and cons have to be considered in the context of the higher day rates applicable to these higher capital cost vessels.

6.2.2 CRANE AND CLAM SHELL GRAB AND HOPPER

Grab and cranes are a combination that offers ultimate flexibility. The technology is well understood and advanced as it is the most common method employed globally for unloading bulk materials. Grabs are capable of being dust suppressed even if their design inherently is not for dust-free operation by the very nature of their action. Grab technology has evolved to provide sealed units (when closed) thus avoiding any spillage when lifting from a hold.

Reception hoppers can also be supplied in a dust-free design with either water mist suppression or dust extraction. Some manufacturers, whose design uses dust filtration systems, offer dust-free (within limits) guarantees.

Dust-free discharge from hoppers on the quay can also be achieved depending on the configuration. Feeding of quayside conveyors can be dust-free with the use of adequate and suitably positioned dust filters/collectors. Where the hopper is feeding a truck, train, or container, dust-free loading chutes can be employed. Various designs are available that either includes integrated dust capture systems or utilise methods of reducing material velocity to stop particle attrition and thus dust generation. Such technologies have evolved and advanced considerably from the simple sock concept which was typically employed.

Crane technology nowadays includes features such as sway control, position control, controlled fill, and other advanced features that minimise dust generation and grab spillage during operation.

The flexibility of a crane is well appreciated by multipurpose port operators as cranes can be easily tasked to handle all bulk cargo types with simple changes of grab type. Breakbulk and general cargoes can be handled with a Hook block and containers with a spreader frame.

6.2.3 PNEUMATIC CONVEYING

Pneumatic conveying utilises air as a conveyor for the material. The material is entrained in a flow of air and transported in pipes at high velocities to a collection hopper. Vacuum conveying is the principal method used for ship unloading. A pneumatic unloader can be considered as a giant vacuum cleaner whereby the nozzle sucks the material out of the hold and transfers it to a reception hopper.

Spillage is very low and throughputs are high for this type of equipment, however, they are not suited to a wide range of materials, the materials handled being limited to those which have very similar properties.

Utilising air as a conveyor requires a great deal of electrical energy when operating when compared with other methods of unloading. In this context, consideration should be given to the WHO guidelines and data presented in Chapter 5 which highlights that the majority of PM in the air comes from the combustion of fossil fuels. The majority of ports at this time utilise electrical energy sourced from generation plants that use fossil fuels as a primary energy source.

The collection system associated with this type of unloader uses dust filters to mitigate the pollution. This filtration, while being effective for the large volumes of material/air processed, the filter can still emit up to 20mg/m3 (20,000µg/m3) of dust particles when operating.

Therefore while this equipment type has some positive attributes, particularly in respect of minimising spillages and increased throughput, the energy consumption and overall pollution effect of the equipment should be considered.

6.2.4 MECHANICAL UNLOADER

Continuous mechanical unloaders utilise various methods of elevating material from a vessel's hold. These devices are typically either screw conveyors, sandwich belt conveyors, or bucket elevators. Material handling technologies of this type have existed for many years and are suitable for handling large volumes of similar products and are also capable of handling different products, thereby offering more flexibility than a vacuum unloader. The dust control ability of a continuous unloader needs consideration as the collection system can generate dust when the material level is low while a material reception system with dust capture equipment will be required. This type of material handler machine tends to be heavy and has a high capital investment and maintenance cost.

6.2.5 DRY BULK CONTAINER/BULK BAG

Dry bulk containers are getting more and more popular with global shippers. The utilisation of containers for the transport of bulk materials benefits from the container handling infrastructure existing worldwide and generally has a very positive pollution impact. Material is loaded at source into an ISO 20ft or 40ft container and transported as a standard container to the end-user. Usually, the container has some special design features to facilitate filling/emptying. Special liners are used to guarantee product quality as well as for pollution protection. Difficult to handle materials may not readily discharge and thus require manual intervention. Material properties must be analysed before being loaded into what is in effect a sealed container as some materials are not suitable for such an environment. Materials such as coal, iron ore, etc. are suitable for transportation in open-top containers reducing the pollution impact. The loading of material into a container requires some automation and/or special equipment and loading rates can be low when compared with other technologies. While the pollution benefits are considerable and the flexibility offered by using containers and associated equipment is attractive, the volumes involved must also be a consideration as economies of scale apply.

Bulk bags, also known as FIBC (flexible intermediate bulk containers), are large woven bags that can be open-topped or fully sealed with a capacity of up to 2000Kg. They have benefits both in respect of pollution prevention as well as safety. Due to the flexible nature of the bag, filling has to be controlled so that the filled bag can be stacked and stored efficiently. Bulk bags are more suited to smaller volumes of material with high commercial value.

6.3 MATERIAL EXPORT

When bulk material has to be exported via sea transport the material needs to be transferred from the quay and loaded into a vessel hold. There are many ways to achieve this using different technologies all with unique features suited to certain products or applications. Table Fig 6 compares the main and commonly used technologies for loading dry bulk materials which are described in detail in the following subparagraphs. Loading of vessels is not simply a case of putting the material into the hold in an ad hoc manner. The vessel captain will want to ensure the correct loading sequence of the vessel in order to maintain stability and coordinate with the ballast regime. Consideration must also be given to the dynamic situation during vessel loading as tides and vessel load distribution will affect the vessel height, trim, and list relative to the quay.

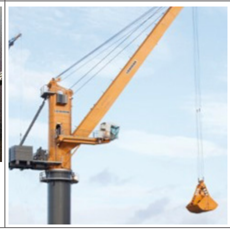
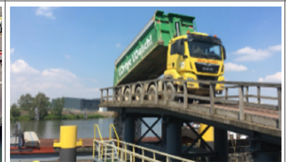
	Self-Loading Ships	Grab and Crane	Pneumatic Conveying	Shiploaders	Direct Tip	Bulk Bag/Dry Bulk Containers
Investment	Low, the loading equipment is supplied by the vessel	High	Medium to high	Medium	Low	Medium, port (or exporter) will need a loading system
Operating Costs	Very High Ship Day Rates (Time Charter Rates) compared to normal bulk carriers	Low	High, increased power consumption	Low to Medium	Very Low	Medium to low, special containers and liners will be needed to protect the product
Advantages	Contained feed, lack of quay-side infrastructure needed, single feed point needed	Flexibility and adaptability – can be configured for various port tasks	Fully contained system with large throughputs	Flexible, mobile and easy to maintain/operate, fully dust controlled	Quick, easy, and suited to low-value commodities	Can be handled by existing port infrastructure (RTG/STS) – no need for a dedicated vessel for part loads/small tonnage, no special storage for products, can be shipped on container vessels with other cargoes.
Dis-Advantages	Material specific and reduced rates, inflexibility – loss of shipping volume. Not designed with effective dust control	Low rate, high dust load, and pollution	High energy usage, dedicated materials only, long setup times.	Not a one size fits all vessel solution	Material degradation, dust generation, control, health and safety	Low throughput, additional cost to fill/empty container. Limited dust control when filling/emptying.
Pollution Impact	Medium	High	Medium closed system, hold pressurised whilst filling, large leak potential	Very Low	High	Medium/Low
						

Figure 6 – Comparison Table of Technologies for Port Operators Exporting Dry Bulk Materials

6.3.1 SELF-LOADING SHIPS

Self-loading ships feature integrated conveyor systems reducing the need for complex or automated portside infrastructure. The ship can load material into the hold(s) after receiving the material at a dedicated point/hopper on the vessel. The port operator may require a conveyor system to load material into the dedicated hopper where a conveyer boom or onboard crane is not available. The vessel conveyors will distribute the material within the hold(s). This has the advantage over other technologies as trimming the vessel is far simpler. This type of vessel also has the advantage of being enclosed thus limiting the production of airborne dust and pollution. Disadvantages include increased day rates for vessel hire/lease, reduced throughputs, and is unsuitable for a wide range of materials. The loading conveyor/system still has to be considered in terms of pollution control.

6.3.2 CLAM SHELL GRAB AND CRANE

Grab and cranes are a combination that offers ultimate flexibility. The technology is well understood and advanced. In its simplest form material can be unloaded directly onto the quay and then collected by the grab for transferring into the vessel. This type of operation gives end-users flexibility in their operations, materials handled and equipment as the crane can be used not only to load dry bulk but also potentially handle containers or other cargoes. A critical consideration as shown in the image below is where the material is routinely "dumped" on a quay for a crane/grab to then collect and transfer to the ship's hold. This process has severe implications not only from the pollution impact and product wastage perspectives but also in respect of a safe operating environment. Quayside workers' presence, reduced crane operator visibility, and numerous vehicle movements increase the potential for serious incidents and injury. Potential structural damage to the quay itself from grabs continually impacting the surface is also an issue. Pollution control with this arrangement is minimal if any at all.

6.3.3 PNEUMATIC CONVEYING

Pneumatic conveying utilises air as a conveyor for the material where the material is entrained in a flow of air and transported in pipes at high velocities to a collection hopper on board or directly to the ship's hold. For ship loading pneumatic conveying is either, Lean Phase for low density and non-abrasive materials, or Dense Phase for heavier materials. Lean phase features material to air volume ratio that is low but supplies a constant feed rate. Dense phase features a much higher material to air ratio and uses slugs of the material being transported so the feed is in batches. Both types of pneumatic conveying are used for vessel loading and both work on a positive pressure basis. Air is blown down an enclosed pipe and into the vessel hold, the material is added to the airflow either through a rotary valve (lean) or via a special blow tank vessel (dense). In both cases, the air is pressurised when compared to atmospheric pressure and the pressurised air has to be accommodated. Typically vessel holds will be closed off and sealed and a dedicated fan/filter unit will be employed to deal with the air used for transport. The balancing of the extraction air cleaning system and the incoming material-laden air is crucial for system performance. The image below shows a typical fan/filter system used when loading cement powder.

Many of the issues highlighted for pneumatic vessel unloading apply to pneumatic vessel loading such as high energy usage, material-specific solutions, and the potential for leaks. A further consideration is product degradation due to the high velocities of product transfer achieved with pneumatic conveying. The velocity of product transfer can be circa 20m/s and upwards and the resultant attritional forces applied can break down many bulk solids more than typically desired. For example, in the case of wood pellets for biomass-fired power stations, the dust generated as a result of this type of handling is an issue for many power stations which are designed to burn and handle pellets and not dust.

6.3.4 SHIPLOADER

A shiploader is a belt conveyor capable of moving material from the quay into the ship's hold. Many types of shiploaders will have a luffing feature to cater to vessel draught changes and tides. Depending on the shiploader configuration and requirements they can be fixed, mounted on rails, or fully mobile on tyres. They are ideally suited to handling a variety of materials and with optimised design and can be configured to provide full dust control. Material input can be from vehicles (i.e. truck, front-end loader, or train for example) or existing conveyors. The complete installation can be made dust-free via filters, covers, and by using proprietary dust-free loading chutes feeding into the vessel hold. Shiploaders with mobility features can also trim vessels quickly preventing vessel movement along the quay. The ability to travel and slew results in increased throughputs and less time in port for vessels.

6.3.5 DIRECT TIP

Where applicable a simple ramp structure can be used with smaller vessels like barges. Rear tipping trucks, like that in the picture below, simply tip the product into the vessel. This type of loading, whilst practical for some products has no environmental protection.

6.3.6 DRY BULK CONTAINERS/ BULK BAGS

Dry bulk containers and FIBC as described in the import section can equally be used for material exports with the same pollution benefits. As previously noted, the container handling infrastructure is readily available and the requirement for specialised bulk ports or investment in large high capital equipment is not required.

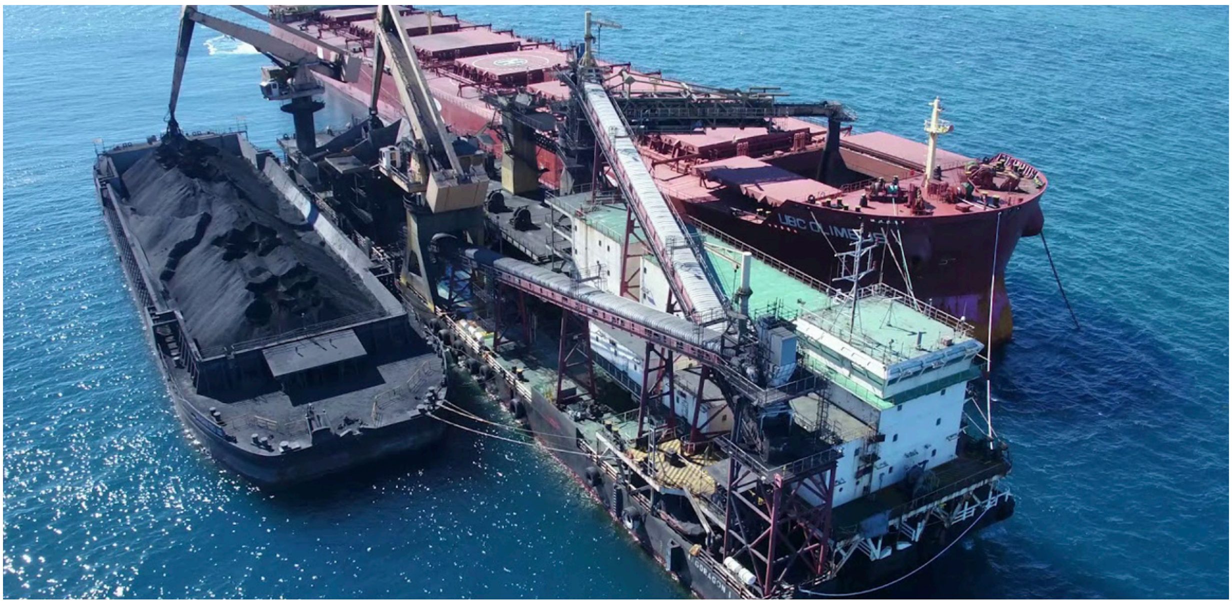
FIBC are commonly used within countries for temporary storage and onward transport of materials to other processing facilities. Many chemical facilities utilise these bags due to their low cost, flexible nature, and suitability to the product handled (e.g. FIBC lined with chemically inert or unreactive liners for product integrity). When large volumes are involved, the cost and processing time needed to load/discharge becomes high negating the benefits of the low bulk bag cost.

6.4 SHIP TO SHIP TRANSFER

Many ports do not have the civil infrastructure required to accommodate large machinery. Equally water depth restrictions prohibit the handling of bulk carrier vessels with large draughts. In such cases, a simple and effective solution can be the deployment of shallow draught barges. Such barges are used to move material to/from the port out to open water where the material can be transferred to or received by a larger mother vessel for unloading or onward shipping. The barge loading/unloading technology options are as described in chapters 6.2 and 6.3 above.

Taking the export scenario as an example, when a barge is loaded and brought offshore to the mother vessel, the material can be transferred in a number of ways. The simplest form is where the mother vessel has ship's gear (onboard cranes with grabs). The barge comes alongside and grabs are employed to move material from the barge into the mother vessel holds. For larger mother vessels, ore carriers for example, without onboard cranes, a transfer vessel is needed. The transfer vessel is a dedicated vessel with onboard material handling equipment capable of removing material from the barge and then transferring the material to the mother vessel. It is worth noting that transfer equipment installed on such a vessel is exposed to a more corrosive atmosphere than in a port environment and that high dynamic forces such as pitch, roll, and heave apply. These factors must be considered during the design and manufacture of equipment for this application. The image below shows a typical example of such an operation where coal brought offshore by barge is then loaded into the mother vessel using a combination of cranes, grabs, hoppers, and shiploading conveyors.

All the onboard technologies have their merits and demerits in respect of performance and pollution control as previously mentioned in chapters 6.2 and 6.3. The critical difference is that this operation is now being carried out offshore and giving due consideration to the "out of sight, out of mind" possibilities, the legislative situation in respect of pollution control and applicable regulations becomes very murky. Vessels operating in international waters do not come under the jurisdiction of the export/import nation, while flags of convenience make pollution mitigation obligations even more unclear.



7. CONCLUSIONS

The combination of economics, political pressure, regulations, and legislation means that ports will have to address and dramatically improve their pollution footprint. There is no escaping the fact that dust pollution associated with bulk handling is going to be monitored and controlled more and more stringently in the future. All port operators need to be fully aware of this situation when planning for current and future cargoes and must adapt to this future landscape.

Port operators should consider infrastructure design and materials handling rationale in their ports if they want to reduce dust pollution. Simple planning measures, informed vendor selection, and ongoing routine maintenance of equipment will provide tangible benefits in the long run.

Whilst many regulations will revolve around harm to human health, operators and those involved in bulk handling should also consider environmental health. The suppression of and reduction in the generation of dust will benefit all.

The generation of dust cannot be eliminated therefore the way that material is handled and the dust suppressed/captured has to be the focus.

The good news is that there are many vendors available that supply solutions that suppress dust and control dust generation with some vendors offering performance guarantees on the maximum level of pollution generated.

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- All tables are based on the authors own experience and interpretations
- All pictures are the authors own or free-sourced from the Internet

9. ABOUT THE AUTHOR

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