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What to do with Produced Solids after Separation: Dewatering, Transport, and Disposal

C.H. Rawlins, PhD, P.E.
eProcess Technologies
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Abstract

The primary role of offshore solids handling is to properly remove and dispose of produced solids, without interruption or shutdown. Most sand management papers focus on the separation component only (i.e., wellhead desander, jetting system, or produced water desander). However, 80% of the capital expenditure (CAPEX) is attributed to separating devices, and 80% of the operating expenditure (OPEX) in sand handling operations involves dewatering, transport, and disposal (D-T-D). The present work outlines questions to ask during facility design and provides guidelines, calculations, and examples on each of the sand handling steps to be implemented after separation. Sand handling is not a waste-stream treatment exercise but a critical flow assurance issue. Following all five steps of Facilities Sand Management (FSM) will maximize hydrocarbon production and minimize the operating costs.

Facilities Sand Management

All oil and gas wells produce sand, and therefore, all production facilities must be capable of managing sand in flow streams. Sand Control attempts to exclude solid particles from the well flow via production limits or completion hardware. When these approaches are not economical, not technically feasible, when they fail, when sand coproduction is employed to stimulate hydrocarbon recovery, or during well testing or initial flowback, Sand Management is then adopted in the surface facilities. Facilities Sand Management (FSM) is a term for the solids handling processes in the hydrocarbon production and processing system from the wellhead to custody transfer based on engineering knowledge and a certain degree of skill.

FSM is not a waste stream treatment exercise but a critical flow assurance issue. Production and uptime are maintained (or increased) even when solids are present, while the operating costs are minimized or reduced. This is accomplished via the use of a proper facility design incorporating the five steps of sand management (as illustrated in **Fig. 1**) to fully manage and handle the sand produced (Rawlins, 2013). Each step—from separation to disposal—must be integrated into the facility design to prevent production interruption or equipment shutdown. These steps are defined as follows:

1. Separate: To partition solid particles from liquid, gas, or multiphase flow into a separate stream. Unit processes include a hydrocyclone desander (liquid or multiphase), production separator, or filter.
2. Collect: Gather the partitioned solids into a single central location and remove them from the process pressure and flow. This is accomplished with the use of a hydrocyclone accumulator, vessel drain, or sump tank.
3. Clean: The adsorbed hydrocarbon contaminants are removed from the gathered sand particles with an attrition scrubbing system. This is an optional step to treat sand prior to overboard discharge.
4. Dewater: Removal of free water from the sand slurry to minimize the disposal volume (by >90%). The simplest methods involve a hanging mesh bag, screen lined bin, or cuttings box.
5. Transport: Transporting the solids to a final disposal location. The design of the transport system depends on the facility location (subsea/onshore/offshore) and environmental requirements. Common options include overboard discharge, truck-to-landfill or ship-to-shore transport, and slurry injection.

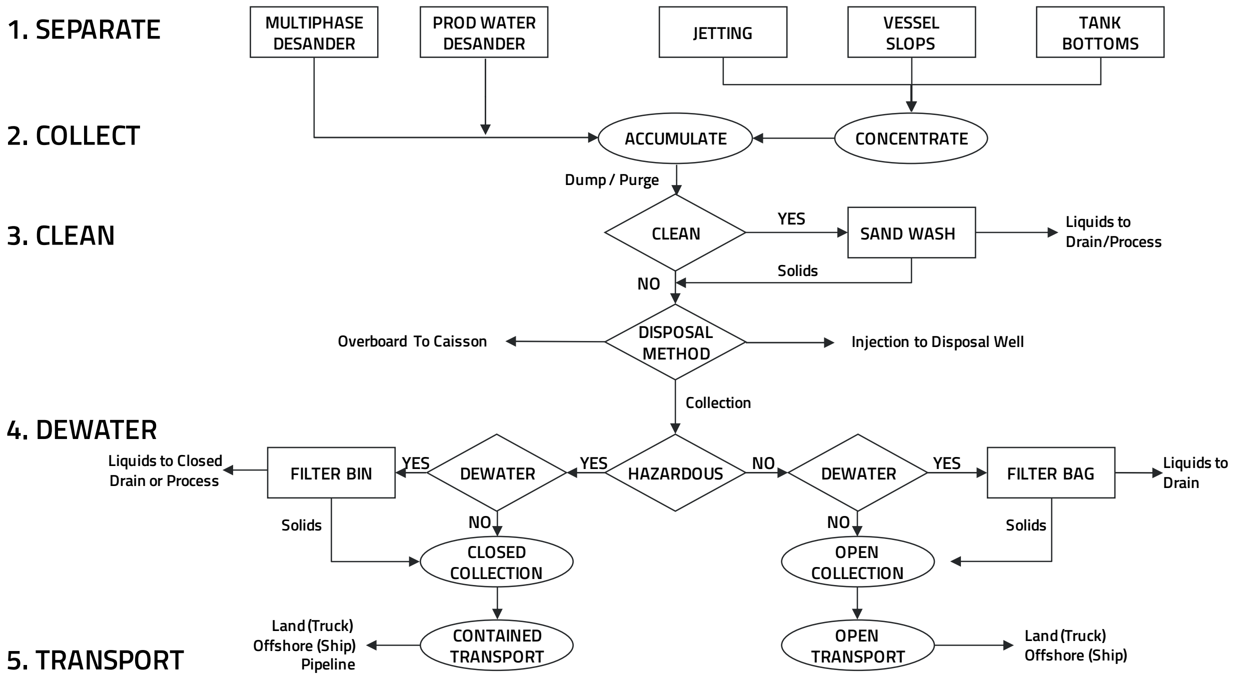

Fig. 1 – Flow chart depicting the five steps of FSM to ensure that sand is properly handled from separation to disposal.

Separation vs. Handling

In addressing sand management within facilities systems, most papers have almost exclusively addressed the separation aspect of Step 1. Separation usually involves a piece of equipment—a desander or jetting system for example—that is installed and operated, with its anecdotal performance reported. The references from Hodson et al., 1994, Lohne, 1994, and Jasmani et al, 2006 all provide a description of a sand separating device and a specific example of its use. The goal is to show how sand is removed from the flow stream under the assumption that it will be dealt with. The collection aspect, i.e., Step 2, is implied in the operation of the separating device.

However, no paper has explicitly addressed solely the handling aspect—what to do with the produced solids after separation. Certain references mention handling or disposal in the title but still focus only on the separation or anecdotal removal of solids from a specific application (Garcia, 1974, Kaura and Macrae, 2001, Guinot et al., 2009, Peruzzi et al., 2013). The design or operations engineer requires guidelines and a methodology targeting the removal of sand from separation to final disposal. This work aims to address the specific aspects of dewatering, transport, and disposal (D-T-D), which comprise the full handling aspect of FSM. The cleaning of sand, i.e., Step 3, is an optional step required prior to overboard discharge disposal and is addressed in other works. Sand cleaning is specific to only certain regions and operations, while Steps 4 and 5 are ubiquitous to all FSM system designs.

Sand handling does not just involve another piece of equipment but pertains to a process and a methodology. It does require fit-for-purpose equipment installed within facilities, but its most important aspect is the process design. An incorrect design will complicate all aspects of sand handling, which will not achieve the goal of preserving facilities uptime. A superficial approach without addressing all five steps in detail may result in the design group installing sand separation equipment (i.e., a jetting header within the production separator) and the operations group subsequently discovering that the produced sand cannot be discharged overboard as intended due to the presence of naturally occurring radioactive material

(NORM). Sand handling then becomes a maintenance issue addressed within the separator, as opposed to a skillfully designed engineered system intended to promote hydrocarbon production.

Role of Dewatering, Transport, and Disposal (D-T-D)

The purpose of solids handling is to transport sand away from the facility and to properly dispose of it. This is accomplished through Steps 4 (Dewatering) and 5 (Transport), as shown in **Fig. 1**, where both steps require equipment and operations. Disposal is a decision point associated with Step 5. Hence, the entire handling route is D-T-D. An improperly designed D-T-D system will likely cause a back-up or congestion of the entire solids management system, thus negating any operating benefit. The starting point for discussion when considering the FSM approach is to first identify the proper (final) disposal route of the solids and then work backward to meet that requirement.

The Pareto principle (or the 80/20 rule) applies equally to sand management as it does to macroeconomics. The 80/20 rule applied to FSM entails that 80% of the capital expenditure (CAPEX) of an FSM system can be attributed to the separating device (Step 1), while the work accounting for 80% of the operating expenditure (OPEX) of the FSM system is associated with the D-T-D method. This is probably why so much focus has been placed on separating devices as it has a clear CAPEX ramification. However, in the long term, the OPEX of sand management should be considered, as the life-cycle cost may be higher than the equipment cost.

The following questions should be asked during D-T-D design to ensure that all aspects are thoroughly reviewed.

- Is the facility located onshore or offshore?
- Does the facility require manned or unmanned operations?
- What is the level of automation required for equipment operation (fully automated systems minimize manpower but with high added capital costs)?
- If the facility is located offshore, can the solids be disposed overboard?
- Does the process contain any hazardous contaminants, such as H_2S, benzene, toluene, ethylbenzene, and xylene (BTEX), heavy metals, or NORM?
- Are solids, such as drill cuttings, already being handled at the facility?
- How will the solids be transported from the separation system to the disposal system?
- What are the similar facilities in your company or the geographic region doing?

Slurry Dewatering

Dewatering is required when the final disposal route involves containerized transport of the solids, as shown in **Fig. 2**. If the solids are to be transported via pipelines as a slurry, dewatering is then not needed. The role of dewatering is to remove free liquids (mainly water) from a sand slurry to minimize the final disposal volume. In most cases, a >90% volume reduction is achieved. In addition, dewatering removes any free-flowing hydrocarbon liquids associated with the solids and aids cleaning. The main idea is to keep the design simple. A dewatering system is typically operated in the batch mode with easy start-stop operations. It should require minimal personnel involvement and never be allowed to impede the solids separation and collection processes in the facility.

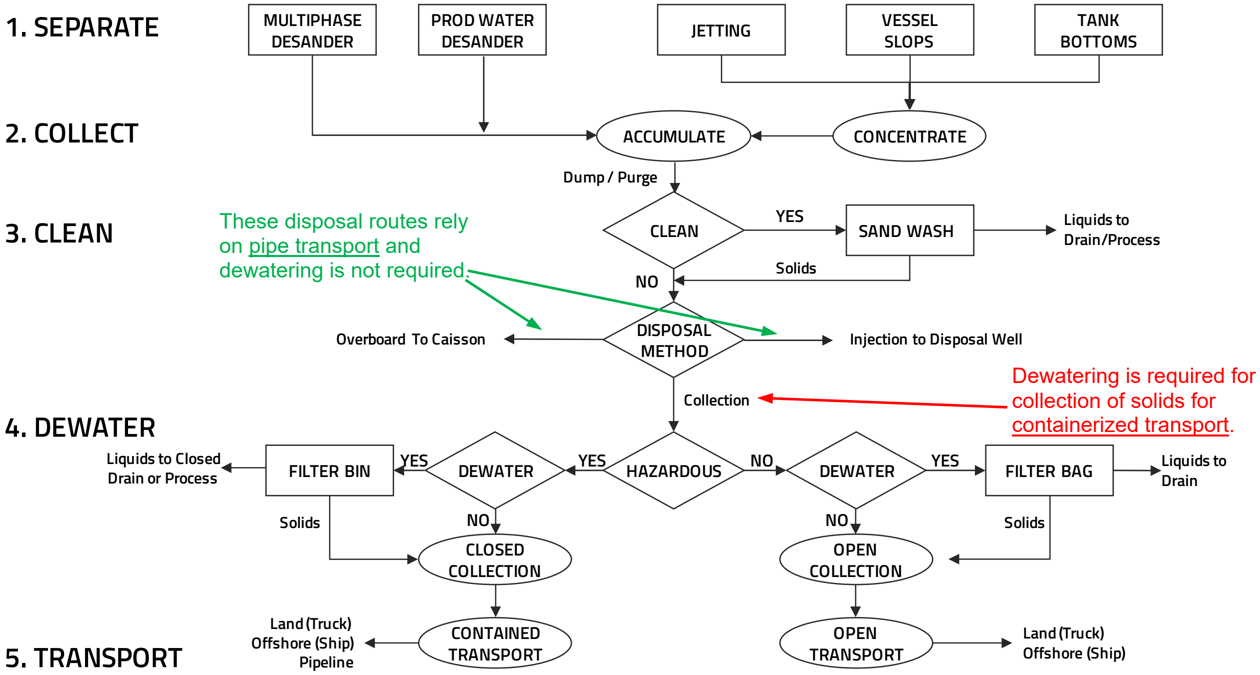

Fig. 2 – Indication on the FSM design chart where dewatering is required.

Slurry from Collection or Cleaning

Sand is separated and collected through a myriad of methods in production facilities, after which the collected sand and associated liquids are sent to handling. The mixture of sand and liquids is termed a slurry. The rate, concentration, duration, and characteristics of this slurry depend on the solid and fluid properties, operating procedure, and separation and collection equipment. The characteristics of the most common slurries handled in an FSM system are listed below to provide a guideline to initiate the process system design.

Slurry from the Desander Accumulator

A multiphase or produced water desander has an accumulator to collect the separated solids (Rawlins, 2017). This accumulator may be integral or secondary—both types contain a batch discharge for the periodic removal of any collected solids. As a design guideline, batch discharge will occur 1-2 times per day over a 15-minute period. The slurry flow rate ranges from 25-50 gpm (5.68-11.34 m^3/h) during the discharge time. The initial solids concentration ranges from 60-70 wt. %, which then decreases until the accumulator has been emptied. A suitable average solids concentration is 25 wt.%. If the slurry is discharged from a multiphase desander, the solids may contain free or adsorbed oil. The oil content can range from 1 wt.% for light oil to 10 wt.% for medium oil. The slurry discharged from a produced water desander will have an oil content <1 wt.%.

Slurry from Sand Jetting

Sand jetting systems, either traditional or cyclonic systems, are commonly employed to remove the collected solids that settle on the bottom of a gravity-based production separator (Rawlins, 2016). The solids are periodically flushed from the separator to the handling system via batch discharge. Batch discharge will occur at 1-day to 2-week intervals, with a 30-60 minute duration per purge. The flow rate during each discharge can range from 100-200 gpm (22.68-45.36 m^3/h) throughout the purge time. The initial solids concentration ranges from 50-60 wt. %, which then rapidly decreases as the flushing process continues (Priestman et al., 1996). On average, a 5 wt.% concentration is suitable as a design guideline. The slurry can exhibit an oil content ranging from 5-10 wt.% depending on the oil density.

Slurry from the Sand Cleaning System

An attrition-based sand cleaning system works on a batch cycle. This cleaning cycle has a controlled operation matched to the dewatering system. Clean sand (containing <1 wt.% oil) will be discharged for 15-30 minutes at 75 gpm (17.0 m^3/h) after the cleaning cycle. The slurry can contain an average sand content ranging from 5-10 wt.% with a 15 wt.% peak value.

Slurry Transport from Collection

The transport of slurry from a desander accumulator, sand jetting, or sand cleaning system follows the same design principles. The pipeline must be designed to transport the slurry without plugging and severe erosion. Details on the piping design and operation to balance the erosion and transport velocities (horizontal and vertical, respectively) have been provided in a previous publication (Rawlins, 2016).

Bulk and Final Dewatering

Depending on the slurry quantity, up to two stages of dewatering may be adopted—bulk and final dewatering. Bulk dewatering, also called the 1st dewatering stage, is not always required, but all dewatering systems will have a final stage. Semi continuous slurry discharge-based systems require bulk dewatering to handle the large liquid volumes that will be removed. This first stage is applied to remove 75-90% of the liquid volume to simplify and shrink the final-stage dewatering and transport equipment. Bulk liquids are sent to open or closed drains (offshore) or to a capture pit (onshore).

The equipment for bulk dewatering may consist of urethane cyclones such as those used for drill cuttings treatment, a gravity settling tank with a liquid decant overflow, or even a spiral classifier (only for large-scale onshore operations). The design of this step requires specifying the slurry flow rate, pressure, duration, concentration and total mass of solids, oil-in-sand concentration, and solid particle size distribution.

The final or secondary stage satisfies the primary purpose of dewatering to minimize the disposal volume and weight of the sand/slurry for final transport. In total, up to 95% of the volume is removed, producing sand with a final liquid concentration <3 vol.%, which is like sand-castle building material. This wet sand has an ~1700 kg/m^3 bulk density. In addition, final dewatering removes all free-flowing hydrocarbon liquids, which are discharged with the drainage water. Flushing with clean water can be included to provide simple oil cleaning. The same design parameters as those for bulk dewatering are required, i.e., the slurry flow rate, pressure, duration, concentration and total mass of solids, oil-in-sand concentration, and solid particle size distribution. Final dewatering may have an open or closed system design.

Open and Closed Dewatering

The two broad categories are open dewatering for nonhazardous systems and closed dewatering for hazardous systems. Open dewatering systems are designed to send any captured liquids to an open drain, while the sand, which may contain volatiles, is exposed to the atmosphere. Closed dewatering systems capture liquids, after which they are sent to a closed drain or returned to the process, while volatilized substances are sent to the vent system, and solids are kept contained away from exposure to the atmosphere or personnel.

Fig. 3 shows an open dewatering system used on a deepwater spar in the South China Sea. The dewatering system employs urethane cyclones for bulk dewatering, followed by a four-place hanging dewatering bag system. The dewatering bags are held in place by a simple support frame (**Fig. 3, upper right**) to allow gravity filtration of the liquid into a drip pan (**Fig. 3, lower right**). The liquids from bulk dewatering flow to the closed drain, while the filtrate from the hanging bags flow to the open drain. The dewatering bags are emptied and reused after cleaning (Loong et al., 2014).

An example of a closed dewatering system is shown in **Fig. 4**. This system adopts the same dewatering bags shown in **Fig. 3**. However, in this system, the bags are encapsulated in caged bins. The slurry is introduced through the bin lid and flows directly into the dewatering bag hanging on an internal frame. The liquid filtrate is captured via an integral drip pan and is drained through the exit nozzle. Vapors are captured through a nozzle and flow to the vent system. Sight glasses are provided to visually monitor the progress, and the bin sets are placed on a load cell platform for the quantitative determination of the sand content. The entire bin system is enclosed in a crash frame designed for lift and transport. The bin is transported to the disposal site where the contents are purged and neutralized before opening the lid. The bin is then emptied, resealed, and returned for use.

Fig. 3 – Two-stage open dewatering system employed on deepwater spars in the South China Sea. Bulk dewatering employs a bank of urethane cyclones (left picture, upper portion) and four-place hanging dewatering bags (left picture, lower portion). The support of the dewatering bag is shown in the upper right photo, while the liquid filtrate removal process is shown in the bottom right photo.

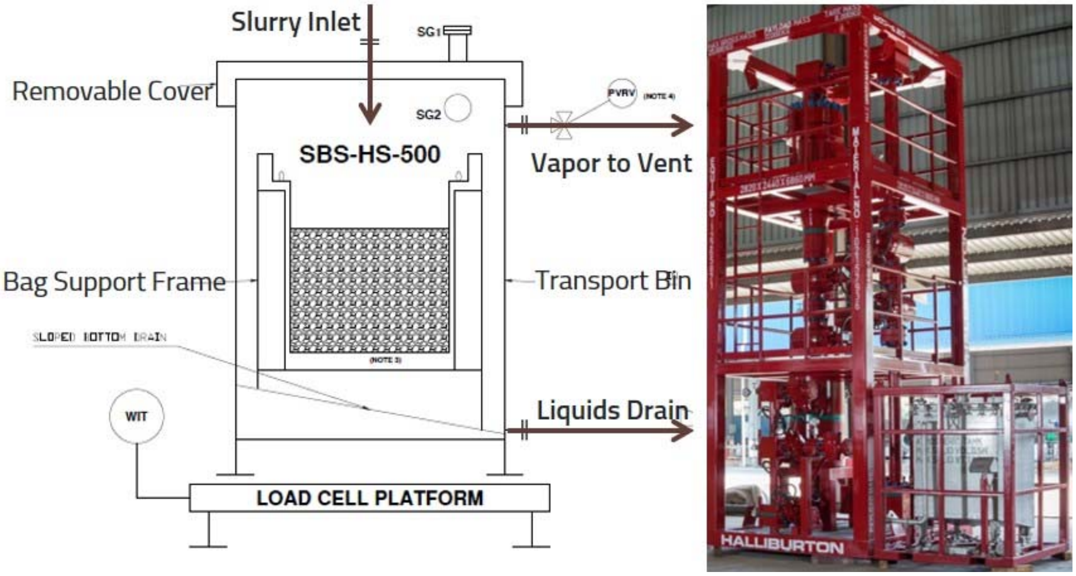

Fig. 4 – Closed dewatering bin showing the flow of slurry, vapors, and liquids (left graphic) and photo of a unit enclosed in a DNV 2.7-1 transport cage sitting next to a 15K wellhead desander for use in Saudi Arabia well test operations.

Dewatering Bin-Bag System

Both the open and closed dewatering systems previously described adopt dewatering filter bags. A dewatering filter bag is engineered for both compact dewatering and transport. It is based on the geotextile principles applied in soil washing and sewage treatment. **Fig. 5** shows a bag during lifting from a simple support frame. The dewatering bag is constructed from a triple-weave polymer that is oleophobic, which enables rapid liquid weeping from slurries. It is designed for atmospheric use and can handle fluids up to 90°C. It should be protected from exposure to direct UV light, concentrated acids, or toluene. The material has a hydraulic flux of 2400 lpm/m², which results in a 10-15 minute full drain time and can retain particles up to 10 microns. The bag holds ~0.5 m³ of solids (~1300 kg) and contains both lifting and inversion straps. It is also washable and reusable.

Fig. 5 – Dewatering filter bag (left photo) being lifted from a simple support frame.

The product of a final dewatering system is shown in **Fig. 6**. The dewatered sand contains no free-flowing liquids and can be stacked or piled without flowing. The left photo shows a dewatered sand-clay mixture of solids removed using a wellhead desander on a deepwater spar in the South China Sea. The right photo shows the sand removed with a wellstream desander from onshore Indonesian gas wells.

Fig. 6 – Dewatered sand from offshore Malaysia (left) and onshore Indonesia wells (right).

Other Dewatering Systems

The equipment commonly used for drilling fluid treatment can be applied for the dewatering of produced solids slurries. These items include shale shakers, desanders, desilters, and centrifuges (ASME, 2005). The above equipment is designed to handle large amounts of solids from drilling and may be oversized for most produced solids rates, but they are designed to fully dewater slurries. Shale shakers remove >74-micron particles that are fully dewatered. Desanding and desilting hydrocyclones are employed to collect finer solids (>30 microns). However, the concentrated solids may require further dewatering with centrifuges to be fully dewatered. Drilling fluid treatment equipment may be readily available at the production site and are easy to adapt for produced solids dewatering purposes.

A cuttings box—used to transport dewatered drill cuttings—can be adopted to dewater small amounts of produced solids. The slurry is discharged into a cuttings box, allowed to settle, and the supernatant is then skimmed or decanted. This same procedure can be performed for a tote tank or unused vessel.

Transport to Disposal

The transport of the dewatered solids to the disposal site is Step 5 of the FSM methodology. The final disposal site or method will determine how the solids are transported. As shown in **Fig. 2,** the solids will be transported either as a slurry via piping or as dewatered sand in a bin or bag container.

When the disposal method entails overboard discharge or injection, the produced solids are transported in slurry form. A dewatering step may be applied to remove any free hydrocarbons, and the solids are then mixed with clean water to form a disposal slurry. This slurry is transported through piping across a distance of 3-100 meters. The piping must be designed for the proper and efficient transport of solids to balance the erosive wear on certain components with the transport velocity (Rawlins, 2016). **Fig. 7** shows an example of short-piping transport from a produced water desander to a mixing tank and then to a slurry injection pump. The total transport distance is 4 meters.

Fig. 7 – Transport of slurry from a produced water desander to an injection pump in an onshore Australian application.

After dewatering, the solids are placed in a bin or bag for transport. The container is transported with a crane or fork truck to lift the container or skip, which is then placed on a ship or truck or other vehicle and transported to the final location. The lifting requirements are generally 1-3 tons. Access or space for bin/bag withdrawal and change-out is maintained. **Fig. 8** shows examples of two transport container systems. The left photo shows a dewatering bag being lifted after solids filling from a high-watercut multiphase desander (Rawlins and Hewett, 2007). The right photo shows a roll-off truck container situated directly beneath a produced water desander. Both applications are open design systems.

Fig. 8 – (left) Crane lift of a dewatering bag after filling with solids from a multiphase desander and (right) truck roll-off container to collect solids directly discharged from a produced water desander.

In either format, slurry or dewatered, solid transport is generally conducted in the batch mode and not continuously. The transport timing is matched to the purge from an accumulator or cleaning system. The transport timing should also be matched to the transport of other solids or waste from the facility, such as that from drilling operations. If multiple steps are required prior to disposal, such as crane lifting of bags, dumping into a skip, lifting of a skip onto a boat, transport on a boat to the shore, lifting from the boat to a truck, and finally trucking to a landfill, it is then important to match the ship access cycle, and some local solids storage may be required.

Produced Solids Disposal

The four main disposal routes are landfilling, overboard discharge, slurry injection, and unique methods. Environmental regulations concerning specific contaminants are the primary factor in the determination of the disposal route (Veil, 2001). The oil and hydrocarbon contents are not critical for landfill disposal or injection but must be reduced to a specific level (i.e., <1 wt.% oil on dry solids per OSPAR guidelines) for overboard discharge. The heavy metal content must meet a certain toxicity limit for overboard discharge, or a specific concentration limit for landfilling, but is generally not a factor for injection. The radionuclide content is similar in that a specific level must be maintained for overboard discharge and landfill disposal but is not a factor in slurry injection.

Landfill Disposal

Disposal at a land-based waste site (i.e., landfill) is performed for both onshore and offshore produced solids. In both cases, the solids are trucked to the landfill in a bag, bin, or other container. Many municipal landfills accept nonhazardous E&P waste. However, the acceptance criteria for the produced solids must be determined for each landfill site. A specific type of industrial landfill, i.e., designated for oil and gas

E&P waste disposal, may be required for the produced solids. Each landfill will have specific guidelines regarding the content of free liquids, BTEX, radionuclides (specifically radium 226/228), TCLP (toxicity), and organics (DRO/GRO). The local, regional, and national agency requirements must be followed to dispose of the produced solids in landfills.

Overboard Discharge

In offshore facilities, the ability to discharge produced solids overboard simplifies the disposal process by eliminating shipping to onshore landfills. Once the produced sand has been processed to meet certain discharge specifications, it is commonly added to the drill cuttings, produced water streams, or drains, followed by discharge via caisson or skim pile.

The regulatory control of offshore oil industry operations falls under a variety of international, national, regional, and local agencies. Each agency should be consulted for the specific and current guidelines. The produced water and drilling mud containing cuttings are subject to specific guidelines for overboard discharge. However, produced solids or sand are often not specifically listed. Due to the very small amounts of produced solids, which are smaller than those contained in drilling and production waste, these types of solids may fall under different regulations. The discharge of produced solids may be covered under oily cutting discharge guidelines. **Table 1** provides an (older) example of regulations for oily cutting discharge (Jones, Leuterman, and Still, 2002). While the main aspect pertaining to solids discharge is the oil content, other limitations such as the toxicity and NORM content may apply. The most often cited regulation for overboard solids discharge is the 1992 OSPAR Convention regulation, which permits a 1 wt.% oil on dry solids content (OSPAR, 1992). Some regions, such as the U.S., Mexico, and Brazil, do not allow any solid waste to be discharged overboard. The industry trend going forward will be to eliminate all overboard discharge practices.

Table 1 – Example of Oily Cuttings Discharge Permitted in Various Oil Producing Regions

Country	Authority	Oily Cuttings Discharge
Angola	Ministry of Petroleum	Cuttings discharge allowed, muds are reused. Oil on cuttings measured, no limit provided.
Australia (Western)	Dept. of Minerals & Energy	1% oil limit on cuttings retention. Restriction on fluids with aromatics >1%
Azerbaijan	State Committee of Ecology	Discharge prohibited other than cuttings generated from low toxicity and biodegradable muds.
Brazil	Instituta Brazil Medio Ambiente	Discharge prohibited.
Denmark (North Sea)		Discharge allowed with limit of 1% oil on cuttings (OSPAR)
Egypt	EGPC/EEAA	100 g/kg, case-by-case
Gabon		Discharge allowed, no standards set. Case-by-case.
Indonesia	Ministry of Mining & Energy	150 g/kg
Mexico	Ministry of Energy	Zero discharge.
Nigeria	DPR	Oil on cuttings limited to 1%, with 0% goal.
Norway	SFT	1% oil on cuttings (OSPAR)
Trinidad		No specific restrictions against, but offshore discharge unlikely to be allowed by Ministry of Energy (MOE) during EIA approval process.
UK	Dept. of Trade & Industry	<1% oil on cuttings, to be reduced to 0.5% in 2000
USA	EPA/MMS	Discharge prohibited.

Slurry Injection

Solids disposal via injection, sometimes termed slurry fracture injection or cutting reinjection, is employed to emplace particulate solids into a subsurface stratum via a carrier fluid. This method has been widely applied for drill cuttings for more than 25 years (Nagel and McLennan, 2010). Typically, this is a batch process where the solids are mixed as a slurry, conditioned to prevent settling, sent to a holding tank, then injected either down an annular space between casing strings or into a dedicated injection well and finally into the receiving formation. The batch volume averages 200 bbl at injection rates ranging from 1-25 bbl/min. Total disposal volumes of up to 2 million bbl per well have been achieved. The injected solids do not require cleaning, and all contaminants (i.e., NORM, metals, etc.) can be injected with the solids.

Unique Methods

Local constraints and creative engineering have produced certain unique methods applied in the field. A shallow water field produced from floating barges in Venezuela applied the produced sand to prepare a cold asphalt mix and treat solid biodegradation (Melchor et al., 2002). An Alaskan North Slope operator added its produced sand to drill cuttings, which were then ground in a ball mill to a very fine size for injection disposal (Schmidt, Friar, and Cooper, 1999). Another company investigated the use of produced sand as onsite grit blasting media, while a deepwater operator added the produced sand back to the oil stream (after separation prior to the production separator) to allow the solids to deposit in the ship hold for annual cleanout. The goal is to keep the design simple and robust.

Subsea Solids Disposal

The primary concern with subsea sand management is what to do with the solids. No new equipment is required to separate the sand-proven equipment from surface facilities for efficient sand removal from the well flow (e.g., a multiphase desander). A previous study investigated three paths for solids handling on the seafloor (Rawlins and Ditria, 2019). These paths included conventional approaches to manage the system configuration using established rules or technologies, treatment to modify the solids in situ to reduce or eliminate their deleterious effects, and removal, which combines the five steps of sand management to handle sand as a separate flow stream. The recommended approaches were as follows:

- Separate and bypass the critical equipment. The sand is separated upstream of the critical processing elements (e.g., chokes, multiphase pumps, or gravity separators) and then added back to the flow line downstream.
- Separate and inject into a disposal well. The sand is separated upstream of the critical processing elements and then injected along with any produced water or as a separate stream into a disposal well.
- Separate and placed in retrievable containers. The sand is separated upstream of any critical processing elements and then collected in a retrievable container adjacent to the subsea processing station.
- Separate and placed in a bag/tube/flexible container for seafloor storage. The sand is separated upstream of any critical processing elements and then collected in a flexible seafloor storage container, such as a geotextile bag located next to the subsea processing station.

Case Studies

The following case studies describe the approaches implemented in various regions and facilities types. The D-T-D route is the focus of each study presented.

U.S. Gulf of Mexico – Offshore

In 1999, an FSM system was installed on a fixed-leg platform in the U.S. Gulf of Mexico (Rawlins and Wang, 2001). The produced solids (sand and fossil shells) are removed from the water and oil streams with separate multiliner desanders. Each desander is purged to a common dewatering-transport bin, as shown in **Fig. 9**. This semi closed bin has a center standpipe with a slotted screen to drain the purged fluids into a collection sump. The sump adopts a diaphragm pump to return the liquids to the inlet of the LP separator. A flame arrestor is provided at the vent outlet to allow the assembly to safely breathe. The bin has a total volume of 2.5 m³, which is sufficient for 4-5 days of operations. Once filled, the bin is lifted onto a transport barge and transported to the shore for landfill disposal. A standby bin is employed to maintain solids handling during the ship-to-shore transport and return.

Fig. 9 – Dewatering-transport semi closed bin on a U.S. Gulf of Mexico fixed-leg platform.

Austria – Onshore

An onshore multiliner desander was installed in 2007 to remove solids from the fluid stream after the sucker-rod lift pump (Rawlins and Hewett, 2007). The collected solids are dumped directly into an open bin located below the desander. The desander and bin are contained in a cabinet enclosure for cold weather protection. The holding bin contains a porous collection bag with a volume sufficiently large for 4-10 days of operations. Water is removed from the slurry by gravity draining and flows into a wellhead cellar. The holding bin sits atop a wheel-rail system for easy access to the dewatering bag by one operator. The dewatering bag is removed using a small crane, as shown in **Fig. 8** (left), for transport by truck to a local landfill disposal site.

Australia – Onshore

A combined desander-deoiler produced water treating system was installed in 2007 in onshore NW Australia, as shown in **Fig. 7**. The solids are first removed to protect the deoilers and prevent the produced water storage tanks from being filled with sand. The separated sand is purged from the desander and transported via a short pipe to a mixing tank. The mixing tank dilutes the slurry to a 15 vol.% solids content, whereupon the final slurry is injected under a 90 bar pressure via a triplex piston pump into a disposal zone.

Malaysia – Deepwater Offshore

The world's largest offshore FSM system was installed on a deepwater spar in the South China Sea starting in 2011 (Loong, Rawlins, and Goo, 2014). At this site, ten wellhead desanders remove solids from the well flow. Each wellhead desander has a secondary 600-liter accumulator that is purged 1-2 times per day. The discharged slurry is directed into a ring-main header that circumnavigates the well bay. Utility water is used to dilute and transport the purged slurry to a common dewatering station. The dewatering station has both bulk and final dewatering systems. Bulk dewatering removes >90 vol.% of the water with urethane cyclones, with the recovered water flowing to the closed drain system. The cyclone underflow is directed into a four-place open dewatering station, as shown in **Fig. 3**. This station adopts a simple frame with gravity-drain dewatering bags, as shown in **Fig. 5**. The filtrate liquid is collected into a sump and returned to the open drain system. Once full, the dewatering bags are lifted by a platform crane and transported to a skip. The dewatering bags are inverted to remove the sand, washed, and returned for use. A full skip, shown in **Fig. 6** (left), transports the solids back to the shore for landfill disposal.

Conclusions

All oil and gas wells produce sand. The separation of sand in the facility, at any point, requires the subsequent handling of any produced solids through disposal. Due diligence should be taken to review the entire sand handling route through collection, cleaning, dewatering and disposal. Solids handling systems should start with the identification of the proper disposal location and then work backward to meet that requirement. The facility location and environmental regulations concerning specific contaminants are the primary factors regarding the disposal route, which may be landfilling, overboard discharge, injection, or a unique method. Proper dewatering, which is the removal of any free liquids from the sand slurry to minimize the disposal volume, simplifies handling during disposal. Often, the dewatering and transport steps can be combined in the use of a dewatering bin or bag.

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Nomenclature

BTEX = *Benzene, toluene, ethylbenzene, and xylene*
CAPEX = *Capital expenditure*
DRO = *Diesel range organics*
D-T-D = *Dewatering, transport, and disposal*
E&P = *Exploration and production*
FSM = *Facilities sand management*
gpm = *Gallons per minute*
GRO = *Gasoline range organics*
lpm = *Liters per minute*
LP = *Low pressure*
NORM = *Naturally occurring radioactive material*
OPEX = *Operating expenditure*
OSPAR = *(Oslo-Paris) Convention for the Protection of the Marine Environment of the North-East Atlantic*
RPSEA = *Research Partnership to Secure Energy for America*
SFI = *Slurry fracture injection*
TCLP = *Toxicity characteristic leaching procedure*

SI Metric Conversion Factors

bar	x1.0	E+02	=	kPa
bbl	x1.59	E-01	=	m^3
gal	x3.785	E-03	=	m^3
L	x1.0	E-03	=	m^3
micron	x1.0	E-06	=	m

Author Biography

C. Hank Rawlins (P.E.) is the Managing Director for eProcess Technologies in Houston, TX, USA. He has 28 years of experience in research and process engineering in the upstream oil and gas industry. He is responsible for development programs in facilities sand management, produced water treatment, and compact separation systems. Dr. Rawlins has fifty-seven publications and is an active member of SPE, where he served as past chair of the Separations Technology Technical Section (STTS) and as a Distinguished Lecturer (2018-2019). He holds a PhD in metallurgical engineering from Missouri S&T University and can be contacted at hrawlins@eprocess-tech.com.