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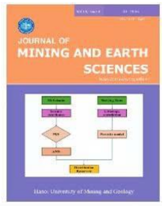

Sand disposal technology selection for oil and gas fields in Malay - Tho Chu basin

Quan Anh Tran [1,*], An Hai Nguyen [1], Vinh The Nguyen [2], Long Khac Nguyen [2]

[1] *PetroVietnam Exploration and Production Corporation (PVEP), Hanoi, Vietnam*
[2] *Hanoi University of Mining and Geology, Hanoi, Vietnam*

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ABSTRACT

The disposal of sand generated during offshore oil and gas production poses considerable environmental and operational challenges that require innovative solutions. This paper presents a comprehensive review and evaluation of sand disposal technologies utilized in the PM3 Commercial Arrangement Area (PM3 CAA) facilities, located within the Malay-Tho Chu basin, offshore Southwest of Vietnam. Given the variety of technologies available for sand disposal on surface facilities, selecting the most suitable approach requires diligent study and assessment to ensure the best fit-for-purpose solution. This study thoroughly evaluates current sand disposal practices while exploring alternative technologies that could enhance operational effectiveness. A systematic approach was taken to establish evaluation criteria that incorporate both technical performance, environmental impact, health and safety considerations, and cost implications, ensuring a holistic perspective on sand management. Three key sand disposal technologies: Sand Bag Skid, Hydrocyclone Desander, and Sand Filter Skid, were analyzed in terms of separation efficiency, pressure requirements, maintenance complexity, and overall integration with existing PM3 CAA infrastructure. Among the various options analyzed, the Hydrocyclone Desander emerged as the optimal choice, providing a well-balanced solution between operational efficiency, cost-effectiveness, and environmental compliance. It demonstrated 98% efficiency in removing particles smaller than 20 microns while requiring minimal manual handling, thereby reducing personnel exposure to hazardous materials such as mercury. Additionally, its compatibility with existing processing conditions in PM3 CAA makes it a viable and practical solution for ongoing sand management challenges. This paper ultimately recommends the Hydrocyclone Desander as the preferred technology based on these findings, contributing valuable insights to enhance sand disposal practices in offshore production environments. The results emphasize the importance of tailoring disposal strategies to specific field conditions, promoting sustainable resource extraction and long-term operational efficiency.

*Corresponding author
E - mail: quanta@pvep.com.vn
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1. Introduction

Sand production in offshore oil and gas is a serious problem in many oil and gas fields in the world. One of the main issues regarding facilities is that it leads to equipment erosion, flow assurance issues. The regulatory concerns also have to be met for oil and gas companies. The Central Processing Platform (CPP) for an oil and gas field in the Commercial Area between Vietnam and Malaysia currently discharges sand slurry overboard without treatment, exceeding regulatory thresholds for oil and mercury content. The objective of this study is to identify and evaluate viable sand disposal technologies to enhance compliance and operational efficiency.

CPP is a Central Processing Platform facility which is bridge linked to Wellhead Riser Platform (platform B) on one side and a Mobile Offshore Application Barge (platform D) on the other. All Wellhead Riser Platforms are tied into the Wellhead Riser Platform and then into CPP, where the full well stream (FWS) fluids will be processed to meet sales gas and stabilised oil export specifications. Stabilised oil will be exported via the FSO vessel and shuttle tanker, while sales gas will be exported via subsea pipelines (Repsol, 2002).

The new Sand Disposal System shall be designed for slurry from CPP 1st Stage Separator, CPP 2nd Stage Separator, CPP Degasser/Skimmer Vessel, platform D 1st Stage Separator and including slurry from CPP HP Gas Separator, V-120 (future tie-in of sand slurry from this vessel). V-2120 has its own sand jetting system. However, the piping for sand jet water and sand slurry drain has yet to be connected.

A thorough Sand Disposal System design requires steps to fully manage and handle the sand produced. Each step is important and shall be integrated to maintain hydrocarbon production and prevent flow interruption:

- Separate - Sand is removed from production separators/vessels by using sand jetting to the Sand Disposal System via the slurry line.
- Collect - All separated sand is gathered into one central location (e.g., Sand Disposal System). The Sand Disposal System removes sand from the slurry stream and stores it temporarily.
- Dewater - Free liquids (water) are removed from sand slurry to minimize disposal volume.
- Transport - The dry sand is then transferred to Sand Drums/ Sand Bins. Sand Drums/ Sand Bins will be transported to onshore for safe disposal. (Rawlins et al., 2000).

Refer to Figure 1 for the overall process schematic diagram showing the scope of work of the Sand Disposal System Project.

2. Research Methodology

The study follows a structured approach:

- Assessment of Existing Facilities: Review of CPP infrastructure and current sand disposal practices.
- Technology Screening: Evaluation of potential sand disposal technologies, including Sand Bag Skid, Hydrocyclone Desander, and Sand Filter Skid.
- Comparative Analysis: Assessment based on separation efficiency, operational feasibility, and environmental impact.
- Safety and Structural Considerations: Hazard analysis and integration requirements.
- Cost and Schedule Estimation: Evaluation of capital and operational expenditures (CAPEX & OPEX).

3. Bottlenecks in the Current BR-A Facility

The CPP facility faces several operational challenges in its sand disposal system, which impact efficiency, compliance, and safety. The key bottlenecks include:

- Inefficient Sand Handling: Sand slurry is discharged overboard without proper treatment, leading to regulatory non-compliance.
- High Mercury and Oil Content in Sand: Produced sand contains mercury and oil concentrations exceeding environmental thresholds.
- Limited Infrastructure for Onshore Disposal: The facility lacks the necessary equipment to safely store and transport sand for onshore disposal.
- Inadequate Processing Capacity: The sand jetting system can only handle limited volumes, creating operational inefficiencies.

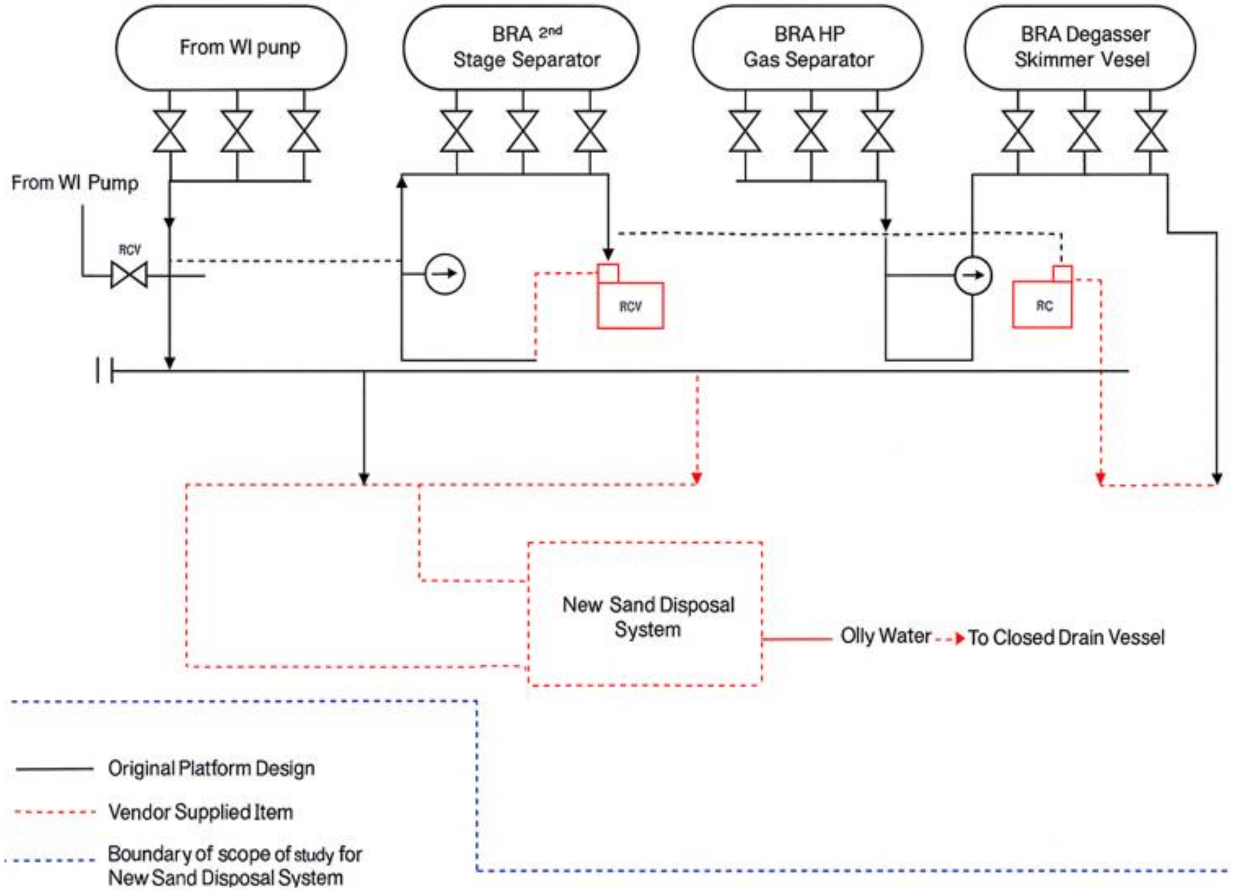

Figure 1. Overall Process Schematic for Existing Sand Disposal System and Boundary of Scope of Study for the New Sand Disposal System at CPP (Repsol, 2002).

- Safety and Environmental Risks: Manual sand handling increases personnel exposure to hazardous substances, including mercury vapor.

4. Technology Assessment and Process Evaluation

The generic technologies identified have been assessed against the following criteria:

- Method of Sand Separation
- Sand Removal Performance / Efficiency
- Inlet Pressure Requirement
- Flowrate Range
- Turn-up/Turn-down Flexibility
- Suitability for sand with mercury content
- Flexibility to cater for variation in sand slurry flow rate
- Overall time to perform one round of sand disposal for all vessels
- Materials of Construction
- Adequacy with Existing Process Facilities
- Cost for implementation includes Capital Expenditure (CAPEX) and Operational Expenditure (OPEX)

To address these challenges, several sand disposal technologies were evaluated through a systematic process assessment.

4.1. Sandbag Skid

The SandBag Skid system operates based on the principle of gravity settling and mechanical filtration. Its main structure includes a pressure letdown device (PLD) and a storage tank equipped with a sandbag filter. The slurry enters the tank, flows through the filter bag, allowing water to pass through while retaining sand inside the bag.

SandBag Skid comprises of pressure letdown device (PLD) at the inlet and integrated tank equipped with a sandbag. The PLD is designed to provide the correct additional hydraulic resistance between the slurry line and the Sand Bag Skid in order to achieve a constant slurry flow rate without the requirement for a throttling valve. Sand bag is used to trap the sand and oily water flows across the sandbag to a suitable oily water return system. The typical sandbag pore size is 400 microns and can store approximately 800kg of dry sand. However, a 2 stages wedge wire screen could be added at the bottom of the tank to improve the separation efficiency to 50 microns. Multiple Sand Bag Skids are proposed in parallel for this configuration.

The technology can be summarized as below:

- Uses gravity settling and filtration.
- Sand captured in replaceable sand bags (pore size ~400 microns).
- A two-stage wedge wire screen can improve separation to 50 microns.
- Simple and economical, but requires frequent manual handling (increased mercury exposure risk).

Adequacy with Existing Process:

- Integrates with minor piping changes, but manual handling does not align with CPP's HSE goals.
- Less effective for fine sand removal, making it less suitable for regulatory compliance.

According to EnerCorp (2023), gravity settling is one of the most cost-effective solutions for managing sand in oil and gas operations. However, its low efficiency and high maintenance requirements make it less suitable for offshore applications.

Arfie et al. (2005) highlighted that sand management in offshore environments requires not only efficient separation but also proper handling strategies to minimize environmental impact.

Iversen et al. (2006) discussed how advancements in multipath screen technology have improved sand control in deepwater wells, reducing operational challenges.

- Advantages: Simple structure, low cost.
- Disadvantages: Low efficiency (~50 microns), frequent bag replacements, high mercury exposure risk.

Figure 2 above shows the typical sandbag skid device, which illustrates the pressure letdown device and the Sand Bag Skid system. The setup consists of a storage tank, a bag filter, and a water discharge system. The flow is controlled to ensure effective sand settling in the filter bag.

4.2. Hydrocyclone desander

The Hydrocyclone Desander operates based on the principle of centrifugal force, separating sand from the fluid stream by creating a swirling motion inside the device.

Figure 2. Pressure let down device & Sand bag skid (DPI, 2018).

- Advantages: Automated, high efficiency (98% of particles <20 microns).
- Disadvantages: Requires a minimum inlet pressure of 2.5 barg.

Sand Disposal Package using hydrocyclone technology comprises of top section containing cyclones that remove the sand from slurry and bottom accumulator section that stores the separated sands. Solids separation in a cyclone is driven by g-forces induced by the position of the inlet or a swirl element. Various cyclone-based technologies, both conventional and advanced, have been developed to remove sand/solids from well streams, multi-phase and single-phase process streams (Sulzer, 2021). The hydrocyclone desander sand separation is up to 98% of particles < 20 microns (Rawlins, 2017). The de-sanded fluid exits from the top section and is either routed to a suitable oily water return system or recycled as motive water for sand jetting. A sand removal system (e.g., Tore, Hi-Per, etc) is fitted at the bottom of the accumulator section for sand removal to the dewatering bin. Motive water is required for the sand removal system as motive fluid to fluidize the accumulated sand. Then the sand will be transferred to a 200L Sand Drum prior to onshore disposal. With increased use and improved prediction models, the multiphase desander has become a valuable tool in overall sand management (Rawlins, 2013). There are few discussions on the application of this technology, such as Balgobin (2005) discussed how hydrocyclone technology is crucial for managing sand production in ultra-high-rate gas wells, improving operational efficiency while reducing downtime. King et al. (2003) compared sand control completion reliability across thousands of wells, emphasizing the importance of hydrocyclone desanders in extending equipment lifespan and maintaining production integrity. Hadfield (1997) emphasized that wellhead desanding hydrocyclones play a significant role in solving sand production issues at the source, enhancing well productivity and reducing equipment wear. Following to eProcess Technologies (2021), hydrocyclone desanders provide one of the most efficient methods for sand separation in oil and gas production, with minimal manual handling and operational disruption. The Hydrocyclone desander technology can be summarized as below:

- Uses centrifugal force to separate sand.
- Achieves 98% removal of particles smaller than 20 microns.
- Fully automated, minimizing manual handling.

Adequacy with Existing Process:

- Seamlessly integrates with CPP's existing sand slurry stream.
- Operates within the available pressure range, fits CPP's safety and operational goals.

Figure 3 above illustrates how the Hydrocyclone Desander is integrated into the current CPP system. The slurry enters the device, where sand is separated and collected at the bottom, while the cleaned water exits from the top. As can be seen from Figure 4, the operation of the hydrocyclone desander can be illustrated. The slurry enters the upper section of the hydrocyclone at high velocity, creating a strong centrifugal force. Due to the density difference, heavier sand particles move outward to the cyclone walls and spiral downward into the accumulation chamber, while the lighter cleaned fluid exits from the upper section. According to Rocsole (2022), a sand removal system at the bottom ensures controlled disposal of the accumulated sand. The typical desander

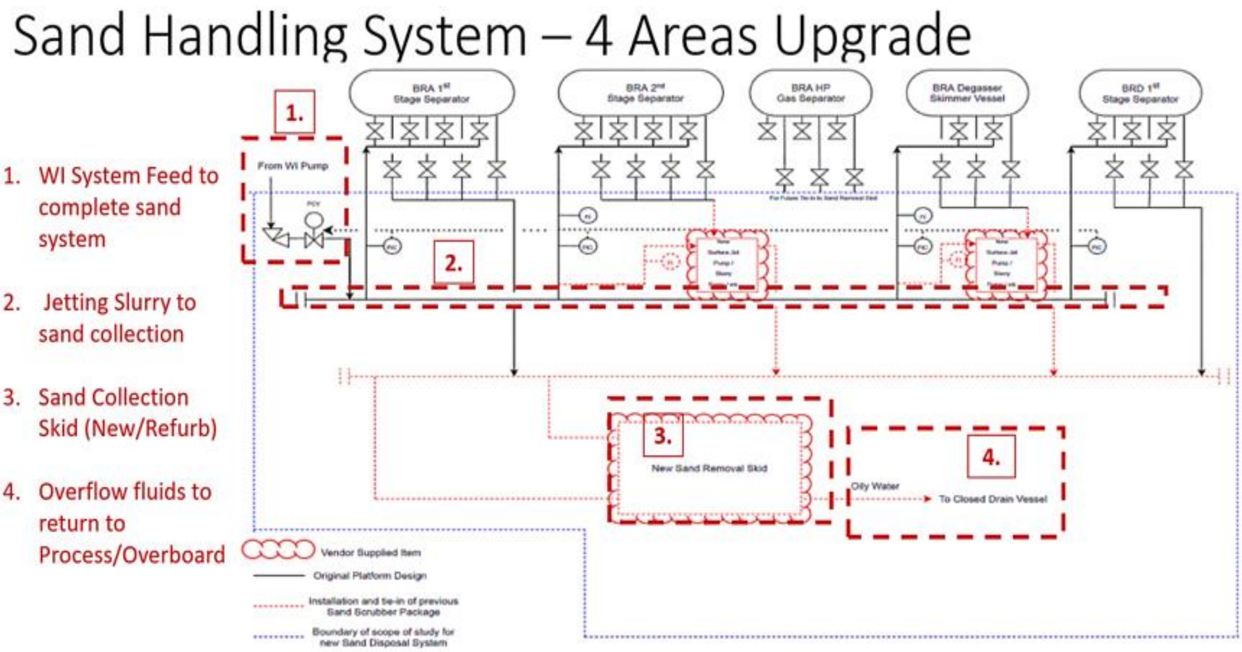

Figure 3. Proposed option for Hydrocyclone desander technology with CPP facility.

Hydrocyclone is shown in Figure 4 below, which describes the flow of fluid with sand into the device, then the sand drops down at the bottom of the equipment for collection.

4.3. Sand Filter Skid

The Sand Filter Skid uses a multi-stage filtration process, with an initial 50-micron filter stage followed by a 2-micron filter stage to separate sand from the fluid stream. FLSmidth (2022) states that multi-stage filtration systems provide superior removal of fine particles but require significant maintenance, making them challenging for offshore environments.

- Advantages: Highest filtration efficiency.
- Disadvantages: Requires high pressure (120 psig), complex maintenance, and high mercury exposure risk.

Sand Filter Package comprises Sand Filters, Sand Bag Tank, AODD Pumps, and Flush Water Tank. The filter element uses a tangential inlet to its advantage as the filter internal is fitted with a concentric outer cylinder which encloses the central filter screen. The slurry enters the vessel via the tangential inlet and is routed into the swirl zone, which creates a cyclonic flow around the filter screen. Large solid particles are transported radially outwards to the swirl tube wall by the centripetal forces created by the swirling flow and exit at the open bottom edge of the swirl tube before settling in the vessel's integrated accumulator. The Sand Filter is able to trap sand particles up to 50 microns. A Dual Pod pleated type filter is required to improve the filtration efficiency up to 2 microns. Once the accumulator is full, the accumulated sand is flushed to the Sand Bag Skid by using flush water pumped from the Flush Water Tank via the AODD Pump. The sand will be collected in the Sand Bag Skid, and flush water will be returned to the Flush Water Tank via the Water Recycle AODD Pump. The sand in the Sand Bag Skid is transferred to the Skip Tank for safe onshore disposal (SV Petroleum,2017). Civan (2000) noted that filtration-based sand management methods are highly effective but require regular maintenance to avoid clogging and performance degradation.

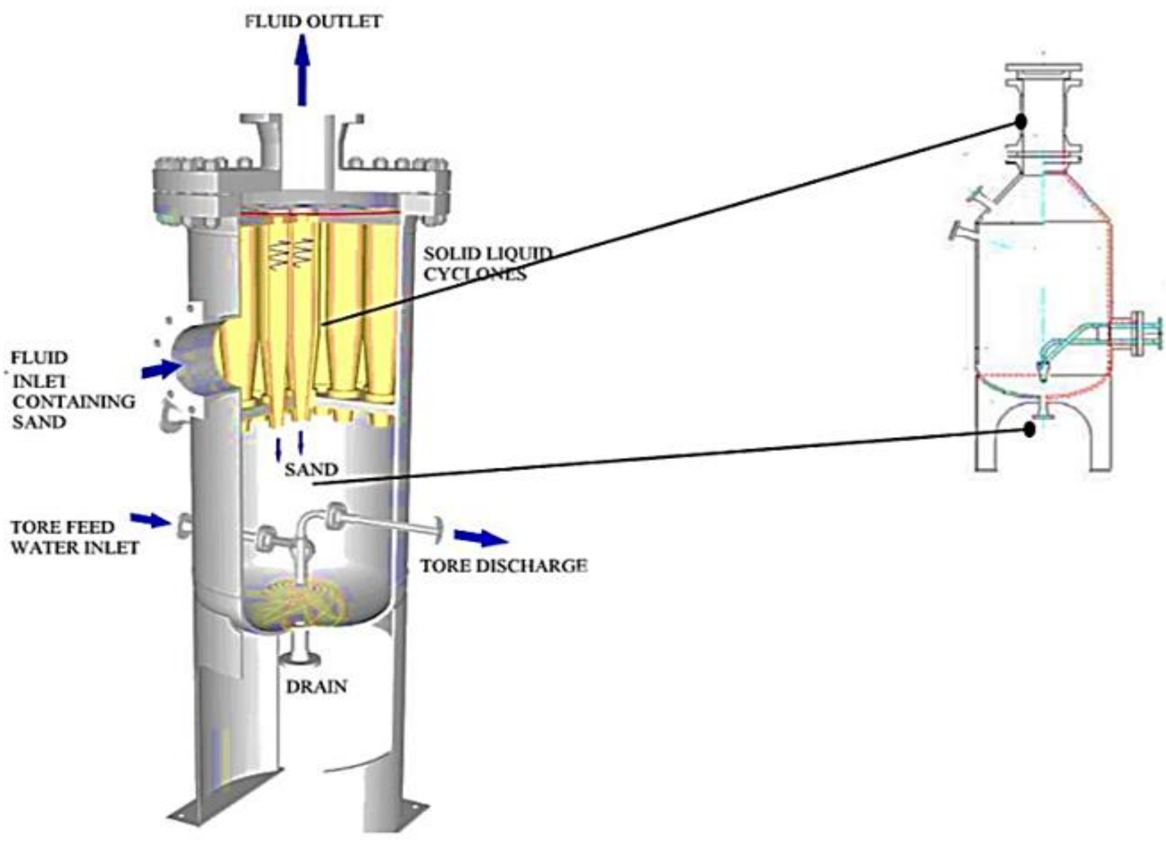

Figure 4. Hydrocyclone desander (Repsol, 2003).

Rawlins et al. (2000) presented a case study on sand separation and handling systems for offshore oil production, highlighting the effectiveness of compact separation technologies in reducing sand-related operational risks. The technology can be simplified as below:

- Multi-stage filtration (first stage 50 microns, second stage 2 microns).
- Highly efficient but requires high maintenance and frequent filter changes.
- Poses significant mercury exposure risks during sandbag handling.
- Requires higher pressure (120 psig) than available, requiring booster pumps.
- Maintenance intensity makes it operationally challenging for remote offshore sites.

Adequacy with Existing Process:

Figure 5 and Figure 6 depict the operational principle and installation diagram of the Sand Filter Skid. The slurry is directed into the filter, where sand is captured in the filter media, and clean water exits. Regular maintenance is required to ensure stable system performance.

With the specification of each technology in Table 1 above, the criteria for assessment will be set to ranking and scoring for each technology. The criteria are as in Tables 2 and 3 below.

These weights were determined through assessment of all aspects, which are facility operation, engineering, and HSE, that could reflect a balance between technical practicality, financial constraints, and compliance obligations. The total score for each technology was calculated using these weights applied to the normalized ratings of each option, as shown in Table 4 of the assessment. Details for the weightage of each criterion are described in Tables 4, 5. The Operability/ Maintainability and Mercury Exposure criteria are detailed in Tables 6 and 7.

4.4. Technology evaluation

- Sand Bag Skid: Simple and low cost, but inefficient and labor-intensive. Moderate fit with the BR-A process.

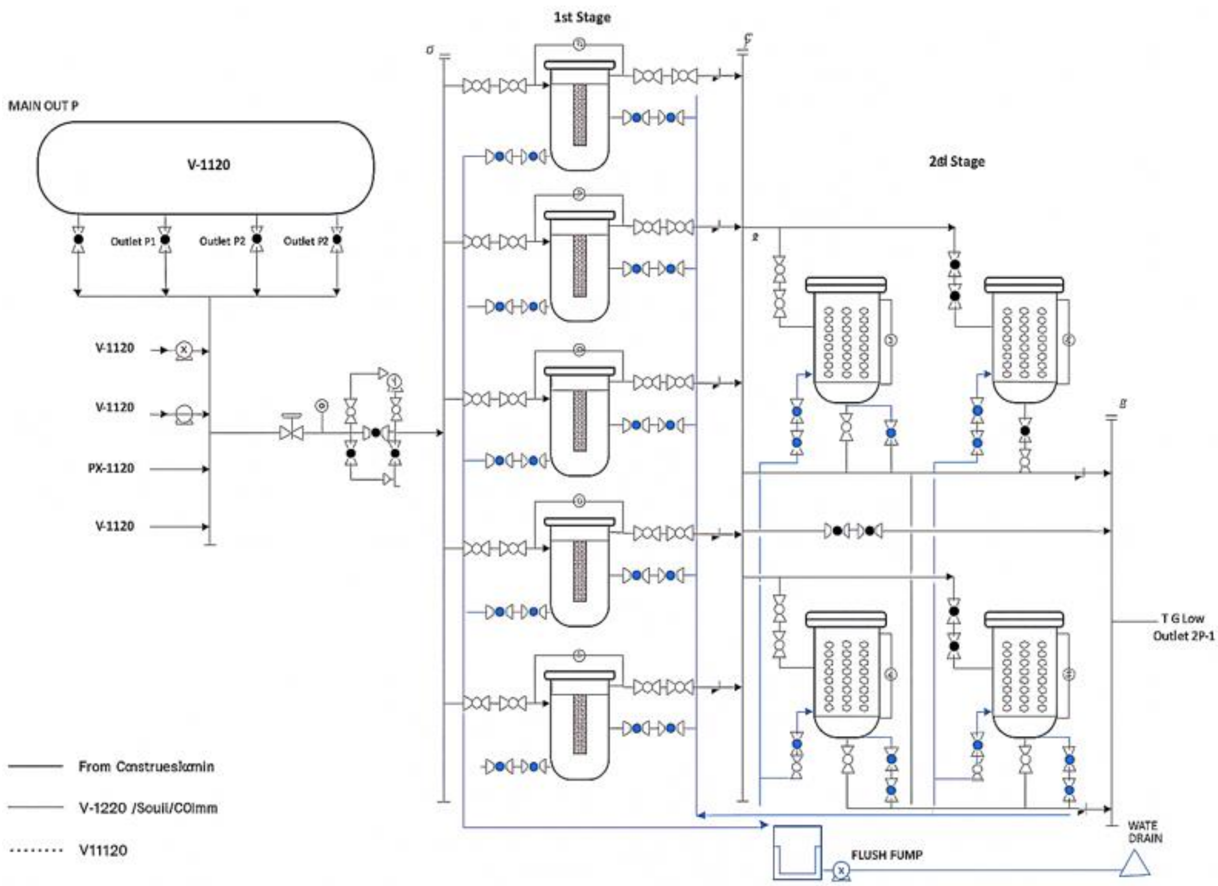

Figure 5. Sand filter technology flow diagram.

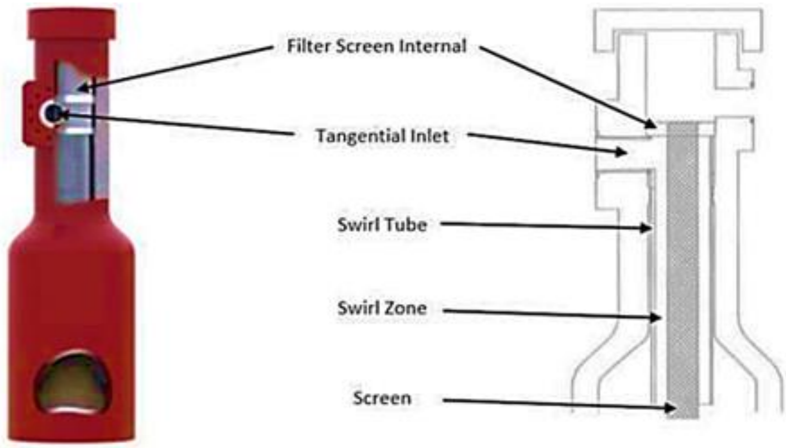

Figure 6. Sand filter.

Table 1. Summary of technology with evaluation criteria.

Criteria	Sand Bag Skid	Hydrocyclone Desander	Sand Filter Skid
Number of Units	6 x 50%	1 x 100%	1st: 6 x 20%, 2nd: 2 x 100%
Method of Separation	Gravity separation	Hydrocyclone	Filtration
Sand Removal Efficiency	50 microns	98% <20 microns*	2 microns
Inlet Pressure Required	PLD-based flow	Min 2.5 barg	120 psig
Differential Pressure	N/A	0.5 - 4 bar	20 psi (clean)
Sand Concentration	10% w/w	10% w/w	No limitation
Flowrate Range	20-30 m^3/hr	8-150 m^3/hr	43 m^3/hr per unit
Turn-up/down Flexibility	+/- 10%	Depends on liners	43 m^3/hr per unit
Accumulator Volume	800 kg/unit	1.34 m^3 (~2400kg)	1250 kg
Sand Removal Process	Manual transfer	Tore/Hi-Per to drum	Flush to bag, lift by crane
Mercury Exposure	Minimal	Minimal	High
Materials	Carbon Steel	Stainless Steel	AISI 4130
Adequacy with Process	Moderate	High	Low
CAPEX	RM 6.3 million	RM 9.8 million	RM 12.5 million
OPEX	RM 3.2 million/yr	RM 1.6 million/yr	RM 4.5 million/yr
*Note: the system can separate all sand particles larger than 20 microns and 98% of particles smaller than 20 microns.			

Table 2. Assessment Criteria.

No.	Assessment Criteria	Score				
		1	2	3	4	5
1	Sand Separation Efficiency	> 50 microns	41÷50 microns	31÷40 microns	21÷30 microns	20 microns
2	Flowrate Basis	No range	Limited Range	Average	Range More	Flowrate Meet Basis
3	Installation / Constructability	Very Hard	Hard	Moderate	Easy	Very Easy
4	Operability / Maintainability	See detail Table 3				
5	Mercury Exposure	See detail Table 4				
6	TENORM Exposure	> 6 hrs	4÷6 hrs	2÷4 hrs	< 2hrs	No Exposure
7	Size / Foot Print	Massive	Huge	Moderate	Small	Not Required
8	Structure Impact (Modification Tonnage)	>30 MT	25÷30 MT	20÷25 MT	15÷20 MT	< 15 MT
9	Project Schedule	>65 weeks	61÷65 weeks	56÷60 weeks	51÷55 weeks	weeks < 51
10	OPEX (RM)	> 9.0 Mil	7.0÷9.0 Mil	5.0÷7.0 Mil	3.0÷5.0 Mil	< 3.0 Mil
11	CAPEX (RM)	> 50 Mil	40÷50 Mil	30÷40 Mil	20÷30 Mil	< 20 Mil

Table 3. Scoring for each technology based on criteria.

Criteria	Weightage	Sand Bag Skid	Hydrocyclone Desander	Sand Filter Skid
Sand Separation Efficiency	10.3%	2	4	5
Flowrate Basis	10.3%	5	4	5
Installation/ Constructability	6.4%	2	3	1
Operability / Maintainability	8.5%	3.6	4.7	2.4
Mercury Exposure	10.9%	4.0	3.5	1.3
TENORM Exposure	10.9%	4	3	1
Size / Foot Print	8.5%	2	3	1
Structure Impact	7.0%	3	3	2
Schedule	8.5%	3	1	3
OPEX	9.4%	1	3	1
CAPEX	9.4%	4	4	3
Total Score	100%	3.13	3.33	2.40

Table 4. Weightage description.

MM	M	E	L	LL
Much More Important	More Important	Important Equally	Important Less	Much Less Important
100%	80%	60%	40%	20%

Table 5. Weightage calculation.

Criteria	Sand Separation Efficiency	Flowrate Basis	Installation/ Constructability	Operability/ Maintainability	Mercury Exposure	TENORM Exposure	Size / Foot Print	Structure Impact	Schedule	OPEX	CAPEX	Weightage
Sand Separation Efficiency	X	E	M	M	E	E	M	M	E	E	E	10.30%
Flowrate Basis	E	X	M	M	E	E	M	M	E	E	E	10.30%
Installation/ Constructability	L	L	X	L	L	L	L	E	L	L	L	6.40%
Operability/ Maintainability	L	L	M	X	E	E	L	M	L	E	E	8.50%
Mercury Exposure	E	E	M	E	X	E	M	M	M	M	M	10.90%
TENORM Exposure	E	E	M	E	E	X	M	M	M	M	M	10.90%
Size/ Foot Print	L	L	M	M	L	L	X	E	E	E	E	8.50%
Structure Impact	L	L	E	L	L	L	E	X	E	L	L	7.00%
Schedule	E	E	M	M	L	L	E	E	X	L	L	8.50%
OPEX	E	E	M	E	L	L	E	M	M	X	E	9.40%
CAPEX	E	E	M	E	L	L	E	M	M	E	X	9.40%

Table 6. Operability/Maintenance detail assessment.

Criteria	Weightage	Sand Bag Skid	Hydrocyclone Desander	Sand Filter Skid
Duration of flushing/ filling	21.74%	10.5 hrs per week (for 21 skid). 15-30 mins per flushing.	3.95 hrs per week (for 79 drum). 3 mins per sand drum filling.	67 hrs per week. 30-60 mins per flushing.
		4	5	2
Requirement of crane lifting to storage area	21.74%	Yes. 21 times lifting per week.	Yes. 4 times lifting per week.	Yes. 28 times lifting per week.
		3	5	3

Requirement of mercury PPE	21.74%	Required only mask and glove.	Required only mask and glove.	Required full suit mercury handling PPE .
		4	4	1
Numbers of breaking connection	21.74%	4 nos. per skid	N/A	1 nos. (top flange)
		3	5	4
Maintenance	13.04%	Low maintenance	Low maintenance	Filter change-out and pump maintenance
		4	4	2
Score		3.6	4.7	2.4

Table 7. Mercury Exposure detail assessment.

Criteria	Weightage	*Sand Bag Skid*	*Hydrocyclone Desander*	*Sand Filter Skid*
Distance of operator from the contaminated source	25.00%	Direct handing during hose disconnects (<1m)	Direct handling during sand transfer to the drum via hose (<1m)	Direct handing during sand bag transfer (<0.5m)
		3	3	2
Total exposure time with total drum/sand bag to fill	25.00%	1.8 hrs per week (for 21 skid) based on 5 mins breaking connection per skid	3.95 hrs per week (for 79 drum) 3 mins per sand drum filling	7 hrs per week (for 28 bag) based on 15 mins sand transfer to Skip Tank
		4	3	1
Physical direct contact with contaminated material	25.00%	No direct contact due to quick connect and isolation valve. Required only mask and glove	No direct contact during sand transfer to drum via flexible hose. Required only mask and glove	Yes, during handling sand bag removal / filter removal. Required full suit mercury handling PPE
		5	5	1
Potential mercury volume	25.00%	0.025mg/m3.hr for 1.8hrs = 0.045 mg/m3 (Assume: 0.025mg/m3 mercury exposure per hour)	0.025mg/m3.hr for 3.95hrs = 0.1 mg/m3 (Assume: 0.025mg/m3 mercury exposure per hour)	1.05mg/m3.hr in air due to vessel entry (Recorded data: 1.05mg/m3 mercury exposure in air)
		4	3	1
Score		4	3.5	1.3

- Hydrocyclone Desander: Best fit - efficient, automated, safe, and compliant with regulatory needs.
- Sand Filter Skid: Excellent filtration, but too complex, high-maintenance, and high exposure risks.

All technologies were evaluated in a safe and environmental manner:

- Complies with environmental standards requirements.
- Mercury-contaminated sand is either injected offshore or disposed of onshore under controlled conditions.
- Hydrocyclone Desander reduces manual handling, improving HSE outcomes.

5. Results and discussion

The combined technology ranking and operational feedback led to the following conclusions:

- Hydrocyclone Desander emerged as the preferred technology due to its compact design, high separation efficiency, and reduced manual handling. Its proven track record in offshore applications further supports this selection.
- Sand Bag Skid, while offering flexibility and moderate cost, presented concerns related to manual handling frequency and long-term operational efficiency. However, it was selected for initial trials due to its rapid deployment and ease of monitoring actual sand production rates.

- Sand Filter Skid was excluded from further consideration due to its large footprint, high clogging risk, and excessive capital cost, which made it unsuitable for offshore deployment.

The selected Hydrocyclone Desander, supplemented with initial Sand Bag Skid trials, offers a balanced approach - combining proven efficiency with a practical, low-risk method to validate actual sand production rates before full-scale implementation.

6. Conclusions

The review and evaluation of some technologies were made, and there are some conclusions as below:

- Hydrocyclone Desander ranked highest in the technology assessment, followed closely by Sand Bag Skid.
- Due to close scoring, a Sand Bag Skid Trial Unit is recommended to:
    - Assess sand separation efficiency.
    - Measure actual sand production and slurry flow rate.
    - Check operability, safety, and mercury/TENORM exposure.
- If the Sand Bag Skid Trial Unit performs well (capturing particles down to 21-30 microns), it could become the preferred technology in Phase 2.
- The trial will also validate sand production estimates (SOR Basis). Lower-than-expected production could reduce CAPEX and OPEX.
- If the Hydrocyclone Desander is selected instead, options include:
    - Procuring a new package.
    - Refurbishing the existing package (only feasible if cyclonic devices can be installed inside separators).
    - Simple refurbishment is not recommended due to insufficient capacity.
- Sand Filter Skid is not considered viable due to:
    - Large footprint.
    - High risk of filter clogging.
    - Excessive capital cost and difficult handling.

The Hydrocyclone Desander is recommended for BR-A's sand disposal system, as it offers the best balance of operational performance, safety, regulatory compliance, and long-term cost-efficiency. Future enhancements could focus on automation upgrades and real-time monitoring for improved operational control. This technology can also be considered to apply to the field under the same conditions in the Malay-Tho Chu basin, where suppliers are available and experience from PM3CAA.

Contributions of authors

Quan Anh Tran - methodology, writing, review & editing; Long Khac Nguyen - writing, review & editing, supervision; An Hai Nguyen, Vinh The Nguyen - review & editing, supervision.

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