Technical sciences

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ENVIRONMENTAL SUSTAINABILITY IN WELL TESTING: TECHNOLOGIES TO REDUCE THE NEGATIVE IMPACT ON THE ENVIRONMENT

Summary. *The article discusses environmental sustainability at the well testing stage, which is considered one of the most sensitive processes in the oil and gas industry. Based on an analysis of international standards, guidelines, and industry data, sources and types of impacts are summarized, including flaring and venting, water discharge, chemicals, and waste/spills. Practices for reducing these impacts are evaluated. It is shown that maximum effect can be achieved by combining in-line testing with multiphase flow meters, trapping and compression, integration into existing systems, product reinjection, and zero discharge of water. Highly efficient flare systems are also important, as well as transitioning to methane measurement and reporting (MRV) programs. Limitations are noted, and directions for future development are proposed.*

Key words: *well testing, environmental sustainability, flaring, venting, in-line testing, multiphase flow meter, reinjection, produced water.*

Well testing remains one of the most environmentally sensitive stages of oil and gas operations. These processes are accompanied by the risks of soil and groundwater contamination, chemical effects from drilling fluids and waste, as well as emissions of pollutants into the atmosphere. It is important to note that these activities pose a potentially significant risk to ecosystems and public health, particularly in sensitive areas such as the Arctic region.

In today's world, there is a strong trend towards using sustainable and environmentally friendly methods. Directional drilling techniques have proven effective in minimizing surface impacts on soil and preventing pollution. At the same time, automated monitoring systems are widely used to ensure the safety of equipment and environment, significantly reducing the risk of accidents and spills. This reflects a shift away from traditional, often harmful testing methods towards more careful and responsible approaches.

With stricter environmental regulations and increased focus on sustainable development, it is crucial to analyze and implement environmentally friendly technologies in well testing.

The aim of this research is to conduct a comprehensive analysis and evaluation of modern technologies and techniques designed to minimize the negative environmental impact of well drilling, with a focus on their efficiency, implementation possibilities, and potential for long-term environmental management.

The regulatory and theoretical framework for environmental sustainability in well testing is based on a combination of international management standards, industry guidelines for environmental safety (EHS), regional marine regulations, and specialized flaring and gas release permit regimes. ISO 14001:2015 serves as a foundation, defining the requirements for an environmental management system, including identification of aspects, compliance with legal requirements, setting goals, monitoring, internal auditing, and continuous improvement. For oil and gas companies, this means that all well development and testing activities must be planned and carried out within the context of a documented environmental management system. This includes assessing emission risks during testing, establishing procedures for avoiding flaring, recording and reporting on generated emissions, and creating an action plan in case of deviations [4].

In the industry, the IFC's Guidelines on OTOS for Offshore Oil and Gas Production play a crucial role, directly addressing operations during well testing. These guidelines emphasize the importance of avoiding flare burning during tests, particularly in environmentally sensitive areas. If flare burning is not feasible, they recommend ensuring high combustion efficiency (over 95%) and estimating the volume of flare emissions in advance. Additionally, they emphasize the need to record and report all flare episodes and consider alternative solutions such as recycling, reinjection, or closed collection systems. These guidelines establish a practical "best practice" standard for designing test programs and selecting flare, separation, and transportation configurations [3].

At the regional level, the OSPAR regime applies to offshore operations in the North Atlantic. This regime sets criteria for water discharges from reservoirs and reporting requirements. The standard for working performance is 30 mg/L of dispersed oil as an average monthly concentration in discharged water. Participating States annually report on any installations that exceed this standard and the measures taken to address it. For well testing programs, this means implementing separation and purification systems, including time lines for testing, to ensure that the 30 mg/L indicator is achieved or to exclude discharge (through removal/disposal) during the testing period [7].

In terms of climate commitments and methane emissions from well testing, in 2020, the United Nations (UN) and the United Nations Environment Programme (UNEP), together with the European Commission (EC) and the European Development Fund (EDF), launched the Oil and Gas Methane Platform 2.0 (OGMP 2.0), a "gold standard" for measuring and reporting methane emissions across the entire oil and gas supply chain. For operators, this means more stringent inventory requirements for methane sources, including cold flares, test breakthroughs, and purge systems. It also means increased data sharing based on direct measurements and expanded reporting requirements for assets managed by contractors. The inclusion of well testing in the OGMP 2.0 framework allows operators to link their flare/venting reduction efforts with methane reduction targets, providing greater transparency for regulators and investors [5].

In addition to the equipment used in the tests, auxiliary vessels and marine logistics also affect the environmental impact. These activities are governed by MARPOL Annex VI, which includes strict limits on sulfur emissions (0.50% from January 1, 2020). This regulatory framework influences decisions about fuel/scrubber selection, flight planning, and accounting for NOx/SOx emissions during the testing period. During well testing, environmental loads are generated from three main sources: emissions to the atmosphere during flaring and venting, discharges to the aquatic environment from handling of produced water and process fluids, and waste generation and risk of accidental spills. The International Finance Corporation (IFC) guidelines on Environmental, Health, and Safety (EHS) for offshore mining explicitly state that flaring should be avoided during planning and execution of tests, especially in sensitive environments. If flaring is unavoidable, it is recommended to ensure high combustion efficiency (>95%) and document each instance, and consider alternative methods even during the design phase of the testing program. This approach is considered "best international industry practice" and serves as a benchmark for minimizing short-term environmental impacts during testing [3].

The figure below illustrates the main sources of emissions and discharges during the testing phase of wells at offshore installations. These include flaring and venting of gas, exhaust emissions from power equipment and auxiliary vessels, water treatment processes, potential spills, and accumulation of drilling waste.

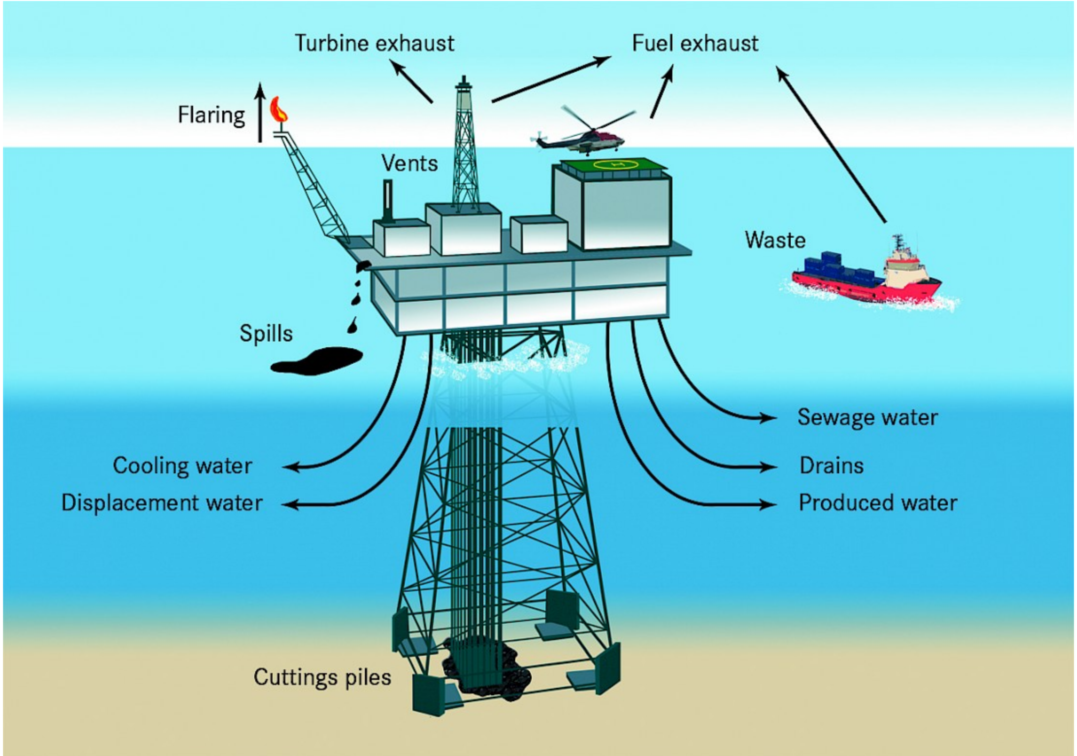

Fig. 1. Sources and ways of negative environmental impact during well testing on an offshore platform [6]

Environmentally sustainable well testing can be achieved through a combination of measures that prevent flare and venting, product recycling and reinjection, water and chemical management, as well as accurate measurement and reporting of emissions. The key to reducing the environmental impact is converting temporary test flows into closed loops, using highly efficient combustion and trapping equipment, and adhering to strict regulatory thresholds for water content and sulfur levels in marine fuels (for offshore operations), as well as implementing leak detection and repair programs (see table below).

Table 1

Modern technologies for reducing environmental impacts during well testing

Technology	Point	Environmental impact	Application in tests	Conditions/restrictions
In-line tests with multiphase flowmeters (MPFM).	Flow rate measurement without a classical separator; the flow returns to the current preparation scheme.	Minimization/exclusion of flare emissions and spills.	Short and extended tests on objects with the ability to return fluids to the process.	Process compatibility and MPFM accuracy are required.
"Green" completions (REC).	Extraction of gas from the flowback / cleanup stream to the line / preparation or to the capture plant.	Drastic reduction of ventilation / flare; useful use of gas.	Onshore/offshore tests when connected to the collection.	Temporary separators, VRUs/compressors, and reception points are needed.
Temporary capture/compression.	Routing of the test gas to the collector through mobile compressors.	Decrease in flare volumes; increase in the share of recycled gas.	Short/EWT near the infrastructure.	Power supply, safety requirements, and playground.
Reinjection of test products and/or "zero discharge" of water.	Compression and reverse injection of gas; aftertreatment or complete abandonment of discharged water.	Exclusion of discharges into the aquatic environment; reduction of fugitive emissions.	Extended tests on injection fields.	Energy consumption, reservoir requirements, and water quality.
Flare systems of increased efficiency.	Optimized burners/backup; closed generators at low flow rates.	High degree of destruction of pollutants; reduction of smoke/soot.	When disposal is temporarily impossible.	We need to adjust and control the heat output and height of the torch.
LDAR and Methane measurement Control (MRV).	Regular leak detection/elimination, transition from calculation to measurement reporting.	Reduction of the fugitive Ch_4; improvement of KPI accuracy.	Temporary strapping, flare / compressor equipment.	Detour schedules, trained staff, and tools are required.

Source: author's development

Even with the active implementation of sample flow capture and discharge in the technological scheme, "faceless" testing is limited by infrastructure and operational modes. Water quality and chemistry also impose limits. In the OSPAR region, the standard for dispersed oil in produced water is 30 mg/L (average monthly); in 2019, 17 offshore installations exceeded this threshold, but the "excess" discharges accounted for less than 2% of the total dispersed oil in the region. The average concentrations for the period 2009-2019 generally stayed within the range of ~12.4-14.1 mg/L. For testing purposes, this requires the deployment of mobile aftertreatment units or the application of reinjection, as non-standard flow rates and composition during EWT (enhanced water treatment) can quickly cause the system to exceed limit values [1].

Some of the limitations relate to the measurement and verification of "sustainable" solutions. For example, multiphase flow meters, which are used for "in-line" and "closed" tests without a flare, have significant accuracy issues depending on the flow mode and composition. A laboratory example of microwave tomography shows a relative error of about 12% with a water content of 65.80% in a water-liquid multiphase stream. This illustrates the limits of applicability and the need for careful interpretation of data when designing "faceless" tests.

Additionally, the UKCS regulator's reports emphasize that the calculation of flare emissions and ventilation accounting is accompanied by high uncertainty due to difficulties in direct measurement and assumptions about gorenje composition/efficiency. This limits the accuracy of short-term monitoring improvements.

Even when using "clean" flare systems, there are physical limits: the efficiency and stability of combustion decreases with low heat content of the mixture and wind turbulence. This increases the risk of incomplete combustion and soot formation, at variable costs typical for start-ups and stops during tests. Flare manuals and techniques emphasize the importance of controlling heat output, air intake, and flare height to ensure a high level of pollutant degradation [2].

Restrictions on the supply of fuel are added to offshore logistics. From January 1, 2020, a global limit of 0.5% sulfur content in marine fuel under MARPOL Annex VI has been introduced, requiring the transition to low-sulfur fuels or scrubbers. This measure reduces SO_2 emissions, but at the same time, it increases the requirements for planning and readiness of equipment for new fuels during testing periods [8].

In the coming years, it is likely that well testing will move away from traditional combustion methods to more closed and low-emission systems. This shift will involve an increase in in-line testing with multiphase flow meters, and a return to current preparation methods. The torch will continue to be used as a safety measure, but it will also be used for rare technological applications. Where it is not possible to return to traditional methods, mobile capture and compression systems will be used to transfer test gas from emission categories to useful resources.

At the same time, the tests will be "digitized" by continuous monitoring of emissions (methane, CO2, black carbon) using a combination of on-site sensors, optical imaging, and remote methods, such as satellites. This data will be linked to technological models and digital systems, allowing for the planning of EWT duration and modes based on specific emission and water limits. Testing coordination will be based on measurable key performance indicators (KPIs) rather than calculated assumptions.

For the aquatic environment, there is a trend towards "zero discharge" during the testing period, through either reinjection or the use of compact mobile post-treatment modules with online quality control.

In terms of chemistry, the use of "green portfolio" reagents is expected to become more widespread, including pre-approved formulations, the rapid replacement of "red" (hazardous) components, and end-to-end accountability.

Regarding engineering, it is likely that closed flare installations and generators will be used for low and variable cost operations, as well as "smokeless" solutions that utilize controlled air and steam supply. Electrification, variable frequency drives, and hybrid power sources are also likely to see increased use in the energy sector.

At the level of management practices, we can expect to see a more rigorous avoid–minimize–measure approach. This includes avoiding flaring or venting where it is possible to dispose of emissions, optimizing test durations, and mandatory reporting on methane emissions with external verification. Additionally, the economy will favor "green" solutions. The growth of carbon pricing and internal emission prices in companies will encourage the capture and reinjection of emissions rather than incineration.

Finally, standardization is expected, including unified test data formats, comparable performance assessment methods for flares, trapping and water, emission intensity benchmarks and open case databases. This will move well testing towards the "default mode - facultless, measurable, considering water and chemistry", leaving traditional schemes as exceptions requiring a separate justification.

Thus, a set of technological and managerial measures can significantly reduce the environmental impact of well testing without losing the informative value of the tests. In practice, priority should be given to closed circuits (in line with MPFM) and gas capture/compression during testing; flare combustion should be used as a backup and safety measure in highly efficient installations. Reinjection into the environment or mobile after treatment are optimal for aquatic environments; for gas environments, transitioning to methane measurement and systematic LDAR programs are optimal.

It is advisable to manage well testing within the framework of ISO 14001 standards and industry guidelines using the "avoid - minimize - measure" principle. Digital monitoring and uniform key performance indicators (KPIs) should be implemented. The main challenges relate to infrastructure, accuracy of multicomponent measurements, and cost of compliance with marine regulations. Overcoming these challenges requires early planning, backup plans for diversion and cleaning, and the step-by-step standardization of processes.

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