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ENVIRONMENTAL SUSTAINABILITY CHALLENGES IN THE OPERATION OF IN-LAND HYDROCARBON PIPELINES: THE CASE OF EASTERN PROVINCE OF SAUDI ARABIA

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Summary. The main focus of this paper is on the environmental sustainability challenges of in-land hydrocarbon pipelines on the example of Eastern Province of Saudi Arabia. Hydrocarbon pipelines have been known for causing significant environmental damage, in addition to requiring vast amounts of natural resources such as water, land, steel, etc. Therefore, environmentally sustainable operation of pipelines is a concern that requires further research. The paper describes environmental challenges of pipeline operations and provides examples of approaches and technologies that can be successfully utilized to make pipelines more environmentally sustainable. It is concluded that the operation of in-land hydrocarbon pipelines can be made environmentally sustainable. This can be achieved by adopting a systematic framework, focusing limited resources on significant environmental aspects and technologies, integrating circular economy into day-to-day activities, and having strong management support.

Introduction

The need for increased environmental sustainability of human activities and businesses is being widely recognized both at national and international levels. Depletion of natural resources, increase of waste generation, climate change, rise in the level of greenhouse gas emissions and other phenomena are gradually pushing the mankind and governments around the world to realize that we have only one planet (Connor et al., 2020. Exploration of oil and gas resources can bring prosperity to a country with a long-term energy policy in place, and balanced, responsible behaviour towards environment. Regrettably, the process of environmental pollution occurs at all stages of the oil industry: exploration, production, transportation, storage and refining (Rossa, Dario, 2013). Although use of pipelines has justified itself as being one of the flexible and cost-effective options, pipelines have been notorious for causing major environmental contamination. Furthermore, the operation of in-land hydrocarbon pipelines requires considerable amounts of natural resources such as water, land, steel, etc. (Goodland, 2005; Longo, 2019; Belvederesi et al., 2018). As a result, environmental sustainability of pipelines is a significant concern.

Methods or Theory

The main objective of this paper is to review environmental sustainability challenges of in-land hydrocarbon pipelines. Eastern Province of Saudi Arabia has been selected as a case study due to being a major hub of pipelines' network. Methods consist of reviewing literature for international best practices and using successful examples from field work.

Results and discussion

A. Environmental Sustainability in In-land Pipelines Operations

Pipelines in Saudi Arabia transport millions of barrels of hydrocarbon products per day and are capable of causing serious environmental damage. Unlike plants and refineries which tend to operate within a fence, pipelines extend for hundreds of kilometers deep into remote, desert areas, and run both under- and above-ground. Moreover, because of their remoteness, pipelines may run in areas with no infrastructure (e.g., telecommunications network) to support deployment of surveillance equipment for pipeline monitoring purposes. This feature of pipelines greatly influences the way environmental challenges are controlled.

Common significant environmental aspects for in-land hydrocarbon pipelines include: a) oil spill; b) gas release; c) fugitive emissions; d) flaring and SO_2 emissions; e) consumption of groundwater; f) discharge of wastewater; g) energy consumption; h) generation of hazardous wastes and others. Consequently, environmental impacts would be soil pollution, air pollution, global warming, depletion of natural resources and so on.

It is argued that in-land hydrocarbon pipeline operations can be made environmentally sustainable by applying a systematic approach based on key principles of ISO 14001 standard:

- *Establish Significant Environmental Aspects:* organizations need to identify environmental risks of pipeline operations and build-up the so-called "Environmental Aspects and Impacts Register". Using a risk ranking methodology, the most significant aspects should be highlighted, and then limited resources should be concentrated on those aspects. This approach is more beneficial than trying to resolve all environmental challenges at once.
- *Set specific and measurable environmental targets and objectives for Operations, Maintenance and Engineering disciplines* (e.g., reduction of flaring, reduction of oil and gas leaks, repair of valves instead of replacement, etc.). The targets and objectives must be approved by management and must be linked to significant environmental aspects.
- *Conduct regular (e.g., quarterly) management environmental reviews* to discuss progress towards achieving environmental targets and objectives.
- *Integrate/embed environmental requirements into operational and engineering procedures.* This is to ensure that work is executed in accordance with such requirements from the very beginning.
- *Deploy intelligent tools and equipment:* focus new technologies and equipment on significant environmental aspects in order to yield maximum benefits.
- *Include environmental sustainability initiatives into the annual budget cycle*: trying to implement environmental initiatives with no planning and budget will produce little value. Instead, such initiatives must be linked to significant environmental aspects and included into the organization's annual budget cycle. Moreover, the cost should demonstrate potential savings and other benefits to be realized in the long run (e.g., reduced maintenance or operating costs, reduction in the number of environmental infringements, improvement in pollution levels, etc.).

B. Environmental Aspects of Oil Spills

Oil spills are one of the significant environmental aspects in in-land hydrocarbon pipeline operations. Pipeline operators may implement extensive inspection regimes in order to preserve integrity of pipelines, but ruptures and oil leaks still take place. In terms of environmental sustainability, a major issue here is that, over a period of time, hydrocarbon spills (small and major) lead to gradual contamination of land around pipelines. This requires systematic clean-up effort which should also be cost-efficient. While prevention of all oil spills may not be always feasible, pipeline operators may consider investing in mobile sand cleaning technologies, among other solutions. One such technology is a thermal desorption unit which has been used in many industries in North America and Europe for the past several decades.

Direct fired thermal desorption unit

This technology heats contaminated material to a high enough temperature to dry it and vaporize contaminants from it. The technology is trailer-mounted and can be deployed with relative ease to remote desert areas. By utilizing such solutions, contaminated lands around pipelines can be purified gradually and

systematically to the specification required by local legislation. This would lead to improved environmental sustainability of pipeline operations.

C. Fugitive Emissions

Fugitive emissions (e.g., volatile organic compounds) are one of the significant environmental aspects in pipelines, with valves being the most common source. Normally, these emissions are identified and remediated by means of annual Leak Detection and Repair (LDAR) Surveys. However, considering remoteness and geographical spread of pipelines, an annual survey may not always be sufficient for ensuring a long-term environmental sustainability of pipeline operations. It is suggested, therefore, that the annual surveys in pipelines can be supplemented by installation of fixed gas leak detection cameras. The latter has functionality to quantify gas leaks and provide an instant detection and alert to the Operations teams rather than having to wait for the next annual LDAR survey.

A relatively new trend in the industry has been the use of so called "Low-E" or "Low-Emission" valves and packing. The rise of popularity of such valves has been driven by environmental enforcement agencies like the US EPA and strict environmental legislation. A key difference between a Low-E and non-Low-E valve is that the former comes with the warranty from the manufacturer that the valve will not leak above 100 parts per million for five years.

To summarize, by enhancing annual LDAR surveys with installation of fixed gas leak detection systems and gradual deployment of Low-E valves pipeline operators in Saudi Arabia can significantly improve environmental sustainability of their operations.

D. Flaring and SO_2 Emissions

Millions of standard cubic feet of gas are flared annually by pipeline operators. Pipelines operate a high number of valves which require maintenance and replacement. In many instances, a valve replacement would lead to a section of pipeline being emptied of gas to allow the crew to work safely. To ensure longer term benefits and environmental sustainability, piloting and testing new technologies should be given high priority. Two types of technologies can be considered. First, mobile gas evacuation units which capture the gas to be flared and divert it from one pipeline to an adjacent pipeline thereby completely eliminating the flare. Second, mobile degassing units are available to incinerate the flare gas at a high efficiency rate resulting in no smoke and noise pollution as well as elimination of hazardous pollutants. While these types of technologies have been extensively used by the industries in North America and Europe, they have not been fully adopted yet in Saudi Arabia although steps in the right direction are being taken. This, therefore, presents an excellent opportunity for further improving environmental sustainability of pipeline operations.

E. Circular Economy

With the growing volumes of wastes and increased consumption of natural resources, the principle of circular economy has been gaining momentum. The economy is defined as "circular" when it focuses on elimination of wastes by reusing, recycling, and refurbishing equipment, products, and machinery for a longer duration (Vanhamaki, 2021; Corvellec et al., 2021). In this regard, pipeline business, just like many others, can successfully adopt the circular economy approach. Numerous opportunities exist for re-use and recycling of products and materials used in pipeline operations and maintenance activities. By integrating circular economy into day-to-day activities, making pipelines an environmentally sustainable business is an achievable and realistic goal. As part of the circular economy, it is advantageous to conduct life cycle assessments (LCA) on products, materials and services procured for pipelines. Even though these assessments have not become commonplace yet, the awareness about them is currently on the rise. This is partly due to ISO 14001: 2015 (EMS) standard which encourages organizations to adopt a life cycle perspective (Bressanelli et al., 2022).

Conclusion

It is concluded that there are plenty of opportunities to make the operation of in-land hydrocarbon pipelines environmentally sustainable. The means available to pipeline operators range from adopting a systematic approach, deploying technologies and focusing on significant environmental aspects, to integrating circular economy into day to day activities. Carrying out life cycle assessments for various products and materials used in pipelines would further help to identify what exactly can be re-used, recycled or extended for longer life. Also, one should not ignore the value of engaging pipeline workforce and engineers to contribute suggestions on how their operations can become more sustainable. Furthermore, management support will play a crucial role in this whole process since it is the management responsibility to allocate necessary resources, provide strategic direction and inspire their organizations to achieve a more environmentally sustainable mode of operation.

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