Strategies for Mitigating Benzene Exposure in the Oil Industry: A Safety Enhancement Proposal

By Emma Bisson, Devon Thomas

Abstract

This proposal delivers a potential solution to reduce benzene exposure to workers in the oil industry. Benzene has been correlated with health issues, particularly cancer. Benzene is released throughout the oil production process and is not adequately managed to ensure optimal worker protection. This paper proposes a transdisciplinary solution to reduce exposure through increased personal protective equipment (PPE) and a pollution mitigation device. The proposed approach incorporates a micro-focus on human health that comes from biochemistry, as well as an engineering design approach from chemical engineering. Furthermore, the proposal expands beyond these disciplines to provide a multifaceted solution to benzene emissions in the oil industry and beyond.

Problem Description

Oil production involves many stages, from extracting crude oil to refining and processing it into usable forms. Throughout this process, numerous chemicals harm human health. Benzene, a hydrocarbon often released in trace concentrations during oil processing, has been extensively studied by biochemists and medical professionals for its carcinogenic properties. It is highly concerning that workers in oil facilities are frequently exposed to benzene.

Oil plants can use several technologies to remove pollutants such as sulfur and nitrogen oxides. However, methods to protect workers from benzene are lacking. Although benzene concentrations at oil refineries can be measured, studies have shown that these values are often underestimated and exhibit significant variation (Hoyt, 2015). Monitoring technology alone is insufficient. If workers wear protective equipment and refineries implement technologies to reduce benzene emissions within oil facilities, exposure levels may decrease.

Chemical engineers have extensively researched emissions of benzene and other chemicals from the oil production process. This research involves quantitative sampling and experimentation to measure the pollutants released from oil processing facilities. These pollutants include benzene and other polycyclic aromatic hydrocarbons (PAHs). The transport of these pollutants from oil processing units to refineries and surrounding areas can pose health risks to workers and nearby residents. Just as the reporting of benzene concentrations is inconsistent, there is also significant variation in benzene levels at different stages of oil manufacturing. These variations can be attributed to differences in the characteristics of the oil, its extraction location, and the processing equipment used (Olajire, 2020). Therefore, it is essential to develop a strategy that can adapt to various conditions while ensuring the safety of workers.

In contrast, biochemists and medical researchers take a more microscopic view of how these chemicals affect the human body. Biochemistry breaks down the chemical structures and the various health problems that arise when these molecules interact with a person's immune system. It also analyzes different factors as to why these compounds may trigger something in the human body, including a third variable to people who are affected by these pollutants and if this may be the underlying reason behind the compounds having a strong effect on humans. Thus, implementing some solutions that can limit exposure to volatile compounds is crucial for ensuring the safety of workers.

While chemical engineering knowledge provides a necessary understanding of how petroleum processing releases chemicals and the quantities released, it does not adequately address the human safety concerns that biochemistry does. Similarly, biochemistry considers the toxic nature of these chemicals, but fails to consider the specific contexts they come from. Both approaches are highly technical and demonstrate proficiency in understanding the transport or harm of these chemicals; however, to ensure human health, these two approaches should be merged to answer the same question: how can workers be protected from the harmful chemicals released during the oil manufacturing process? This question highlights the value of a transdisciplinary approach that can truly account for, and thus prevent, pollutant transport from oil manufacturing to human bodies.

A Transdisciplinary Solution

New PPE Design in the Oil Industry

In modern times, current levels of safety wear for workers in oil industries exist, such as safety glasses with side shields. However, this has not been enough to successfully limit the amount of exposure to volatile organic chemicals (VOCs) like benzene, which are known carcinogens (Ramirez et al., 2017). Much more efficient personal protective equipment (PPE) must be used for these workers to help limit the exposure from any direct contact with chemicals in the environment. Different levels of PPE in industry practices are used; however, Biosafety Level 4 (BSL-4) is the type of PPE that should be used with some new modifications. It is important to acknowledge that while this problem does have a cost analysis component, this will not be discussed in this proposal.

Current practices of PPE in the oil industry consist of filtered helmets, fabric gloves that cannot protect fully against any liquids or strong chemicals, safety boots, and, most importantly, air purifying respirators if "a workplace has unsafe atmospheric conditions" (Bahadori, 2015). A BSL-4 PPE design would consist of disposable gloves able to protect against any direct chemicals, scrub suits for an extra layer of protection, overshoes to prevent the user from spreading VOCs through personal wear, and a new addition of a positive pressure suit (Bahadori, 2015). This suit ideally would be made to have HEPA filtering or some clean air filter to constantly supply the worker with clean air. The suit could have valves to help the flow of air and, most importantly, it would be worn at all times, regardless of how safe the environment is. Known carcinogens will always be of risk, and this design should be implemented to help prevent exposure to these chemicals.

Engineers, chemists, and oil refinery operators and workers can collaborate to design this suit. Approaches would need to be taken on how to create a sustainable filter with measures that can specifically filter any VOCs.

New Pollution Device Design in the Oil Industry

Benzene and other volatile organic chemicals (VOCs) are commonly released from oil refinery processes. Since workers spend long hours inside these refineries, a pollution mitigation device can be designed to collect benzene emissions and reduce their overall chemical exposure.

Several types of technology exist to reduce emissions from oil refineries. Sulfur oxides are produced from petroleum industry operations, similar to benzene and other VOCs. Sulfur oxides have been associated with a variety of human and environmental effects. Numerous technologies have been developed to minimize, control, and treat sulfur oxide emissions. These include treating streams that come out of specific machines within the manufacturing process. For example, a sulfur recovery unit might be used on streams from amine-treating units and sour water strippers in the manufacturing process (Jafarinejad, 2022). Scrubbers and tail gas treatment units are also common (Jafarinejad, 2022).

Technological methods could be created that collect any excess benzene emissions before workers can become exposed. Similarly to the approach for sulfur dioxides, this solution should first be used to identify primary sources of benzene within the entire oil production process. Several studies indicate that benzene emissions are common in offshore drilling, especially for flotation and pipeline insertion gauge (PIG) operation jobs (Ridderseth, 2023). Exposure commonly occurs when operators open process devices for sampling or maintenance (Bratveit et al., 2007). Since benzene is a component of oil and natural gas, benzene collection devices can be placed throughout oil facilities, especially at locations near flotation and PIG areas.

Engineers, chemists, and oil refinery operators and workers can collaborate to design a mechanism for capturing benzene. Currently, there do not seem to be many devices that target benzene and other heavy hydrocarbons. However, some research has explored the use of scrubbers to remove VOCs, including benzene (Wu et al., 2022). Much like how scrubbers remove sulfur oxides, this concept could be further refined to capture excess benzene in the air.

An Integrated Solution

There are several limitations to the individual aspects of this solution, which is why our proposal incorporates a combination of disciplines and methodologies. For instance, PPE places all responsibility for health on workers, introducing the risk of human error or negligence, which can increase the likelihood of harmful exposure. Furthermore, it shifts the responsibility away from oil plants and refineries, which should also be tasked with protecting their workers. Consequently, the proposed technological solutions aim to equip oil refineries with tools to reduce worker exposure. Benzene collection methods will lower ambient concentrations of benzene, subsequently decreasing reliance on PPE. However, current technologies for benzene collection are limited and may not be the most effective until further research is conducted. Therefore, PPE remains critical for ensuring worker protection.

PPE and pollutant collection devices are also most effective when combined because this creates an adaptable solution. There are numerous stages in the oil production cycle and, in turn, a variety of specific jobs. Some stages of the oil process release more benzene than others. Even within a single stage, these values can vary from one refinery to another depending on equipment and raw materials. Therefore, a nuanced solution is necessary to protect different workers across a range of circumstances. For example, an engineering device may be less efficient at certain concentrations of benzene, so PPE can provide the necessary additional security. Similarly, PPE may not be enough at very high concentrations of benzene, so a collection device is needed to reduce the ambient concentration to a level that can be adequately protected against using PPE. As with any transdisciplinary approach, a solution that draws on expertise from multiple fields is more situationally adaptable. In an industry that is predisposed to variation which can threaten human safety, a solution must demonstrate the flexibility and situation dependence of a transdisciplinary approach.

But how will these products be approved by government regulations and what are the steps to get them approved? Health policymakers can take five distinct stages to integrate these biochemistry and engineering solutions into practice. The first is, of course, the cost of these materials and the feasibility of getting manufacturers on board to cover these costs. The designs that were mentioned will no doubt have multiple components that will need multiple quotes. Once there is a quote on using the designs in the industry, workers will need to be trained on proper PPE use and collection device operation.

Health policymakers must ensure that these products comply with regulations. Organizations such as the FDA and WHO must verify that these products have been tested and deemed safe for use in the United States, as well as by other regulatory bodies around the world for their respective regions. Engineers need to gather data on how effectively the collection device lowers the ambient concentration to a level that can be adequately protected against with

PPE. The engineering design cycle is another crucial aspect, where multiple prototypes must be developed until the final product is ready for worldwide use. Furthermore, there is a marketing element to consider when selling this product to major oil companies, with the argument that not using these technologies poses risks to the company by creating unsafe working conditions and increasing the likelihood of unnecessary lawsuits.

Limitations

A potential limitation of this transdisciplinary approach is that engineering designs for pollutant collection devices are expensive. Most existing technologies for sulfur oxide or nitrogen oxide emissions are used because governments regulate the maximum allowable emissions of these pollutants. For a benzene collection device to be utilized, governments will likely need to set strict limitations on benzene emissions within and outside of oil facilities. One workaround for this limitation is taking each component separately by using the PPE design and not the collection device. While this is less effective, PPE is generally less restricted and regulated in terms of industry standards. This removes the transdisciplinary approach but could still be effective.

Time is a significant limitation of the proposed transdisciplinary approach. Not only do government regulations take time, but pollution collection devices also take time to research, develop, and install. Existing research on benzene collection may not be adequate for making an effective device. It is important to note that not all designs will immediately be approved, as there has to be conclusive evidence that they can work in a real-world setting. Even if the PPE and technology have been developed, implementing them in the industry will require significant time and resources.

Future Potential

This solution may encourage increased government and health policy on benzene emissions. Relying on government regulation to enforce this proposed solution is a serious limitation. However, these regulations can also become a powerful method of ensuring benzene reduction measures are adopted across all facilities. Thus, health policy can expand the scope of the proposed solution, improving the lives of more workers.

Health policy related to benzene can have even more far-reaching effects. For example, it may spur additional research into benzene, especially concerning human health. Additional research will only advance progress in protecting workers and can even inform engineering solutions or oil refinery processes. Furthermore, oil refineries are not the only producers of benzene. Ideally, these reduction measures can be applied to other industries and protect other workers.

While this solution focuses on workers, it is possible that nearby residents can also benefit from reducing benzene concentrations in refineries. For example, pollutant collection devices will also reduce the amount of benzene released into the atmosphere. The well-being of nearby residents will be greatly improved with less air pollution.

While this solution offers many potential benefits, it is essential to recognize that it may impose additional burdens on workers. Employees must wear appropriate PPE at all times. They will need training on how to use, maintain, and repair pollution collection devices, or refineries may have to hire extra personnel to maintain these devices. Some workers might also feel apprehensive about adopting these new industry practices. Most importantly, this solution fails to address the root of the problem, as it only reduces emissions rather than the actual amounts of benzene released during the oil production process.

Concluding Remarks

The designs, which are developed from engineering and scientific perspectives, along with those of other integrated disciplines, provide a potential solution for reducing benzene exposure among workers in the oil industry. Benzene is released during several stages of the oil production process and is not properly managed to ensure optimal worker protection. Although there are design components that could be implemented independently to address this issue, a transdisciplinary solution is a far more effective strategy to reduce exposure by enhancing personal protective equipment (PPE) and pollution mitigation devices. This multifaceted approach decreases volatile organic compounds in the environment while safeguarding workers from direct contact with these hazardous chemicals. Proximity issues for workers will be eliminated while they are on the job. Despite the limitations and complex challenges of introducing new PPE and collection devices, these solutions will make long-lasting changes to the oil industry.

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