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# *Large Scale Integration of Wireless Sensor Network Technologies for Air Quality Monitoring at a Logistics Shipping Base*

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**Abstract**— The future of logistics shipping bases will be to seek efficient flows of materials to meet the needs of business partners. Supply chain and operations managers of supply bases will need to integrate technologies that allow for greater automation, digitalization, flexibility and improved communications among stakeholders. The technologies that are likely to boost integration will consist of a plethora of Industrial Internet-of-Things (IIoT) technologies that may include Wireless Sensor Network (WSN) technologies and could be applied for improved monitoring of healthy and safe industrial workplaces for workers. However, little is known regarding how WSN technologies can be implemented on a larger scale and its implications when integrated on standard logistics and operations of industrial workplaces such as a shipping base. The WSN sensor units represent an integrating resource that are capable of monitoring air temperature, humidity and levels of carbon dioxide (CO<sub>2</sub>) and other gasses and of disseminating this information to different actors in the production system. Air quality factors play a critical role in the perceived levels of workers' comfort and in reported medical health. The low cost of wireless sensor network (WSN) technologies offer potential for continuous, autonomous and importantly networked assessment of industrial workplace air quality that may have implications for operations management and quality of production. This paper initially presents a case study that monitors air quality that is collected with WSN technologies from two workshops carried out by a large on-shore logistics base that supports offshore petroleum logistics. The case study demonstrates a monitoring and visualization approach for facilitating BD in decision making for health and safety in the shipping industry. However, with the advancement in IIoT technologies and the emergence of smart sensing and actuating devices, it is possible to form a *digital closed-loop* system that we argue is essential for managers to link together information about air quality with supply chain and operations management decisions. We propose that central to effective decision making is the data analytics approach and visualization of what is potentially, big data (BD) in monitoring the air quality in industrial workplaces. We discuss how WSN technologies can be integrated into the logistics management and operations of the shipping base. Through an analytical discussion of BD we explore how to extend the potential application of IIoT and Visual Analytics to facilitate a smart workplace for the Industry 4.0 era.

**Keywords**—Big Data analytics; IIoT; Wireless Sensor Network Technologies; health and safety; shipping industry; air quality.

## I. INTRODUCTION

Logistics shipping bases offer complex varieties of handling and transportation services supporting offshore petroleum search and production activities. This complex working environment requires that all parties operate and manage business with a clear understanding of Health, Safety and Environment (HSE) requirements. For these businesses much is invested in the systems of preparedness and response. In this context, Industrial Internet of Things (IIoT) technologies in particular WSN sensors and networks can be applied to improve the monitoring of healthy and safe industrial workplaces; in such cases increasing connectivity between people at work and their managers to secure workplace quality. In particular, indoor air quality is important for worker satisfaction, safety and health. Measures of air quality that are used in general assessment of air quality include: CO<sub>2</sub> levels, temperature, and relative humidity. Specialized organizations can be brought in to measure air quality in designated test sites for limited periods. However, there can be variability in measurements due to periodic organization activities.

Safe workplaces in the petroleum industry, such as on-shore shipping bases, encompass a duality of ethical concern that seeks to ensure as well the quality of oil production. The logistical shipping base can be described as a node in the supply chain that supports everyday production on the offshore platform. The shipping base is part of a complex network that is prone to a high degree of uncertainty [1]. Ensuring quality working conditions is from an ethical viewpoint an aim in itself. However, the spill-over of securing worker well-being also secures quality production in the complex system that on-shore and off-shore petroleum production inherently is. This means that securing an environmentally safe workplace at the logistics supply base must be seen as a part of its networked system characterized by interacting complex supply and production processes.

"Industry 4.0." denotes increasing automation and data exchange in manufacturing technologies; cyber-physical systems, the IIoT, cloud computing and cognitive computing. Strange and Zucchella [2] report that the digital technology can disrupt how and

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