Working tool redesign to reduce ergonomic risk of salt evaporation field workers based on RULA and REBA assessments using esMOCA Instrument

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Abstract. What are the ergonomic risks of Indonesian salt evaporation field workers especially in Madura? This problem has not been much noticed, though salt production from Madura is the largest contributor to national salt production. This study aims to assess the level of ergonomic risk of salt evaporation field workers in Madura. Conduct ergonomic risk analysis and reduce the level of ergonomic risk through redesigning work tools with the REBA and RULA approaches. REBA and RULA assessments are conducted with esMOCA instrument application. This research shows that five activities of salt evaporation field workers pose a high ergonomic risk with a REBA and RULA score above 6. These five activities are, chopping salt deposits on salt field, scraping salt deposits on salt field, collecting and pile up salt deposits, picking up salt to the carrying basket, and packing salt into sack. One of these five activities, picking up salt activity poses the highest ergonomic risk with REBA score 11. Efforts undertaken to reduce risk were made by replacing shovel tool with pan hoe tool, REBA score dropped to 5.

1. Introduction

Although Indonesia's salt production reached 2,192.168 tons, this production did not meet the national salt demand of 3,611,990 tons[1]. To meet national salt needs, Indonesia imports salt and this is regulated by the Indonesian Ministry of Industry[2]. Of course increasing national salt production capacity is also put through. Madura as the main supplier of national salt production[3] still has the potential to increase its salt production on the southern coast of the island[4]. The salt production process in Indonesia is carried out by evaporation of sea salt water in the salt evaporation fields. The Indonesian salt industry, particularly in Madura and Bali, is still intensely using traditional processes and workers[5][6]. Occupational health and safety of salt industry sector workers receive less attention[7][8]. The research in this paper reveals the ergonomic risk problems experienced by salt evaporation field workers in Madura and designs work tools to lower ergonomic risks.

Some researchers have brought outcomes to improve the welfare and empowerment of salt industry workers. Akhmad, et.al.[9][10] has created a food supply chain network model for the Indonesian salt industry to minimize the distribution costs of the salt industry. Hidayaturrahman, et.al.[8], Sudaryana and Pramesti[7] have brought policy recommendations for the central government, regional governments, industry, and community in an effort to improve the welfare of salt industry workers.
Nuswardani [8] in his community service has empowered and provided legal protection for salt industry workers.

2. Related work
There have been studies on the welfare of salt industry workers, but not many researchers have observed the occupational health and safety of the salt industry in Indonesia. Similar research in India shows workers’s low knowledge and low awareness of the occupational risks faced in the salt industry [11][12][13][14][15]. The work risks that workers face are ulcerate, injure, callouse, feet and hand palms, eye irritation,[11] ophthalmic symptoms, muscular and joint pains, dermatitis, dizziness,[12][13] back pains[15]. Several studies on occupational health and safety in traditional Indonesian industries have been carried out. Among them carried out by Listiani[16] examined the condition of the physical environment in small to medium enterprise. Suprapto and Komariah[17] examined the physiological load response of workers in the Surakarta traditional market. Mulyati[18] examined the relationship between work posture and musculoskeletal problems in healthcare workers in Bengkulu. Tambun[19] analyzed the ergonomics risk of traditional weaving workers in Pematang Siantar. Djiono and Noya[20] have analyzed and redesigned the work station in paint production with the RULA approach. Jauhari, Prabowo, and Fridianti[21] quest the causative factors for musculoskeletal disorder in the Indonesian industry. Gitasari, Tjahajawati, and Wihardja[22] observed a musculoskeletal disorder in dental practitioners in the city of Bandung. Nurdin, et.al.,[23] developed a paddy harvesting machine based on the ergonomic aspects of Indonesian farmer.

Figure 1. (a). esMOCA sensor hardware is being tare. (b) esMOCA sensor hardware deployed on the operator’s body limb

Figure 2. (a) Graphic User Interface of esMOCA REBA. (b) Graphic User Interface of esMOCA RULA

Observation of body posture is the basis of ergonomic, musculoskeletal, biomechanical and physiological analysis in the above research studies, while body posture is still assessed subjectively by researchers[24][25][26][27]. To minimize subjectivity of assessment and improve reliability of body posture measurements, some researchers have developed instruments to assess the body posture of workers. Arendra and Sabarudin[28][29][30] have developed esMOCA, a motion capture instrument based on inertial measurement unit to assess worker posture and conduct biomechanical analysis, REBA and RULA analysis. Schall [31] also uses inertial measurement units sensor for body posture
3. Objective and research method

This research aims to reduce ergonomic risk due to awkward working postures. Assess posture of salt evaporation field workers by measuring the orientation angle of workers' body limb. Posture of the hands, forearms, upper arms, shoulders, neck and head, trunk and legs, was assessed with REBA and RULA approaches using the esMOCA instrument. The REBA and RULA assessments are conducted on the production activities of salt workers in the salt evaporation field. Then the next step, selecting activities that pose the highest ergonomic risk. Efforts to reduce ergonomic risk in high-risk activities are carried out by improving the design of working tools, taking into account the comfortable working posture and avoiding awkward postures.

4. Experiment setup and measurement

The esMOCA V2 instrument was used to assess ergonomic risk based on REBA and RULA approaches. This esMOCA instrument consists of nine inertial measurement unit sensor nodes to capture movements of the operator's body limb (Fig.1). The entire set of sensor nodes is connected by means of wireless sensor network to the computer with esMOCA V2 application (Fig.2). The orientation angle data of the operator's body limb is transmitted using the UDP protocol via TCP/IP to the computer with the esMOCA V2 application. Digital human models in esMOCA applications move dynamically in real-time, keeping pace with the motion of the sensor-mounted operator's body limb. Then the REBA and RULA modules in the esMOCA V2 application perform a digital human model posture assessment. REBA and RULA score assessment can be obtained in real-time so that ergonomic risk can be known immediately when the operator is working. Further analysis is followed up to seek activities and working postures that are most at risk for further action.

5. Result and discussion

There are eight activities performed by salt evaporation field workers. First, chopping salt deposits so that they can be easily scraped. Second, scraping salt deposits. Third, collecting and pile up salt deposit. Fourth, picking up the pile of salt into the carrying basket. Fifth, carrying salt in the basket to the drying place. Sixth, packing salt in several sacks. Seventh picking up salt sacks to transport. Eighth, lifting up salt sacks onto truck.

Three of the eight activities are manual material handling activities. The three activities of the manual material handling were not included in the REBA and RULA analysis because these activities were more suitable to be analyzed by the biomechanical approach or NIOSH lifting index. So the activities observed in this research are (a) chopping salt deposits, (b) scraping salt deposits, (c) collecting and pile up salt deposits, (d) picking up salt to the carrying basket, and (e) packing salt into sacks. The results of the REBA and RULA assessments from the five activities using the esMOCA instrument are summarized in Table 1.

It can be seen from Table 1 that the activity with the highest ergonomic risk is picking up salt to the carrying basket. The REBA score reaches 11 due to some uncomfortable work postures. Among them are trunk position posture which bends at an almost flat position along with trunk side bending. This posture gives a trunk score of 5, the highest score for trunk position. In addition, the upper arm position is located in the area of the extension with the upper arm score 2 and the lower arm position forming an angle of less than 70 degrees with the lower arm score 2.
Table 1. Summary of REBA and RULA assessment results from the activities of salt evaporation field worker

| Activity                                | REBA Score | RULA Score |
|-----------------------------------------|------------|------------|
| Chopping salt deposits                 | 6          | 7          |
| Scraping salt deposits                  | 6          | 7          |
| Collecting and pile up salt deposits    | 10         | 7          |
| Picking up salt to the carrying basket  | 11         | 7          |
| Packing salt into sacks                | 7          | 7          |

Figure 3. The redesign proposal for the picking up salt working tool uses the pan hoe tool.
Based on this analysis, it is proposed to improve the picking up salt working tool that previously use the shovel replaced by using the pan hoe tool. By using this tool, the worker posture can be more upright and no longer bent, the arm position is in a neutral region with the upper arm score 1 and lower arm score 1. The digital human model simulation results in the esMOCA V2 application renders the REBA score 5 and the RULA score 5.

6. Conclusion
This research concludes that the esMOCA V2 instrument is capable of being used in harsh environments such as salt field environments. The results of the REBA and RULA score assessment are displayed in detail scores of each body limb segment in real time. It is known that salt evaporation field workers face high ergonomic risk especially in salt picking up activities with the REBA score 11 and RULA score 7. Improvements to redesign of picking up salt working tools oriented to work posture are more comfortable according to REBA and RULA. The use of pan hoe replacing the shovel can reduce the ergonomic risk in picking up salt activities from the original REBA score 11 and the RULA Score 7 down to the score of the REBA score 5 and RULA score 5.

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