# 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 worker'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 muculoskeletal problems in health care 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 statsion 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 prcatitioners 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

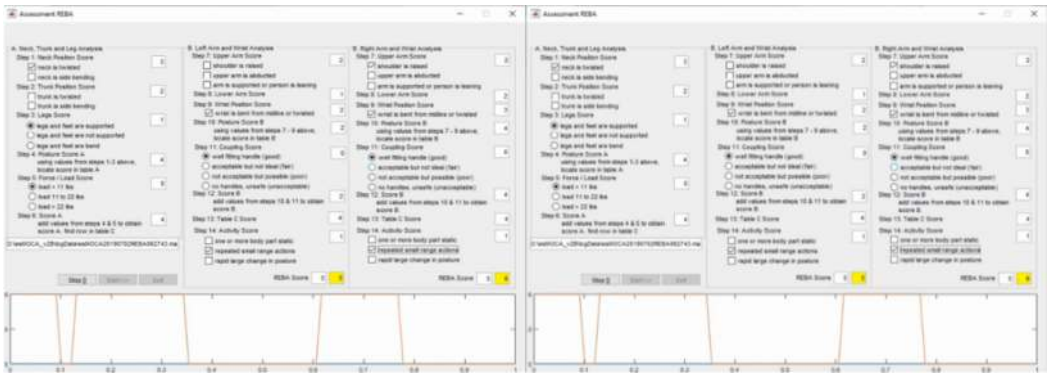

**Figure 2.** (a) Graphic User Interface of esMOCA REBA. (b) Graphic User Interface of esMOCA RULA

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

measurement instrumentation. Colombo, et.al.,[25] and Plantard, et.al.[32][33] in their research, analyzing ergonomic risks using the Kinect camera to capture the movement of the operator's posture. Sinden, et.al.,[26] have used marker-less digital video cameras to analyze Fire-Fighter postures. Maiguma, et.al. [27] have used orientation sensors found on smartphones to conduct Lumbar Burden evaluations. Research in this paper uses an esMOCA instrument developed by Arendra and Sabarudin[34] to assess ergonomic risk in salt evaporation field workers.

## 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 conduct 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 work 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 posture of salt evaporation field worker (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, keep 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 follow 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 NIOS 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 filed worker

| Activity | REBA Score | RULA Score | Posture |
|---|---|---|---|
| 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.

## References

[1] K. F. Rahmantya, A. D. Asianto, D. Wibowo, T. Wahyuni, and W. A. Somad, *Analisis Data Pokok Kementrian Kelautan dan Perikanan 2015*. 2015.
[2] A. Hartarto, *Permenperin No. 34 Tahun 2018.pdf*. .
[3] Wisnu, S. Alrianingrum, Artono, and C. Liana, "Salt briquette: The form of salt monopoly in madura, 1883-1911," *J. Phys. Conf. Ser.*, vol. 953, no. 1, 2018.
[4] E. Sukiyah, V. Isnaniawardhani, A. Sudradjat, and F. Muhamadsyah, "The Salt Potentials in Indonesia," *J. Geol. Sci. Appl. Geol.*, vol. 2, no. 1, pp. 59–68, 2017.
[5] I. K. Wijaya, "Making Salt Hegiens With Sunlight in Bali," in *Ergofuture International Joint Conference APCHI*, 2014, pp. 351–354.
[6] T. Kurniawan, "Potential Conflicts in Saltworks Sector at Sampang District," *Int. Res.*, vol. 2, no. 1, pp. 43–50, 2013.
[7] B. Sudaryana and P. Pramesti, "The Strategy of Welfare Improvement for Salt Farmers in Indonesia," *MATEC Web Conf.*, vol. 150, p. 05062, 2018.
[8] M. Hidayaturrahman, N. Laily, and E. Agusrianto, "Empowerment Salt Farmers to Alleviate Poverty," in *International Conference "Sustainable Development Goals 2030 Challenges and Its Solutions"*, 2017, no. August, pp. 89–97.
[9] S. Akhmad, Miswanto, and H. Suprajitno, "INTERVAL MODEL OF FOOD SUPPLY CHAIN NETWORK AT THE MULTI STAGE DISTRIBUTION SYSTEMS," *Int. J. GEOMATE*, vol. 16, no. 55, pp. 125–130, 2019.
[10] K. Winarso and S. Akhmad, "Surat Pencatatan Ciptaan No. EC00201849441 Manajemen Rantai Pasok Tembakau Madura EC00201849441," 2018.
[11] K. R. Haldiya, R. Sachdev, M. L. Mathur, and H. N. Saiyed, "Knowledge, attitude and practices related to occupational health problems among salt workers working in the desert of Rajasthan, India," *J. Occup. Health*, vol. 47, no. 1, pp. 85–88, 2005.
[12] D. Durairaj, S. Murugan, T. Nadu, and T. Nadu, "A Study on Health Hazard of Salt Workers in Tamilnadu Coastal Areas," *Int. J. Pharm. Sci. Rev. Res.*, vol. 40, no. 29, pp. 137–141, 2016.
[13] S. Murugan, K. Muthalagu, and D. Durairaj, "Opinion on occupational health problems among salt workers at saltpan in Tamilnadu," *Int. J. Pharm. Sci. Rev. Res.*, vol. 41, no. 2, pp. 302–305, 2016.
[14] M. B. Bhattacharya, "Evaluating Overall Social and Health Status of Salt Workers in Experimental Salt Fields at Bhavnagar, Gujarat, India," *MOJ Public Heal.*, vol. 5, no. 3, pp. 97–99, 2017.
[15] S. Prakash and N. M. N. Soris, "A Study on the Working Condition of Salt Pan Workers in Thoothukudi," *Int. J. Sci. Eng. Manag.*, vol. 3, no. 4, pp. 545–548, 2018.
[16] L. N. Huda, "Standard Regulation of Occupational Health Requirements of Heat Environments at SMEs," *Adv. Soc. Sci. Educ. Humanit. Res.*, vol. 141, no. ICOPOSDev 2017, pp. 53–56,

2018.
[17] M. Suprapto and A. Komariah, "The Effect of Load on The Back to Physiological Response of Heaver in Pasar Legi Surakarta," *Adv. Eng. Res.*, vol. 175, no. Icase, pp. 123–125, 2018.
[18] S. Mulyati, "The Relationship Between Work Posture And Musculoskeletal Disorders (Msds) In Laundry Workers In The Area Of Puskesmas Sukamerindu Bengkulu," *Adv. Heal. Sci. Res.*, vol. 14, no. February 2017, pp. 171–174, 2019.
[19] M. Tambun, "Ergonomics Risk Analysis In Ulos Weaving Workers In The Martimbang And Kebun Sayur Village Pematang Siantar City," *Adv. Heal. Sci. Res.*, vol. 6, pp. 1–11, 2017.
[20] Y. Kusnandar and S. Noya, "Working Posture Analysis and Design Using Rula ( Rapid Upper Limb Assessment ) Method in Production Process At Pt . Indana Paint," *J. Ilm. Tek. Ind.*, vol. 12, no. 2, pp. 111–125, 2013.
[21] A. Jauhari, K. Prabowo, and A. Fridianti, "Analysis of Related Factors With Subjective Complications Musculo Skeletal Diseases," *Adv. Heal. Sci. Res.*, vol. 14, pp. 393–397, 2019.
[22] N. I. Gitasari, S. Tjahajawati, and R. Wihardja, "Body Discomfort Due to Musculoskeletal Disorders among Dental Practitioners in Primary Healthcare Center in Bandung City," *Adv. Heal. Sci. Res.*, vol. 4, no. Idsm 2017, pp. 167–171, 2018.
[23] S. Nurdin, A. Ahlan, S. Sugiarto, M. W. Lestari, K. Hidayat, and M. Adhi Prasnowo, "Design of Ergonomic Paddy Harvesting Machine," *J. Phys. Conf. Ser.*, vol. 1114, no. 1, 2018.
[24] S. Lee and T. J. Armstrong, *Field Tool for On-Site Biomechanical Analysis During Ladder Climbing*. The Center for Construction Research and Training, 2014.
[25] G. Colombo, D. Regazzoni, C. Rizzi, and G. De Vecchi, "Preliminary Analysis of Low-Cost Motion Capture Techniques to Support Virtual Ergonomics," *Int. Conf. Res. into Des.*, pp. 423–434, 2013.
[26] K. E. Sinden, J. C. MacDermid, T. R. Jenkyn, S. Moll, and R. D'Amico, "Evaluating the Reliability of a Marker-Less, Digital Video Analysis Approach to Characterize Fire-fighter Trunk and Knee Postures During a Lift Task: A Proof-of-Concept Study," *J. Ergon.*, vol. 06, no. 01, pp. 1–10, 2016.
[27] M. Maiguma, H. Tamura, and K. Tanno, "A Study on the Lumbar Burden Evaluation of Work using One Smartphone," *J. Robot. Netw. Artif. Life*, vol. 23, pp. 550–553, 2018.
[28] S. Akhmad and A. Arendra, "Development of esMOCA RULA, Motion Capture Instrumentation for RULA Analysis," *J. Phys. Conf. Ser.*, vol. 953, no. 1, 2018.
[29] A. Arendra and S. Akhmad, "Performance Measurement of esMOCA Biomechanics V2 for Biomechanics analysis," *Int. Conf. Life, Innov. Chang. Knowl. (ICLICK 2018)*, vol. 203, pp. 191–193, 2018.
[30] A. Arendra and S. Akhmad, "Development of esMOCA Biomechanic, Motion Capture Instrumentation for Biomechanics Analysis," *J. Phys. Conf. Ser.*, vol. 953, no. 1, 2018.
[31] M. C. Schall, "Application of inertial measurement units for directly measuring occupational exposure to non- neutral postures of the low back and shoulder," University of Iowa, 2014.
[32] P. Plantard, E. Auvinet, A.-S. Pierres, and F. Multon, "Pose Estimation with a Kinect for Ergonomic Studies: Evaluation of the Accuracy Using a Virtual Mannequin," *Sensors*, vol. 15, no. 1, pp. 1785–1803, 2015.
[33] P. Plantard, A. Muller, C. Pontonnier, G. Dumont, H. P. H. Shum, and F. Multon, "Inverse dynamics based on occlusion-resistant Kinect data: Is it usable for ergonomics?," *Int. J. Ind. Ergon.*, vol. 61, pp. 71–80, 2017.
[34] S. AKHMAD and A. ARENDRA, "Surat Pencatatan Ciptaan No.EC00201852233 EsMOCA V2 (ERGONOMI-SISMAN MOTION CAPTURE) UNTUK ANALISIS BIOMEKANIKA DAN PENILAIAN POSTUR KERJA," 2018.