# Improving the Life Quality of the Metal Casting Industry Employees through Participatory Ergonomics and 5R-based Cleaner Production Strategies

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**Abstract**-Waste dust in the metal casting industry is an issue which so far has not been completely resolved as it is generated during the cooling process of the liquid metal from a temperature of $1000^0$C into room temperature, thus the molds made of quartz sand and other materials during this liquid steel cooling process will also turn very dry even some changes into fly ash. Such an environmental condition certainly affects the physical environmental conditions of employees and reduces health and stamina as well as work performance indicated by lower motivation and productivity of work, resulting in not optimum achievement of a company' predetermined target. Employees cannot enjoy their job and the results obtained which eventually causes the life quality of the company's internal and external employees to be very low. A research approach which does not focus only on processes and products, but which also considers humans as the primary factor in performance improvements and humanizes people through the principle of participatory ergonomics is necessary. Humans are regarded as a company's assets and therefore they should become the major concern, fitting the job to the man before fitting the man to the job. Implementation of the 5R-based strategies (*Rethink*, *Reuse*, *Reduction*, *Recovery*, *Recycle*) in cleaner production has managed to make the work environment more healthy and secure, while participatory ergonomics can make humans more productive or healthy both physically and psychologically and in relation to their social relations. This is experimental research employing a treatment-by-subject design. The research was conducted for 8 months. The data on employees' life quality were collected using WHOQOL-BREF questionnaires, these employees filled out the questionnaires after completing their work in the first and second periods. The findings suggested that these employees' life quality increased. The analysis of significance showed that the means of the employees' life quality scores generated for both periods differ significantly ($p < 0.05$). Implementation of participatory ergonomics managed to make humans the center of the whole work improvement, their physical and psychological conditions and social life should be protected and the 5R-based cleaner production strategies managed to improve those employees' life quality relating to the performance of the metal casting manufacturing industry's work environment. In relation to the employees' improved life quality after the transformation (0-100%), the following results were generated, namely the Physical Domain by 6.80%, the Psychological Domain by 16.75%, the Social Domain by 28.17% and, finally, the Environmental Domain by 16.53%.

**Index Terms**— life quality, manufacturing industry, participatory ergonomics, cleaner production



## 1 INTRODUCTION

The metal casting manufacturing industry is one of the industries generating byproducts such as fly ash waste. This is a high risk industry determining the quality of the environment [10]. The waste generated by this industry determines the performance of the quality of internal and external environment. Among the countermeasures taken to reduce the waste generated is by makin an investment in the dust fly treatment to parse and capture the resulting fly ash, however the company management remains considering this method ineffective because it requires relatively huge costs. Another method is to evaluate or re-arrange any activities in each work station, so that the waste generated as a by-product of the metal processing will be minimal. Product development should also be eco-friendly [12].

This activity was undertaken using the 5R-based cleaner production strategy approach (i.e., Rethink, Reuse, Reduction, Recovery, Recycle), namely rethinking the processes and products made in a company in order to be more efficient and provide optimal benefits to the company (*Rethink*), reusing the resulting waste or residual materials without any treatment to reduce the waste generated and economize on raw materials (*Reuse*), reducing the resulting waste or the residual materials from the generated source (*Reduction*), reusing the residual materials or the resulting waste either with or without treatment (*Recovery*), recycling the residual materials or the resulting waste to create new products or derivative products of another manufacturing industry (*Recycle*). Metal products can be used by the derivatives industry [23].

The results of processing industrial residual mate-

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rials are expected to be used by another derivatives industry [21]. This method gives better than the method where a company's management undertake direct processing of the resulting waste. The implementation of the 5R-based cleaner production will improve the performance of the work environment conditions [8,7,9,11]. The implementation of the 5R-based cleaner production strategies by companies included evaluation and they were carried out simultaneously with each process activity. These strategies had an impact on process cost reduction so that company managed to make savings each period. As the resulting impact of the 5R-based cleaner production strategy implementation, the company also improved the performance of its surroundings so as to generate environmentally friendly products. Among the indicators that the company has implemented the 5R-based cleaner production are changes made in the technical, economic and environmental aspects (*triple win*). The implementation of these 5R-based cleaner production strategies provides an opportunity for the company to switch from an open industrial system into the partially or fully closed one. The cleaner production implementation model was combined with several systems, including the Environmental Management System ISO 14001 and the Safety Management System OHSAS 18001 [17]. The implementation of cleaner production creates environmentally friendly conditions, reducing the effects of toxic substances on humans and the environment[2].

Nevertheless, this 5R-based cleaner production strategy implementation is still considered not perfect as the humans or employees in the industry are viewed as objects, rather than the subjects which are part of the company's assets. Even if a company manages to achieve its optimum profitability, but the high rate of absenteeism or complaints the employees have due to occupational diseases (i.e., work-related illnesses) can reduce the company's performance. Employees' income will be allocated to their physical medication costs. In general, occupational diseases are hard to detect, making it difficult for the company's employees to make a claim about such diseases. In other words, the income they earn will be disproportionate to the costs of medication to recover their work stamina.

Health is viewed from the physical, mental and social aspects. Life quality is a subjective multidimensional construct [20]. This condition affects employees' physical conditions. Similarly, it also influences the employees' psychology which is difficult to measure and detect. The psychology of individual employees can influence employees' attitudes and behavior in completing their daily activities. These attitudes and behavior will be manifested in their work patterns. Therefore if employees behave positively towards their job, the level of human error on the job itself will possibly be small and, conversely, if the employees behave negatively towards their job and display pessimism and even lack of attention towards their job, their productivity will decrease.

Employees' opportunity to interact with their fellow employees and socialize with their surroundings such as neighbors, other family members and the other family is a necessity and part of their role in social life. If the employees are not physically healthy, their number of productive hours and hours of socializing with and explore themselves among the surroundings will also reduce, resulting in inequality in life. Even, employees with a healthy condition but the lack of balance between work time and time to explore and socialize with their community will also experience such decreaases in their life quality. Environmental conditions also determine to an employee's life quality level. The opportunity to be physically healthy and to have positive perceptions of work manifested in the psychological aspects, the ability to interact and socialize with people social and a healthy environmental condition are all part of the improved life quality.

To view humans as a subject to any work improvement activity and as a means of treating humans appropriately, to make the most of them as the most perfect creatures on earth will require the concept of participatory ergonomics. This approach also will enhance the implementation of 5R-based cleaner production. It provides a role that every work activity must suit the weakness, skill and ability of a human, known as *fitting the job to the man*. If neither machine nor equipment can be changed or adjusted as any product or machine design cannot always be modified for human convenience, therefore it is now the time to suit humans or employees to their job, known as *fitting the man to the job*. In addition to empowering the employees in the metal casting manufacturing industry, the participatory ergonomics can also reduce the company's costs. It generates more comfortable and safe products in accordance with customers' expectation [18].

On the other hand, this activity requires a relatively long time and set-up costs. However, as the creativity and invention are made by the employees themselves who know the problems and constraints on their everyday job, therefore the solution generated and its implementation will be more appropriate and suit the real conditions. This activity provides better results when compared with hiring external consultants who will require more time to study the issues in advance and the solution they provide is not necessarily affective, despite the huge amount of payment the company has to pay.

The participatory ergonomics is also part of improvements in employees' life quality, the employees as part of the ecosystem of company society also concerned with their own abilities and the company's interests to continue to gain optimal profitability. It brings a number of impacts such as

treating people appropriately, making them more productive as their creativity and the ideas get higher appreciation as well as making them feel more healthy and comfortable while perorming their job as physical conditions have got more attention. The basic needs and the company's environmental conditions which are healthy and clean have been taken into account. This participatory ergonomics is an activity involving various parties to interact with one another. The interactions involves all parties, from product users, interdiscipline to product developers [18].

## 2 METHODS

### 2.1 Subject

The research subjects were calculated based on Colton's formula [3] plus 25%, selected using random sampling so as to obtain 14 samples, all the subjects were males, had worked as employees in the metal casting manufacturing industry for 17.7 ± 7.78 years in average, aged 36.79 ± 3.16 years in average, with the BMI belonging to the normal category with means by 22.87 ± 1.67 kg/ $m^2$

**2.2** Procedure Research

This is experimental research employing a treatment-by-subject design [1,13]. The research was conducted for 8 months. The WHOQOL-BREF questionnaires were filled out after completing their work in Periods I and II. Before filling out the questionnaires and the research began, the subjects got an explanation regarding the purpose and objective of the research and then filled out the informed consent

**2.3** Procedure of the analysis

The statistical analysis was undertaken using SPSS version 17. The resulting means of WHOQOL-BREF scores after working in Periods I and II were examined using the normalization test using the Shapiro-Wilk test at a significance level by $\alpha = 0.05$, followed by a parametric test to test differences between means using the paired t-test as the data were normally distributed (p> 0.05). The data were collected in four repetitions and with a Washing Out Period (WOP) for 2 days and adaptation to new work conditions for 7 days

2.4 Research Hypotheses:

Ho : $\mu_0=\mu_1$ the mean of the subjects' life quality in Period I is equal to the mean of the subjects' life quality in Period 2

Ha : $\mu_0 > \mu_1$ the mean of the subjects' life quality in Period I is higher than the mean of the subjects' life quality in Period 2

*Decision rule:*

Ho accepted there was no significant decrease in life quality scores between subjects in period 1 to period 2, with a P value> 0.05

Ho rejected there was a significant reduction in life quality scores in subjects with Period 1 Period 2, with a P value <0.05

## 3. RESULT AND DISCUSSION

Life quality is the outcome of the improvement in work life quality, the work life quality itself is a combination of several inputs such as employees' performance, productivity, occupational health, mental burdens in the form of psychological burdens, interactions between employees and non-employees, or social relations as humans which need one another and conditions of the surrounding the environment that provide an indirect influence on the life quality aspects. The analysis results using SPSS of the normality test on the life quality score data are presented in Table 1 as follows.

**TABLE 1.**
**RESULTS OF THE NORMALITY TEST TO THE QUESTIONNAIRE DATA (I.E., THE SHAPIRO-WILK TEST).**

| Period | Shapiro-Wilk | | |
|---|---|---|---|
| | Statistic | Df | Sig. |
| WHOQOL-BEF Score for Period I | 0.925 | 14 | 0.263 |
| WHOQOL-BEF Score for Period II | 0.950 | 14 | 0.559 |

The data normality test results in Table 1 generated a significance value by p > 0.05, meaning that the data were normally distributed. The test on differences in life quality between Periods I and II therefore was conducted using a parametric test, namely the paired t-test.

Results of the test examining differences in the life quality of the employees using the parametric test generated a p value by < 0.05, meaning that Ho was rejected. There was a significant difference between Periods I and II. The life quality of employees in the metal casting manufacturing industry increased after making improvements in the work conditions through participatory ergonomics and implementation of 5R-based cleaner production strategies. The participatory ergonomics undertaken consisted of several process stages, namely collecting and identifying the problems in the environment or the working station of the metal casting industry, by conducting several meetings involving interdiscipline, which managed to obtain several inputs from several employees and observers of relevant disciplines. Afterwards, normalization was undertaken to the inputs and scores were given in order of priority to the problems to be solved. To make it easier to uncover the problems, several

meetings and role plays were held using the Ishikawa diagram. Then, the participants changed the positive statements into negative ones. After the negative statements had been obtained, this step would provide a basis for the field implementation of the action plan. Then, for a certain course of time the action was implemented with the assistance of the Gantt chart of activities. The next step was to evaluate the results and analyze the suitability of the implementation, including recording any discrepancies in the action implementation. Furthermore, standard operating procedures (SOPs) were established in order that the activities implemented could be recorded and evaluated on a continuous basis.

This participatory ergonomics will be successfully implemented if all the employees taking part, including experts or other disciplines involved to solve the company's problems get involved from the initial planning to the evaluation of the results obtained, thus any failure or success is resulted from joint efforts and realized together. The whole team was involved directly and physically present to provide alternative solutions together, mutually beneficial and complementary interactions took place among the employees and, likewise, they made work-related improvements together, came together to the production floor to make observations and overcome any obstacles and prepared alternatives for work completion if the concept selected and run requires improvement.

These differences in the work quality were also resulted from improvements in several human aspects and the aspects of the work environment condition. Improvements in the work environment went in line with the improvements in the employees' life quality. The more attention the human aspects taken into account receive, the higher the life quality of a company's employees is, and likewise the more productive the employees in the production floor of the metal casting industry are, the higher their life quality is, resulting in their better life quality.

### 3.1. WHOQOL-BREF Questionnaire Scores for Each Domain and the Magnitude of the Changes in the Life Quality in Periods I and II

Period I was a period where the employees carried out their usual activity every day, which have been carried out for decades, while in Period II, these employees completed their work activities in new work conditions, i.e. any existing problems were listed and selected in order of priority using the participatory ergonomics approach. Problems related to the work environment were solved using the 5R-based cleaner production strategies. The new work conditions brought an impact, i.e. changes in the work activities where employees became more productive and more efficient. The company regarded its employees as its human capital, improvements occurred in the environmental conditions as the people or employees in the company improved, so that there was a shift in several domains of the WHOQOL-BREFT questionnaire into a better work quality condition. The life quality scores of the metal casting manufacturer employees are presented in detail in Table 2.

**TABLE 2.**
**RESULTS FOR THE TRANSFORMATION OF THE LIFE QUALITY SCORES IN EACH DOMAIN**

| Domain | Transformed Score 0-100 Period I (%) | Period II (%) | Changes (%) |
|---|---|---|---|
| Domain 1 : Physical | 91.85 | 98.10 | 6.80 |
| Domain 2 : Psychological | 71.99 | 84.04 | 16.74 |
| Domain 3 : Social | 15.85 | 20.31 | 28.17 |
| Domain 4 : Environmental | 84.38 | 98.33 | 16.53 |

The domain of physical health increased by 6.8%, this condition was resulted from several work improvements. Environmental conditions affected employees' health, especially their respiratory system [24]. The resulting impact of these physical improvements included a lower incidence of occupational diseases, a lower level of anxiety and more time off, improved nutrition or energy recovery conditions, a decreased level of fatigue felt by the employees, improvements in the adjustment between the work load and the work capacity. Moreover, the psychological domain also increased by 16.74%, which was significantly higher than the increase in the occupational health domain, this condition occurred because their positive feelings and ability to think increased as their ideas found a place to evolve and were appreciated and they had opportunity to learn and try new things, to instill confidence in them.

In relation to the social domain, the increase amounted to 28.17%, this health domain occupied the highest rank. This condition was resulted from changes in the activity in Period II, where all the employees were given the same opportunity to interact with their fellow employees and to communicate with one another and to develop ideas and there were increases in various creativity to produce a better work mechanism. It was this activity which provided the greatest contribution to the increased social condition score. Humans naturally require a balanced interaction between one another as social beings

although on some occassions at work as part of their professional demand to work in accordance with the standard operating procedures (SOP) set by the company. These social relations included interpersonal and intrapersonal relationships with their work environment, surrounding community and family.

Domain 4 was the environmental domain, the score generated by this environment domain was almost the same as that of the psychological domain, i.e. by 16.53%. However, there was a relationship between the psychological burden of the employees and the company's environmental conditions. Perhaps this relationship occurred in the abstract and was difficult to quantify, as emotional relationships or the relationships with self-perception can only be done in a descriptive study. These improvements in the environmental domain occurred due to influences arising from several factors, including an increasing rate of physical safety and security at work, changes in the environment into eco-friendly and healthy products and processes, increased financial income sources of the company, improved health and CSR by the management and employees of the company, opportunities given to the employees to acquire new skills and information to find ideas and processes to realize their ideas, the existence of opportunities to work on more representative environmental conditions without detrimental impacts on health.

### 3.2. The Implementation of 5R-Based Cleaner Production Which Does Not Consider Ergonomics

The implementation of 5R (namely, *Rethink, Reuse, Reduction, Recovery* and *Recycle*) emphasized on the processes and product implementation, the human health factor is considered to have improved as a result of waste management undertaken by the company, requirements to acquire knowledge about the development in the adoption of the latest technology, selection and determination of the focus of the waste management strategies. Sometimes a company requires a considerably huge amount of money to make investments in new equipment capable of operating with more eco-friendly effects. As for the metal casting manufacturing industry, this industry still belongs to type I where the energy and materials enter into the system and then produce products, by-products and waste [16]. Improvement-making efforts among others included optimizing the use of existing natural resources, encouraging the industry to move toward a closed material cycle and minimizing emissions, undertaking dematerialization processes, reducing the level of dependence on non-renewable energy sources [4]. The implementation of the 5R-based cleaner production is described in detail in Table3

**TABLE 3.**
**THE IMPLEMENTATION OF 5R (*RETHINK, REUSE, REDUCTION, RECOVERY* AND *RECYCLE*)-BASED CLEANER PRODUCTION IN THE METAL CASTING MANUFACTURING INDUSTRY**

| | |
|---|---|
| **Rethink** | a. Changes were made to either the process or product in order to minimize waste or residual materials, resulting in additional profits for the company.<br>b. The resulting waste or residual materials of the work activities were optimized, especially the ones with the potential to be processed further into inputs for another derivatives industry<br>c. Thinking about ways to always improve the environmental quality.<br>d. Thinking about ways to generate optimum profitability for the company |
| **Reduction** | a. Waste reduction attempts were undertaken directly from its source, based on the predetermined work procedures and standard operating procedures.<br>b. Process-oriented improvements. |
| **Recovery** | a. Collection of residual materials was undertaken using a machine or tool available in the market whose optimal function has undergone examination in advance |
| **Recycle** | a. To do recycle, the resulting waste can be sold to the derivatives industry to be reprocessed to generate a new derivative product. |

The environment quality was improved by reprocessing residual materials as raw materials for a production process with an added-value, Kalundborg City as the cleanest industrial city [22]. Some of the advantages offered by the implementation of the 5R steps presented in Table 4 above are realization of the company's primary business goal, changes in the ways of thinking, attitudes and behavior that lead to self-regulation, rather than on the basis of command and control in attempts to maintain the environment. Viewing the industrial system as a system of unity, mutual interaction, interplay between systems, optimizing improvements of the "product" and "process"occurring in the production floor. Waste management offers an additional advantage for the company, by enhancing its image.

3.3. The Implementation of the 5R-Based Cleaner Production Which Considers Ergonomics

At the beginning, the team which had been formed would have to work harder because it had to accommodate the expectations and needs of many people involved. It took time starting from the preparation until the implementation of the 5R-based cleaner production with a relatively longer time than the Top-Down method. The principle of participatory ergonomics will give another burden to the team if it is not accustomed to working in accordance with the commitment and empowerment of humans or employees in the production floor, within new work conditions and methods that provide the widest possible opportunity for employees to show their creativity and exploration of ideas to improve individuals' health, psychology and social relationships as well as performance of the work environment.

**TABLE 4.**
**THE IMPLEMENTATION OF 5R (*RETHINK, REUSE, REDUCTION, RECOVERY* AND *RECYCLE*)-BASED CLEANER PRODUCTION WHICH CONSIDERS ERGONOMICS IN THE METAL CASTING MANUFACTURING INDUSTRY**

| | |
|---|---|
| **Re think** | a. Humans became the primary factor of all the work-related improvement activities, from the beginning until the end of the production process.<br>b. Redesigning the tools or machines both for waste management and improvements in the work attitude with the implementation of participatory ergonomics<br>c. Improvements in the environmental quality and the company's profits were in line with improvements in the employees' physical health and psychology. |
| **Reduction** | a. Reduction of fly ash generated by activities producing dust waste, paying attention to safe and comfortable work attitudes, preventing employees from inhaling the fly ash directly.<br>b. Minimization of dust waste inhaled by employees using tools while completing their work. |
| **Recovery** | a. Recollecting fly ash using an engine design examined using the participatory ergonomics approach.<br>b. The size of the engine design or the tool was consistent with to the employees' anthropometric data |
| **Recycle** | a. The process of recycling residual materials considered safe work attitudes, not posing new problems detrimental to employees' health.<br>b. The process of packaging and finishing considered the handling capacity and weight in order not to exceed the maximum lifting capacity. |

The implementation of 5R-based cleaner production by taking into account the aspect of ergonomics referred to activities putting humans in the first rank viewed from the abilities, skills and limitations so that the sustainability of the metal casting manufacturing industry in the future can be assured.

Participation in ergonomics gave rise to better results compared to policy-based improvements which did not involve users or employees as it is the employees themselves who better know the field problems because they dealt with them every day. In other words, it is the employees serving as the key driver of the company's business.

3.4. The Improved Work Conditions in Terms of the Aspects of Task and Work Organization

Work-related improvements will not have optimum impacts on employees' physical condition if not supported by improvements in the work organization [19]. Human activity-based improvements in the standard operating procedures should be evaluated on a continuous basis. Task complexity makes people have different levels of performance. The ergonomics analysis starts from the task and then viewed holistically [5].

Humans are expected to balance their task demands and responsibilities, their work attitude to accept changes, information, and substitutes as an alternative answer to the desire to improve themselves [15]. Activities in the participatory ergonomics began with improving work conditions in the aspect of tasks [5]. Work convenience has an impact, namely improved performance of the employees and the company, however uncomfortable and non-ergonomic wwork conditions, if it is not addressed immediately, will pose problems to work comfort and safety [13]. A company's activities will provide information about the magnitude of the work life quality with the outcome in terms of the employees' improved life quality. The Quality of Work Life (QWL) is resulted from interactions between the individuals and their job, to feel that the job belongs to them [24]

## 4. CONCLUSION

The present research draws the following conclusions: these employees' life quality increased viewed from the means of the employees' life quality scores generated for both periods which differ significantly ($p < 0.05$). The concept of participatory ergonomics fitted out the 5R strategies developed in cleaner production. The implementation of participatory ergonomics along with the 5R strategies in cleaner production managed to make humans the center of the whole work improvement, in a synergy with the improved quality of the wotk environment. The highest improvement in the work quality was in the social domain while the lowest one was in the physical improvement domain. In order of magnitude, the employees' improved life quality scores after the transformation (0-100%) were the Physical Domain by 6.80%, the Psychological Domain by 16.75%, the Social Domain by 28.17% and, finally, the Environmental Domain by 16.53%.

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