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Ergonomics for Sustainable Groundwater Conservation Program

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***Abstract*— This article aims to describe the importance of ergonomics implementation for the sustainability of groundwater conservation programs. Ergonomics concept has been applied in research on groundwater conservation in Denpasar City, Bali, Indonesia (2013-2018), started from problem identification, data collection to engineering groundwater conservation programs through rainwater harvesting wells. In each stage of research, the application of ergonomics was more focused on human activities. In identifying problems, involving all relevant elements to obtain various inputs including constraints and limitations of existing potential; in the data collection process was more focused on the convenience, safety, and health of data takers; and in engineering groundwater conservation programs more focused on the community, Industry, or government as users of the programs. Through this ergonomics application, it is expected that all related elements are motivated to participate actively, increases sense of belonging, so that the groundwater conservation program can be sustainable.**

***Keywords*— Ergonomics; Groundwater; Conservation program**

I. INTRODUCTION

The groundwater conservation program is very complex. To maintain its sustainability, it is a must to consider all aspects related holistically, including technical, economic, environmental and social cultural aspects. To be able to create appropriate groundwater conservation program, it requires accurate technical data, an overview of the economic condition of the community, as well as local social cultural conditions. Each stage of the program design is very dependent on human activities, especially if it done with less high technology. Humans have abilities and limitations. Humans also have desires and hopes. Programs that are not in accordance with human abilities and limitations and do not meet human desires and expectations are very difficult to maintain sustainability. So this is where the important role of ergonomics is needed.

Ergonomics can be defined as the science and art of designing work systems that are in accordance with human abilities and limitations, adjusting the work system with workers, harmonizing the relationship between work tools and workers, and achieved optimum mutual adjustment of people and their work [1] [2] [3]. To design sustainable work system that is safe, comfortable, healthy and productive in which fulfills human desires and expectations, then in every stage of design it is necessary to consider ergonomics aspects.

Sustainable development has become a global issue trend at the end of this decade, but the role of ergonomics in maintaining program sustainability has not been widely known, especially in developing countries such as Indonesia.

Denis [4] states that macro ergonomics is able to make an important contribution in mitigating natural disasters, even though indirectly, at both the planning and deployment stages of this kind of programs. Application of the ergonomic program is in line with philosophy of the Corporate Social Responsibility and sustainable development, which placed health and psycho-physiological aspect in the first consideration, and influenced the workers quality of life and the life cycle of the product [5] [6]. To achieve the target of sustainable program is not simple, especially in developing country such as Indonesia, a big country, contains thousand islands, with very high density of population. The mindset of policy makers is often far different from the people or community, causing the abandonment of large and strategic programs, which is very costly. The program often set based on the political interest and ego-centrist with less consideration of the knowledge as well as the limitation of the people. Djeflat [7] reported that knowledge capabilities are highly correlated with levels of sustainability African development program. Sustainability science is interdisciplinary approaches, integrative analysis, and linkage with practical applications for sustainability challenges [8] [9]. Therefore, the involvement of all elements including the user community is important to be involved in every stage of program preparation. This concept is in line with the model of Ergonomics SHIP approach, which is consisting of Systemic, Holistic, Interdisciplinary, and Participatory [10].

Based on these findings and references, studies on the implementation of ergonomics have been carried out in the design of sustainable groundwater conservation programs. The ergonomics approach is synergized with the hydrogeological approach to obtain the design that are in accordance with the capabilities, limitations, and the conditions of the socio-cultural local community, so the sustainability of the program could be maintained. The synergy of ergonomics and hydrogeological approach has been motivates the community to involve both in

the preparing and implementing the water conservation program actively.

II. METHOD

The study of water conservation program was done through Ergo-hydrogeological approach that synergized the ergonomics and hydrogeological approach. The study was conducted in Denpasar City, Bali Indonesia. Some of the outputs of the research that more focus on the hydrogeological aspect have been published both in conferences and journals. This article is focuses on the influence of ergonomic SHIP approach in the research process. The ergonomics approach implemented the model of Ergonomics SHIP Approach [10] as Figure 1.

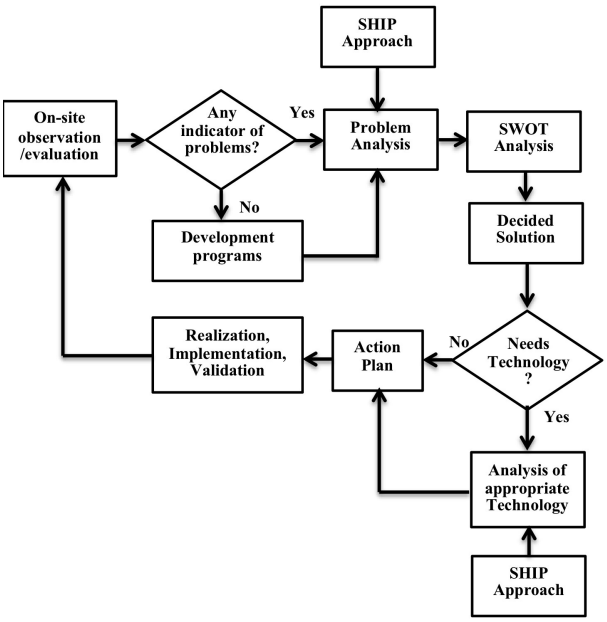

Fig. 1. Total Ergonomics SHIP Approach for Sustainable Development Program [10].

SHIP approach means **S**ystemic (all sub system considered as one); **H**olistic (the overall program is planned in its entirety); **I**nterdisciplinary (all problems are analyzed based on various related disciplines); **P**articipatory (involve relevant elements in discussing strategic issues) [11]. The implementation of Ergonomics SHIP Approach was focuses on the three aspects, including task, environment, and management in each step of the study. Figure 1 shows that the implementation of Total Ergonomics SHIP approach was for problem analyses and appropriate technology analyses. The figure also indicated that Total Ergonomics is never ending process. Overall, the process of sustainable development program is started from on site observation and evaluation.

In this study, on site observation / evaluation was done by walk through survey, interview with the policy makers or governments, public figure, and communities. The result of the first stage was the list of problems indicators.

Next step was problem analyses and solving the problem, which was done through full day Focus Group Discussion (FGD) that involved six parties, including governments (Water resources management-WRM, Energy and mineral resources management-EMRM, environmental agency-EA, and Public Work Departments-PW); non-government organization (NGO); academicians; Local Government Water Company (LGWC); public figure; and communities. The participants of FGD were divided into 4 groups with 10 members in each group, which was consisting of all parties. Each group leads by the facilitators that organized the group, started from the explanation and emphasized that there is equality among the members; everybody has freedom to express their opinion without being burdened by officially different positions. When the group settled, then, go on to the breaking the ice by introducing and telling success story of each member. After getting to know each other, then choose the chairman and group secretary. Then the group was handed over from the facilitator to the elected group leader. The position of parties in each group arranged as shown in Figure 2. Each parties representatives by 4 participants that placed in each group, so there were 4 groups participant in FGD. The FGD was conducted at the Town Hall Denpasar City.

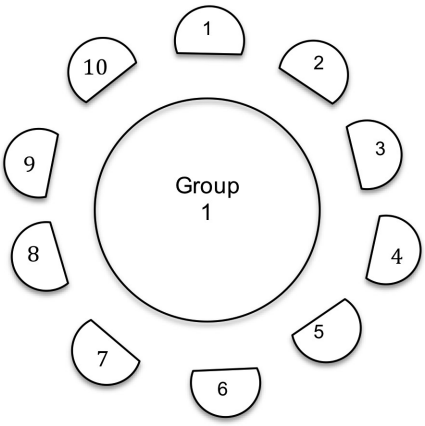

Fig. 2. The composition of each group in Ergonomics SHIP Approach Model of FGD

Notes:

1. Facilitator	6. EMRM
2. Public figure (Group Chair)	7. EA
3. NGO (Group secretary)	8. PW
4. WRM	9. Academician
5. Community	10. LGWC

Figure 2 shows that each group consists of all elements related to groundwater conservation programs. With this composition, it is expected that all elements can express their opinions from different point of view freely and at the end of each session, a group opinion can be concluded that has accommodated all input from group members. Ergonomic SHIP approach creating a relaxed atmosphere, without pressure, positioning each participant without differences so that the critical thinking of each participant can be expressed well, increase self-confidence to express opinions, feel participating in decision making, thereby increasing the sense of belonging and in the end there was a desire to maintain the

sustainability of each program that had been established together. With this atmosphere, it is hoped that the root problems on groundwater resources can be clearly formulated, solutions taken for effective and targeted problem solving, and in the end the groundwater conservation program could be maintained its sustainability.

III. Result and Discussion

The application of ergonomics in this study focused on three aspects, including task, environment, and management.

A. Problem Analyses

Problem analyses were conducted through ergonomics SHIP approach model of FGD as described in research method. Through participatory approach in which involved all relevant elements built a holistic overview based on the expertise and wide horizon of practical experiences and confirmed the priority issues of the problems. This study is in line with the report by Derek et all [12] that participatory model is effective as it offers a possibility to initiate discussion between experts and stakeholders bringing together different expertise. Moreover, Beall [13] specifically reported that participatory models could serve as effective facilitation tools for the problems and conflicts that come with the management of natural resources.

The first step of Ergonomics SHIP Approach model of FGD for sustainable ground water conservation agreed that the development of the tourism industry in Bali increased groundwater use and must be accompanied by groundwater conservation efforts. Ground water conservation through reforestation and *biopori* have been carried out and programmed by the Bali regional government, but the creation of rainwater harvesting wells has never been done. Therefore it has been agreed that the research conducted is more focused on the innovative design of rainwater harvesting wells.

B. SWOT Analyses

Based on the result of session one, each group continued to the second session, discussing about SWOT analyses in implanting rainwater harvesting wells for ground water conservation programs through rainwater harvesting wells. SWOT analyses were conducted describing the internal origin about the position against the program and the external origin to identified best future opportunities and highlight current and future threats, which were grouped in Strengths, Weaknesses, Opportunities, and Threats [14]. The priority list of SWOT analyses is presented in Table 1. It shows that there have been regulation and government has an authority on the policy of water conservation programs, but less empowerment and supervision on the implementation of the regulations, which causes less concerned about the existing regulations. Industries know about the existing regulations, but often deliberately ignore them or pretend not to know because there is no supervision or punishments. Government has commitment, but there is a limited annually budget for water conservation program, which causes the program to run very slowly. Most of the community is under low economics level and lack of knowledge that leads to the less awareness on water conservation programs. However, there are a lot of opportunities to build awareness and run the water conservation programs. Water crisis became a global strategic issue that encourages all parties including world organizations, NGOs, Government of developed countries, even personal to be concerned and deliver the grants on green managements including the water conservation programs. This global issues and opportunities can be used as a strong basis for developing action plans on various groundwater conservation programs.

TABLE I. The priority list of SWOT analyses for Water Conservation Program

Internal Origin	
Strengths	**Weaknesses**
S1. Government regulation on groundwater conservation S2. Government authority; S3. Government commitment; S4. Relevant departments; S5. Experts (Academician) S6. Government information media S7. Budget for environmental conservation increases yearly	W1. Less empowerment of Regional authorities W2. Less supervision on the application of regulations W3. Lack of groundwater conservation counseling W4. Poor management of surface water W5. The government has not been able to meet the needs of clean water
External Origin	
Opportunities	**Threats**
O1. Water crisis become a global strategic issue O2. Overseas grants of funding resources O3. NGOs that care about the environment O4. Global concern on green management O5. Less research on groundwater O6. Water is essential for life	T1. Climate change T2. Lack of Engineering Data T3. Lack of technology T4. Lack of awareness on the importance of water conservation T5. Water conservation program is costly T6. Low economics level of community

C. Engineering data assessment

The accuracy of engineering data as a basis for designing groundwater conservation programs is very important. Since the measurement of technical data in this study is almost all done manually, the accuracy of the data is strongly influenced by the physical and mental conditions of the data takers. If the data taker is in a less fit condition, then the level of accuracy, vigilance, and endurance becomes less optimal and the data obtained can be less accurate and biased. Therefore, the intervention of ergonomics is importantly needed.

Since the engineering data assessments were mostly conducted outdoors and under the heat stress, then the intervention of ergonomics were focused on the environment and management (shift work and nutrition). Ergonomics intervention on environment was conducted for the data takers during the pumping test of deep wells. Pumping test was done to assess the data that represent the existing condition of groundwater indirectly. It took quite long and the maximum was 72 hours non-stop. Long working hours associated with poor health, stress and psychological distress [15]. Workers easily fatigue, less of vigilance, low consistency, weak durability, and lack of accuracy [16]. To create the comfortable, and optimum level of the consistency and durability of work, ergonomics intervention was done in the form of [17]:

- Providing the shelter around the working area of the assessment to minimize the heat stress;
- Providing an ergonomic working table and chairs to avoid awkward posture, early fatigue and minimize the musculoskeletal disorder.
- Setting shift work (08.00–16.00; 16.00–00.00; 00.00–08.00) to maintain the working durability. Two data taker were on duty in each shift work with one supervisor in charge.
- Good working nutrition to maintain the balance between intake and energy usage by providing breakfast, lunch, dinner, and snack in between.

Through the application of the basic principles of ergonomics, it is expected that the level of accuracy, vigilance, and endurance of the data taker is maintained and the measurement results are accurate.

D. Water Conservation Programs

Groundwater is the main resource of clean/drinking water. It is also importance for agriculture and supporting industries, especially in tourism such as in Bali Indonesia. Tourism in Bali became the main pillar of economics and a source of foreign exchange for Indonesia. Bali is one of the small islands in Indonesia, which has been globally known as the most famous tourism destination in the world. Tourism industries increased drastically, followed by the increasing of population, infrastructures, housing, land use, and the needs of clean water. At the other hand, it followed by the decreasing of catchment area and ground water level that threat to environmental damage. Unicef data [18] reported that clean water and sanitation is as the 7th goal of Millennium Development Goals (MDG) in 2017. To meet this goal, means Indonesia needs to achieve increased access to clean water up to 68.9 percent and 62.4 percent, for sanitation. It was also reported that in Bali, percentage of household with better access of clean water is less than 60%.

Water crisis is common issue for urban city or developing countries. Baron et all [19] reported that urbanization increased the runoff coefficient from 0.01 to more than 0.40 and reduced the evaporation rate from nearly 80 % of infiltration to less than 20 % in in the Southern River catchment in Western Australia. Sunarta et all [20] also reported that tourism present negative impact on ground water through indicators of the increasing in runoff discharge about 3,255 lt/sec/year and declined the water table and changed the shallow into deep groundwater. Moreover, Sudiajeng et all [21] reported that the exploitation of groundwater through deep wells drilled by the hotels in Denpasar reached between 70–200 m under ground level of depths. Means, that Bali, including Denpasar faced some indicators of ground water crisis and it is a must to immediately implement a groundwater conservation program more seriously and effectively by synergizing various potentials.

Based on the engineering data of hydrogeology and the result of FGD, this research was focused on the water conservation program through rainwater harvesting recharge wells. Two types of rainwater harvesting or recharge wells were designed as the output of this research [21] [22]. Indonesian people usually place wells in the backyard corner, in the back services area, and not become part of the beauty of the yard or landscape. This perception causes the term well to get less attention. But ergonomic intervention on the design of rainwater harvesting wells has succeeded in changing this perception. Ergonomic rainwater harvesting wells are designed to be safe and beautiful, very flexible, can be placed anywhere depending on land availability, and are beautifully designed and integrated with the beauty of the yard as presented in figure 3 and 4.

Type 1 is more rigid and needs more space of land compare with type 2. It made of a single concrete pipe with 4 to 6 m of depth, needs at least about 9 m2 of land, while type 2 is very flexible depended on the available land. It made of HDPe (High-Density Poly Ethylene) pipes with 4 m of depth. Both type 1 and type 2 was designed safe and beautiful, at first glance it doesn't look like a wells. Both was supported by filtering pond to guaranty that the rain water fills the wells under threshold limit of quality; and the sedimentation pond to minimize the sedimentation material fill the wells and causes the silting of the wells.

Further evaluation of community interest to implement the recharge wells shows that they prefer type 2 with scores of 21.977 compared to type 2 with scores of 13.818. The main reason for this choice is that type 2 has better flexibility, especially related to land availability, and the readiness of technology and labor [18].

By involving all related elements, started from problems analyses, SWOT analyses, determination of solutions, technical and ergonomically design, and the evaluation of the effectiveness of the implementation, it is proved that the sustainable of the implementation of the water conservation programs will be maintained. Recently, there have been build 9 of recharge wells type 2 in Denpasar city and will be continued on 2019 with other 5 wells. Moreover, one of the NGOs in Bali, it is the IDEP Selaras Alam Foundation in collaboration with Politeknik Negeri Bali develop and implementing the type two in all over 9 districts of Bali Province.

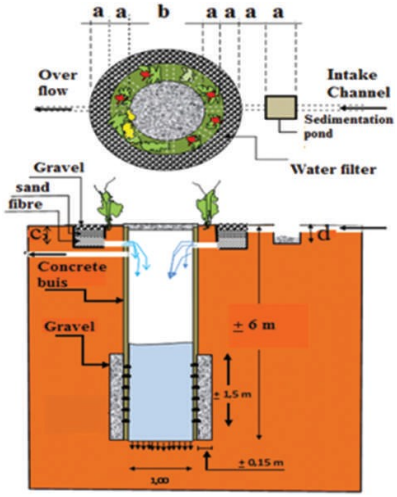

Fig. 3. Recharge wells type 1 [21]

(a) the width of the water filter and sedimentation ponds (40 cm)
(b) the diameter of the wells (100 cm), made of concrete pipe.

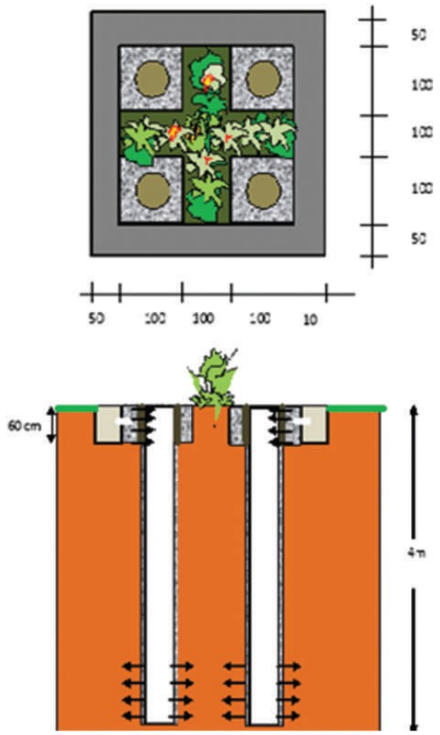

Fig. 4. Recharge wells type 2 [22]

IV. Conclusion

Water conservation program is complicated. The success of the program is very dependent on the human activities. Humans have abilities and limitations. Humans also have desires and hopes. Programs that are not in accordance with the human desires and expectations are very difficult to maintain sustainability. So this is where the important role of ergonomics is needed.

Ergonomics SHIP approach considered all sub-system holistically, interdisciplinary analyses, involve all relevant elements, built a holistic overview based on the expertise and wide horizon of practical experiences, and confirmed the priority issues of the problems.

Ergonomic SHIP approach influenced in every stages of the study, started from the problems analyses, SWOT analyses, determination of the solution, engineering data assessment and design of rainwater harvesting wells, and the evaluation of the effectiveness of water conservation programs.

Involving all elements in each stages of the program increased the sense of belonging and in the end there was a desire to maintain the sustainability of each program that had been established together. With this atmosphere, the root problems on groundwater resources can be clearly formulated, solutions taken for effective and targeted problem solving, and in the end the groundwater conservation program could be maintained its sustainability.

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