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A Short Review of Appropriate Technology and Engineering Design Education for Underdeveloped Countries

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저개발국가를 위한 적정기술과 공학설계교육에 관한 고찰

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ABSTRACT

During the past decades, dramatic technology changes affected the life of billions of people around the globe. Although these changes resulted to economic benefits, mostly for the developed countries, the undiscerning development also resulted to many side effects, such as environment pollution, scarce natural resources, global warming, and an increase of the gap between “those who have” and “those who have not”, among others. Also, since these developments were based on high technologies, they were not suitable for 90% of the underdeveloped countries. In this review, the possible ways of increasing the quality of life in underdeveloped countries are described, by providing adaptive solutions using appropriate technologies. Some successful applications of appropriate and intermediate technology are introduced, and the need for a new undergraduate education course of engineering design based on appropriate technology is proposed for Korea.

Keywords : Appropriate Technology(적정기술), Climate Change(기후변화), Industrialization(산업화), Alternative solutions(대안적 해결책)

1. Introduction

In the modern world of complex systems and large-scale industries, it is rare to face problems that humanity has long forgotten. As Israeli historian and writer Y. N. Harari writes in his book ian and wri [1]: sToday, more people die from obesity than from starvation; more people die from old age than from infectious diseases; and more people commit suicide than are killed in war.”oday, more people die frincreased efforts of people from essential fields such as technology, economics, and politics, positive change can be developed in the world. This, however, does not mean that people are set free in poverty. People living on less than $1.90 a day are considered extremely poor (World Bank’s Internatio nal line of extreme poverty). The poorest areas for living include regions of sub-Sahara and South Asia. People living there have poor healthcare systems and little or no clean water, resulting to poor sanitation. In addition they do not have access to

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proper or even basic education. Also, basic infrastructure, such as roads, bridges, and wells is insufficient.

In South Asia, some countries face an issue of rapid population growth and unbalanced distribution among the nations, leading to the capacity of natural systems being exceeded. The inability of such systems to cover basic needs for a "normal" life as experienced in developed countries results in poverty. There are almost 700 million people (almost half of them being children) living in extreme poverty, accounting for 10% of the world poverty, n pe Due to the COVID-19 crisis, which affects all countries around the globe, the population number is predicted to decrease [2]. This worldwide pandemic is predicted to directly affect major industries and world economies. For example, fossil fuel producing industries are facing a problem of oversupply and reduced demand. With countries being in lockdown, the demand for oil and gas has shown an obvious drop, as everyone has restricted mobility and economic activity. People in underdeveloped countries are suffering more due to the COVID-19 virus.

On the other hand, demand in renewable energy sources is continuing to rise. As it was stated in the IEA report on energy production, "demand is expected to increase because of low operating costs and preferential access to many power systems" [3]. The total use of renewable energy is predicted to rise by 1%, with a 5% rise (from 26% to 31% till the end of 2020) in renewable electricity generation. At this point, it is important to mention that for the first time in such a long period of time, the pollution rates are decreasing, fact affecting positively the climate change. As it is stated in the same IEA report, "not only are annual emissions in 2020 set to decline at an unprecedented rate, the decline is set to be almost twice as large as all previous declines since the end of World War-II combined." Global emissions in 2020 are projected

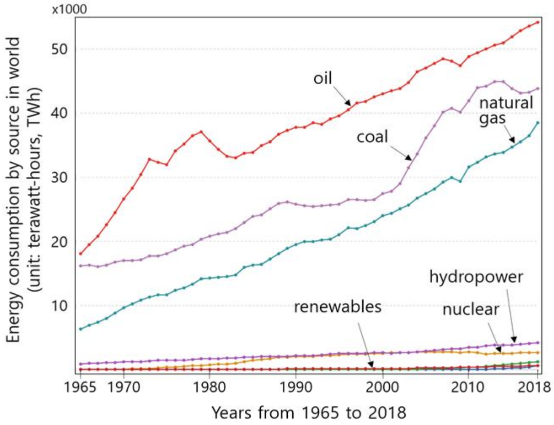

Fig. 1 Pimary energy consumption by sources in world from 1965 to 2018 [3]

to be 8% lower than in 2019 (30.6 giga-tons) [3].

Even though there are some positive trends regarding renewable energy production and decreasing pollution rates, almost everything that people consume is made using fossil fuel resources, as shown in Fig 1.

The sectors responsible for majority of emissions are transportation, electricity, manufacturing and construction, and agriculture. Even though there is a tremendous amount of ongoing research to reduce those emissions, trends in pollution are still rising. It is impossible to do away with using all goods that we currently consume in order to reduce pollution rates, but we need to switch to more environmentally friendly products. However, the eco-friendly products are generally more expensive, so people in underdeveloped countries cannot have access to them.

It is important to emphasize the significance of technologies people use to solve the ongoing problems of poverty and global climate change. Even if locals in the poorest countries cannot use the highly complex and capital-intensive technologies available in developed countries, they at least need skills to meet their basic human needs. There are technologies small and simple enough to be managed at a local level, to manage more workforce than capital-intensive, being efficient, and environmentally friendly in terms of energy consumption, without any harmful disposal. The concept of these technologies was born between the 60s and 70s, when scholars began to notice industrialization that helped developed countries to acquire wealth, and avoid helping developing countries.

This paper summarizes the trends and concepts of appropriate engineering and technology, in order to understand engineering design work in underdeveloped countries. It also aims to introduce the successful application of appropriate technology, taking into account its effectiveness in the fight against poverty in rural areas. Last but not least, it proposes the development of relevant engineering education programs, to address the climate change issue and lead to a sustainable future.

2. Appropriate Technology (AT)

2.1 History of AT

In the 20th century, the ruling parties of developing countries were mostly concerned with capital growth and technology transfer from industrialized and developed countries. Governments began to face problems of low capital, but they overworked, so it was decided to choose a development approach using capital-intensive technology. Due to the capital-intensive nature of imported technology through increased production, governments in developing countries could only employ a small number of their population to work towards technology implementation. In this case, high productivity occurred only in urban areas, where most of the population worked towards doubling the economy and neglected the surrounding area. This approach increased general unemployment and therefore poverty.

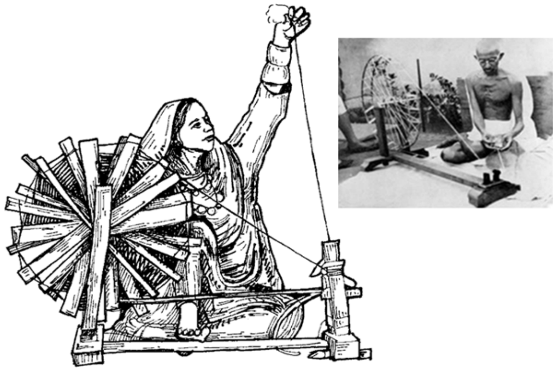

Fig. 2 Sketch of hindoo spinning-wheel and a photograph of M. Gandhi operating the spinning-wheel [4]

The needs of people living in the periphery could have been met, if local and small-scale technologies had been implemented. Mahatma Gandhi, the father of AT movement, was the first who saw the need for development of a nation which would give priority in village development in the same way as development of massive industries in urban areas [4]. Under the leadership of Gandhi, a spinning wheel called Charkha was invented to produce small-scale industrialization in rural areas of India (see Fig. 2).

In the 1930s Gandhi established organizations such as ‘All India Spinners Association (AISA)’ and ‘All India Village Industries Association (AVIA)’ to help villages around India to operate and produce an output as significant to the country’s economy as an urban sector. One of the figures who shared Gandhi’s views and further developed the concept of AT was Dr. Ernst Friedrich “Fritz Schumacher” [5].

In the post-war period, Schumacher was considered a great economist, who worked for more than 20 years as a senior economist and economic advisor to the British National Coal Board (NCB), where he witnessed the organization’s indifference towards workers’ problems with lung diseases. In Burma, it has been shown that capital-intensive technology transfer from developed countries can have detrimental effects on the economies of developing countries. In 1973, after visiting India and studying economics founded by Gandhi's movement, Schumacher published his work named "Small is Beautiful: Economics if People Mattered" [6]. He developed the concept of 'Intermediate Technology' as a type of technology which is far more productive than primitive technology used centuries ago, but also much cheaper than the highly capital-intensive technology used in the modern society of that period. In order for the intermediate technology to be useful and applicable, he made the following propositions: a) workplaces must be created in the areas where the people are currently living, and not primarily in metropolitan areas where people tend to migrate, b) the production methods employed must be relatively simple, so that demand for high skills is minimized, not only in the production process itself but also regarding organization, raw material supply, financing, marketing, and so on.

2.2 Definition of AT

According to Schumacher, the general definition of an appropriate technology (AT) was that it is always small, simple, cheap, and labor-intensive [6]. However, this does not necessarily make big in scale, or complex technologies inappropriate. Indeed, most computers and technological devices invented in the 70s were larger in size than similar smart devices we use today.

On the other hand, the AT can be misunderstood as a single culture of technology that must replace all advanced technologies transferred to third world countries. It is important to not forget that the primary goal of AT is to cover the needs of poor people often living in rural areas of these countries. Elite groups can benefit from industrialization in their home country, but the needs of poor villagers are often not taken into account. That is why diversity in technologies should exist, to support and cover all the basic needs of people in poverty. Towards this goal, the need for regular engineering educational programs related to AT has steadily increased.

It is worth mentioning that AT is not a panacea that can solve all the problems of the third world at once. Depending on situations and circumstances, some technologies might not be applicable in a poor, underdeveloped society, even if they are appropriate for another one. Hence, AT cannot be considered as a technological device working in all environments. It is mostly about the approach that by addressing the social and economic conditions of a society we can tackle problems with regards to its development. As a result of using such an approach, users will become wealthier and more skilled, further to their increased ability to use more developed and advanced technologies.

In addition to the aforementioned, it should be reminded that besides considering social and economic aspects when implementing AT, we also need to consider the environmental aspects.

3. Applications

Before introducing the applications of AT, it is required to specify the most fundamental areas that must be covered for the further development of a community, them being agriculture and water purification. In this paper, we summarized these two areas as successful AT applications.

3.1 AT for Agriculture

Agriculture in sub-Saharan Africa (SSA) countries is facing water shortages. As a solution, farmers are encouraged to cultivate drought-tolerant crops, which can be used as water storage in uncertain times, when the dry season lasts longer or rain patterns are not consistent. Unfortunately, small farmers cannot rely on sophisticated irrigation or water storage techniques, so they rely mostly on rainfall. Almost 62% of all crops in Africa depend on rain, the other 38% being dependent on irrigation [7]. In Kenya, providing additional irrigation of 60-80 mm, increased the grain yields up to 1 ton per hectare for sorghum and 2.5 ton per hectare for maize. In Nigeria, farmers achieved a yield increase varying from 65% to 500% after installing 50,000 tube wells [8]. High unpredictability of rainfall due to the rapid climate change is making it even harder for farmers to plan the planting seasons, making this dependence on rain dangerous for food security.

In addition, it was estimated that by 2018, almost 78% of large and small irrigation systems would utilize surface water [9]. Thus, it is important to increase the productivity of irrigation systems and improve groundwater pumping techniques, because, as mentioned earlier, relying on surface or rainwater can be dangerous due to climate change. Referring to the application of AT for irrigation problems, it is worth mentioning the use of treadle pump, which was originated in Bangladesh in early 1980s, and ten years later it was commercially spread in Senegal and Mali. Being classified as a manual irrigation pump, this technology helps lift 5000 to 7000 liters of water per hour from wells, boreholes, or surface water [10], employing the human's bodyweight and requiring legwork, while other traditional pumps require the engagement of upper body and arms, as shown in Fig. 3. The main reason of classifying treadle pump as AT is that it can be manufactured from locally available materials and equipment commonly found in most of SSA cities [11]. The treadle pumps are much more affordable compared to other similar products and can be easily maintained in small-sized farms. In 2014, a study conducted by Cornell University in Zambia revealed that 86% of farmers were able to have from two to three meals per day with the use of treadle pumps [12].

In addition to the pumping technology, there is still a huge need for optimization of various aspects of the irrigation system. The example shown in Fig. 3 is relatively old, and the need for further advancements is increasing every year. In addition to pumping, new technologies and techniques for water distribution for crop cultivation have been developed. For example, a gravity feed drip irrigation system can reduce water evaporation and hence reduce water loss by small but sufficient percentage [13].

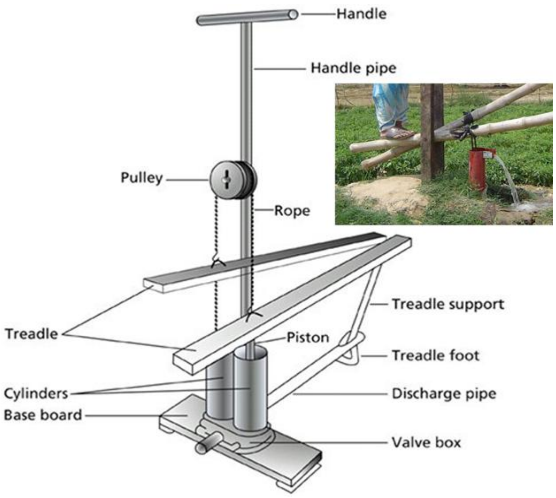

Fig. 3 Schematic diagram of a treadle pumping system [12]

Recently, due to the climate change, and subsequently the rise of temperature, hot regions of Africa have become hostile for the cultivation of many crops, so the need drought resistance is relevant more than ever before. Identifying this need, Sanoussi Diakité came up with the idea of making a machine that would be able to satisfy time and labor limits. In 1993, he made the first prototype of Fonio Husking Machine. If 1-2 kg of fonio normally took an hour of husking, with the use of this machine it became possible to husk up to 50 kg during the same time. "The Fonio Husker Machine effectively husks and cleans the fonio grains as they pass through the shifting and flexible paddle, which is set on a vertical axis and on top of a fixed plate. The separation of grain and husk is done simultaneously by an incorporated ventilation system. This process requires just 1.5 kilowatts for power, increasing yields by more than 65%", as shown in Fig. 4 [14].

Although the Fonio Husking Machine can be considered as breakthrough technology, helping the fast-growing population of African countries who live in dry climate conditions, it cannot be fully considered as AT, as it is considered expensive (between $1320 and $2200 per device) for local use in rural communities. Still, this technology is mostly supplied by the government for the people in need.

3.2 AT for Water Purification

To understand the full importance of water, we need to consider its role in our life. We use water for drinking, food preparation, hygiene and washing.

Fig. 4 Photograph of fonio husking machine in Senegal [15]

Fig. 5 About 2.2 billion people still don't have access to clean drinking water (photo by Ravikumar)

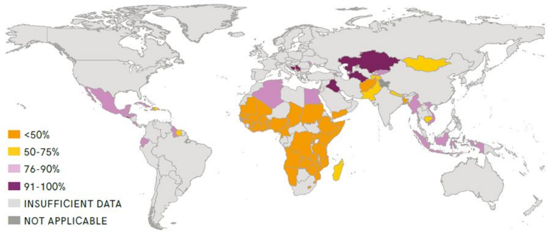

Fig. 6 Proportion of national population with handwashing facilities including soap and water at home, 2015 [16]

There are billions of people living under extremely poor conditions, with little or no access to clean water, whereas people living in developed countries have no major issues with water and take it for granted (see Fig. 5).

According to the report published by Joint Monitoring Programme (JMP) between WHO (World Health Organization) and UNICEF (United Nations International Children's Emergency Fund), in 2017 [16], 5.3 billion people in the world had access to safely managed drinking and washing water (see Fig. 6). 1.4 billion people used basic services, 206 million people used limited services, 435 million used unimproved services and 144 million people could drink untreated surface water. Especially in Africa, almost half of the population does not meet the standards of healthy living, due to the scarcity of drinking water. The lack of drinkable water and basic sanitation results in 3.1% of the global annual death (1.7 million people), and 3.7% of annual burden (54.2 million people) [14].

To be classified as safely managed, water should be accessible, available for at least 12 hours per day, and free from contaminants. There is a pressing need to develop AT that help people around the globe, and especially in Africa, to cope with the scarcity of drinkable and safe water. Most purification techniques use chemicals or specific tools and materials available in laboratories, but few have helped clean up contaminated water from

(a) (b)

Fig. 7 (a) Hari Govinda Prajapath ceramic candle filter and (b) Indian ceramic candle filter [18]

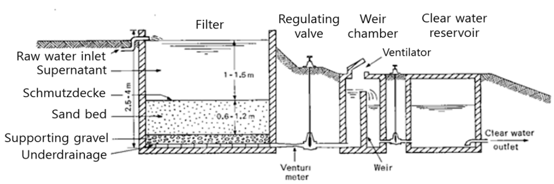

Fig. 8 Sketch of a slow sand filter (Huisman & Wood, slow sand filtration) [19]

decades ago.

Towards this goal, a ceramic water filter (CWF) is a device that contains a porous ceramic membrane, a plastic or ceramic receptacle, and a plastic tap [18]. Water is poured to receptacle's upper portion, and it is safely stored there until accessed through the tap. Based on differences on membrane assembly and shape there are two types of CWF, the candle filter and pot filter, as shown in Fig. 7(a) and 7(b).

A candle filter has an upper receptacle placed above and separated from the storage receptacle. The candle components, hollow ceramic membranes, cylindrical in shape, are attached to the barrier that divides the two receptacles. Water poured from the top can only reach the bottom by flowing through the candle elements, where filtration takes place. The pot filter is much simpler, having only one concave membrane, which sits inside the rim of the receptacle.

The CWF is considered to be a much cheaper way of water filtration, compared with boiling water or buying already filtered water in gallons. A similar technology based on a biologic, self-forming membrane, is a slow sand filter. As shown in Fig. 8, this filtering system consists of a reservoir of supernatant water, a bed of filtering medium (almost always sand), an under-drainage system which supports the filtering medium, but does not block the flow of treated water, and a system of control valves to regulate the velocity of flow through the bed. The reservoir can be 2.5 to 4 meters deep and built partly or wholly below the ground [19].

A brief explanation of the filtering process is explained below. First, untreated water is poured into the reservoir until reaching a 1 to 1.5 meters level and it remains there from 3 to 12 hours. Heavy particles settle and smaller particles aggregate, making their removal easier. Under direct sunlight, algae grow and absorb carbon dioxide, nitrates, phosphates, and other nutrients from the water, forming cell material and oxygen. Subsequently, the oxygen dissolves in the water and interacts with impurities. An organic filter skin is formed on the surface of the sand, through which the water can pass. This skin consists of thread-like algae and numerous other forms of life. All interactions between dead algae and living bacteria take place on the surface of this filter skin, with only inorganic salts being able to pass further.

These are only some of the available technologies that are both affordable for local communities, and helpful towards reducing the presence of contaminated water. Hundreds of other inventions based on AT are used in poor communities every day for water transportation (e.g. Hippo Water Roller, Q-drum), water harvesting (e.g. air moisture, rainfall), hygiene (e.g. dry toilets, Arborloo, SanPlat) and others.

4. Conclusion

Considering all the devices and technologies described above, we can conclude that they are small, simple to operate and economical, but yet allow us to effectively implement sophisticated technology towards the fight against poverty. In this short review, examples of the application of appropriate technologies (AT) were mentioned to raise awareness among people from various fields, such as engineering, natural and social sciences, medicine, and entrepreneurship, among others. If inventors of all mentioned devices and techniques could clearly see the need for help and demand in innovations, they could subsequently act and solve problems in appropriate ways for the local communities.

Until now, there have been educational trials with AT in Korea. However, the engineering education programs for undergraduate and graduate students should be developed even more for the third world populations [20-21]. In summary, we believe that the curriculum of engineering colleges needs to train students to develop the right and related skills to change the world.

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