Accounting embodied economic potential of healthcare waste recycling – a case study from Pakistan.

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Abstract

 Proper management of healthcare wastes is a key concern across resource-constrained countries in South Asia. Existing scientific research on this topic usually involves epidemiological and behavioral studies. Similarly, environmental impact assessment of healthcare wastes is mainly conducted from an end-user or anthropocentric point of view. In this study we took a novel approach by analyzing healthcare wastes using an ecocentric position. Here, we utilize a case study of a general public hospital in a major city of Pakistan to analyze the embodied energy of its waste fractions by category. We used Emergy analysis to assess the true economic potential of recycling these waste items. While doing so, we compared the economic potential of current waste recycling practices with the scenario of 100% recycling of useful waste fractions. We discovered that the latent embodied energy of different recyclable waste fractions made them far more valuable than their existing market prices indicate. This value increased further if the useful waste fractions were completely recycled. In conclusion, this study used empirical evidence to argue in favor of source-segregation and recycling of healthcare wastes so that the higher costs associated with natural resource extraction and processing can be avoided. Future studies considering hazardous healthcare wastes can use the approach taken in this paper to analyze the impact of other practical waste treatment procedures.

Key Words

Resource conservation; low carbon development; Circular Economy; developing country.

1. Introduction

 Natural resource conservation is one of the key agendas in the Sustainable Development Goals (Stafford-Smith et al., 2017). Sustainable development requires consumption of such resources in a manner that does not hinder the ability of future generations to utilize them. This is all the more important in the rapidly urbanizing countries of Asia that need these resources to continue to grow their economies. Of the proposed solutions for conserving such resources, the 3R principle of reduce, reuse and recycle has recently gained popularity in some of the Asian countries (Sakai et al., 2011). Similarly, legislatures in these countries have established principles and standards to transition their economies from open-loop supply chains to closed-loop production systems thus leading to a Circular Economy (Ali et al., 2018a). Recently, there have been different studies analyzing the conservation of material and energy across different industries, eco-industrial parks and even model cities in countries such as China and Japan (Geng et al., 2013). Similarly, countries in South Asia have seen rising foreign direct investments in energy, trade and transport infrastructure to make them more efficient. In these countries, researchers usually scrutinize public infrastructure projects such as power plants and dams to analyze their environmental loads. Hitherto, there haven’t been sufficient studies to assess the scope of Circular Economy in health or education sectors in such countries. In this study, we aim to assess the environmental footprint of wastes generated at a general hospital in Pakistan.

 In Pakistan, a general hospitalis one of the most common and significant healthcare institutions for providing tertiary medical care. A strong focus on health, safety and environment (HSE) is vital for the safety of the patients, the visitors and the staff at such an establishment. However, healthcare establishments also consume large quantities of energy and other resources in their daily activities, and the potential for savings in resource conservation is quite large (Garcia-Sanz-Calcedo, 2014). These savings can free up resources which can, in turn, help implement better health services for a greater number of people. In developed countries sophisticated controls have been implemented to collect and recycle useful hospital waste components. On the other hand, developing countries face difficulties in implementing efficient healthcare waste recycling practices (Ali et al., 2017b) .

Most existing studies regarding hospital waste management in developing countries focus only on estimating their economic value or the impact of their pollution on the environment (Ali et al., 2016a). However, it is also important to take an ecocentric view, which can help discover the investment made by *Nature* in producing such items. Such a view involves estimating the embodied energy of waste components over their entire life cycles. In this paper we will use the concept of Emergy (explained ahead), to understand the intrinsic economic value of such waste items.

1. Study area

The present study involves ecological accounting of wastes produced at the largest hospital in Gujranwala, a major city of Pakistan. Gujranwala is located at 32.16° North, 74.18° East in the economic and political heartland of the country. The city has 41 hospitals in whole, of which DHQ is the only large (>100 beds) public hospital (Ali et al., 2017c). Previous studies have pointed towards poor environmental controls at this hospital (Ali et al., 2017a; Ali et al., 2017c). For instance, most of the waste at this hospital remains unsegregated thus limiting the amount of waste fractions that can actually be recycled. In this study, we aim to discover the embodied energy of these waste items so that their true economic potential can be assessed. This will highlight the importance of recycling such items instead of rejecting them to open dumping sites or incineration plants, as is the current practice (Ali et al., 2016b). While previous studies have focused on municipal solid wastes, healthcare wastes haven’t received due attention from Circular Economy practitioners and researchers. As such this is perhaps the first study accounting for the embodied energy of healthcare waste items. This case study can be used as a benchmark to compare findings in similar hospitals across other cities in the region.

1. Materials and Methods

 In this paper, we use Emergy analysis to account for the intrinsic value of waste items produced at DHQ. Emergy is a thermodynamic concept that represents a technique to convert all resources on a common platform. It disaggregates the resources on an energy scale and expresses them in terms of their solar energy equivalents using appropriate conversion factors called “transformities” or Unit Emergy Values (UEVs) (Brown and Ulgiati, 2004; Odum, 1996). Larger UEVs indicate that a large quantity of equivalent solar energy went into creating the product/resource/service thus ranking it higher in the energy hierarchy in nature.

During the last two decades researchers have used transformities for an Emergy analysis of systems ranging, to name but a few, from power production (Brown and Ulgiati, 2002) to waste management (Ali et al., 2018b) to industrial production (Zhang et al., 2009) to agriculture (Ali et al., 2018d). One advantage of using Emergy as compared to other sustainability assessment methods, is the use of a common and consistent set of units, thus widening its application to include a host of systems and processes. This is because different materials and resources can be differentiated viz-a-viz the quality of energy contained within them during their evolution into their present state. The difference in quality of the consumed resources determines the amount of energy stored into the eventual product or system. This stored energy can be represented in the units of Emergy to help make comparisons and create benchmarks (Ali et al., 2018b). In other words, Emergy is a useful tool in tracing the material and energy pathways as they are transformed into products, services or waste items.

 In order to collect relevant data for Emergy analysis, field visits were conducted at DHQ between October 2014 and January 2015. Information about hospital waste generation and disposal was obtained through physical measurement of waste fractions by weight and composition. Data regarding economic value of different waste fractions was obtained through market surveys. The surveys revealed that most of the recyclable waste fractions consisted of paper, plastics and glass items. Metal items mainly consisted of sharps made from steel. In this analysis we focused only on recycling due to the lack of availability of relevant data for incineration, composting and other waste disposal techniques for Pakistan. Moreover, recycling is considered as a more environment friendly waste disposal technique than incineration (Ali et al., 2018c). Recycling also has obvious advantages in the context of Circular Economy as it leads to conservation of natural resources and mitigates extraction of virgin materials. Incineration on the other hand, diminishes the availability of resources through fuel consumption and near-complete destruction rather than valorization of waste fractions. However, for some specific kinds of healthcare wastes, incineration is more suitable due to public health concerns (Ali et al., 2017b).

 Results & Discussion

 Figure 1 displays the Emergy system diagram of the studied hospital. It shows hospital solid waste entering as an input to the system after which its different fractions go through recycling. For this study, we only accounted for the Emergy of the waste fractions. As such, the Emergies of external inputs such as fuel, equipment, labor, etc., were not taken into account during the analysis. Similarly, renewable energy resources such as solar, wind and geothermal inputs were excluded. Finally, the Emergies of products leaving the system such as recycled materials and byproducts such as Ash were also unaccounted for.



Figure 1. Emergy system diagram of waste management for DHQ.

 Table I provides the Emergy values for different waste fractions at DHQ. It can be seen that in terms of embodied energy, pathological items such as human organs had the highest value among medical waste items. In general waste, plastic items had the highest embodied energy due to a combination of their relatively higher UEV and larger quantity as compared to other waste fractions.

Table I – Emergy accounting of waste fractions at DHQ.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Note** | **Item** | **Unit** | **Amount** | **UEV (\*)** | **Ref.** | **Emergy** |
|   |   |   | (unit/yr) | (sej/unit) |  | (sej/yr) |
| *Medical waste* |  |  |  |  |  |   |
|   | Plastic | Kg | 1.86E+03 | 7.45E+12 | (Agostinho et al., 2013) | 1.39E+16 |
|   | Paper | Kg | 2.43E+03 | 4.94E+12 | (Agostinho et al., 2013) | 1.20E+16 |
|   | Glass | Kg | 2.43E+03 | 2.75E+12 | (Agostinho et al., 2013) | 6.68E+15 |
|   | Textile | Kg | 2.83E+04 | 8.34E+10 | (Agostinho et al., 2013) | 2.36E+15 |
|   | Rubber | Kg | 1.77E+03 | 1.69E+11 | (Agostinho et al., 2013) | 2.99E+14 |
|   | Pathological\*\* | Kg | 2.40E+03 | 2.03E+13 | (Kamp and Østergård, 2012) | 4.88E+16 |
|   | Sharps | Kg | 1.82E+03 | 8.57E+12 | (Agostinho et al., 2013) | 1.56E+16 |
| *General waste* |  |  |  |  |  |   |
|   | Plastic | Kg | 8.47E+03 | 7.45E+12 | (Agostinho et al., 2013) | 6.31E+16 |
|   | Paper | Kg | 5.17E+03 | 4.94E+12 | (Agostinho et al., 2013) | 2.55E+16 |
|   | Glass | Kg | 2.66E+03 | 2.75E+12 | (Agostinho et al., 2013) | 7.32E+15 |
|   | Mixed  | Kg | 2.21E+04 | 3.78E+11 |  (Ali et al., 2018b) | 8.34E+15 |

\*All references correspond to the new Emergy baseline of 1.2E+24 sej (Brown et al., 2016). \*\* Corresponds to the value for meat.

 In order to interpret these results more clearly, it is useful to compare the economic and ecological values of these resources. Table II compares these values for different recyclable waste fractions. According to the market survey, the prices of different recyclable articles included 0.07 to 0.08 USD kg−1 for paper, 0.3USD kg−1 for plastic, 0.08 USD kg−1 for glass and 0.35–0.4 USD kg−1 for metal as per the exchange rate between Pakistani Rupees and US dollars at the time of the survey (Ali et al., 2017a).

Presently, the economic value of most of the products in the world is primarily expressed in monetary units. This is because money is the primary medium of exchange between buyers and sellers. Thus, to communicate with the wider non-scientific audience, it is useful to express the value of services provided by *Nature* in appropriate monetary units. Emergy analysis achieves this through the concept of Emergy Money Ratio (EMR). This ratio is obtained by dividing the Gross Domestic Product (GDP) of the country with the total Emergy use in the country. Estimating the total Emergy use in a country is a complex exercise involving detailed analysis of a country’s total production, exports and imports. Fortunately such values have already been estimated by researchers and reported in the National Environmental Accounting Database (NEAD, 2017). Total GDP of Pakistan was obtained from the World Bank’s database (World Bank, 2016). To express the Emergy values of the waste fractions in economic terms, we multiplied each of the Emergies given in Table II with the inverse of the Emergy money ratio for Pakistan thus resulting in ‘Emergy dollars’ expressed as Em$. The concept of Em$ has been used extensively in recent literature where comparisons between the market value of a good or service is compared with its embodied economic potential (Brown and Ulgiati, 2018).

The Emergy money ratio for Pakistan for 2014 was reported as 7.64E+12 (Liu, 2018). As such, this ratio expresses the embodied economic value for each dollar of output produced in the country. By dividing the Emergy of each waste fraction by this ratio we can obtain its corresponding intrinsic economic potential.

Table II – Comparison of ecological and economic values of waste fractions at DHQ.

|  |  |  |  |
| --- | --- | --- | --- |
| Note | Item | Ecological value | Economic value |
|   |  | (Em$/yr)\* |  (USD/year) |
| Medical waste |  |   |
|   | Plastic | 1.82E+03 | 5.58E+02 |
|   | Paper | 1.57E+03 | 1.82E+02 |
|   | Glass | 8.74E+02 | 1.94E+02 |
|   | Textile | 3.09E+02 |   |
|   | Rubber | 3.91E+01 |   |
|   | Pathological | - |   |
|   | Sharps | 2.04E+03 | 6.37E+02 |
| General waste |  |   |
|   | Plastic | 8.26E+03 | 2.54E+03 |
|   | Paper | 3.34E+03 | 3.88E+02 |
|   | Glass | 9.58E+02 | 2.13E+02 |
|   | Mixed  | - |   |

\*Based on Emergy money ratio of 7.33E+15 sej/$ for the year 2014 (Liu, 2018).

 Table II shows that at the time of the survey the combined annual economic value gained from recycling plastic, paper and glass was USD 3141.55. This value could increase to USD 4713.20 in case of 100% recycling of both the medical and general waste fractions. In ecological terms, the combined annual economic potential from recycling plastic, paper and glass could be Em$ 12550.76. This could increase to Em$ 19202.85 in the case of 100% recycling of these fractions in addition to all the fractions in medical waste (excluding pathological items). This shows that the actual economic value of the waste fractions was relatively greater than their prevailing market rate.

 This case study stresses the importance of recycling for resource conservation, which can help mitigate the costs of extracting virgin resources. The present system at DHQ can be improved through waste minimization and enforcement of relevant environmental regulations. Eventually waste reduction and recycling facilities can be used for carbon credits thus leading to economic as well as environmental and social benefits (Ali et al., 2019; Ali et al., 2018a). Finally, there is a need to highlight the subject issue through scientific and journalistic outlets to stimulate further research and gain due attention from the concerned authorities. The population of Gujranwala district is greater than that of major European cities such as Rome or Berlin and as such the environmental and epidemiological impact of waste management controls in the city can affect a significantly large population.

State institutions in developing countries are usually financially constrained for implementing proper waste management controls (Buenrostro and Bocco, 2003). Hence, a public-private partnership is needed to improve the safety and recycling rate for healthcare waste management at public hospitals. Policy makers can promote public awareness drives through local union council officials to help people realise the importance of the intrinsic value of wastes. In a country like Pakistan, religious opinion leaders can also aid this effort by stressing the importance of resource conservation in their sermons.

 Conclusions

 Ecological accounting is a novel field of study which has experienced a growing interest from Circular Economy practitioners in recent years. One of the reasons for its popularity is the advantage of having a consistent set of units which can help compare different products and services on a common scale. Recently, there has been a surge in studies involving embodied energy analyses of municipal solid waste. We used this study to account for the ecocentric value of waste fractions at a case study hospital. The subject of embodied energy in healthcare wastes has hitherto been neglected in scientific studies and this study attempts to fill this important gap in the existing literature. This study empirically proved the value of 100% recycling of wastes. It also showed that the market-value of the recycled waste fractions could be higher, as expressed in the form of Em$.

 A limitation of this study is that we extrapolated the survey results regarding waste generation at DHQ over the whole year in a linear fashion without taking into account seasonal variations. Since consumption patterns and diseases affecting patients vary with season, the quantity and composition of wastes generated from the hospital can also vary with the seasons. Another limitation is the lack of data regarding proper waste recycling procedures such as composting, incineration and controlled material recycling. This is because developing countries like Pakistan lack proper facilities for waste disposal and recycling. Hence, inventory data for a cradle-to-grave life cycle assessment is not readily available. Similarly fuel, labor, etc., are usually considered to be critical contributions to the energy history, and bounding the focal system will make a tremendous difference to the final calculations and transformities involved. The decisions made to bound the system in such ways is an integral part of the analytical process. As such, lack of availability of relevant data restricts the potential replicability of this study.

 Future studies can reduce the uncertainty associated with the data used in this paper by monitoring waste fractions for an extended duration. Moreover, different healthcare facilities can be monitored to assess the combined ecological value of such waste fractions for the whole city, province or even the country. This can help drive home the importance of resource conservation through recycling and create greater awareness among policy makers as well as the general audience.

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