論 文 の 内 容 の 要 旨

Abstract of Dissertation

Title of Dissertation: Material flow analysis for recycling and waste management system in Bangladesh

（バングラデシュにおけるリサイクル／廃棄物処理のマテリアルフロー分析）

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We are leading towards an alarming supply restriction scenario due to increasing global consumption of resources which will particularly affect the economic growth. The inevitable sustainability push, therefore, necessitates mankind to delve into means of more efficient utilization of the planet's remaining stock and to investigate practicable resource decoupling options. Economic activity will eventually increase with the increase of human well-being which invigorates the resource use. Some developed nations already have achieved tremendous experiences. One of the important knowledge obtained from these experiences is a better understanding of the current situation through monitoring material flows which are equally important as the direct measures for efficient resource use. Bangladesh as one of the developing nations can learn from these experiences. But, unfortunately this country is seriously lagging behind of having the reliable information of different socio-economic indicators. From the available reliable international statistics, only some part of the inflows information is available though they show inconsistency with real situation. According to that, the most of Bangladesh's material consumption is biomass in terms of weight and this is quite understandable since this country is at the very early stage of her economic development. But now, considering the economic development, Bangladesh is gradually demanding other kind of inflows. At the same time, outflow issues possess the same story having no reliable statistics.

Recently, material flow analysis (MFA) has been a widely applied tool in industrial ecology in order to offer the fundamental information for the discussion of sustainable resource use/management. However, due to the data-oriented nature of this analytical technique, MFA is not common in developing nations with less organized statistics, although having huge potential of unraveling story, such as metal recycling. Therefore, the primal objective of this study is to see the opportunity of applying MFA in Bangladesh. Besides, this study is a move to reveal the importance of the flows associated with waste management/recycling for Bangladesh having no huge manufacturing industries.

This thesis comprises of five separate chapters. Chapter 1 describes the aforementioned backgrounds and rationales of this research. Apart from that, objectives of this research have been summarized in this chapter. The objectives of this research are to know the material flows of Bangladesh by means of municipal solid waste (MSW) as the biggest outflow and characteristics of the ship breaking industry (SBI) in Bangladesh (which recently has drawn huge attention from all over the world) as steel is the most consumed materials in this country and the biggest inflow is coming from the SBI.

Chapter 2 describes the current status of MSW management system in Chittagong, the second largest city and the commercial hub of Bangladesh. The unchecked migration of a large

number of people in Bangladesh is causing unplanned urbanization and slum development which consequently leads to the uncontrolled generation of MSW. The total MSW generation in Chittagong City Corporation (CCC) area increased steadily over the last 10 years; from 538 tons/day in 1999 to 984 tons/day in 2005 and 1,890 tons/day in 2009. In 2009, waste generate rate in CCC is 0.55 kg/capita/day. The waste compositional data reveals that around 80% MSW of Chittagong is compostable. The waste collection coverage in Chittagong City increased from 45% in 1999 to 64% in 2008 and it is almost 70% in 2009. It was found that the recycling in Chittagong as well as in other big cities of Bangladesh is being carried out by the informal sector. Only 0.16 % (2,116 kg) waste which is mainly of organic origin is processed daily to produce compost, fuel and fiber. From the available two disposal sites of CCC, the waste pickers collect on an average a total of 3,302 kg of different categories of recyclable waste daily with a current market value of US$ 417.3. Waste generation flow of Chittagong city as it is revealed from this study is compared with that of the whole country to get an objective view. In Chittagong, 689,000 ton of municipal waste generated of which 397,000 ton was collected in 2009 and the remaining (207,000 ton) portion was uncollected which is creating environmental nuisance to the city dwellers. About 85,000 ton of inorganic wastes were recycled in the same year of which 1,200 ton were recycled from the final disposal side. On the other hand, recycling activity in the whole country is not satisfactory. As a whole, in 2005 about 0.69-1.04 million ton of inorganic wastes were recycled in Bangladesh. Over all waste collection coverage is 50% in the same year for the whole country. In 2005, about 2.00-2.63 million ton of MSW reached till the destination of final disposal and about more than double amount of wastes being uncollected. Per capita generation of MSW in 2005 was 0.13-0.20 kg/day in Bangladesh. Bangladesh doesn't implement anything rather that recycling as the intermediate treatment. Besides, 61-64% MSW are of food waste. Basically everything of MSW is going to landfill site directly. Therefore, 6.22-9.37 million ton of MSW are landfilled. MFA of MSW in CCC reveals that in spite of having a good waste collection rate, recycling success is not satisfactory. The source segregation could act as a better panacea in this regard and lessen the burden in the segregation process in the final disposal.

SBI was also studied with an especial emphasize on the inflow perspective. Owing to this, in Chapter 3, characteristics of ship breaking industry in Bangladesh along with the material flows of steel industry have been summarized. Apart from these, other material (apart from steel) recovered from ships have also been analyzed in this chapter. Dismantling (or "breaking") of ships invigorates global shipping by replacing older ships and recycling or reusing as much as 95% of their materials. Bangladesh dominated global ship breaking from 2003 to 2007 and continues to be a top breaker globally. In the beginning of this chapter, it was aimed basically at expounding the inflows of SBI in Bangladesh from the perspectives of origin, types, and lifespan of dismantled ships in order to develop a better understanding on the nature and dynamics of this industry. Five cross-referenced consolidated databases were utilized. The average weight of ships dismantled in Bangladesh was 7,558 LDT (light displacement tonnage) in 2007 which rose to 12,319 LDT in 2010. SBI owners from Bangladesh showed inclination to oil tankers and cargo carriers; although the types of ships imported became more diversified as the industry grew larger. Preference to larger ships could be linked to their high steel content and the close linkage of SBI to the growing domestic steel industry and it in turns explained the shorter lifespan of dismantled ships. Interestingly, ships dismantled in Bangladesh were relatively younger with mean age of 27 years compared to the rest of the world of 30 years. The major hurdle faced during this research was the unwillingness of stakeholders in disclosing available but relevant information due to widespread

suspicion which needs to be resolved in future to know the industry more objectively. MFA of steel in Bangladesh by placing SBI in context was carried out. SBI stood out to be the sole source of re-rollable scraps for small re-rolling industries in Bangladesh and cumulative reinforced bar (rebars) output in 2008 from these industries became two-folds higher compared to 2005. This time frame coincided with period when global ship breaking gradually came out of recession. Besides, induction furnace based larger rolling industries were observed to meet bulk of their input needs by steel scraps both from the SBI and through import. While analyzing the import of scrap iron and DRI, a sharp increase was observed during the world ship breaking recession and when SBI in Bangladesh faced temporary ban in 2010. Induction furnaces in Bangladesh in FY 2010 produced 438,000 MT of billets from ship sourced scrap which was 16,000 MT higher than that from imported scrap. Rolling industries output in FY 2010 was 1,448,000 MT and 1,303,000 MT of it was rebars; the rests were other bar and shaped steels. This output took 29% input from ship breaking sources, 27% from imported scraps and the rest 44% from imported billet/ingot. Dismantled ships also generate high quality reusable steel scraps meeting the demands of manufacturing, repair shops, the domestic shipbuilding industry and the construction sector. The total aggregated domestic steel consumption in FY 2010 was 2,894,000 MT in Bangladesh; 39% of it was met from SBI. Also, SBI contributed approximately 53% of the steel raw material demand. Besides, for the first time, the intensity of steel use in Bangladesh was analyzed. In 2008 the country's steel consumption was 3,162,000 MT i.e., 22kg per person and the intensity of steel use stood at about 40 g/USD. In comparison to the slow economic development of Bangladesh, the country exhibited a larger steel consumption relative to its GDP which also indicated the contribution of SBI. In case of outflows from ships dismantled, it was observed that, on an average, reusable/recyclable steel comprised 85% of the total weights of ships; the rest were machinery, hardware, fittings, and consumable items such as oil. Almost all the materials recovered were processed and consumed domestically and only a tiny fraction got exported. Machinery, hardware, and fittings accounted for 8.6% of total weight in FY 2010. They were usually reused after cutting, grinding, repairing, or other kinds of processing. Machinery such as generators, boilers, pumps, motors, and home electronics are collected and used domestically by non-ship-associated consumers. Maritime machinery and equipment are collected and used as spare parts. In addition, some high-quality steel plates as well as non-ferrous metal plates, mesh, and bars are recovered and reused without further processing. On the basis of survey, this reusable portion accounted for 22% of total ship weight in FY 2010; about 8% of the total weight was reused in other ships. Consumable items accounted for 1.8% of total weight and were used domestically in the same period. Apart from these, the monetary flow related to ship breaking industry in Bangladesh in FY 2010 has also accounted. It was revealed that SBI earns about USD 545 million from all recovered materials and generates some additional values (USD 72 million). At the same time, the final consumers pay about USD 637 million for all recovered materials from SBI in FY 2010.

In chapter 4, some recommendations to improve existing recycling and waste management system in Bangladesh have given based on the findings while conducting MFA in two abovementioned case studies. It was revealed that there is no national policy for waste management in Bangladesh. Although it was estimated that most (93%) of the materials from the ships were collected, recovered, and reused or recycled domestically or reused in ships, this is not a zero-emission industry. In the cutting, dismantling, repairing, and other processes, some portion of miscellaneous scrap metals, plastics, and glass escaping the recycling/reuse flow and spilling into the environment were observed. The industry still has no controlled final disposal sites for

hazardous and non-hazardous wastes. On the other hand, city corporations responsible for waste management in the big cities of Bangladesh are simply overburdened and cannot cope with increased volume of waste due to lack of management policy and also due to decreasing trend of landfill sites. At the same time, the position of CCC is special in terms of solid waste management just because of the presence of ship breaking facility nearby. Most of the products from ship breaking facilities are coming inward to city area and adding a special component needing special attention in part of MSW activities of CCC. Almost all types of wastes from SBI are hazardous in nature. At the same time, so many hazardous wastes are mixing up and getting their final destination to the landfill sites coming from healthcare or other such facilities which the CCC authorities need to deal. At this point, Bangladesh has ample opportunity to implement the lesson from developed nations like Japan. According to current waste management system of Japan, all wastes are classified into two different types of waste viz. MSW (general waste) and industrial waste by their origin and characteristics. Everybody is sharing their responsibility according to the existing framework which is increasing the country's waste management efficiency. Implementation of the 3R concept of "Reduce, Reuse and Recycling" with ensuring the appropriate treatment of the residuals can help Bangladesh to manage wastes more efficiently. Therefore, a common waste management strategy brining both MSW and waste from SBI could be a good option for the policy maker in Bangladesh and will contribute decoupling both of resource use and environmental impact from its economic development.

Finally, in Chapter 5, some conclusions were drawn. This research having the aforementioned background will help to know about the fact that how the recycling industry contributes to Bangladesh's economic development in quantitative manner, while it still has more space to improve its efficiency of resource use. Moreover, this research offers some fundamental information for planning the waste management policy in Bangladesh as well as provides both citizens and industries to understand current situation. Finally, this study will be a good starting point to understand the current situation of Bangladesh in the sense of material flows.