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# MATERIAL FLOW ACCOUNT OF COPPER IN BANGLADESH WITH SPECIAL EMPHASIS ON SHIP BREAKING AND RECYCLING INDUSTRY

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***Abstract-*** *Copper industry is flourishing in Bangladesh due to increasing use of Cu in electrical, plumbing, mechanical and other products. In ships, Cu-alloys are used for power cables and pipework. Accordingly, Shipbreaking and Recycling Industry recovers substantial amount of Cu. The flow of Cu throughout the economy of Bangladesh is yet to be quantified which is necessary for sustainable Cu-consumption. Accordingly, this material flow account (MFA) of Cu aimed to quantify inflows, hidden flows, outflows, emissions, stocks of Cu in Bangladesh for 2015 based on publicly available data. The study indicated 0.4 kg/capita Cu consumption in Bangladesh with building and construction sector accounted for half of the total Cu requirements. Respective values of the Domestic Material Input (DMI), Domestic Processed output (DPO), Resource Consumption Efficiency (RCE) and Resource Recycling Efficiency (RRC) for Cu in 2015 were 68969 MT, 136108 MT, 3.020487 million USD/MT and 0.7705635.*

**Keywords:** Copper, MFA, MFA of copper, MFA indicators

## 1.INTRODUCTION

Globally, concerns for environment is growing due to rapid depletion of natural resources and associated environmental pollution as development collateral. Industrial ecology has emerged as a paradigm for sustainable development. It is characterized by minimal physical exchanges with the environment, with internal material loops being driven by renewable energy flows [1, 2]. However, industrial metabolism is overloading the environment with wastes and emissions [3] which arrests us to meet our demand from geological reserves to recycle of large in-use stocks of metals in society [2, 4, 5]. Metals, in their ubiquity, act as a vital component of nature, humans and the modern society [6, 7]. Globally, after Fe and Al, Cu is the third most widely used malleable metals [8-13]. This nonferrous metal has often-irreplaceable applications in electrical power generation and distribution systems, electronics, building and constructions, vehicles, telecommunications, domestic and industrial piping and general infrastructure. Building and construction sector is the largest end user of Copper [14]. Beside imports, ship breaking industry (SBI) in Bangladesh recovers and supplies substantial amount of non-ferrous metals (in the form scraps, sheets, nets and bar materials), estimated at 7,500 Metric tonnes in 2015 worth about Taka 1.2 billion [4].

The extensive use of Cu will make it to become a scarce resource by the end of the century [7, 15, 16]. The depletion of nonrenewable resources and the availability of alternative raw materials are of great concern in the metallurgical industry, as in other base material industries. Hence, it is inevitable that we have to enhance the efficiency of its resource and recycle it through decoupling.

Material flow accounting (MFA) indicates potential measures to conserve resources for environment protection, and encourages industrial system to meet the requirements of sustainable development [17, 18]. Substance flow cycles provide a picture of resource uses and losses through a geographic region, allowing us to evaluate regional resource management and estimate gross environmental impacts [10, 17, 19-21]. Consequently, the use of MFA gains increasing importance to companies operating in those regions where primary raw materials are limited. In a growing economy like Bangladesh the ensuing criticality of metals like Cu needs serious consideration. However, an MFA of Cu has not yet been conducted in Bangladesh, primarily because of poorly kept and inaccessible public and private statistics. To meet that gap, this research performed a dynamic material stock and flow analysis of copper in Bangladesh [22, 23]. In this study, our aim was to conduct the first MFA of Cu in Bangladesh, with special emphasis on SBI. Specifically, this study was designed to map the data sources, to identify data gaps with data collection and refinement to form Cu-MFA database. Based on it an EW-MFA of Cu in Bangladesh for 2015 was done with pertinent scenario and hotspot analyses. MFA indicators for Cu were also calculated.

## 2. MATERIALS AND METHODS

### 2.1 Definition of System boundary

In an MFA, a target material is characterized in terms of flows, processes and stocks of that material and overall environmental impacts of that material within a predefined region and timeframe [24]. In the current study the spatial system boundary was the geographical border of the Bangladesh, while the temporal boundary was the year 2015. Because there is no operating Cu-mine in Bangladesh, imports are the main inputs. Fig. 1 shows every Cu flow and stock that were determined, including imports and exports, losses into the environment as wastes and emissions etc.

### 2.2 Flows and stock estimation

The system under study concerned only material flows. The calculation of both stocks and flows, which was then based only on the principle of mass conservation is performed by Eq. (1) [25].

$$I + P = C + \triangle S + E + \text{Loss through emission} \quad - - - (1)$$

Here, I is imports, P is production, C is consumption, S is stock and E is export flows.

### 2.3 Data collections

The actual data collection from each individual stage is preferred. However, it was not feasible due to the large scope of the present study. Data were collected various international databases as shown in Table 1, namely UN Comtrade [26], the World Bank [27], World Integrated Trade Solution and some local database mainly Statistical yearbook by Bangladesh Bureau of Statistics [28]. As, local data were not available over a continuous time range, we prioritize international data sources for analysis. However, UN Comtrade data were unavailable for import and export in 2014 for which we relied on the local databases for these instances (see Table 1 for details). Noteworthy to mention that data were obtained and analyzed utilizing both UN Comtrade and World Bank, at the initial phase of data collection, however because a similar trend in both datasets, we decided to continue with UN data for final calculation.

### 2.4 Dealing with data uncertainties

Data uncertainties arose from various reasons as methods of data collection are different and statistical integrity of data collection is not same in all cases. Another uncertainty arose from unclear definition of system boundary. To deal with above mentioned uncertainties in this study we tried to follow some consistent data sources and made some rules prior to selection of data.

In the case of UN Comtrade, export and import data varied when Bangladesh was the reporter and other countries were partners and vice versa. To deal with this, the data of World Integrated Trade Solution Database was used for more accuracy. Again, in case of UNComtrade data was available for 2006 to 2013 and for 2015. But there is no data available for the year 2014. Hence, data was used from Statistical Year Book Bangladesh, 2017 to fill the gap for 2014.

Data from Copper industry through personal interview were not always available in the case of manufacturing products and semi-products. Reports from different online news sources were used.

### 2.5 Data Calculations

### 2.5 .1 Fabrication and Manufacturing

Sources of import and export data are shown in Table 1. There was no data on the allocation of either Cu-based products in different categories of finished products manufactured in Bangladesh. It was assumed as shown Table 2 that the products are manufactured with the same ratios as they are imported.

Table 1: Year wise data sources used for analysis

| | 2006-2013 | 2014 | 2015 |
|---|---|---|---|
| Import | [26] | [28] | [26] |
| Export | [26] | [28] | [26] |

Table 2: Ratio of different category of Cu-based products

| **Copper** | **Ratio** |
|---|---|
| **Copper products** | 0.45 |
| **Alloy products** | 0.42 |

### 2.5.2 Use

Manufacturing stage produces Cu-containing final products (electrical wires, power cables) or assembled products (engines, electronic goods) used in diversified sectors including building and construction, manufacturing, automobile and infrastructure (energy distribution network, telecommunications). India's per capita Cu-consumption was used under the consideration that GDP per capita Bangladesh is quite similar with GDP per capita in India and that both countries has similar kind of infrastructure and life standards [14].

### 2.5.3 Waste Management

From the use sector different types of waste flows entered into the waste management process stream. For calculating the waste flow, the following data given in Table 3 were used.

Table 3: Copper compositions in different types of wastes

| Year | Waste types | Weight of waste (MT) | Cu in waste (%) | Cu (MT) | Reference |
|---|---|---|---|---|---|
| 2015 | MSW | 2920000 | 0.19 | 5614 | [29] |
| 2015 | WEEE | 1240000 | 5 | 6200 | [14] |
| 2015 | C & D | 224000000 | 0.025 | 56000 | Personal Interview |

### 2.6 Tools and Software used for Analysis

All the Calculations and graphs were prepared using Microsoft Excel Package 2010. Computation and steps are implemented by using the STAN (version 2.6.801) soft-ware because it is free, easily accessible and user friendly. So, MFA of copper has been generated by using the software for the study.

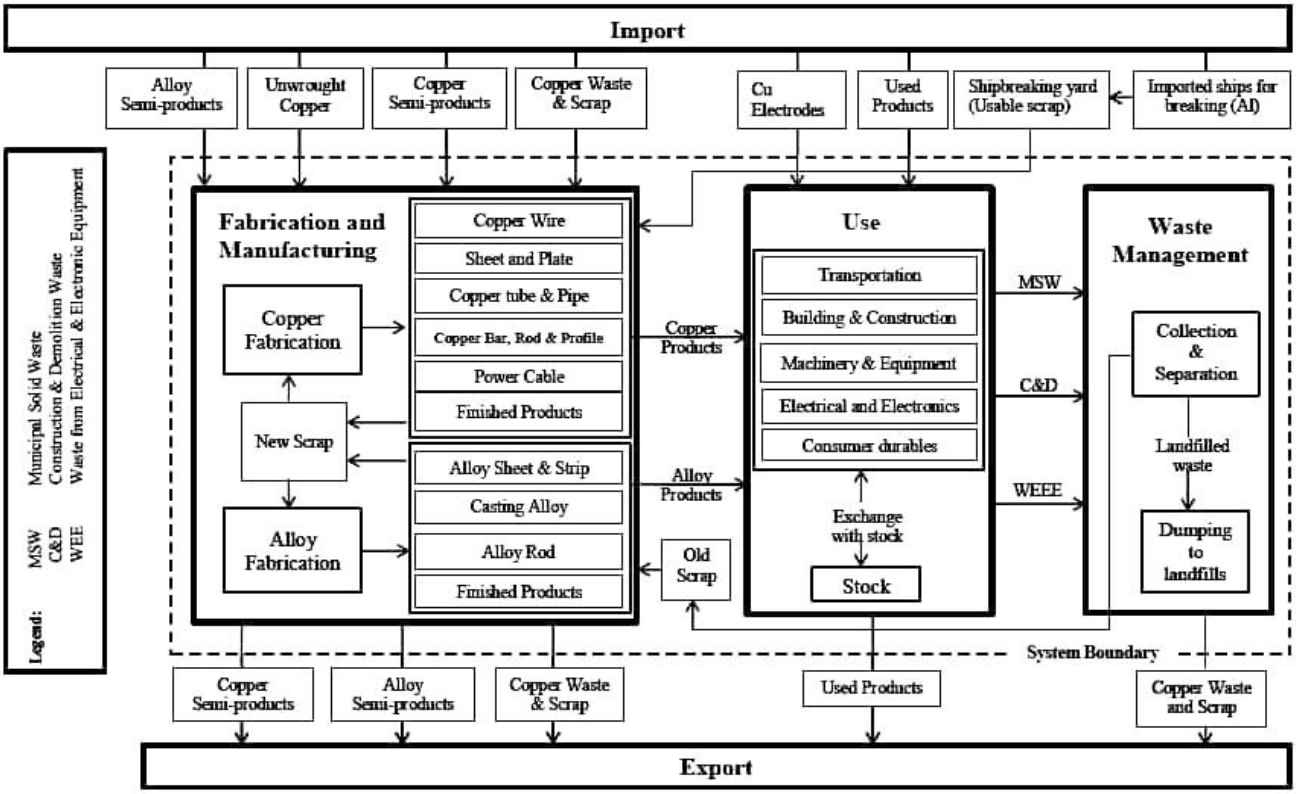


Fig. 1: System boundary for MFA of Copper in Bangladesh for 2015

## 3. RESULTS AND DISCUSSION

### 3.1 Trend of Copper import and export in Bangladesh from 2006 to 2015

An aspect of MFA is to estimate the inflow of concerned material from outside the geographic boundary of a country in the form of import. Fig. 2 shows year wise import of Cu in Bangladesh for the year 2006 to 2015 which indicated that in 2015 the import volume was the highest 33.67 thousand metric tons. The trend shows increasing imports with GDP growth ince 2010.

As UN Comtrade database was used for import data, it might be low or high from the actual data. However, the figure reflects that import has been increasing over time with increasing GDP in Bangladesh. This will continue with the increase due to increasing consumption of Cu in different sectors in Bangladesh. In contrast, the export of Cu from Bangladesh is still quite low but it is increasing over time. Export insignificantly increases and decreases after 2008 than the previous three years but was the highest in 2013 (10.06 thousand metric tons).

### 3.2 Copper flows into fabrication and manufacturing process

Imported copper was the only inflow into Bangladesh unwrought Cu, Cu-semi-products, alloy semi-products, Cu waste and scrap and others. Fig. 3 shows increasing inflow of alloy semi-products into fabrication and manufacturing process. The trend line is linear ($R^2$=0.999). No temporal trend could be established. Alloy semi-products and unwrought Cu entered the inflow of fabrication and manufacturing process showed linear trend line with low $R^2$ compared to alloy semi-products. Alloy semi-products import was higher in 2015 (6.48 thousand metric tons) than the previous years and same trend stands for unwrought and for Cu waste and scrap were 18.50 thousand metric tons and 527.33 metric tons, respectively.


Fig. 2: Year wise import and export of Copper in Bangladesh

### 3.3 Copper flows into different end-use sectors of society in Bangladesh

Copper is widely used in electrical power, electronics, energy, petrochemicals, transportation, machinery, metallurgy, light and other new industries and some high-tech fields. The consumption pattern of Cu in Bangladesh is different from the global consumption pattern. The

demand for the Cu (Fig. 4) has been predominantly from the building and construction sector (49%) followed by electrical and engineering sector (20%), transport and consumer goods sectors (11%) and machinery sector (9%). Total domestic consumption was about 64000 metric tons in 2015.

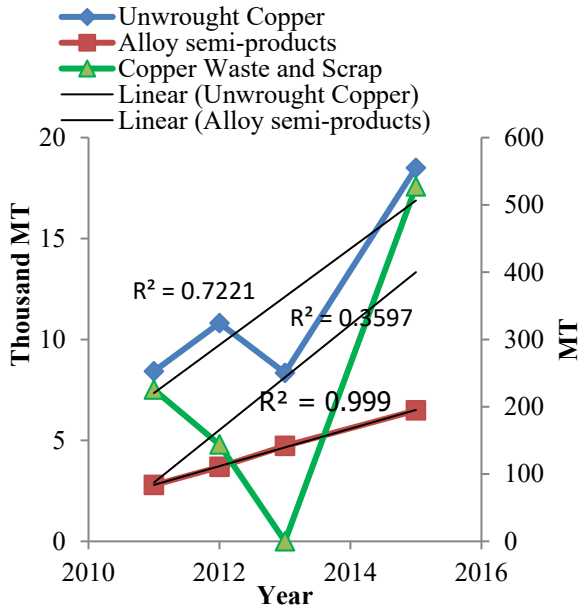


Fig. 3: Category wise Copper flows into Fabrication and Manufacturing

### 3.4 Top Copper sources for Bangladesh (2015)

As seen in Fig. 5, Bangladesh imported about one-third Cu form Korea and the rest from Singapore (22%), China (14%), UAE (7%) and Thailand (5%).

### 3.5 MFA of Copper in Bangladesh 2015

MFA of Cu is shown in Fig. 6. About 15264 metric tons of unwrought Cu, Cu semi- products, alloy semi-products and Cu waste and scrap imported from different countries entered into the fabrication and manufacturing process. From ship breaking 29900 metric tons of Cu scrap entered as inputs. Cu and alloy products were outputs from fabrication and manufacturing. There is no data on their allocation; hence it was assumed that the products were manufactured at the same ratio as they were used. System loss of 10% from the fabrication process was added to the waste management process. About 85526 metric tons of finished and semi-finished products entered use stage along with 5443 metric tons of electrical equipment. Substantial amount of MSW (5614 metric tons), Electrical waste (56000 metric ton) and construction waste (44000 metric ton) were generated of which 53145 metric tons were recycled into the system. Copper waste and scrap were exported from waste management process. There was some hidden flow through different processes which were calculated. After all data input into three processes, the STAN software calculated the stock at every process.

Fabrication and manufacturing stock were 24789 metric tons which means after the production process some material remains in the system which can further used as a raw material. In-use stocks were 4161 metric tons which means people don't bother about the huge generation of waste at every stage. Waste management stock 28549 metric tons means disposed in dumping station.

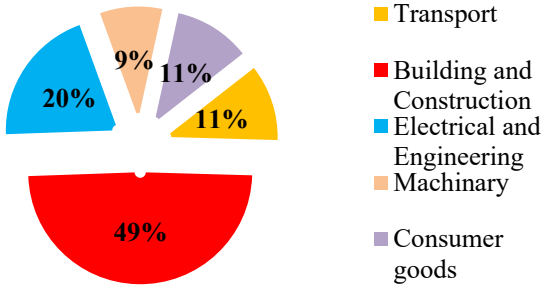


Fig. 4: Cu-usages by end-use sectors in Bangladesh

Copper waste and scrap were also exported from waste flow. Combining all the sub-processes, the total amount of imported Cu was 68969 MT/year and the total exported amount was 31063 MT/year. The total calculated stock amount was 37905 MT/year.

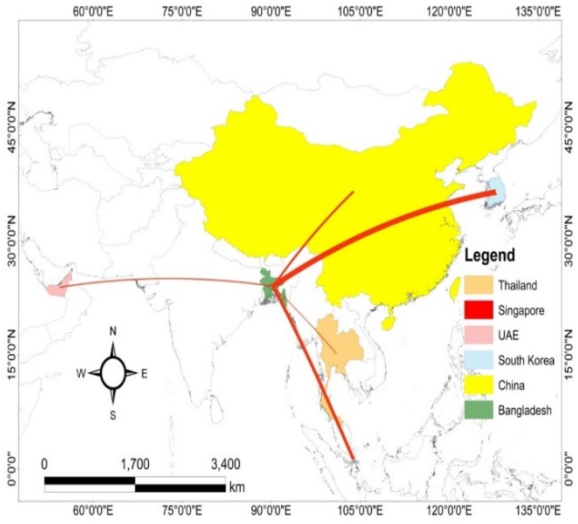


Fig. 5: Cu suppliers for Bangladesh for the year 2015

### 3.6 MFA indicators for Copper in Bangladesh

Table 4 illustrates the MFA indicators for the MFA of Cu in Bangladesh. Resource consumption efficiency indicates significant amount of waste from the flow of material being unutilized that ultimately lowers the efficiency, but it is also related with the unavailability of data that how much waste had been recycled in 2015. Resource consumption efficiency in 2015 was $3.020487*10^{-3}$ and resource efficiency of material extraction was 0.1311604. The total calculated stock amount was 37905 MT/year which can be used to reduce the pressure on ferrous metal.

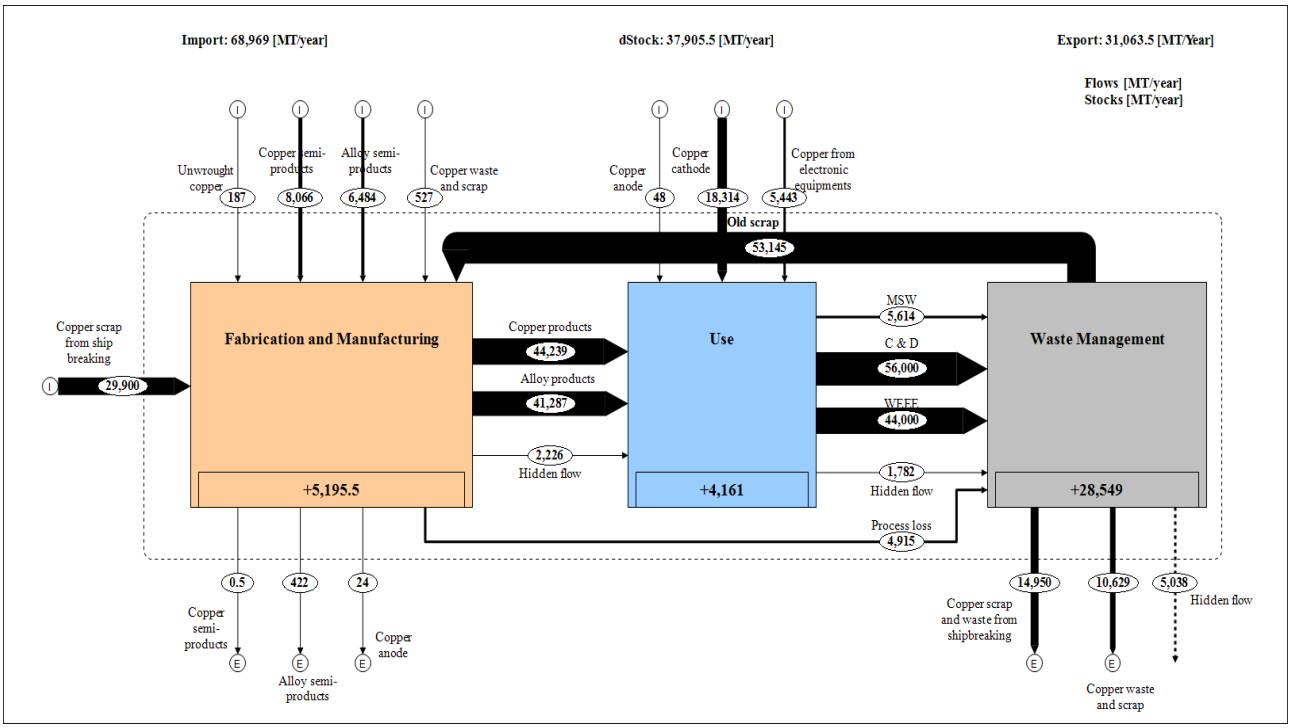


Fig. 6: MFA of Copper in Bangladesh 2015

Table 4: MFA indicators for Copper in Bangladesh

| Type | Indicators | Definition | 2015 | Unit |
|---|---|---|---|---|
| **Input** | Direct Material Input (DMI) | Domestic raw material + Imports in MT | 68969 | MT |
| | Total Material Requirement (TMR) | DMI + HF* in MT | 72977 | MT |
| **Output** | Domestic Processed Output (DPO) | Emissions + waste in MT | 136108 | MT |
| | Total Domestic Output (TDO) | DPO + relevant HF in MT | 141146 | MT |
| **Efficiency** | Resource Consumption Efficiency (RCE) | GDP/DMI | $3.020487*10^{-3}$ | Billion $/MT |
| | Resource Recycle Efficiency (RRE) | Recycling waste/DMI | 0.7705635 | Ratio |
| | Resource Efficiency of material extraction | Unused/used= HF/DMI | 0.1311604 | Ratio |

## 4. CONCLUSIONS

This is the first effort to conduct the MFA of Cu in Bangladesh for 2015 based on the available data. The resulting MFA diagram constructed showed the major flows related to Cu by considering the geographic boundary of Bangladesh as the system boundary. As a developing country the total consumption of Cu in Bangladesh was low amounting to 64.48 thousand metric tons in 2015. Building and construction sector was the largest end user of Copper accounting for 49% of the total copper demand. Flow of Copper within the system boundary has also been produced for 2015 which can be used as a baseline in any future studies related to Cu use in Bangladesh considering industrial ecology perspective for sustainable development of this industrial sector to attain sustainable development goals (SDGs) 7, 9 and 12.

## 5. ACKNOWLEDGEMENT

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