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Tracking the Carbon Emissions from Polyester Fibre Processing Industrial Unit

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ABSTRACT

Climate change and global warming are major concerns now-a-days, which are directly related to greenhouse gas emissions, especially carbon emissions. This study focuses on the estimation of carbon emissions of the polyester fibre industry in Pakistan. A GHG protocol and IPCC guidelines were adopted for the calculation of carbon footprint. March 2015 to March 2016 was selected as a base year. The total carbon emissions came to be 92241.8 tCO_2e. The highest carbon emissions were from direct sources due to use of multiple fuels. The calculations performed in the study will enable and encourage industries to calculate their carbon footprint and try to reduce it.

INTRODUCTION

Climate change is attributed to greenhouse gases (GHGs,) which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chloro-fluoro-carbons (CFCs) that are naturally present in the atmosphere in the form of blanket and maintain the temperature of the earth. Within the United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods" (Nizami 2010).

Recently, Conference of Parties (COP 21) took place in Paris, which invested in low carbon, resilient and sustainable future that was agreed by 195 nations. The main aim of the agreement was to keep the global rise temperature below 2 degrees Celsius and to lower the temperature increase even further to 1.5 degrees Celsius (UNFCCC 2016).

Carbon footprint: The consumption and production pattern of humans are responsible for CO_2 and other greenhouse gas emissions into the atmosphere. Carbon footprint is "a total set of greenhouse gas emissions caused directly or indirectly by an individual, organisation, event or product" (EAUC 2007). It is a measure of full scale life cycle impact related to a specific operation. According to greenhouse gas protocol, all six elements should be included in the measurement of particular operation which is enlisted in the Kyoto protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Usually for practical and other most types of activities, CO_2 is kept under consideration while others are ignored. It is the most abundant greenhouse gas and every air emission is converted into CO_2, for which carbon footprint emission is expressed in "tons of CO_2 or CO_2e" (GHG Protocol 2015).

The total footprint of any organisation includes direct emission from fossil fuel combustion as well as indirect emissions from the use of electricity and natural gas. It also includes miscellaneous emissions that are mostly produced from products and services provided by the organisation during its manufacturing. It includes life cycle assessment of the products which release emissions (USEPA 2008). This classification is based on the definition given in the Greenhouse Gas Protocol, introduced by World Business Council for sustainable development and the world resources institute (USEPA 2008).

Pakistan stands 135th at position, among the countries responsible for greenhouse gas emissions. It proves that Pakistan is not a major contributor and is responsible for

only 0.8% of total GHG emissions, which is based on its per capita GHG emissions. In 2008, an estimated number of Pakistan's total GHG emissions were about 309 million tons (mt) of carbon dioxide equivalent consisting of 54% CO_2, 36% methane, 9% nitrous oxide and 1% of other gases (Government of Pakistan 2010).

IPCC guideline for national greenhouse gas inventories: Intergovernmental Panel on Climate Change (IPCC) plays an important role in assessing the science relating to climate change at a global level (Ali et al. 2014). Kyoto protocol established under UNFCC was ratified by Pakistan in 1997, but implemented in 2005. By adopting clean development mechanism, it reduces global carbon emissions (Ahmed et al. 2012).

Most common methodological approach regarding the 1996 guidelines and IPCC guidance is to combine activity data with the coefficient of emission factor for calculating carbon footprint (Rypdal 2006).

$$\text{Emissions} = AD \times EF \quad ...(1)$$

Where, AD = activity data, EF = emission factor

Textile is the backbone of Pakistan as it contributes more than 60% exports, which are equal to US $ 5.2 billion, and the overall contribution to GDP is 9 %. Pakistan ranked as the 10^{th} largest producers of textile in the world and 8^{th} largest textile exporter from Asia (Hertwich et al. 2009 and Nasir 2012).

Study area: The study area located at Sheikhupura Road, 30 km from Lahore, is an ISO 9001 certified industry. It is one of the leading polyester manufacturing industries in Pakistan and involved in the manufacturing of synthetic fibre which uses more amount of energy to produce the fibre as compared to natural fibre. Energy is needed to undergo reaction, to form polymer till the formation of fibre. Polyester is used at national and international level. The process includes continuous polymerization, pumping of polymer into spinning machine, polymer release from spinneret, its solidification and its collection in form of ribbons that pass over a wheel which rotates in a bath of spin finish. This ribbon is then mixed with other ribbons coming from spinning positions. The polymer is stretched to approximately four times the actual length of polymer between the rollers with the help of draw machines. It is then cut through machines into appropriate sizes, labelled, dispatched and transported to the destination.

MATERIALS AND METHODS

Goal identification: The goal of this study was to find out the industry's GHG emissions into the environment. Calculating carbon footprint will help to get information about the effect of facility's activity on global warming and then adopt methods to reduce the impact (Kazmi et al. 2014).

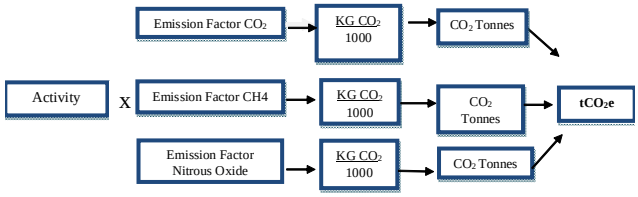

Fig. 1: Carbon footprint calculation.

Selection of base year: March 2016 to March 2017 was selected as the base year.

Scope of the analysis: The scope of analysis includes all areas that were planned to be the part of a study and lead to the setting up of system boundaries. IPCC guidelines and GHG protocol have been taken into account for this research. The boundaries were aligned in regard to the following three scopes (Akhtar et al. 2013).

- Scope 1: Direct GHG emissions
- Scope 2: Indirect GHG emissions
- Scope 3: Miscellaneous GHG emissions

Data collection: The primary and secondary data were collected within the system boundaries through checklist preparation, industrial visits, IPCC guideline for national inventory and current emission factors.

Carbon footprint calculation: The collected data were summed up to make calculation of carbon footprint. These calculations referred to as CO_2e involves the conversion of all GHGs into CO_2e.

IPCC guidelines provide a common methodological approach for the calculation of carbon footprint as mentioned in Fig. 1.

- The collected data were first converted into GHG emissions, by multiplying the emission factor with the activity data. This results in the reduction of GHG emissions per functional unit of product.
- In addition, individual figures of GHG emissions were multiplied with the appropriate global warming potential (GWP) factor, so that it can be converted into CO_2e emissions.

RESULTS AND DISCUSSION

Scope 1 emissions: These include all stationary and mobile source activities taking place in the industry that can be controlled and release emissions in the environment, including emissions from combustion or burning processes in industry owned generators, boilers and vehicles. Scope 1 emissions were further divided into stationary fuel combus-

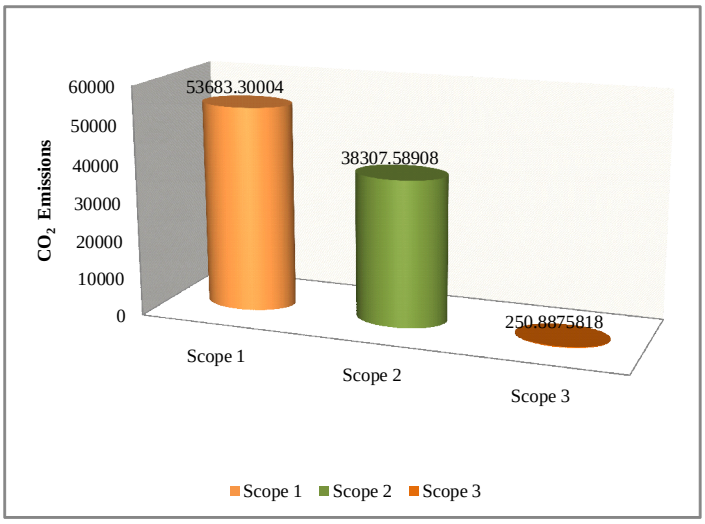

Fig. 2: Scope-wise carbon emissions.

tion and mobile fuel combustion. Stationary fuel combustion includes data regarding boilers and generators fuel combustion, and the mobile include data related to industry owned vehicles. Three types of fuels are being consumed by the industry as given in Table 1. The need to rely on more than one fuel has increased as the rate of energy crisis has increased in the country. The consumption of HFO is greater as compared to diesel, but the industry is slowly shifting to coal. The carbon emissions from HFO are greater in comparison to the rest of two fuels. The HFO and diesel consumption was in litres, whereas coal consumption was in tons, the consumption of HFO was greater than both of the other fuels, but the emission factor of HFO is lowest. The coal consumption was less, but the emission factor was higher as compared to HFO and diesel. Diesel was only one fuel that was being used by the industry in mobile sources of emission. The amount of carbon emissions also depends on the type of fuel used for burning in the vehicle (ISA 2007).

It can be seen from Table 1 that the total emissions from scope 1 are 53683.30004 tCO_2e which are very high as compared to the other two scopes. It is basically due to the combustion of fossil fuels, these are oils derived from beneath the earth's surface. If 1 trillion barrels of oil consumed, it will result in the release of 115 billion tons of carbon into the atmosphere (Hale 2011). Since the mid of 19^{th} century, fossil fuels tend to release about 1100 $GtCO_2$ in the atmosphere. The industry is completely dependent on fossil fuel for electricity generation and for doing other industrial activities, because currently fossil fuels are mostly used in order to generate electricity, supply heat and for transport purposes, it mainly accounts for about 70% of the total emissions such as carbon dioxide, methane and nitrous oxide (Sims et al. 2007).

Scope 2 emissions: GHG protocols define the purchase of electricity and natural gas under scope 2 that are brought into the organisational boundary of the industry. It is a fact that Pakistan is mostly using fossil fuels for electricity generation. The US based emission default factors have been taken into account for the computation of total emissions from the use of electricity and natural gas as given in Table 1. The electricity and natural gas in the industry are used for different purposes within the industry such as in appliances, during manufacturing of fibre within the machines and when load increases. The tCO_2e from electricity emissions came out to be 5126.417439 and the emissions from natural gas in tons came out as 33181.17164 MMBTU. The tCO_2e when calculated after adding both the values of scope 2, the total emissions from scope 2 was calculated to be 38307.58908 tCO_2e.

Scope 3 emissions: Table 1 provides scope 3 emissions. It includes emissions from industries upstream and downstream activities like miscellaneous emissions related to waste, emissions from business air travel, etc. These emissions are optional to include and are not controlled by the industry.

In polyester fibre industry under observation there was no such solid waste except for wood waste that was calculated to be 9.775 tons.

Rest of the solid waste was categorized as high, low and medium quality. High quality of solid waste was reused by the industry in process, low quality of waste was being sold outside the industry and medium quality of waste was being used to make popcorns.

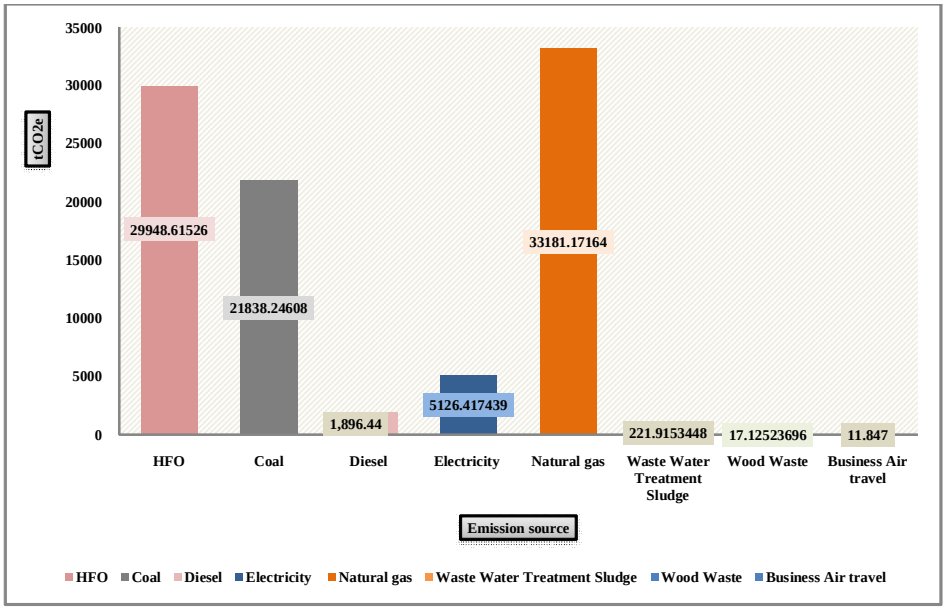

Fig. 3: Source-wise carbon emission.

Approximately 1103194 m^3 of water was being used in the industry during the manufacturing process which has to be treated. Two activated sludge treatment plants were installed at the manufacturing site of the industry to treat the effluent produced, as it is a chemical industry, in order to dispose wastewater safely into the environment. The treatment process releases greenhouse emissions which disrupt the beauty of nature (Akhtar 2013). In Table 1 carbon emissions from treatment plant as well as from wood waste can be seen. The amount of sludge and wood waste present in tons which was simply multiplied with the respective emissions factors of CO_2, CH_4 and N_2O.

Although scope 3 is an optional category, but air travelling results into carbon emissions. Various factors kept in notice while calculating business travel are number of passengers, number of return flights (one return flight is equal to two visits), origin and destination of the flight. The air travel data as elaborated in Table 1, the carbon emissions were calculated using the on-line calculator which gives the approximate value of carbon emissions in kg CO_2e by using the formulas based on UK DEFRA specification for domestic, short and long international flights (Flight Emissions Calculator 2016). Total emissions from business air travel came out to be 11.847 tCO_2e.

Total carbon emissions: The total carbon emissions came out to be 239.0405818 tCO_2e. Emissions from scope 1 were 53683.30004 tCO_2e, from scope 2 it came out to be 38307 .58908 tCO_2e and scope 3 emissions were 250.8875818 tCO_2e as shown in Fig. 2. The total carbon emissions by adding all the scopes were 92241.7767018 tCO_2e. In the same type of studies conducted in the paint industry and denim textile industry of Pakistan, the carbon footprint was found to be 2105.733 tCO_2e and 298568.6 tCO_2e respectively (Saif et al. 2015 and Akhtar et al. 2013).

Fig. 3 demonstrates source-wise emissions. It can be seen that tCO_2e from natural gas is maximum, it is due to the fact that natural gas is considered primary fossil fuel, it is then followed by HFO which has the second highest carbon emissions, and then comes coal which is the third highest emitter of CO_2.

CONCLUSION AND RECOMMENDATIONS

1. As per the relevant calculation of the leading polyester processing industry the carbon emissions estimated to be 92241.7767018 tCO_2e in the year 2015. It is observed that emissions from scope 1 are majorly responsible in contributing in such high rate of emissions i.e., 53683 .30004 tCO_2e due to the use of fossil fuels for the production of energy. It is then followed by scope 2 which is also a contributor but indirectly participating in facility's emissions and they are less as compared to scope 1. The last one is the scope 3 which is least responsible in total emissions; it includes emissions that are not controlled by the industry.
2. Carbon emissions concentration is already increasing in the environment and the industry under study is also

Table 1: Total carbon foot print calculations of polyester fibre processing industrial unit.

Scope 1 Emissions

	Fuel Type	Activity Data	Units	Emissions Factor	kg CO_2	CO_2Tons	tCO_2e
Stationary Fuel Sources	HFO	9491875.99	Liters	CO_2=3.155	=29946868.75	=29946.86875	29948.61526
				CH_4=0.00012	=1139.025119	=1.139025119	
				N_2O=0.000064	=607.4800634	=0.6074800634	
	Coal	18167.701	Tons	CO_2=1201.9	=21835759.83	=21835.75983	21838.24608
				CH_4=0.119	=2161.956419	=2.161956419	
				N_2O=0.01785	=324.2934629	=0.3242934629	
	Diesel	151240	Liters	CO_2=2.68	=405323.2	=405.3232	405.3811056
				CH_4=0.0003612	=54.627888	=0.054627888	
				N_2O= 0.000021672	=3.27767328	=0.00327767328	
	Diesel	554327	Liters	CO_2=2.68963	=1490934.529	=1490.934529	1491.05759
				CH_4=0.00014	=77.60578	=0.07760578	
				N_2O=0.000082	=45.454814	=0.045454814	

Total Scope 1 Emissions = 53683.30004 tCO_2e

Scope 2 Emissions

	Energy Combustion Type	Activity Data	Units Factors	Emissions	KG CO_2	CO_2 Tons	tCO_2e
	Electricity	12293567	KWH	0.417	5126417.439	5126.417439	38307.58908
	Natural gas	625351.8968	MMBTU	53.06	33181171.64	33181.17164	

Total Scope 2 Emissions =38307.58908 tCO_2e

Scope 3 Emissions-Miscellaneous Emissions

	Type of Waste	Activity Data	Unit	Emissions Factors	kg CO_2	Tons	tCO_2e
	Sludge	80.635	Tons	CO_2=2751.84	=221894.618	=221.8946184	
				CH_4=0.252	=20.32002	=0.02032002	221.9153448
				N_2O=0.00504s	=0.4064004	=0.0004064004	
	Wood	9.775	Tons	CO_2=1747	=17078.88	=17.0788	17.12523696
				CH_4=4.68	=45.747	=0.04574	
				N_2O=0.0624	=0.60996	=0.00060996	

Total Scope 3 Emissions=239.0405818 tCO_2e

Scope 3 Emissions-employee Business Travel

	Number of return flights	Origin	Destination	CO_2 Emissions for one return flight	Total CO_2 Emission (KG CO_2)	tCO_2e
Indirect emissions Empolyee business travel	22	Lahore	Karachi	163	3586	3.586
	11	Lahore	Islamabad	42	462	0.462
	16	Lahore	Multan	49	784	0.784
	9	Lahore	China	429	3861	3.861
	3	Lahore	UK	665	1995	1.995
	1	Lahore	Thailand	433	433	0.433
	3	Lahore	Sri Lanka	363	726	0.726

Total Business Travel Emissions = 11.847 tCO_2e

Table cont....

...Cont. Table

GHG Inventory tCO_2 Emissions by Source (March 2015- March 2016)

Scope 1 Direct Emissions (tCO_2e)			Scope 2 Indirect Emissions(tCO_2e)		Scope 3 Miscellaneous Emissions (tCO_2e)		
HFO	Coal	Diesel	Electricity	Natural gas	Waste water treatment sludge	Wood waste air travel	Business
29948.61526	1,896.44	21838.24608 tCO_2e (Scope1) 53683.30004	5126.417439	33181.17164 tCO_2e (Scope2) 38307.58908	221.9153448	17.12523696 tCO_2e (Scope3) 250.8875818	11.847
tCO_2e (Scope1+ Scope2+ Scope3) = 92241.7767018 tCO_2e							

a major contributor.

3. In order to lower the emissions, it is suggested to gradually switch to renewable sources and limit the use of fossil fuels. Fossil fuel used during combustion activities emit large portion of GHG into the environment and these gases stay for long duration in the atmosphere depleting the ozone layer, which results in global warming.
4. It should be the basic priority of the industry to offset the carbon footprint through environmental friendly ways which is possible by investing in cleaner and green projects such as planting trees.
5. More advanced environmental technologies should be considered to promote sustainability. And make the use of resources that are available within the country to increase the capita and focus on producing not only the quantity, but quality of the product too.

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