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Analysis of External Cost of Detergent Powder Production (Case Study: Tolypers Inc. - the Largest Iranian Manufacturer in Detergent Powder Industry)

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Abstract

The aim of this study is to analyse the external cost of detergent production in Tolypers Company in 2011. This study used fuel analysis technique to analyse the external cost of air pollution resulting from combustion in production process of detergents. Results from analyses show that external cost resulting from mazut is 2.6 times more than that from natural gas. It was also found that CO_2, SO_2 and NO_x gases account for 56.2, 15.1 and 28.7%, respectively, of the external cost resulting from detergent production in 2011. Other results indicate that the amount of external cost of detergent production resulting from air pollution is strongly sensitive to the type of consumed fuel. To be more precise, although mazut provided only 8.3% of the thermal energy required in a year, it accounted for 19.3% of the external cost of detergent production in 2011. Accordingly, provision of sustainable energy of natural gas for Tolypers, utilization of cleaner alternative fuels when necessary, optimal utilization of fossil fuels to allow full combustion can effectively reduce the external cost of these produces.

Keywords: external costs, air pollution, fuel analysis technique

Introduction

In addition to their positive effects on society, Manufacturing industries involve the negative effects such as environmental pollution. Producers of goods and services and primarily markets only calculate financial costs and direct payments when pricing goods and services; they do not include the external costs imposed on the environment and environmental degradation in the calculation of prices of goods and services. In fact, the prices claimed for goods and services are mot real and complete; instead, they only include a fraction of the cost of production, and it is obvious costs and private costs, while real costs and prices for goods and services must include external costs imposed on the environment.

This is also true for detergent production industry. One of the major products of this industry is detergent powder. These powders are mainly produced by chemical and mineral raw materials; the powders are divided into hand-washing and machine-washing powders. In addition to advantages such as health directly and employment, income and social welfare indirectly, production of detergents has negative effects such as environmental pollution, particularly air pollution. These products are produced in such a way that it causes environmental pollution in air, water as well as negative effects on employee health. Therefore, it is essential to analyse the costs imposed to environment, particularly human health (external costs).

Review of studies conducted on external costs show that, although considerable studies have been occasionally conducted in this area, it has been never properly attempted to analyse this type of costs; instead, the research mainly focused on estimation of external costs of an industry, company or a specific product. However, it should be noted that a detailed analysis of these costs considerably helps identifying the source of external costs. Based on a more accurate understanding of the original sources of pollutants, a better combination of fuel energy can be chosen to provide the energy required in the manufacturing process and somehow, the condition of combustion can be directed to complete optimal combustion.

The purpose of this study is to analyse the effect of detergent production on quality of environment and human health and to calculate costs and damages imposed on the environment by emissions from producing detergent powders. It is noteworthy that when negative effects caused by pollutants resulting from a process are analysed, higher weight (or volume) of a pollutant does not necessarily mean more pollution; instead, their impact factor on environment is also effective, which is here called as external costs per unit weight of pollutant. In fact, the combination of these two (weight and external costs per unit weight) together determines the importance of a pollutant. Therefore, this paper emphasizes on the fact that the monetary value of costs imposed on society, rather than weights of emissions, is important in the environmental analyses, and these two concepts (weight and external costs per unit weight) are two different concepts. Eventually, the problems analysed in this study are as follows:

- Problem 1: what are the fuels used in detergent production process? How much do these fuels separately create the thermal energy required?
- Problem 2: what are the primary pollutants forming external cost of detergent production? How much do these pollutants separately cause external costs?

This study focuses on air pollution caused by fossil fuels; therefore, it is essential to answer the above questions by calculating the weight of pollutants separately; then, the amount of external cost per unit detergent will be estimated by unit cost estimation considering data from energy balance sheet published by the Department of Energy (2011) to valuate air pollutants. Then, private costs derived from producing 1kg detergent powder including fixed costs and investment and variable costs and overloads and other costs of production are estimated and calculated by data available in accounting department of Tolypers based on cost accounting method. By sum of internal and external costs, the social cost resulting from these powders will be measured. Next, external cost derived from detergent production will be analysed separately for major pollutants and the combination of consumed fuel will be evaluated for different seasons.

Theoretical Background

External costs are the costs imposed on society (in the absence of economic interventions) that are not taken into account by consumers. In these circumstances, the consumer will be motivated by an incorrect or misplaced incentive in the process of supply and demand, which eventually will lead to lower prosperity. In order to provide an appropriate definition of external costs, it is necessary to identify the following concepts correctly:

- The private (or internal) costs will be borne directly by consumers, such as above-mentioned examples.
- Social costs reflect the costs associated with producing goods including private costs (such as capital costs, operating costs, etc.) and all indirect costs incurred by the community (including environmental costs etc.) resulting from production of a certain good.

External costs refer to the difference between social costs and private costs. However, this definition is not sufficient to obtain quantity of external costs and it needs to be explained in more detail. Based on the theory of economic welfare, consumers should pay for all social costs arising from their consumption (Maiback et al, 2008). Economic theories suggest that optimal prices should reflect external costs under optimal production conditions. This means that the optimal price is where marginal costs of external damages are equal to marginal costs of avoidance.

Costs of air pollution, mainly due to emissions of air pollutants such as particulate CO_2, CO, NO_X, SO_2, include the cost of health, building and material damages, losses and other damages on ecosystem (biosphere, soil and water). Status of research on this type of costs is more advanced than other cost elements. Essentially, there are four types of emission estimation technique based on which weight of emitted pollutants can be estimated. These techniques, called as EETs, are as follows: direct measurement, mass balance, emission factors, fuel analysis, and other engineering calculations.

Researchers can choose any one or any combination of these techniques consistent with purpose and data of the study. Obviously regardless of the technique of choice, it is necessary to have adequately reliable data.

Direct measurement

There are two types of techniques for direct measurement including sampling data and continuous emission monitoring system (CEMS). Each of these two techniques is separately and briefly explained, as follows.

1. Sampling data

For a sufficient number of sampling data to be sure of data, it is essential to collect samples several times over a period of time so that the samples are a representative of processes and operations during a year. In this technique, the pollution data is calculated in terms of kilograms per hour; then, the annual rate of pollution can easily be calculated. In this technique, sampling is performed under normal operation, so that the obtained information represents the average normal operation.

2. Continuous emission monitoring system (CEMS)

CEMS presents recorded pollution data continually over time, usually by reporting pollutant concentration. Once the pollutant concentration is found, the rate of pollution can be determined by multiplying the concentration of pollutants in gas volume of that pollutant. In this technique, sampling is performed under normal operation, so that the obtained information represents the average normal operation. This technique assumes that the chosen period is representative of the actual annual operating conditions. This technique requires a longer period so that the period is a better representative of the entire year.

Mass balance

This technique seeks to determine whether the amount of pollution can be obtained in a particular process based on analysis of operating parameters, material composition and amount of material consumption. By quantifying materials imported to and exported from the system, this technique considers the difference between these two values (input and output) as emissions to the environment. This technique is particularly useful when the input and output streams can be easily identified; in most cases, it happens when the size of operations and processes is not too big.

Fuel Analysis Technique and Engineering Calculations

Another technique to estimate the weight of pollutants is the fuel analysis technique based on engineering calculations. In this technique, a relationship or engineering formula is used as the estimation method. This relationship is usually based on the physical and chemical properties and some mathematical relations between them. Fuel analysis is an example of engineering calculations that can be used to estimate emissions. This method is based on the conversion rules. In this way, it is necessary to have the rate of fuel or the fuel consumption per unit of time (e.g. one hour, day, month or year). This method can use the available value of elements existing in the fuel to estimate pollutions caused by them. For example, sulphur can change to sulphur dioxide, which is a pollutant, during combustion. These techniques can calculate pollutant emission rates based on the rate of fuel consumption.

The basic equation of fuel analysis for calculations to estimate emissions is as follows.

$$E_{kpy,i}=Q_f * (C_i / 100) * (MW_P / EW_f)*OpHrs \quad (1)$$

Where:

$E_{kpy,i}$: value of the emitted pollutant i in the environment in terms of kilograms per year

Q_f: the amount of fuel consumed in terms of kilogram per hour

C_i: concentration of pollutant i in fuel, in percentage

MW_P: molecular weight of emitted pollutant, kg/kg-mole

EW_F: atomic weight of pollutant in fuel, kg/kg-mole

OpHrs: Number of hours of operation in terms of hours per year

For example, the amount of SO_2 pollution from fuel combustion can be calculated based on the concentration of sulphur in the fuel. This method assumes that all the sulphur in the fuel is converted to SO_2, which occurs in complete combustion. Thus, the amount of pollutants can be calculated using these techniques in cases where combustion occurs fully or nearly complete.

Emission factors

While little is known about fuel, operation or process, default emission factors can be used to estimate the pollution. Emission factors are extracted by measuring the main sources of pollution. This information can be used to establish a relationship between the emitted quantity and the scale of activity or the device. Pollution factor is a tool to estimate the amount of pollutants released into the environment. This factor attributes the amount of pollutants released from a source to the same amount of pollutants released from another common source (of which data is available). Emission factors can be obtained from resources in the United States, Europe and Australia. These factors are usually reported as the weight of released material divided by the unit weight, volume, distance or duration of the activity which creates pollution.

Empirical Literature

To estimate the external costs of economic activities, many studies have been conducted, particularly in the areas of electrical power generation and transportation activities. Review of these studies show that little research has been conducted to analyse the components of these costs; in fact, the conducted studies focused on estimation of external costs. Some of these studies are as follows:

Khoshakhlagh and Hasanshahi (2002) estimated damage to residents of Shiraz from air pollution by contingent valuation method (CVM) and marginal willingness to pay (MWTP) index in order to measure the damage from air pollution which is inversely the same quality of air. For this study, 750 households were selected randomly (cluster and systematic) and provided with a questionnaire and a poster containing four different states of air quality in Shiraz to estimate MWTP value for residents. The results show that each citizen, on average, wills to pay 2927 rials as annual tax to prevent deterioration of existing air quality, while now 900 rials of the annual tax is spent which accounts for only 30% of the real willingness.

Sadeghi et al (2007) examined the social costs of SO_2 emitted from Shahid Rajai Power Plant under two scenarios, normal and maximum load. For this purpose, the social, private and external costs were calculated individually for each unit of the power plant. Private costs included the cost of maintenance, cost of investment and the cost of fuel. The cost of fuel for each steam unit and combined cycle was calculated by considering the subsidized prices and FOB of Persian Gulf. Eventually, private costs of the power plant were estimated in 652,257 and 534,371 rials/kWh.

Sulphur dioxide SO_2 emitted from the power plant was compared with international outdoor standard under both normal and maximum load in four seasons of the year. Its external costs were calculated as 262096 and 421226 rials/kWh. Results from analysing the social costs of steam unit and combined cycle show that social costs of steam unit has been higher in autumn and winter due to the high consumption of mazut in these two seasons.

Using simplified methods developed by international agency of atomic energy, Shrestha and Lefevre (2003) estimated the external cost from electric energy generation in two power plants in Tailand generating electricity by coal fuel. The results show that effects of deaths from chronic illnesses were significantly more likely than other types of health effects in both plants. Despite the installation of emission control technologies in the 300-megawatt power plant of Mamo, its monetary damages and external costs was more than that of 1,000-megawatt power plant in Tapsaky.

Yusuke and Kenichi (2010) analysed the external costs resulting from motor vehicles in Japan. Using the unit cost method, the results show that the disordered traffic (heavy traffic) had the largest contribution (42.4%) among all components of external costs resulting from motor vehicles. The total external cost imposed on society by motor vehicles was 36 trillion yen. This amount accounts for 4.7% of GDP in 2004. Other results show that the external cost of heavy vehicles is approximately 3 to 4 times higher than that of other motor vehicles.

In addition, review of the empirical literature shows that the literature regarding detergent powders is limited; regarding other fields, studies most focused on estimation of external costs rather than quantitative analysis. This study tries to fill this gap.

Empirical Results

In this study, the value of private, external, and social costs were obtained by data related to 2011. The amount of pollutants produced during one year was estimated by calculating emissions using the law of mass conservation developed by National Pollutant Inventory (NPI) and Environment Protection Agency of Australia (equation 1). In order to quantify external costs of air pollution caused by detergent production, valuations conducted by studies of the World Bank and the Environmental Protection Agency were used.

Table 1: values of external cost resulting from pollutants to current prices in 2011 and calculation of total external cost generated in this year by Tolypers

Pollutant	Weight of pollutant generated per kilogram burned gas, in kilograms	Weight of pollutant generated per kilogram burned mazut, in kilograms	Weigh of pollutants emitted from burning natural gas, in kg	Weigh of pollutants emitted from burning mazut, in kg	The total weight for pollutants from burning natural gas and mazut in 2011, in kg	External costs per kg pollutants in 2011, in Rails	External costs of air pollutants during one year ended in march 2011, in rials, current prices in 2011
CO_2	2.713	3.080	23179518.4	1892690.8	25072209.2	329.5	8261292923.7
SO_2	---	0.060	0.0	36870.6	36870.6	60130.2	2217036552.1
NO_x	0.025	---	213596.7	0.0	213596.7	19768.8	4222551261.4
CO	Small	Small	0.0	0.0	0.0	6177.8	0.0
Total	---	---	---	---	---	---	14700880737.2

Next, the amount of pollutants produced per a single unit of produced powder was calculated. Using unit cost estimation method considering data available in the energy balance sheet to valuate any single unit of pollutants and the value of these valuations based on the current prices in 2011, the value of external cost was valuated per single unit of detergent powder. By sum of internal and external costs resulting from detergent production, finally, the social cost was measured. The results are presented in Table 1.

The results presented in Table 1 show that Tolypers Company imposed 14,700,880,737 Rials external costs on society during 2011. Let us examine this amount versus weight (tonnage) of the detergents produced in 2011; the value of external cost will be obtained in unit weight of the powder, for example, external cost of one-ton powder or one-kilogram powder. The following tables report the results of these calculations.

Table 2: values of annual production in 2011 and weight of different types of powders

Measure	Hand-washing	Machine-washing	Total
Tonnage of hand-washing powder, in ton	75883.2	50588.8	126473.0
Amount of produced powder in kg	75883200	50588800	126472000
Portion of weight from total production, in %	60%	40%	100%

Table 3: external cost of producing 1kg detergent by Tolypers during 2011

Measure	Hand-washing	Machine-washing	Total
External cost of production, in Rials	8820528442	5880352295	14700880737
Tonnage of produced powder, in kg	75883200	50588800	126472000
External cost of producing 1kg powder, in Rial	116.2	116.2	116.2

As the data listed in Table 3 shows, the external cost of producing 1kg powder was calculated for both hand and machine-washing powders to be similar (116.2 IRR). This is because of the fact that both processes used the same tower; therefore, it is not possible to separate the pollution caused by combustion whereby calculate the external costs separately. However, these two types of detergent powders have different private costs; thus, social cost will be estimated separately. For this purpose, it is necessary to have the known values of private cost or the finished cost of a variety of powder. This information was provided by the accounting office.

Table 4: private cost or finished cost from producing 1kg hand-washing powder by Tolypers in 2011

Description of cost items and consumables	Consumption in terms of units	Fee in terms of RLS
Active (active ingredient)	20	2841.4
STTP	8	721.5
Sodium sulfate	43.5	760.1
Sodium Carbonate	15	444.3
Sodium Silicate	8	260
Optical	0.15	70.6
CMC	1.2	128.4
Essence	0.1	148.8
Humidity	4	---
Total Consumption	---	5375.1
The total cost of packaging	---	1450

Direct wage	---	250
Overload	---	400
The share of administrative and selling expenses	---	400
The share of financial costs	---	300
Total costs of packaging and other costs per kg	---	2800
The total finished price per kilogram of hand-washing powder	---	8157.1

Table 5: private cost or finished price from producing 1kg machine-washing powder in Tolypers in 2011

Description of cost items and consumables	Consumption in terms of units	Fee in terms of RLS
Active (active ingredient)	9.5	1597
STTP	22	3871.7
Nonionic	4	1044
Stearic acid	4	632
Sodium sulfate	22	418
Sodium Carbonate	9	261
Sodium Silicate	8.5	310.3
Optical	0.15	86.2
CMC	1.5	180
Essence	0.1	101.7
TED	2.2	1144
Sodium perborate	9	1306.2
Total Consumption	---	10952.1
The total cost of packaging	---	1450
Direct wage	---	250
Overload	---	400
The share of administrative and selling expenses	---	400
The share of financial costs	---	300
Total costs of packaging and other costs per kg	---	2800
The total finished price per kilogram of hand-washing powder	---	13752.1

For this purpose, the cost of raw materials including active (active ingredient), STTP, sodium sulphate, sodium carbonate, sodium silicate, optical, CMC, essence, etc., are summed together to obtain the total cost of consumables. Then, other costs including total cost of packaging, direct wages, overload, administrative costs and sales, financial costs are added to obtain the private cost or the finished cost of one unit detergent which is considered 1kg here. The above calculations show that the private cost or the finished cost of hand and machine-washing powders produced by Tolypers Company in 2011 were 8157.1 and 13752.1 RLS, respectively. It is clear that the private cost of machine powder was 69% higher than the private cost of machine powder in 2011. This difference is mainly due to differences in raw materials of powders and hence the difference in prices of these raw materials. Thus, a common number (116.2 RLS) was estimated and reported for the external cost, despite the fact that both types of detergent powders used an identical tower. However, social cost of two types will be different due to differences in their private cost. Given these results, it is clear that the private, external and social costs are 8157.1, 116.2 and 8273.3 RLS, respectively, for hand-washing powder and 13752.1, 116.2, 13868.3 RLS for machine-washing powder. Furthermore, the contribution of each external and private costs can be calculated from social cost of each powder.

Table 6: percentage of external and private costs from social cost for both types of powders

Cost measure	Hand-washing	Machine-washing
Percentage of external cost from social cost	1.40%	0.83%
Percentage of private cost from social cost	98.60%	99.17%

Results presented in the above table show that the percentage of external cost from social cost is relatively lower than the percentage of private cost from social cost. To be more precise, these ratios are 1.40% and 0.83% for hand and machine powders, respectively.

In the following, the contribution of consumed fuels to the external cost as well as the contribution of major pollutants to the external cost will be analysed. The following table presents information related to thermal value, the thermal energy generated during a year and duration of fuel consumption in a year.

According to reports of Tolypers, the thermal energy required for detergent production, which was mainly used to keep the towers warm, was provided by natural gas for 11 months of the year and mazut for the remaining 1 month. In fact, the natural gas pipeline network was not able to provide the factory with gas in this 1 month due to the peak gas demand. In this 1 month, the network was not able to provide the gas for highly consuming units including Tolypers. During this time, Tolypers had to rely on other fuels such as mazut. The results from above table show that the total thermal energy required for producing 126472000kg detergent during 2011 was provided by relatively 5% (theoretically considering values of the consumed fuels and their thermal value) to 8% (experimentally considering the reports on number of months when each fuel was used) mazut and the rest, i.e. 92% to 94% natural gas. According to above, 8% mazut is considered for the calculations hereafter. In the following, the weight and external cost of both fuels are analysed separately.

Table 7: thermal value, the generated thermal energy and consumption duration of each fuel during 2011

Fuel	Thermal value	Unit	The total thermal energy derived from any particular fuel in the considered year, Kcal	The relative share of each fuel in providing the energy requirements of towers in the considered year (based on thermal value)	Consumption duration of each fuel in the considered year	The relative share of each fuel in providing energy requirements of towers in the considered year (based on the declared period)
Natural gas	8600	Kcal/M3	102909354400	94%	11 months	91.7%
Mazut	9790	Kcal/kg	6016052900	6%	1 month *	8.3%
Total	---	---	108925407300	100%	12 months	100%

* according to reports of Tolypers, The amount of mazut used to provide thermal energy required for towers during 2011 has been reported for almost one month, while The relative contribution of

the thermal energy produced theoretically shows that this amount of fuel is only able to generate the thermal energy required for 22 days. Despite this, the small difference in figures can be explained by a potential difference in combustion efficiency of natural gas and mazut in the factory. However, the calculations were based on the reports, i.e. one month (8.3% of the year) to consider the potential difference in thermal efficiency of fuels in calculations.

Table 8: weight and external cost of each fuel separately for major pollutants in 2011

pollutant	Weight of pollutant generated per 1kg burned gas, in kg	Weight of pollutant generated per 1kg burned mazut, in kg	External costs per 1kg pollutant in 2011, in Rails	Weight of pollutant emitted from burning natural gas, in kg	External costs of air pollutants from burning gases during 11 months of the year 2011, in RLS and current prices	External costs of air pollutants from burning gases during 1 month, in rials, current prices in 2011	Weight of pollutant emitted by burning mazut, in kg	External costs of air pollutants from burning mazut during 1 month, in rials, current prices in 2011
CO2	2.713	3.080	329.5	23179518.4	7637651305.1	694331936.8	1892690.8	623641618.6
SO2	---	0.060	60130.2	0.0	0.0	0.0	36870.6	2217036552.1
NOx	0.025	---	19768.8	213596.7	4222551261.4	383868296.5	0.0	0.0
CO	Negligible	Negligible	6177.8	0.0	0.0	0.0	0.0	0.0
Total	---	---	---	---	11,860,202,566.5	1078200233.3	---	2840678170.7

Table 8 present the weight and value of external costs generated by each of the two types of fuel separately for their major pollutants. The seventh column shows the external cost resulting from natural gas combustion which happens in 1 month to compare this value with the external gas resulting from mazut combustion in a similar period. These results show that the external cost resulting from mazut combustion is relatively higher for providing thermal energy required for the factory to produce detergent in a similar duration (1 month) and for providing the same amount of detergent powder. Therefore, the external cost resulting from mazut is relatively higher than that resulting from natural gas. To be more precise, the external cost from mazut is 2.6 times higher than that from natural gas. However, the assumption made here is that the amount of monthly production is almost identical in Tolypers. Evaluation of the amount of powders produced in different months of 2011 shows that the trend is almost uniform throughout the various months of the year and the assumption is not too far-fetched. In these calculations, the fact that mazut generates energy under conditions (winter) different from natural gas (various seasons) (because the rate of heat exchange with the surroundings in the form of heat loss is different in various seasons) has been discarded.
Table 9 presents the relative contribution of each pollutant in external cost of air pollution caused by Tolypers regarding the fuels consumed in 2011.

Table 9: relative contribution of each pollutant in air pollution caused by Tolypers considering the fuels used

Pollutants	External costs of air pollutants from gases during 1 month, in rials, current prices in 2011	External costs of air pollutants from mazut during 1 month, in rials, current prices in 2011	External costs of all air pollutants during the year ended in march 19, 2011, in rials, current prices in 2011	The relative contribution of each pollutant in the total external costs, in percentage
CO2	7637651305.1	623641618.6	8261292923.7	56.2
SO2	0.0	2217036552.1	2217036552.1	15.1
NOx	4222551261.4	0.0	4222551261.4	28.7
CO	0.0	0.0	0.0	0.0
Total	11,860,202,566.5	2840678170.7	14,700,880,737.2	100.0

The above table shows that CO_2, SO_2 and NO_x gases account for 56.2, 15.1 and 28.7%, respectively, of the external cost resulting from detergent production in 2011. This is depicted in the schema below.

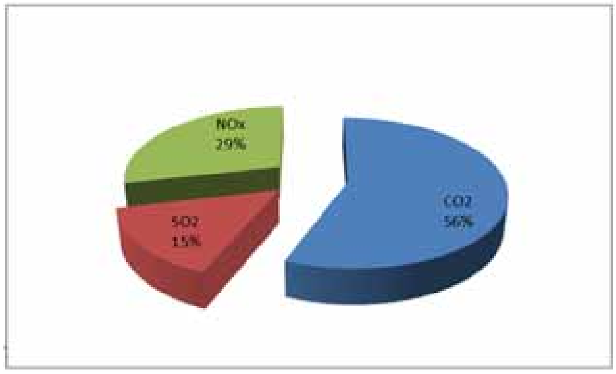

Figure 1: relative contribution of each pollutant in air pollution caused by Tolypers considering the fuels used

For more explanations, the following schemas present the relative contribution of each pollutant in external cost separately for the fuels used.

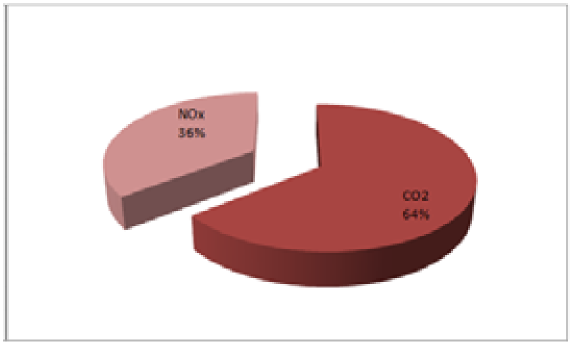

Figure 2: relative contribution of each pollutant in external cost of detergent production using natural gas, percentage

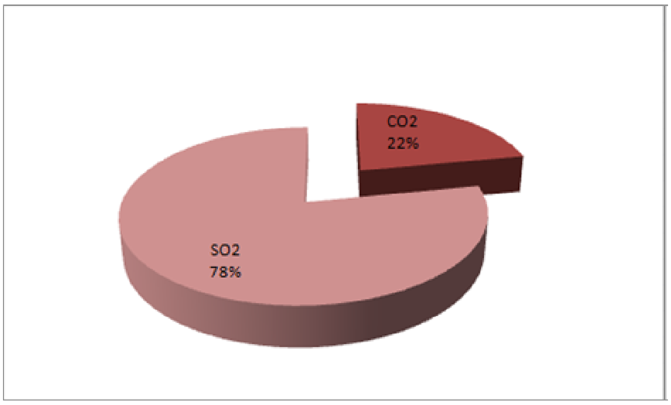

Figure 3: relative contribution of each pollutant in external cost of detergent production using mazut, percentage

The above figures show that the main part of external cost results from CO_2 emission while using natural gas (64%). The main part of external cost results from SO_2 emission while using mazut (78%). Moreover, NO_x gases account for 36% of the external cost resulting from natural gas, while CO_2 gas accounts for 22% of the external cost resulting from mazut. The table below followed by two figures compares the relative contribution of fuels in providing the thermal energy required for detergent production with their relative contribution in the external cost.

Table 10: relative contribution of each fuel in providing energy and comparison with contribution of each fuel in the external cost of detergent production considering the used fuels

Fuel	The relative contribution of each type of fuel to provide the required heat energy in percentage	The relative contribution of each type of fuel in total external costs, in percentage
Natural gas	91.3%	80.7%
Mazut	8.3%	19.3%

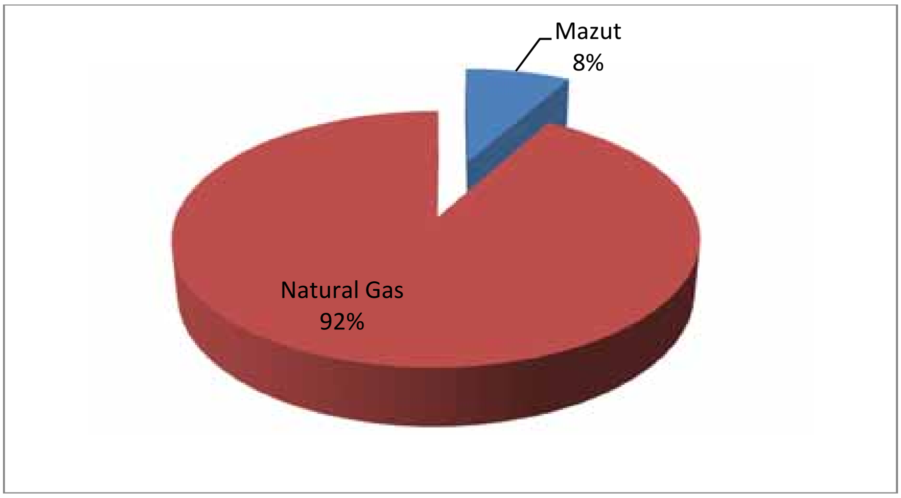

Figure 4: relative contribution of fuels in providing energy required for detergent production considering the used fuels

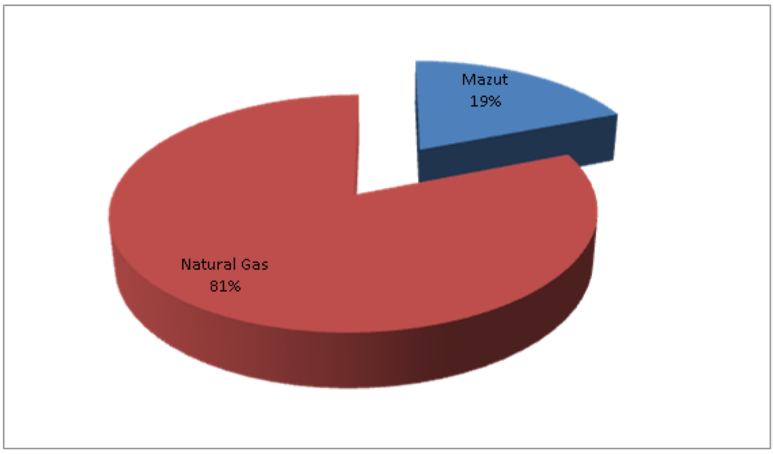

Figure 5: relative contribution of fuels in external cost of detergent production considering the used fuels

The above results indicate that the amount of external cost resulting from air pollution is strongly sensitive to the type of consumed fuel. Although mazut only provides 8.3% of the required thermal energy, it accounts for 19.3% of the external cost annually. Thus, increase in consumption of mazut (for example due to the lack of natural gas during winter for a period longer than one month) will increase the amount of external cost of detergent production.

Conclusions and Recommendations

Detergent industry, one of the most important manufacturing industries of Iran, has various products which play a vital role in providing health care to the community. In addition to essential needs of consumers, the domestic production of detergents provides direct and indirect effects such as employment, income and social welfare for other social groups. Besides the advantages mentioned above, the production of detergents has also negative effects. These products are produced in such a way that it causes environmental pollution. Therefore, it is essential to calculate the costs imposed on the environment. Given the importance of analysing components of external cost separately, this study aimed to analyse different components of these costs. In the following, the results from estimations and analyses are provided briefly.

Results of estimates showed that the private cost or finished price of hand and machine powders produced by Tolypers Company in 2011 has been 8157.1 and 13752.1 RLS, respectively. It is clear that the private cost of machine powder was 69% higher than that of machine powder in 2011. This difference is mainly due to differences in raw materials of powders and hence the difference in prices of these raw materials. Thus, the private, external and social cost of detergent production have been 8157.1, 116.2 and 8273.3 RLS, respectively, for hand-washing powder and 13752.1, 116.2, 13868.3 RLS for machine-washing powder. Other results showed that the contribution of external cost in social cost was relatively lower than the contribution of the private cost in social cost. In other words, these ratios were 1.40% and 0.83% for hand and machine-washing detergents.

Other results also showed that the external cost from mazut is 2.6 times higher than that from natural gas. It was also clear that CO_2, SO_2 and NO_x gases account for 56.2, 15.1 and 28.7%, respectively, of the external cost resulting from detergent production in 2011. The more detailed analysis of pollutants resulting from fuels showed that the main part of external cost results from CO2 emission while using natural gas (64%). The main part of external cost results from SO2 emission while using mazut (78%). Moreover, NOx gases account for 36% of the external cost resulting from natural gas, while CO2 gas accounts for 22% of the external cost resulting from mazut.

The above results indicate that the amount of external cost resulting from air pollution is strongly sensitive to the type of consumed fuel. Although mazut only provides 8.3% of the required thermal energy, it accounts for 19.3% of the external cost annually. Thus, increase in consumption of mazut (for example due to the lack of natural gas during winter for a period longer than one month) will increase the amount of external cost of detergent production.

Based on findings of this study and other related studies, the following recommendations are presented:

- To provide sustainable energy of natural gas for Tolypers to decrease the external costs of detergent production (lack of sustainable natural gas can increase external costs)
- To use methods and filters which own the eliminability and attractiveness of the major components of external cost (for example, SO_2 for mazut)
- To use cleaner fuels when natural gas is not available
- Optimal utilization of fossil energies to provide complete combustion
- To upgrade the technical knowledge by increasing contributions of research and development costs and attracting spillover of foreign research and development
- To update knowledge of management in order to optimize resource management and application of new methods in the field of environmental management

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