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**ORIGINAL ARTICLE**

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

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**ABSTRACT**
*This paper aims to measure the external cost in the production of detergents by Tolypers Company during 2011. The used methods included sequenced consequence approach to quantify the external cost of air pollution resulting from the combustion in production process of detergents, fuel analysis techniques to obtain the weighted value of each pollutant per unit of fuel, and unit cost estimation to estimate the total external cost for detergents produced in the factory during one year. The results show that external cost of 1kg detergent powder produced by Tolypers Inc. in 2011was 116.2IRs according to prices of the current year. Calculations indicate that the private, external and social cost of hand-washing detergent powder was 8157.1, 116.2 and 8273.3 IRs, respectively, and 13752.1, 116.2 and 13868.3 116.2 IRs for machine detergent powder. These results indicate that the contribution of external cost has been lower than the social cost, compared to the contribution of private cost than social cost. In other words, these ratios were 1.40% and 0.83% for hand and machine-washing detergents which are lower than the same ratios in electric production industry with 20% and 40% as mentioned in empirical studies. Nevertheless, the relative amount of cost is still of great importance to provide practical solutions in order to improve processes to reduce the external costs of producing detergents, considering the massive amount of powder detergent produced in Iran, and the fact that the current study merely calculated the external costs resulting from fuel combustion (rather than the external costs caused by polluting sources). Accordingly, the focus on manufacturing methods that are less polluting, internalizing the external cost of detergent powder in its market price by tax and providing the necessary infrastructures for development of investment in the manufacturing sector to provide cleaner production technologies can effectively reduce the external cost of these products.*
***Keywords****: external costs, air pollution, sequenced consequence approach, fuel analysis techniques, unit cost estimation*

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## INTRODUCTION

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. One of strategically important products is detergent. These powders are mainly produced using chemical and mineral raw materials; these are divided into hand-washing and machine-washing powders. 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 in air, water as well as negative effects on employee health. Therefore, it is essential to calculate the cost of damage to environment, particularly human health. Reviews show that several studies examined the external costs of electricity generation, cement production, transport and roads; however, there has been always a gap in the context of external cost estimates for detergent industries.

The purpose of this study is to examine the effect of producing detergents on the environment quality and human health and to calculate environmental costs and damages from production of 1kg detergent powder. The studied variables included external costs resulting from production of detergent powder including costs related to illnesses and mortality, and reduced quality of environment. Finally, the study determines social cost or the real finished cost of 1g detergent and provides policy recommendations and

suggestions to internalize the external costs of detergent powders. Accordingly, the following questions are considered:

- Question 1: how much is the external cost of producing 1kg detergent powder in Tolypers?
- Question 2: how much is the social cost of producing (real finished cost) 1kg detergent in Tolypers?

In this study, private cost of producing 1kg detergent powder including fixed costs and investment and variable costs and overloads and other costs of production are estimated and calculated through data available in auditing department of Tolypers based on cost accounting method. Then, pollution sources (e.g. combustion of towers on the production line) and various types of pollution that can occur in different units and production processes will be determined. Then, the effects of pollution caused by core processes and support lines on the environment (water, air, earth and human) will be briefly reviewed. This study focuses on air pollution caused by fossil fuels; therefore, the amount of pollution will be calculated; then, the amount of external cost per 1kg detergent will be estimated by unit cost estimation considering data from energy balance sheet to value air pollutants. Finally, the social cost of producing these powders will be measured by sum of both internal and external costs.

Figure 1 briefly describes raw material procurement, production and supply of detergents in Tolypers, production process of detergent powder and sulfonic acid in Tolypers and its environmental effects. Obviously, various steps of production cause different pollutions which are not addressed here. Some of these pollutions include ground contamination from raw material infusion to the ground (their chemical structure can cause contamination of agricultural lands); water pollution from raw material infusion to the ground; disposal of wash water to the underground water; infusion of raw materials during storage and handling in warehouses; land pollution caused by waste incorrect disposal of infused raw material and wastes from the surface of reservoirs; water pollution caused by transfer of infused raw materials with used water for wash; If not cleaned and not separated, air pollution caused by spread of suspended dust particles from handling and transport of raw materials; air pollution from emissions of fine suspended particles released into the air; air pollution from emissions of produced gases ($NO_X$, CO, $CO_2$ and $SO_2$); water pollution resulting from infusion of wastewater; air pollution due to the release of powder particles (fine) during the process (output of equipment) during packaging; noise pollution caused by abnormal noises from equipment operation; infusion of waste products during loading, transport and unloading; water pollution due to increased alkalinity and PH of effluent from the factory. Despite the multiplicity and diversity of various pollutants produced during the manufacturing process of detergents in Tolypers, this study only estimates the external cost caused by combustion of towers which is the main cause of air pollution.

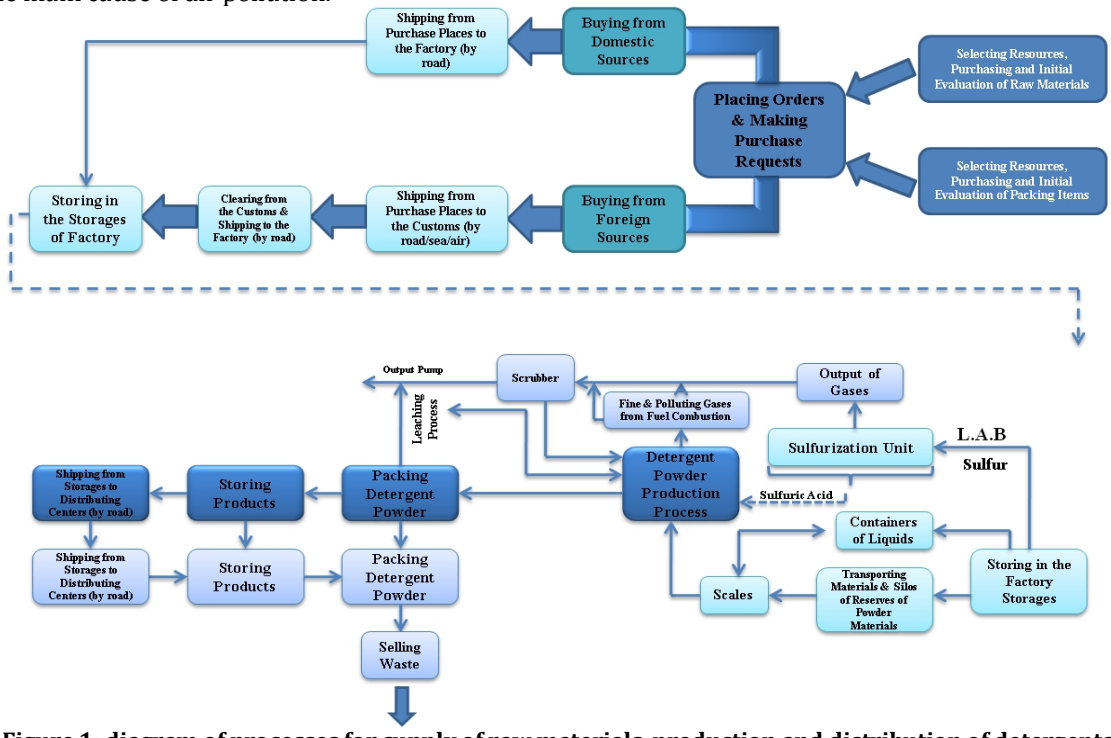


**Figure 1: diagram of processes for supply of raw materials, production and distribution of detergents produced in Tolypers**

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## THEORETICAL BACKGROUND

Pigou [1] was the first to organize and codify the effects of pollution on economic efficiency. In his analysis, there is a difference between private costs of production and consumption activities (including fuel, raw materials, labour costs, etc.) and social costs of these activities. He noted that pollution causes external costs which make a gap between public and consumption costs. The social costs of production or consumption are derived from total private costs, and any other external costs, if exist.

Although the private market has favorable effects on society and economy, some pollutants may diffuse in the environment which have unfavorable effects on human health and environment. These pollutants include emissions, industrial waste, hazardous toxic waste, etc. that can be released by industries. There are two types of commodity in the marker: private commodities which are produced, distributed and valuated by the producer and eventually are consumed by the household; and public commodities which environmental goods and services with open access and common property such as PAL weather and beautiful nature. The market system is unable to evaluate the environmental gifts because it cannot reflect the real external costs from producing goods and services in prices, and this may result in market failure.

The method to examine the inability of free markets in maintaining environmental quality is to evaluate the external costs resulting from market activity which indeed reflects the effects of pollutants from production and consumption influencing the third party of the market. Price is the most important mechanism of the market place, which is characterized by supply and demand; however, it is called market failure if it fails to show all of actual cost of a product in the market. The effects which produce costs are termed as negative externalities or external cost.

The material presented in Figure 2 is described in detail.

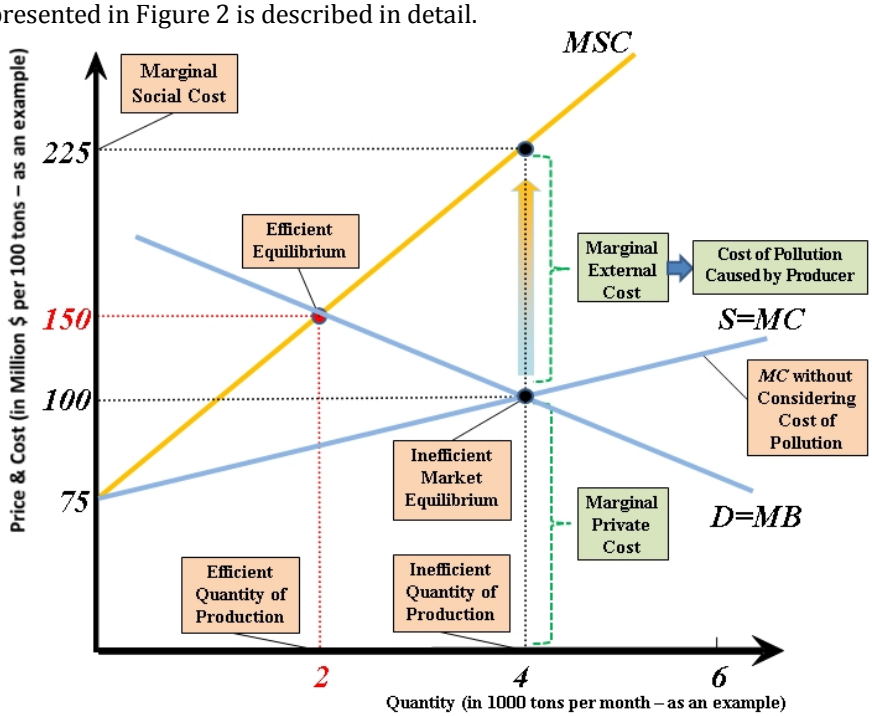


**Figure 2: description of theories of external cost**

*. The numbers in the diagram are considered hypothetical.

Internalization of external costs into production costs is a highly efficient policy tool under which the external effects can be reduced. Internalizing external costs to production costs is an approach which can be considered as a factor for economic valuation to reflect social costs of production. Basically, external costs are generated when calculation of private costs and benefits are completely different and apart from cost and benefit valued by society. Due to damages to society, Pollution generates external cost, while it is not reflected in market transactions. Finally, if the private cost of production (cost of investment, operation, maintenance, etc.) is summed with the external cost (the cost of pollution generated and imposed on society), the social cost of production will be achieved. Economic theories suggest that optimal prices should reflect external costs under optimal production conditions. This means that the optimal price is where costs of final external damages are equal to final avoidance costs.

The cost of air pollution is one of the main subtypes of external costs. Today, a significant amount of research is available on methodology as well as studies to estimate the total, average and final cost of air pollution. During the research projects in Europe, sequenced consequence approach was developed during the ExternE Project in 1997; afterwards, it has been used by many researchers [14]. Since then,

further research was conducted to develop, improve and modify this approach. This approach can be seen as the most advanced approach to estimate the costs of air pollution. Accordingly, this approach is suggested as a best practical methodology to estimate the cost of air pollution [15].

Sequenced consequence approach, sometimes called ExternE, is essentially a bottom-up approach to estimate the ultimate cost for different manufacturing conditions. The advantage of this approach is the stability, durability and consistency and to account for different detailed input variables (detail). However, it would be a costly procedure to undertake a study at the national level by this method. For such cases, a top-down approach has been simplified and is considered as an alternative. Although these two approaches are similar on some assumptions (such as the Dose Response), they may have different numerical values due to different models of air pollution and different properties of emissions. Figure 3 depicts a clear sketch of the most important steps of sequenced consequence approach, which has been established by studying ExterneE.

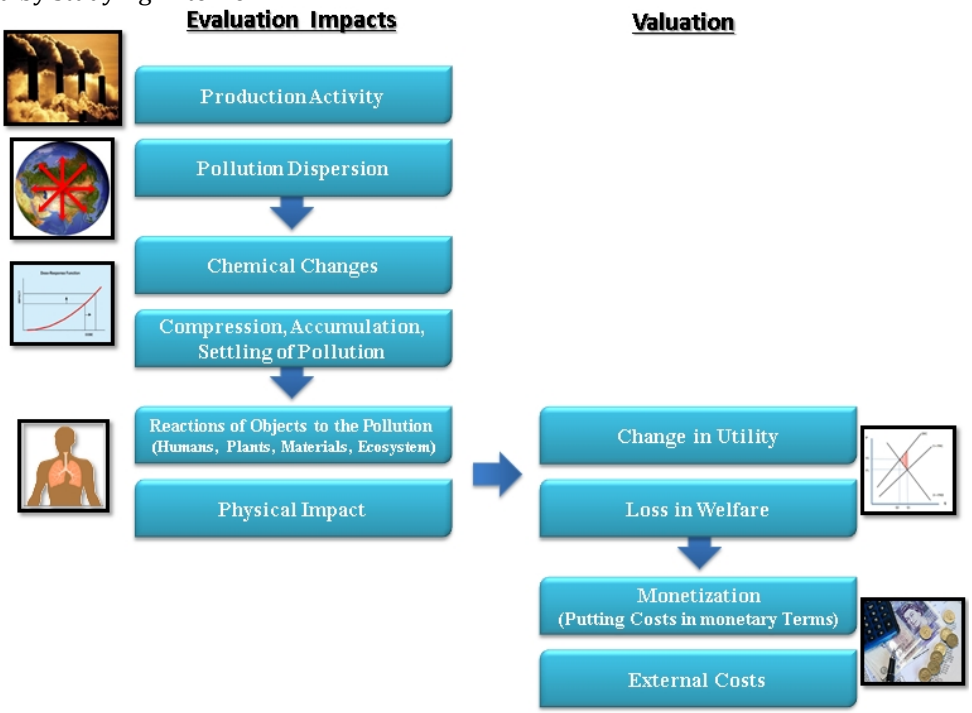


**Figure 3: sequenced consequence approach to quantify the final external cost resulting from air pollution and noise pollution**

If the amount of pollutants created in the manufacturing process can be calculated, the amount of external cost of each pollutant can be estimated considering the available valuations of external costs for each type of pollutant. Essentially, there are four types of emission estimation technique based on which the amount 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.

Among these techniques, researchers can select 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. This study only uses the fuel analysis technique which is described as follows.

**Fuel Analysis Technique and 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 relationship 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 the contamination. 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:

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$E_{kpy,i}$: 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 the cases where combustion occurs fully or nearly complete.

**EMPIRICAL LITERATURE**

Given the importance of calculating external costs of economic activities in calculations of social costs and economic estimates, so far, many efforts have been globally conducted, particularly in the areas of electrical power generation and transportation activities. In 1997, the first attempt to calculate the external cost of electrical power generation has been made in Iran. These calculations were performed at the Department of Energy and they have been included in the balance sheet, 1997. Estimation of external and social costs has attracted more attention in recent years in both global and local levels. However, most of these studies are done in several categories of economic activity, including electrical power generation and transportation. Evaluation of external costs of production has remained unnoticed in subdivisions of the industries, although studies are almost identical or at least similar in theories and methodologies. However, a part of the research done on the estimated external and social costs of various economic sectors will be reviewed in two separate sections in the following. At the end of this section, a summary of other studies will be mentioned.

Sadeghi and Torki [2] evaluated the external costs of electricity generation in Iran. This case study done for the power plant of Rajai using special valuation (preference, cost of illness and biostatistics) shows that concentration of emitted $SO_2$ in autumn and winter under normal conditions and peak load is higher than the standard 24-hour (365 micrograms per cubic meter); given its negative effects on human health (respiratory deterioration in the short-term and long-term respiratory symptoms such as chronic bronchitis), minimum and maximum external costs are estimated equal to 124.151 and 218.000 RLS/kWh, which is 3 km from the emission source. Comparing these values suggests that negative external costs are highest under maximum load.

Rita et al [3] examined the economic costs of air pollution resulting from transportation focusing on its effects on health in Australia, France and Switzerland. This study conducted by a research team consisting of 15 people has been funded by the Department of Environment, Australia. In order to assess the health costs, two methods were used including tend to pay and partial method or the human capital approach. The results showed that health costs resulting from transportation activities for 74 million residents of the three countries (a part of the population of the three countries examined in this study) has been 27 billion euros in 1996, which is equal to 1.7% of gross domestic product (GDP) of this population. Accordingly, the health cost resulting from transportation activities in these areas averaged 360 euros per person in a year. Other findings showed that premature mortality was the dominant phenomena explaining for about 70% of the costs in all three countries.

Matthews et al [4] estimated the external costs of air pollution in industries in the United States. The results showed that the external costs were nearly $180 billion in 1992. The other results of this study indicated that the external cost of electrical power generation was 34% of the production value. In other words, the external cost of producing $1 power has been 34 cents which is relatively higher than other industries. In addition, the average ratio of external cost to production value has been approximately 4% for 500 sub-industries. Table 1 reports a summary of these studies and other selected studies conducted in this area.

**Table 1: summary of empirical literature**

| Author | Title | Year | Country | Level | Methodology |
|---|---|---|---|---|---|
| Sadeghi and Torki | External cost of electrical power generation in Iran (case study: power plant of Rajai) | 2008 | Iran | Rajai power plant | Special methods of valuation (preference, cost of illness and Biostatistics) |
| Sadeghi et al | the social costs of Rajai power plant | 2007 | Iran | Rajai power plant | Sum of private cost and external cost |
| Khoshakhlagh and Hasanshahi | The estimated damage to the residents of Shiraz from air pollution | 2002 | Iran | Shiraz | Contingent valuation method (CVM) and marginal willingness to pay(MWTP) |

| | | | | | |
|---|---|---|---|---|---|
| Jabarian Amiri and Raeisi | Environmental and social costs of electricity generation in Iran | 2004 | Iran | Country | Direct estimation method and adapted estimation methods |
| Zahed and Rezai | External cost estimates of roads on the social environment (focusing on road accidents) | 2006 | Iran | Country | DALY |
| Azizi et al | Economic and environmental effects of Bistoon thermal power plants in Kermanshah | 2006 | Iran | Kermanshah | Scenarios |
| Moharam Nejad and Zade Dabagh | Environmental review and determination of external costs (economic and health) for open flame oil wells in Ahvaz | 2005 | Iran | Ahvaz | Survey and valuation of respiratory disease |
| Rita et al | the economic costs of air pollution focusing health effects resulting from transport sector | 2003 | Australia, France and Switzerland | Countries | Willingness to pay and partial method or the human capital approach |
| Shrestha and Lefevre | Estimation of External Cost Associated with Electricity Generating Options in Thailand Using Simplified Methodologies | 2003 | Thailand | Mamo and Tapsaki power plants | Previously simplified procedures provided by the International Atomic Energy Agency |
| Matthews et al | External costs of air pollution in industrial production | 1995 | U.S. | Country | Comparison of industrial sectors |
| Yusuke and Kenichi | An Analysis of Road User Cost and External Costs of Motor Vehicles | 2010 | Japan | Country | The unit cost method |

Overall, the empirical literature in the field of external cost estimates indicates that no study has been specifically conducted in the field of detergents in Iran. This study attempts to fill this gap.

## RESULTS AND DISCUSSION

In this section, we first briefly introduce the variables and collected data; then, based on these data, the external cost of production of detergents is estimated. In the first step, the amount of air pollutants produced during one year is estimated by calculating emissions using the law of mass conservation by National Pollutant Inventory (NPI) and Environment Protection Agency of Australia. In order to quantify external costs of air pollution caused by production of detergents, sequenced consequence approach and valuations conducted by studies of World Bank and the Environmental Protection Agency can be used. This study will use the above-mentioned study considering the report of environmental energy review of Iran published in the energy balance sheet, 2003. Next, the amount of pollutants produced per powder produced is calculated. Then, the amount of external cost is valuated per a single unit of powder using unit cost estimation considering data available in energy balance sheet for valuating one unit of air pollutant.

To estimate any model, the first step is to gather data related to the required variables. Therefore, the sectional statistic data related to 2011 is used to estimate the external cost of producing detergent powders. This section addresses these variables and data.

Private costs of production includes the cost of fuel, cost of raw materials, labour costs, investment costs, costs of operation, maintenance, packaging, administration, finance and all expenses which are paid in cash by producers of goods and the market considers them when pricing goods and services. To collect data relating to the private cost of producing powder, this study uses the Accounting Office of Tolypers Company in 2011.

In addition to private costs paid for goods and services, producers impose types of environmental pollutions to the society, such as air, water, soil pollution and types of environmental deteriorations and damages to buildings and facilities. However, they do not pay for these pollutions; they do not even consider these expenses in pricing their goods and services. In fact, these expenses are a fraction of production cost of goods and services called as external costs. The focus of this study is only on that part of external costs caused by air pollution and merely that part of air pollution caused by combustion to

provide thermal energy required for factory towers. Hereafter, the term "external costs" refers to the external cost due to the above-mentioned part.

**Modified Model for Calculating Weight of Pollutants**

As noted above, four different methods are able to explain the amount of emissions from combustion process by constraining real world and accepting some assumption. This research uses fuel analysis based on the law of mass conservation. Prior to modifying the model used by this study to achieve the weight of pollutants, it is necessary to explain the types of fuels used in the factory as well as chemical process of their combustion. Then, the weight of pollutants will be calculated based on a modified model.

Mazut or fuel oil is a fraction of distilled crude oil. Fuel oil is mainly a liquid for burning in furnaces, boilers or engines used in power generation. Mazut is composed of long-chain hydrocarbons, particularly cycloalkanes and aromatics. Natural gas is the other fuel used in Tolypers. Methane is the main component of natural gas (95%). Other complexes include ethane, propane, butane, pentane, nitrogen, carbon dioxide and other gases. In addition, there is a small amount of sulphur compounds in natural gas. Since a major portion of natural gas is methane, properties of this fuel are very similar to methane gas. This fuel has a high calorific value and it cannot be stored. The fuel reacts quickly with air and does not cause smoke and soot.

The table below compares chemical components of natural gas, mazut and coal.

**Table 2: chemical components of natural gas, mazut and coal**

| Compounds | Natural gas | Mazut | Coal |
|---|---|---|---|
| Carbon | 74% | 84% | 41.11% |
| Hydrogen | 25% | 12% | 2.76% |
| Sulfur | --- | 3% | 0.41% |
| Oxygen | Very small | 1% | 9.89% |
| Nitrogen | 0.75% | Very small | 1.22% |
| Suspended particles | --- | Very small | 38.63% |
| Water | --- | Very small | 5.98% |

Now, the weight of main pollutants can be estimated by fuel analysis knowing concentration and atomic and molecular weights of pollutants involved in combustion of natural gas and mazut. This estimate is based on [1] called as the fundamental relation of fuel analysis presented in the theoretical background.

The information related to external cost of one unit air pollutant has been cited in terms of kilogram in energy balance sheet of the department of energy (2012). Considering the fact that mass balance equation is used to estimate the weight of pollutants emitted during a year in terms of kilogram, it is necessary to calculate the values of consumed fuel (11966204$m^3$ natural gas and 650000lit mazut) using density of the fuels during the considered year in terms of kilogram. This is done in Table 3 below. Table 4 reports weight of pollutants emitted from a fuel during a year and total sum of these pollutants resulting from both fuels.

**Table 3: volume, density and weight of fuel consumed during 2011**

| Consumption and density | Natural gas | Mazut |
|---|---|---|
| The volumetric value of fuel consumption in 2011 | **11966204 $m^3$** | **650000 lit** |
| Density | **0.714 kg/$m^3$** | **0.9454 kg/lit** |
| The weight of fuel consumed in 2011, in kilograms | **8543870 kg** | **614510 kg** |

**Table 4: weight of pollutants emitted from fuels and total weight of these pollutants during 2011**

| Pollutant | Weight of pollutant generated per kilogram burned gas, in kilograms | Weight of pollutant generated per kilogram burned mazut, in kilograms | Weight of pollutant emitted from burning gas, in kilograms | Weight of pollutant emitted from burning mazut, in kilograms | Total weight of pollutants from burning gas and mazut during 2011, in kilogram |
|---|---|---|---|---|---|
| $CO_2$ | 2.713 | 3.080 | 23179518.4 | 1892690.8 | 25072209.2 |
| $SO_2$ | --- | 0.060 | 0.0 | 36870.6 | 36870.6 |
| $NO_x$ | 0.025 | --- | 213594.7 | 0.0 | 213596.7 |
| CO | Small | Small | 0.0 | 0.0 | 0.0 |

The unit cost method is a well-known estimation technique which is widely used in almost all areas of expertise and types of businesses. Under this method, the total estimated cost ($C_t$) can be found by multiplying the number of units (N) in a ratio called cost per unit (U). Based on this method, we have:

$$C_t = U \cdot N \quad [2]$$

This method requires that the unit cost coefficients are continually reviewed and revised or updated at short intervals, in accordance with the conditions. This will always show current situation and the changes in costs will vary time and inflation [16]. In order to calculate the external costs of major pollutants from burning process, the unit cost method will be used. To calculate external costs of major pollutant resulting from burning process, the cost unit method will be used. To be more precise, the number of air-polluting unit are called N and indeed is the number of kilograms or the same weight of emitted pollutants obtained from chemical calculations based on mass balance and fuel analysis by analyzing combustion of the considered fuels. Then, the external cost factor for each pollutant, called U, is achieved from the energy balance sheet. Since the unit cost coefficients should be updated to represent the current situation and the changes in costs vary in time and inflation, this study updates the coefficients of the cost, by considering the price indexes.

The table below represents the external costs of environmental degradation caused by consumption of fossil energy carriers in Iran. These costs are achieved by studies of the World Bank and Environment Protection Department in a report titled as environmental review of energy in Islamic Republic of Iran which is the major resource in calculations of external cost in energy balance sheet. It is noteworthy that this data is based on constant prices in 2002 (Energy Balance Sheet, 2011).

**Table 5: external costs imposed on society for pollutant gases based on constant prices in 2002, energy balance sheet**

| Year | The numerical value of price index of goods and services (CPI) | External costs per kg of $CO_2$, based on RLS | External costs per kg of $SO_2$, based on RLS | External costs per kg NOx, based on RLS | External costs per kg of CO, on Rails |
|---|---|---|---|---|---|
| **2002** | 75.1 | 80 | 14.600 | 4.800 | 1.500 |

Above numbers are in fact the same unit cost coefficients required for unit cost method. As already mentioned, the data and information listed in the table above are related to fixed prices in 2002; however, the unit cost method requires that the unit cost coefficients represents the current situation and the changes in costs vary time and inflation. The consumer price index measures the changes in a level of prices of goods and services purchased by households. Therefore, the coefficients of cost will be updated considering the CPI price index for the base year which is 2011 here. Now, the value of external cost related to pollutants can be calculated by current prices in 2011 as well as the total external cost generated in this year by Tolypers, as shown in the table below.

**Table 6: values of external cost of pollutants to current prices of 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 |

The results show that Tolypers Company imposed 14,700,880,737 Rials external costs on society during 2011. Let put this amount in front of weight 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 table shows the results of these calculations for a kilogram of powder.

**Table 7: values of annual production in 2011 and weight portion of different types of powder**

| Measure | Hand-washing | Machine-washing | Total |
|---|---|---|---|
| Tonnage of hand-washing powder, in kg | 758832 | 505888 | 126473.0 |
| Amount of produced powder in kg | 75883200 | 50588800 | 126472000 |
| Portion of weight from total production, in % | 60% | 40% | 100% |

**Table 8: 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 8 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 both process use the same tower; therefore, it is possible to separate the pollution caused by combustion whereby calculate the external costs of them separately. However, these two types of detergent powder have different private cost; thus, social cost estimation will be allowed separately. For this purpose, it is necessary to have the known values of private cost or the finished cost of a variety of powders. This information was provided by the accounting office . For this purpose, the cost of raw materials including active (active ingredient), STTP, sodium sulphate, sodium carbonate, sodium silicate, optical, CMC, essence, etc., are added together to obtain the total cost of consumables. Then, other costs including total cost of packaging, direct wages, overload, administrative costs, sales and 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 despite the external cost of both types of detergent powder due to identical towers. 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 detergent powder.

Furthermore, the contribution of each external and private costs can be calculated from social cost of each powder. Results show that the portion of external cost from social cost is relatively lower than the portion of private cost from social cost. To be more precise, these ratios are 1.40% and 0.83% for hand and machine powders, respectively.

## CONCLUSIONS AND RECOMMENDATIONS

Given the importance of calculating external cost of detergents, this study aimed to estimate their external, private and social costs. The overall results of the estimates are presented briefly. It is noteworthy that the estimates were made using data obtained in 2011.

Results of estimates show that external cost of producing 1kg detergent produced by Tolypers in 2011 has been 116.2 RLS in terms of current prices of the same year. Calculations showed that the private cost or finished cost of hand and machine powders of Tolypers Company in 2011 has been 8157.1 and 13752.1 of RLS, respectively. Thus, private, external and social costs 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 detergent powder.

Other results showed that the portion of external cost from social cost was relatively lower than the portion of the private cost from social cost. In other words, these ratios were 1.40% and 0.83% for hand and machine-washing detergents which are lower than the same ratios in electric generation industry with 20% and 40%.

Based on findings of this study and other related studies, the recommendations are as follows:

- To provide sustainable energy of natural gas for Tolypers to decrease the external costs of producing detergent powders (lack of sustainable natural gas can increase these costs)
- To use cleaner fuels when natural gas is not available
- Optimal utilization of fossil energies to provide complete combustion (studies show that incomplete combustion reduces the thermal efficiency to 70% and, naturally, it is necessary to

burn more fuel to provide the required heat, which means an increase in private costs and external cost of production)

- To improve the quality of the produced fuels
- To focus on production methods which are less polluting
- To pay subsidies for cleaner fuel by the government, in order to encourage producers to use these fuels
- To internalize the external cost of producing detergent powder into market price
- To provide opportunities for investments in production in order to provide cleaner technologies
- 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

For future studies, it should be noted that research in areas such as

- estimation of external cost due to other contaminants in the manufacturing process, such as water, soil pollutants, sour gas
- utilization of other valuation methods, other techniques for weight estimation of pollutants and other estimates of external cost in estimation of external cost for detergent powders
- time-series analysis of external cost to review the historical procedure of this variable during time in confronting restrictive environmental laws
- adaptive study of the ratio of external cost to production value on a single product in various companies to examine the environmental performance of different companies seem helpful for future studies.

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