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A Survey of Economic Indices of Plastic Wastes Recycling Industry (A case study)

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ABSTRACT

Numerous small recycling units of plastic wastes have been currently constructed heedless to study of economic indices in Iran. Pay attention to the prominent performance of the industrial sector for economic development and its priority for fortifying other sectors to implement job opportunities, survey of the economic indices beckon the stakeholders and industries owners. The main objective of this study was a survey of economic indices in small recycling unit of plastic wastes. Therefore, the practice of computing the economic indices was performed using empirical equations, professional experiences and observations in site of the industry in terms of sustainability performance. Current study had shown the indices values such as value-added percent, profit, annual income, breakeven point, value-added, output value, data value, variable cost of good unit and production costs were found 62%, $ 366558, $ 364292.6, $ 100.34, $ 423451.25, $ 255335.75, $ 678787, $ 389.65 and $ 314494.4 respectively. The breakeven point about 15.93%, the time of return on investment about 1.12 (13.7 months) were represented that this industry slightly needs long time to afford the employed capital and starts making a profit.

Keyword: Economic indices, Industry, Recycling, Plastic Wastes

Nomenclature	
PSW	Plastic solid wastes
HDPE	High Density Polyethylene
PET	Polyethylene Terephthalate
US	United States
MSW	Municipal Solid Waste
PE	Polyethylene
UK	United Kingdom
LDPE	Low Density Polyethylene
PP	Polypropylene
HP	Horse Power
KWH	Kilo watt hour

INTRODUCTION

The first industrial scale generation of synthetic polymers (plastics) started in the 1940. Nowadays the production, usage and waste generation amounts of PSW have been increased considerably. Plastics are a small quantity but significant components of the waste stream. It is encouraging to note that the amount of plastics being recycled have grown significantly. In 1997, about 700 million pounds HDPE bottles and 650 million pounds of PET bottles were recycled in the USA. In US, PSW found in MSW have increased from 11% in 2002 to 12.1% in 2007. In 2002, 388,000 tons of PE were utilized to produce various components of textiles, of which 378,000 tons were provided from PE discarded articles. Plastic consumption was 515,000 tons in Greece in 2002 with an increasing rate from 2001 to 2002 equal to 10.9% and the percent amount recovered and recycled was approximately 2.2%. Present statistics for Western Europe point the total annual consumption of plastic products out 48.8 million tons as 98kg per capita in 2003 while this rate approximately was 64 kg/capita in 1993. 61% of the plastic wastes generated disposed to landfill and the rest 39% recovered. The bigger percentage has been disposed for energy recovery (4.75 million tons, percentage 22%), while 15% were mechanically recycled (3.13 million tons), with only 2% recycled chemically (0.35 million tons). Over 78 weight percentages of this total devoted to thermoplastics (mainly Polyolefins, LDPE-17%, HDPE-11%, PP-16%) and the remaining to thermosets (mainly epoxy resins and Polyurethans). In the UK, 95% of PSW obtained from process scrap (250,000 tons) has been recycled in 2007 [1].

Polyolefins (LDPE, HDPE, PP) are a main kind of thermoplastic utilized throughout the world in such applications as bags, toys, containers, pipes (LDPE), house wares, industrial wrappings and film, gas pipes (HDPE), film, battery samples, automotive ingredients, electrical compounds (PP) or (greenhouses, mulches, coating and wiring, to packaging, films, covers, bags and containers). Thermoplastics encompass the total plastic consumption by roughly 80%, and are used for typical plastics applications such as packaging. Therefore, it is only reasonable to reach to a considerable amount of PSW in the final stream of MSW. The plastics are found in all major MSW categories, containers and packaging plastics represent the highest rate. In durable goods, plastics are used in appliances, furniture, casings of lead-acid batteries, and other products. In the UK, recent studies claim that PSW encompass 7% of the final waste stream. Packaging accounts for 37.2% of all plastics applied in Europe and 35% worldwide [2].

PSW recycling procedures could be classified in the four major categories, re-extrusion (primary), mechanical (secondary), chemical (tertiary) and energy recovery (quaternary). Each practice procures a unique set of privileges that make it particularly beneficial for certain locations, applications or requirements. Re-extrusion recycling is the re-introduction of scrap, industry or single-polymer plastic edges and parts to the extrusion cycle so that generate products of the analogous materials. This process utilizes scrap plastics that have analogous frames to the original products. An example of re-extrusion recycling is the injection moulding of out of specification LDPE crates. Nowadays, the most common procedure to retrieve of the PSW is via primary recycling techniques. Mechanical recycling is type of physical treatment, whilst chemical recycling and treatment generate feed stock chemicals for the chemical industry. Mechanical recycling of PSW can only be fulfilled on single-polymer plastics, especially for the case of foams and rigid plastics e.g. PE, PP, PS, etc. It is just an economic and viable route for PSW recovery. Energy recovery involves complete or partial oxidation of the compound to form heat, power and / or gaseous fuels, oils and chars as well as by-products that must be disposed. One of several practices of sorting PSW (especially in Asian recycling lines) is the density sorting. Separation, washing and preparation of PSW is all urgent to make up high quality, clear, clean and homogenous end-products. Grinding could be used to remove coatings, e.g. chrome from plated plastics can be eliminated by simple grinding, sometimes assisted with cryogenic practices to improve the liberation process and to impede the plating materials from being surrounded in the plastic granules. These cryogenic practices form excellent liberation, but the actual segregation of plastic particles from the paint is problematic. Crates that do not meet the properties are palletised and transferred into the recycling cycle or the final steps of the manufacturing [2, 3].

Numerous small recycling units of plastic wastes have been currently implemented heedless to study of economic indices, modern technologies and facilities are developing day by day in Iran. On the other hand, the plastic industry has properly assigned effective technologies for recovering, treating, and recycling of wastes from disposed products and regard to the number of existing industries in developing countries and the world, quality of obtained products and quantity of usage, it is necessary that focus on the performance, economic aspects of this industries and the sustainable development aspects. Damjan *et al*. have explained many descriptions of sustainability encompass the environmental performance, societal responsibility and economic assessments. Economic estimates of indices concerns the impacts of the industry on the economic identity of its stakeholders on layout feasibility to implement [4]. Economic study describes the different components of the financial and economic aspects of recycling plastic wastes and examines closely the associated costs. The major costs can be divided into organization and control costs incurred by the central office, collection cost and operational costs of the final storage facility prior to recycling costs. Cost computations are based on detailed estimate that reflects typical investment costs, interest rates, transportation costs, materials, equipments and fixed, working costs and etc to set up and recover the plastic wastes [5,6]. In present research was used for economic indices such as value-added percent, profit, annual income, breakeven point, time of return on investment, value-added, output value. Marchetti *et al*. have studied the economic indices such as evaluate productivity, raw material consumption, economic competitiveness and environmental impacts of each process [7]. Bradley *et al*. have discussed on the relationship between oil prices and some of key macro-economic variables. Also, investigation on the crude oil prices on output, prices of consumer, unemployment, and stock [8]. The main objective of the present study was a survey of economic indices in a plastic wastes industry. To achieve for this purpose, was surveyed requirements of the industry as a case study.

MATERIALS AND METHODS

In the current study was determined a working shift of 8 hours per day, for 270 working days per year. The required electrical energy and water were calculated on 300 working days per year. The required water was calculated 100 L/person – day. Total daily required water for the fire fighting was calculated by a factor of 1.5. The salaries of the staff were computed for 14 months including 23% of total salaries for insurance costs and pensions with $ 100 transportation costs per month, for each individual. In present research was neglected from getting a loan. The equipments cost which contributes to the capital costs was calculated from the data of the market of Tehran, professional experiences, collected data and observations in site of industry in West Azarbaijan, Iran. In current study all requirements have been supplied from Iran and there was not any import. Finally, economic evaluation was performed with empirical equations 1 to 11 [9,10].

$$Q = MC'T \quad (1)$$

$$W = 0.75(\sum e) \times A \quad (2)$$

$$C = 0.005 \times P \quad (3)$$

$$V = p - ((\sum)e + A' + F + Cf) \quad (4)$$

$$\%V = V \times 100 / p \quad (5)$$

$$Qp = V - ((\sum)I + L + D + S) \quad (6)$$

$$Cv = Cvd / Cp \quad (7)$$

$$Ph = Tf / Cv - Cs \quad (8)$$

$$Cpi = Cvp + Cfp \quad (9)$$

$$Ai = Ts - Cpi \quad (10)$$

$$Vt = If / Ai \quad (11)$$

In equations 6 to 16, Q, M, C, T, W, e, A, C, P, V, A, F, C_f, Q_p, I, L, D, S, C_v, C_{vd}, C_p, P_h, T_f, C_s, C_{pi}, C_{vp}, C_{fp}, A_i, T_s, V_t and I_f, are the required heating rate (kj), flow rate (m^3/h), thermal capacity, temperature (k), required electrical energy, sum of electrical energy consumption (facilities, manufacturing line apparatus, building and campus), area (m^2), selling costs, selling price, value-added, initial materials (Additives, materials, packages), maintenance, unforeseen costs, profit, insurance, cost of interest and fees, depreciation, salary, variable costs of good unit, variable project costs, production capacity, breakeven point, total fixed costs, selling cost of good unit, manufacturing costs, variable manufacturing costs, fixed manufacturing costs, annual income, total selling price, time of return on investment and fixed capital respectively [11,12].

RESULTS AND DISCUSSION

The steps utilized to retrieve the plastic wastes encompass major four steps. Operational processes of all steps contain the following has been explained.

1-Sorting Wastes (First step)

Plastic wastes are classified after collecting based on the types of materials such as PE, PP, soft and hard degree.

2-Crushing and grinding (Second step)

The soft and hard compounds should be crushed individually by different mills. The obtained particles are often altered based on its usage is usually applied as it has a size of less than one inch.

2.1-Washing

The ingredients produced from the crushing and grinding should be washed. Soda or conventional detergent powders can be applied so that washing that consumption amounts depend on the circumstances of wastes. Usually, an average of half a gram of detergent for each kg of plastic wastes are sufficient.

3-Dewatering and drying (Third step)

The particles are cleaned with water and moisture that is how they must be dried in the heating furnace or passed through evaporation in the evaporator of the winding machine granulator.

4-Granules (Fourth step)

To prepare the milled particles for use in downstream apparatuses or to incorporate with raw materials the grinding particles washed must be converted as cubes or granules. Then, extrusions are utilized for pelletizing are three kinds for PET or PVC (ABC, PC, HIPS, PP, AS, PE, etc). The bulk of dyes and pigments can be added to plastics in the present step. The aforementioned shear system which utilized to process on initial wastes is cooled by gas.

4.1-Extrusion moulding

PSW flakes or particles are molten and extruded through a mould by single or twin screws to make a new framework up. Products from this process encompass pipes, sheets, film and wire covering.

4.2-Injection moulding

Heated molten PSW are injected into a mould to solidify and make the product up expected. Products made this procedure encompass washbowls, buckets and plastic models to larger products such as bumpers and pallets.

4.3-Blow moulding

A hollow plastic melt produced by extrusion or injection is joined in a mould, and swelled with air to form bottles for all types of uses, such as shampoo bottles.

4.4-Vacuum moulding

A heat-softened sheet is occupied in a mould, and the hollow space between the sheet and mould is insulated and discharged to make products up such as cups and trays.

4.5-Inflation moulding

Extrusion moulding is used where a molten PSW is swelled into a cylinder to make a film up. This procedure is used to make products such as shopping bags.

Figure 1 represents the layout of recycling unit of plastic wastes in the case study industry [13, 14].

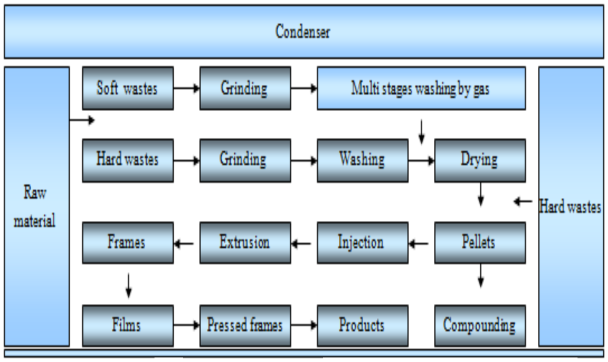

Fig. 1: Layout of recycling unit of plastic wastes (Source: this study)

Pellets (very low density), grinded pellets are products of plastic wastes recycling industry. These types of materials can be used in some applications such as additives of bituminous and polymer materials as modifier of asphalt and so many other usages. Requirements of plastic wastes industry as case study was estimated according to Table 1.

The investment rates to set up an industry unit are estimated by fixed and working capitals. Table 2 represents the fixed and working capitals.

Table 1: Requirements of plastic wastes recycling industry

Main annual material and equipments	Total annual rates	Total cost $
Conveyor system 2.5 meters	1 Number	1272.6 [a]
Stainless steel washing chamber (2m^3)	1 Number	1908.9 [a]
Automatic dewatering machine (2 m^3 Stainless steel)	1 Number	3817.8 [a]
Drying machine equipped to flame and fan (1 m^3 Stainless steel)	1 Number	2757.3 [a]
Device to produce the pellets (Twine, 100 kg / hour)	1 Number	1230.6 [a]
Storage cone (Length= 2 meters)	1 Number	222.6 [a]
Packaging machine (50 kg packs)	1 Number	2545.2 [a]
Screening	1 Number	2227 [a]
Condenser	4 Number	882 [a]
Grinding machine equipped to washing machine (500 kg / hour- automatic 40 Hp)	1 Number	5408.5 [a]
Poly propylene or polyethylene wastes with low density (LDPE)	1000 tons	90909
NaCo$_3$ (0.5 g per kg wastes)	0.5 tons	150
50 kg packages	12600 Number	126000
Grinded pellets	400 tons	400000
Pellets (Very low density)	230 tons	278787
Required electrical energy	538200 (KWH)	6727.96
Required water (6 m^3 / day)	1800 m^3	124.1
Water supply facilities		15625
Split AC (Internal wiring, transformers and emergency power generators)		13125
Fire extinguishers (Total)	54 Number	3402
Stoves (Total)	4 Number	120
Cooler (Total)	2 Number	60
Ventilation system (Total)	7 Number	140
Office equipments, furniture and etc	-	2500
Lab equipments (for quality control)	-	5000
Transportation (A vehicle weighing 4 tons, car and fork)	3 Number	40000
Staffs salary	9 Persons	30000
Required fuel (Stoves)	1080 L	162
Petroleum expenses (Transportation vehicle and cars)	16200 L	3544
Required land	7600 m^2	38000
Construction of infrastructure (Buildings)	2175 m^2	217500
Pavement and asphalt	2771 m^2	26844
Landscaping	1000 m^2	1000

[a] With 5% cost of installation

Table 2: Fixed and working capital

Fixed capital		
Description		**Costs $**
Required land, landscaping, buildings, pavement and asphalt		283344
Investment in facilities		39972
Investment in equipments and the installations costs		22272.5
Investment in transportation cars (A vehicle weighing 4 tons, car and fork)		40000
Unforeseen costs	3% investment (Fixed and working capitals)	12937.42
Costs before of the operation		10011
Total cost		408536.92

Working capital			
Description	**Time**		**Cost $**
Additives, packages and required materials*	45 days		35176.5
Energy consumption (Water, fuel, petroleum and electrical costs) *	65 days		2541.74
Staffs salary *	68 days		5589
Other costs	-	5% costs (∑*)	2165.4
Cost of sales	20 days		185.96
Total cost			45658.6

According to the Table 2 the cost of additives, packages and required materials include the NaCo3, PSW, packages (50kg). The cost of energy consumption contains the water, fuel, petroleum and electrical costs. Sum from costs related to the water supply facilities, Split AC (Internal wiring, transformers and emergency power generators), Fire extinguishers (Total), stoves (Total), Cooler (Total), Ventilation system (Total), Office equipment, furniture and etc and Lab equipments (for quality control) are called the investment in facilities. Cost before of the operation includes the costs related to initial studies, training, pilot, running, operating period and etc. In an industry are calculated costs for depreciation, maintenance, operational and non-operational. Table 3 represents the depreciation costs, maintenance, operational and non-operational fixed annual capital.

Total costs of manufacturing are equaled with sum from fixed and variable manufacturing costs. Tables 4 and 5 show total fixed, variable manufacturing costs and total manufacturing price respectively.

Table 3: Depreciation costs, maintenance, operational and non-operational fixed annual capital

Description	**%Rate**	**Capital value $**	**Costs of maintenance $**
Landscaping, buildings, pavement and asphalt	2	245344	4906.88
Facilities and equipments	10	39972	3997.2
Equipments without installations costs	5	21158.87	1057.95
Office equipments, furniture, etc	10	2500	250
Transportation cars (A vehicle weighing 4 tons, car and fork)	10	40000	4000
Unforeseen cost	5	11384.93	569.3
Total cost			14781.33

		Depreciation costs of fixed capital	
Description	**Depreciation rate**	**Capital value $**	**Cost of depreciation$**
Equipments without installations costs	10	21158.87	2115.88
Landscaping, buildings, pavement and asphalt	5	245344	12267.2
Office equipments, furniture and etc	20	2500	500
Transportation cars (A vehicle weighing 4 tons, car and fork)	10	40000	4000
Facilities and equipments	10	39972	3997.2
Costs before of the operation	20	10011	2002.2
Unforeseen cost	10	12937.42	1293.742
Total cost			26176.22

Table 4: Total fixed and variable manufacturing costs

Description	%Fixed cost	Cost $	%Variable cost	Cost $
Additives, packages and required materials	-	-	100	217059
Maintenance of fixed annual capital	10	1478.133	90	13303.2
Energy consumption (Water, fuel, petroleum and electrical costs)	20	2111.6	80	8446.4
Unforeseen cost of fixed capital	-	12937.42	-	-
Staff salary	85	25500	15	4500
Depreciation of fixed capital	100	26176.22	-	-
Interest and fees	100	-	-	-
Insurance (0.2% of total investment)	100	817	-	-
Unforeseen costs of working capital	-	-	-	2165.4
Total cost		69020.4		245474

Table 5: Total manufacturing price

Description	Cost $
Additives, packages and required materials	217059
Staffs salary	30000
Energy consumption	10558
Maintenance cost	14781.33
Depreciation of fixed capital	26176.22
Cost of insurance	817
Cost of interest and fees	-
Unforeseen costs*	5987.9
Total cost	305379.5

*(2% total manufacturing costs)

According to the Table 5 2% sum from costs related to additives, packages and required materials, staffs salary, energy consumption, maintenance cost, depreciation of fixed capital, cost of insurance and cost of interest and fees are called unforeseen costs and sum from all prices are the total manufacturing costs in this Table. Table 5 represents that total manufacturing price is equal with 305379.5 for two products. The required selling price is the price of the products which are required to encompass all costs (variable, fixed and overhead), recover the total investments and provide the specified return of the employed capital. In the end, Table 6 shows economic indices.

Rates of value- added, value- added percent, profit, annual income, breakeven point, time of return on investment and investment rate are mainly economic indices. The time of return on investment is the least time that will prosecute high profit as well as environment protection, business and sustainable development aspects. Analysis of breakeven point identifies the relationship between costs and incomes. Using of this practice in the present study represents the time of return on investment clearly. The breakeven point is shown fixed and variable costs of the project at contrast with the running income. The breakeven point prosecutes the lowest level of production which at this level profitability advents and at this level income of industry ample surrounds the fixed and variable costs. In an industry is indispensable figuring the breakeven budget out to identify an expected market price for products at some points in the future or to assess the choice of retained ownership or sale of products.

Table 6: Economic indices

Economic indices	Cost $
Data value	
Grinded pellets	400000
Pellets (Very low density)	278787
Total value of annual selling of products	678787
Output value	
Additives, packages and required materials	217059
Maintenance	14781.33
Energy consumption	10558
Unforeseen costs of fixed capital	12937.42
Total cost	255335.75
Value- added	423451.25
Value- added percent	62%
Profit	366558
Variable cost of good unit	389.65
Breakeven point	15.93%
Production cost	314494.4
Annual income	364292.6
Time of return on investment	1.12

Based on the studies of technical and economical view-point by Jonidi *et al.* the indices values such as value-added percent, profit, annual income, breakeven point, value-added, output value, data value, variable cost of good unit and production costs were found 56.34%, $2795396.8, $2775522.94, $260.83, $2955795.3, $2289986, $5245781.3, $535 and $2470258.36 for the used motor oil reprocessing industry equipped to acidic sludge recycling unit respectively. The breakeven point about 6% and the time of return on investment about 0.26 (3.2 months) represented the economic success of the project [15]. In other research by Jonidi *et al.* the indices values such as value-added percent, profit, annual income and breakeven point value-added, output value were obtained to be 68.2%, $ 249552.5, $ 248370.5, $ 131.4, $ 285134.75 and 132521.5 respectively. A low breakeven point is about 14.7% and the time of returns on investment 1.05 (about 13 months) also were indicative of the economic success of the project recycling acidic sludge to bitumen [16]. Iranian industry organization (2000) had reported the breakeven point percent, time of return on investment and value-added percent 22.5%, 0.9 (11 months), 36.3% respectively, for used motor oil reprocessing industries without acidic sludge recycling unit.

Van Kasteren *et al.* have been studied on the conceptual design of a production process with sensitive key factors such as the raw material price, plant capacity, glycerol price and capital cost in the conversion of waste cooking oil to biodiesel for three plant capacities (125,000; 80,000 and 8000 tons biodiesel/year) with the existing alkali, acid catalyzed and a supercritical trans-esterification processes. The economic assessment showed that biodiesel can be sold at US$ 0.17/L (125,000 tons / year), US$ 0.24/L (80,000 tons / year) and US$ 0.52/L for the smallest capacity (8000 tons / year) [17]. Zhang *et al.* showed that for three biodiesel plants with capacities 100,000 (1994), 7800 (1996) and 10,560 (1999) tons / year the breakeven prices $ / ton 340,763, 420 were found respectively, on the economic feasibilities of three continuous processes to produce biodiesel, including both alkali- and acid-catalyzed processes, using waste cooking oil and the standard process using virgin vegetable oil as the raw material [18]. Richard *et al.* to decline four water quality indicators (sediment yield, surface runoff, nitrate in surface runoff and edge-of-field erosion) so that growth Switchgrass showed that was produced between 527,000 and 1.27 million metric tons of Switchgrass per year on cropland in the Delaware basin in Kansas. The break-even price per Mg was calculated around $41 without used nitrogen to slightly less than $ 25 at 224kg N haKh-1 used. Most rates of break-even had a $ 30 Mg-1 or less [19].

Haenlein has reported the breakeven point 30, 37, 38% of total milk production in commercial factories with three types of classification (840.44, 991.16 and 982.87 liters) such as large, medium and small respectively. These breakeven points show that the small Livestock owners can cover its total costs in comparison with livestock owners of medium and large easily [20]. Cutler based on research on the oil extraction costs reported that decrease in the oil rates and energy return on investment has been raised to the energy costs of extraction of petroleum in the US. Energy return on investment covers the ratio of energy delivered to energy costs [21]. Greene *et al.* represented that a feebate rate of $ 500 per 0.01 gallon per mile produces a 16 percent increase in fuel economy and 29% around $ 1000 so. Saving fuel for 3 years declines unit sales about 0.5%. But sales will follow an increase, because the added value of implementation fuel economy technologies outweighs the decrease in sales [22]. Gonzalez *et al.* showed cost of $ 0.49 L^{-1} of ethanol, cash cost of $ 0.46 L^{-1} and CAPEX of $ 1.03 L^{-1} of ethanol on the technical and financial performance of high yield Eucalyptus biomass. The main costs encompass the biomass, enzyme, tax, fuel, depreciation and labors. Profitability of the process is very depending on biomass, carbohydrate percentage in biomass and enzyme cost [23]. Haas reported that generation cost of soap-stock biodiesel is US$ 0.41/L and about 25% less and biodiesel generated from soy oil [24]. Song *et al.* represented that based on studies on the costs of raw materials and the potential market, the petroleum-based succinic acid process will be replaced by the fermentation succinic acid production system in the close future [25]. Banat *et al.* reported on the key factors such as membrane lifetime and plant lifetime to treatment water, the estimated cost of potable water procured by the compact unit was $15/m^3, and $18/m^3 for water produced by the large unit [26].

CONCLUSION

The study of economic indices represent the confidence of performance the industries and job opportunities. The results of this research showed that these industries have important role in economic cycle of country and decrease huge quantity of plastic wastes and conversion the wastes to valuable products due to available numerous small industries in Iran.

ETHICAL ISSUES

Ethical issues have been completely observed by the author

COMPETING INTERESTS

Author has no conflict of interests

AUTHORS' CONTRIBUTIONS

Author himself completed the design, conduct of the study, drafting, revising and approving of the manuscript.

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