International Journal of Theoretical & Applied Sciences, **4**(2): 95-101 (2012)

ISSN No. (Print) : 0975-1718
ISSN No. (Online) : 2249-3247

A Goal Programming Approach in Dairy Waste Minimization

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(Received 21 September, 2012, Accepted 22 October, 2012)

ABSTRACT: Environmental risk production planning and decision making is needed to analyze several alternatives in terms of multiple non commensurate criteria which involve conflicting preferences of different stakeholders.
In this paper, a goal programming model for tracking and tackling such environmental risk production planning problem that includes minimization of damages and wastes in the milk production system has been proposed. This model is explained by taking "SARAS" dairy production system in India.

Keywords: dairy, goal programming, production planning.

I. INTRODUCTION

Demand for milk and milk products in many countries have lead to advancements in veterinary science. This has caused vast growth of dairy industries in most countries of the world. Consequently, the amount of wastewater and waste material generated and discharged from these industries has also increased. The environmental impacts associated with the primary production of milk and the subsequent processing of dairy products.

It is estimated that about 2% of the total milk processed is wasted into drains (Munavalli and Saler [8]). The dairy industry is one of the most polluting of industries, It generates about 0.2–10 liters of effluent per liter of processed milk (Vourch *et al.* [12]) with an average generation of about 2.5 liters of wastewater per liter of the milk processed (Ramasamy *et al.* [9]).

Dairy industries discharge wastewater and waste material which is characterized by high chemical oxygen demand, biological oxygen demand, nutrients, and organic and inorganic contents. Salt and various chemicals is critical ingredient used in the manufacture of various dairy products. They aid in the expulsion of whey, controls microbial growth, and provides flavor. However, these chemicals contain chloride and other various toxic substances. High concentrations of these salt and chemicals may be injurious to people suffering from heart, kidney and other diseases.

Such wastewaters and waste material, if discharged without proper treatment, severely pollute receiving water bodies. The minimization of waste and reductions in material and energy inputs are the most important environmental aims. The various recent advancements in the treatment of dairy wastewater and the areas where further research is needed have been identified have been discussed by Kushwaha *et al.* [6].

Watkins and Nash [13] examine the properties of dairy factory wastewaters, their potential effects on land to which they are applied, and biological marker compounds that could be used to trace any contaminants that may be discharged off-site and potentially contribute to environmental degradation.

Vourch *et al.* [12] presented a work which was related to investigations about practices of water management of 11 dairy plants. Treatment of the process water produced in the starting, equilibrating, stopping and rinsing processing units was proposed to produce water for reuse in the plant and to lower the effluent volume. Mann [7], Robinson [10], Habteselassie *et al.* [5] and Danalewich [4] discussed in detail about dairy waste, real value of waste, waste minimization, treatment of waste and reuse after waste treatment. Bumble [2] discusses using computer simulation programs to solve problems in plant design before they occur. He covers design issues for stationary and non-stationary sources of pollution with

Computer Simulated Plant Design for Waste Minimization/Pollution Prevention.

Brião *et al.* [1] presented a Work to identify the effluent is generating areas in a dairy company for purpose of changing concept pollution prevention. Methodology consisted measuring volumes and collecting samples effluents production sectors.

Cagno *et al.* [3] given a concept "reduction at source", based on idea that generation pollutant can be reduced or eliminated by increasing efficiency in use raw materials, energy, water and other resources.

Mathematical techniques play an important role in waste minimization. Sharma *et al.* [10] suggested a goal programming model for solving environmental risk production planning problem in dairy production system.

The main environmental impacts related with all dairy processing activities which are the high consumption of water, the discharge of effluent with high organic loads and the consumption of energy. Solid wastes, refrigerants, hazardous wastes, noise, odor and solid wastes may also be concerns for some plants.

Dairy waste can be minimize through a procedure

Avoid all sources those create waste

⇩

Reduce waste

⇩

Reuse waste material

⇩

Recycle waste material

⇩

Treat and dispose

II. PROBLEM DESCRIPTION

In particular, the goal programming problem formulation for dairy waste minimization considered in this paper is stated as follows. We are given

1. In sequence of dairy waste minimization, 11 market oriented dairy product have been considered.
2. In problem formulation dairy products are representing by 11 decision variables, shown in Table-1.
3. Our study focused on 9 goals direct or indirect related to dairy waste minimization, define as-

   Goal 1: Production requirement
   Goal 2: Raw milk utilization
   Goal 3: Salt utilization
   Goal 4: Electricity utilization
   Goal 5: Steam consumption
   Goal 6: Oil expenditure
   Goal 7: Recycling cost
   Goal 8: Reuse of recycled waste water
   Goal 9: Cleaning cost

4. Other constraints towards attainment of the above goals are given as-

   (a) Refrigeration capacity,
   (b) Man power requirement.

5. Dairy product and their production targets (assumption base) shown in Table 1. Over production, as market requirement increase storage capacity and increment in storage capacity create liquid and solid wastage and least production not fulfill market requirement so we will minimize deviational variables (d_k^-, d_k^+, k = 1,2,…,11) in order to avoid over and under achievement of production requirement goals.

TABLE-1			
Decision Variable	**Product Specification**	**Aspiration Level (kgs)**	**Notations**
X_1	Whole milk	65350	b_{1WM}
X_2	Toned milk	193448	b_{2TM}
X_3	Standardized milk	45819	b_{3SM}
X_4	Skimmed milk	17995	b_{4SKM}
X_5	Skimmed milk powder	11150	b_{5SMP}
X_6	Flavored milk	10356	b_{6FM}
X_7	Butter	37972	b_{7B}
X_8	Ghee	36100	b_{8G}
X_9	Cream	10234	b_{9C}
X_{10}	Cheese	13245	b_{10CH}
X_{11}	Lassie	12123	b_{11L}

TABLE-2		
Targets Description	**Notations**	**Aspiration Level**
Raw milk utilization	b_{12RM}	3.42969
Consumption of steam	b_{13CS}	1.30000
Electricity utilization	b_{14EU}	0.29800
Salt utilization	b_{15SU}	0.00380
Oil expenditure	b_{16OE}	6.00000
Recycling cost	b_{17RC}	2.70800
Reuse of recycled waste water	b_{18RW}	1.60000
Cleaning cost	b_{19CC}	2.90231

6. Other goals (goal 2 to 9) and their aspiration level with notation given in Table 2. In order to minimization of dairy waste, Raw milk utilization, Salt utilization Electricity utilization, Steam consumption, Oil expenditure Recycling cost, Reuse of waste water after recycling Cleaning cost should be minimize, so we will minimize deviational variable (d_k^+, k = 12,13,…,19), in order to avoid over achievement of goals (goal 2 to 9).

7. Required resources and quantity available with notation shown in Table 3.

8. Contribution of decision variables in each goal shown in Table 4, all numerical values based on our assumption.

Cost contribution of each decision variable in recycling process calculated as-

- **i.** First find total quantity of waste (liquid and solid) comes from each product.
- **ii.** Calculate contribution ratio of each product in total waste.
- **iii.** Distributed total cost of recycling process in contribution ratio of each product.

Similarly, cost contributions of each product in cleaning process have been calculated in same manner.

TABLE-3

Resources Description	**Notations**	**Quantity Available**
Refrigeration capacity	A_{RCa}	0.26200
Man power	A_{MP}	0.00900

TABLE-4

Contribution of Decision Variable	**Decision Variable**										
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
C_{RM}	0.02050	0.58900	1.48000	0.05760	0.00000	0.00000	0.00000	0.00000	0.18133	0.00000	0.00000
C_{CS}	0.01200	0.01300	0.01100	0.01000	0.02500	0.01800	0.75000	3.84200	0.01150	0.00900	0.01900
C_{EU}	0.01900	0.02000	0.01800	0.01500	0.05600	0.06750	0.09000	0.34600	0.01600	0.01950	0.01100
C_{SU}	0.00015	0.00017	0.00014	0.00013	0.00028	0.00035	0.00026	0.00085	0.00042	0.00016	0.00023
C_{OE}	0.15168	0.16400	0.13900	0.12640	0.31600	0.22750	0.94800	48.5800	0.11898	0.15340	0.32300
C_{RC}	0.18133	0.19229	0.16300	0.11400	0.30100	0.27600	0.33126	0.55126	0.14140	0.22517	0.29150
C_{RW}	0.13133	0.11222	0.14143	0.10540	0.21123	0.05126	0.07132	0.03133	0.23133	0.28125	0.25550
C_{CC}	0.41122	0.37290	0.40990	0.22127	0.20222	0.26133	0.25590	0.20998	0.21737	0.23630	0.19392
C_{RCA}	0.02400	0.02500	0.02300	0.02100	0.09500	0.03400	0.00000	0.00000	0.01900	0.02500	0.01800
C_{MP}	0.00001	0.00009	0.00009	0.00002	0.00300	0.00125	0.00278	0.00277	0.00007	0.00037	0.00040

III. GOAL PROGRAMMING PROBLEM FORMULATION

Formulating the objectives (goals) and the constraints towards attainment of the objectives (goals) using the goal programming as-

$$\text{Minimize } z = \sum_{k=1}^{11} (d_k^- + d_k^+) + \sum_{k=12}^{19} (d_k^+)$$

Goal constraints

Goal 1: Production requirement

$$X_1 + d_1^- - d_1^+ = b_{1WM}$$

$$X_2 + d_2^- - d_2^+ = b_{2TM}$$

$$X_3 + d_3^- - d_3^+ = b_{3SM}$$

$$X_4 + d_4^- - d_4^+ = b_{4SKM}$$

$$X_5 + d_5^- - d_5^+ = b_{5SKMP}$$

$$X_6 + d_6^- - d_6^+ = b_{6FM}$$

$$X_7 + d_7^- - d_7^+ = b_{7B}$$

$$X_8 + d_8^- - d_8^+ = b_{8G}$$

$$X_9 + d_9^- - d_9^+ = b_{9C}$$

$$X_{10} + d_{10}^- - d_{10}^+ = b_{10CH}$$

$$X_{11} + d_{11}^- - d_{11}^+ = b_{11L}$$

Goal 2: Raw milk utilization

$$F_{RM}(X) + d_{12}^- - d_{12}^+ = b_{12RM}$$

Goal 3: Salt utilization

$$F_{SU}(X) + d_{13}^- - d_{13}^+ = b_{13SU}$$

Goal 4: Electricity utilization

$$F_{EU}(X) + d_{14}^- - d_{14}^+ = b_{14EU}$$

Goal 5: Steam consumption

$$F_{CS}(X) + d_{15}^- - d_{15}^+ = b_{15CS}$$

Goal 6: Oil expenditure

$$F_{OE}(X) + d_{16}^- - d_{16}^+ = b_{16OE}$$

Goal 7: Recycling cost

$$F_{RC}(X) + d_{17}^- - d_{17}^+ = b_{17RC}$$

Goal 8: Reuse of recycled waste water

$$F_{RW}(X) + d_{18}^- - d_{18}^+ = b_{18RW}$$

Goal 9: Cleaning cost

$$F_{CC}(X) + d_{19}^- - d_{19}^+ = b_{19CC}$$

Capital Required Constraint

Refrigeration capacity

$$F_{RCA}(X) \leq A_{RCA}$$

Man power requirement

$$F_{MP}(X) \leq A_{MP}$$

Non–negativity Constraint and Complementary Constraint-

$X_i \geq 0,\ d_k^-, d_k^+ \geq 0,\quad d_k^- \times d_k^+ = 0,$ for all

$$i = 1, 2, 3, \ldots, 11 \text{ and } k = 1, 2, 3, \ldots, 19$$

Where

$F_{RM}(X) = C_{RM}\, X^T$, $F_{CS}(X) = C_{CS}\, X^T$, $F_{EU}(X) = C_{EU}\, X^T$, $F_{SU}(X) = C_{SU}\, X^T$, $F_{OE}(X) = C_{OE}\, X^T$, $F_{RC}(X) = C_{RC}\, X^T$, $F_{RW}(X) = C_{RW}\, X^T$, $F_{CC}(X) = C_{CC}\, X^T$, $F_{RCA}(X) = C_{RCA}\, X^T$, $F_{MP}(X) = C_{MP}\, X^T$ and $X = X_i \quad \forall \quad i = 1, 2, 3, \ldots, 11$

C_{RM}, C_{CS}, C_{EU}, C_{SU}, C_{OE}, C_{RC}, C_{RW}, C_{CC}, C_{RCA}, C_{MP} are Contribution coefficient of decision variable for goals. Notations and data (assumption based) have been given in Table-1, Table-2, and Table-3 respectively.

IV. SOLUTION

Above goal programming problem formulation solve by usual simplex method using Tora computer software. Weights corresponding to each decision variable and priorities corresponding to each goal are not consider in this study. After solution the values of decision variables and deviational variables (which represent under or over achievement of required goal) shown in Table- 5.

TABLE-5

Decision Variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Values	**65350**	**193448**	**36691**	**17995**	**11150**	**10356**	**37972**	**36100**	**10234**	**13245**	**12123**

V. DISCUSSION AND CONCLUSION

The values of decision variables shown in Table 5 and values of deviational variables had shown in Table 6. Result analysis shows that there is possible increase of 52.36% in Skimmed milk powder goal and decrease of 19.92% in standardized milk goal. Consumption of steam goal, oil expenditure goal, recycling cost goal and cleaning cost goal underachieved. While reuse of recycled waste water goal, salt utilization goal overachieved. Rest goals achieved their corresponding target values.

Goal programming technique provides better results in optimization problems. Study in this paper concludes that in order to waste minimization it proven a valuable tool. Presented work with goal programming problem formulation in this chapter provides better results in dairy waste minimization. Lac of practical data only 9 goals considered for dairy waste minimization. Presented goal programming formulation provides a framework in order to achieve many dairy and other industrial waste minimization goals by taking actual data. It can be extended to all the products with different grades and sizes. This can be applied to any industry for waste minimization having a number of end products.

TABLE-6

Deviational Variables	Values	Deviational Variables	Values	Deviational Variables	Values
d_1^-	000000	d_7^-	000000	d_{13}^-	0.29392
d_1^+	000000	d_7^+	000000	d_{13}^+	000000
d_2^-	000000	d_8^-	000000	d_{14}^-	000000
d_2^+	000000	d_8^+	000000	d_{14}^+	000000
d_3^-	0.09128	d_9^-	000000	d_{15}^-	14.81480
d_3^+	000000	d_9^+	000000	d_{15}^+	000000
d_4^-	000000	d_{10}^-	000000	d_{16}^-	0.00026
d_4^+	000000	d_{10}^+	000000	d_{16}^+	000000
d_5^-	000000	d_{11}^-	000000	d_{17}^-	0.28752
d_5^+	0.05839	d_{11}^+	000000	d_{17}^+	000000
d_6^-	000000	d_{12}^-	000000	d_{18}^-	000000
d_6^+	000000	d_{12}^+	000000	d_{18}^+	0.15823
		d_{19}^-	0.37266	d_{19}^+	000000

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