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Techno-Economic Evaluation of Chromium Recovery Pilot Plant Installed at Kasur Tanneries Complex, Pakistan

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1. INTRODUCTION

Chromium metal is widely used as a tanning agent worldwide. The process called chrome-tanning is accomplished in three steps: Pickling, Tanning and Basification1 (Pakistan Tanners Association). Chromium sulfate is the most widely used chemical in this process. Approximately, 60–70 percent of chromium sulfate applied is taken up by the hides and skins, while its 30 to 40 percent remains un-used and is discharged as a component of wastewater into natural water bodies such as rivers, streams, etc., which has adverse environmental impacts on living organisms particularly to humans and animals [Weitz and Luxenberg (n.d.)], and water animals such as fish [Eisler (1986)]. The diseases especially encountered in humans, are of nervous disorders. The pollution from tanneries effluent particularly their chromium component has formed the basis that many developed countries have banned tanning on their soils. Chrome tanned leather, being the need of people all over the world, has the edge that its manufacture cannot be stopped. This has given some economic advantage to some developing countries including Pakistan to manufacture leather and export it to the developed countries. To sustain, different methods have been developed to recover chromium from the tannery effluents before their drainage in the natural water bodies. A few examples of these methods are High Chrome Exhaustion, Direct Recycling of the Spent Tanning Float and Chrome Recovery and Reuse [Arrafay Labs (2003)].

The tanneries of Punjab, the largest province of Pakistan are mostly located in five major clusters: Sialkot, Lahore, Multan, Gujranwala and Kasur. These are being provided environmental services under "Introduction of Cleaner Technologies Programme—(ICTP) in Tannery Clusters of Punjab since December 1997 as joint ventures between different tanners associations of Pakistan and different national and international organisations for upgrading environmental conditions in and around the tanneries. Under these ventures different pollution abatement measures have been suggested and implemented in complexes and some also in individual tanneries. An important example of the measures suggested at the complex level is the Common Effluent Pre-treatment Plant installed at Kasur. Majority of the suggested measures at the individual tannery level are based on the principle of waste minimisation at source. Among the Cleaner Production Options/Technologies, one is Chrome Recovery. It can be accomplished as narrated above.

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Chrome recovery and reuse process, besides the elimination of environmental concerns related to chrome, has also economic benefits to the tanners as the chromium discharged as effluent component as claimed by Pakistan Tanners Association, can be 100 percent recovered . The recovery cost has been reported to be about 30 percent of the fresh chromium cost. The pay back period for the recovery of investment in the system applied has been reported as one year. It has been also claimed that the quality of chromium recovered and that of the leather prepared with its use meet the desired quality standards.

2. MATERIALS AND METHODS

The research methodology involved two major stages: Collection of Data and Data Analysis. These are described below.

2.1. Collection of Data

The primary information about KTWMA and Kasur Tanneries Pollution Control Project was gathered from a report published by KTWMA for general information about Kasur Tanneries Pollution Control Project (KTWMA) and from “Proceedings of the International Conference on Pollution in Tanning Industry of Pakistan”, held at Lahore on June 11 to 13 [KTWMA (2002)]. These two publications were extremely helpful in getting the information about the general situation of tanning industry in Pakistan, technology of effluent treatment to meet the requisite standards, methods and technology involved in chromium recovery , general benefits of the Kasur treatment plants, etc.

Next step was the organised visits to Kasur to see the main pretreatment plant recently installed by the cooperation of provincial, national and international governments, organisations and agencies to see the work-in-progress and to dig out information through interviews with the General Manager KTWMA and other concerned officials and to get detailed information about the Chromium Recovery Pilot Plant. The plant was visited, while it was in operation. All the sub-processes involved and the sub-process equipment were carefully viewed. A flow sheet diagram was, subsequently, constructed. The GM told us that it is an Italian Plant exactly the one, currently, in operation in Florence. The information about price of the machinery and equipment, cost of land and building, cost of labour and other inputs was provided by the Plant Supervisor by filling the questionnaire sent to them well before the dates of visits.

2.2. Data Analysis

The data were analysed by the standard techniques of project analysis [ADB (2001, 2003)]. Both expenditure and returns were projected over ten years that is the project life and discounted to the Base Year (1999-2000) at 10 percent discount rate as the plant started functioning in December 2000. From the discounted amounts, B/C Ratio and NPV of the Project were calculated, which were compared with the criteria for decision-making. The evaluation was also done by Payback Period Method to compare our results with the results reported by some workers who have carried out some studies in Pakistan.

2.3. Cost Analysis

The project evaluation was based on the following assumptions:

Project Life: 10 Years
Base-Year: 1999 (1999-2000)
Evaluation Year: 2004
Average Discount Rate in Pakistan: 10 percent
Starting and Closing of Financial Year: July 1 to June 30
Scrap Value of Machinery and Equipment: 10 percent of Suppliers Price.

2.3.1. *Initial Fixed Investment*

2.3.1.1. *Land*

Total Area = 2,500 Sq, ft (11 Marlas)
Constructed Area = 1,500 Sq ft
Open Space = 1,000 Sq ft
Cost of Land per Marla = Rs 45,000
Cost of Land = Rs 495,000

2.3.1.2. *Building*

Cost of Construction per Sq ft = Rs 700 per Sq ft
Cost of Construction =Rs 1,050,000
Cost of Construction of Drainage System for Feeding into Recovery Plant and Disposal of Treated Effluent = Rs 10,000
Original Estimated Cost of Electrical Works **=** Rs 116,800
Total **=** Rs **(**1,050,000 +10,000 +116,000) = Rs 1, 176,800

2.3.1.3. *Machinery and Equipment*

The details of plant machinery and electrical equipment are given below.

Cost of Plant Machinery, Equipment and Electrical Works (Table 1)	Rs 4,000,000
Site Visits for Civil Works by Contractors	Rs 150,000
Sales Tax	Rs 747,000
Laboratory Equipment	Rs 100,000
Total	Rs 4,997,000

Table 1

Original Estimated Cost of Electrical Works— Rupees

S.N.	Item Description	Qty (No)	Unit Price (Rs)	Amount (Rs)
1	TFM Breaker and Board	1	1,500	1,500
2	Breakers (Toshiba 4-6.3A)	16	350	5,600
3	Magnetic Switches(LG)-5.5 Kw	12	1,500	18,000
4	Main Board-Z.T Panel	1	3,000	3,000
5	Electric Motor-2HP	8	3,900	31,200
6	Electric Motor 2HP	2	2,500	5,000
7	Electric Motor ½ HP	2	1,500	3,000
8	Water Pump	1	4,500	4,500
9	Tube Lights and Other Items	25	Different Rate	45,000
				Total 116,800

2.3.1.4. *Vehicles: Two Motor Cycles* Rs 150,000

2.3.1.5. *Generators* Rs 400,000

2.3.1.6. *Pre-production Expenditure*

Project Supervisor	Rs 200,000
Assisting Staff	Rs 100,000
Consultants	Rs 500,000
Chemicals and Other Expenditure Before Commissioning the Plant (Five Trial Batches)	Rs 46,900
Total	Rs 846,900

Total Initial Fixed Investment = Rs (495,000 +1, 176, 8 00 + 4,997,000 + Rs150, 000 + Rs 400,000 +Rs 846, 900) = Rs 8.065,700

2.3.2. *Operating Cost*

The operating cost components and their costs are given below.

2.3.2.1. *Raw Material Cost:* The raw material is the effluent that is to be disposed off. Thus, there is no cost of the raw material.

2.3.2.2. *Cost of Other Inputs*

Chemicals = Rs I325 per Batch
Water = Rs 1100 per Batch.
Fuel for Generators, etc. = Rs 300 per Batch
Cost of Electric Power/Batch = Rs 60
Cost of Other Inputs per Batch =Rs 2785
Cost of Other Inputs per Annum = Rs 2785 X 240 = Rs 668,400
Cost of Filter Cloth, etc. = Rs 30,000
Total Cost per Annum = Rs (668,400 +30,000) = Rs 698,400

2.3.2.3. *Total Labour Cost per Annum* = Rs 69, 000 ×12 = Rs 828,000 (Table 2)

Table 2

Labour Cost per Month

	Number (No.)	Per Month (Rupees)
Plant Supervisor	1	20,000
Operators	2	28,000
Laboratory Assistant	1	8,000
Semi-skilled Labourer	1	5,000
Unskilled Labourer	1	4,000
Laboratory Attendant	1	4,000
Labour Cost per Month		Rs 69,000

2.3.2.4. *Maintenance Cost at 10 percent of Sale Price of Supplier*

Plant Machinery and Lab Equipment	Rs 410,000
Generators	Rs 40,000
Vehicles	Rs 15,000
Total Maintenance Cost	Rs 465,000

2.3.2.5. *Cost of Laboratory Reagents per Annum* Rs 100,000

2.3.2.6. *Depreciation at the Rate of 10 percent of Purchase*

Price (Plant Machinery and Equipment + Lab Equipment +Vehicles + Generators) Rs 554,700

Total Operating Cost per Annum =
Rs (698,400 + 828,000 + 465,000+ 100,000 + 554,700) = Rs 2,646,100

2.3.2.7. *Expenditure in the Base Year*

Initial fixed Investment = Rs 8,065,700
Operating Cost = Nil

2.3.2.8. *Expenditure in Future Years*

In future, no investment in terms of machinery and equipment will be involved. Operating cost as in the first year of operation (2000-2001) will be there in all the years. It may change with the change in salaries of the employees and change in the prices of other inputs such as utilities and requisites for maintenance. If it is assumed that the salaries of labour undergo an increase of 15 percent after every three years and prices of utilities and other requisites for maintenance undergo an increase in cost by 10 percent every year. The operating cost was calculated as below.

Operating Cost = Cost of (Labour +Utilities and Chemicals + Maintenance + Laboratory Reagents + Depreciation): The picture is presented in Table 3.

Table 3

Operating Cost in Future Years

Operating Cost = Cost of (Labour +Utilities and Chemicals + Maintenance + Laboratory Reagents + Depreciation):
2000-2001: Rs (828,000 + 698,400 + 465,000+ 100,000 + 554,700) =
Rs 2,646,100 Or Cost of (Labour + Depreciation + Utilities and Others)

	Labour	Depreciation	Utilities and Others	Operating Cost
2000-2001	828,000	554,700	1,263,400	2,646,100
2001-2002	828,000	554,700	1,389,740	2,772,440
2002-2003	952,200	554,700	1,528,714	2,911,414
2003-2004	952,200	554,700	1,681,585	3,188,485
2004-2005	952,200	554,700	1,849,744	3,356,644
2005-2006	1,095,030	554,700	2,034,718	3,541,618
2006-2007	1,095,030	554,700	2,238,190	3,887,920
2007-2008	1,095,030	554,700	2,462,009	4,111,739
2008-2009	1,095,030	554,700	2,708,210	4,357,940
2009-2010	1,259,285	554,700	2,979,031	4,793,016

2.3.3. *Benefits*

The benefits were calculated on the basis of the following data:
Volume of Effluent Processed per Batch = 10,000 M^3
Volume of Effluent Processed per Annum = 10,000 M^3* 240 = 2.400,000 M^3
Amount of Chromium Recovered per Batch = 150 Kg
Cost of Chromium Recovered per Kg = Rs 25
Cost of Chromium Recovered per Batch = Rs 3,750
Cost of Chromium Recovery per Batch = Rs 2,425 (Only chemicals and consumables considered)
Revenue Return per Batch =Rs 3,750 – Rs 2,425 = Rs 1,325
Revenue Earned per Batch if Only Chemicals and Consumables are Taken into Account = Rs 1,325*240 = Rs 318,000

2.3.3.1. *Revenue Return per Annum* **=** Rs 3,750 X 240 (Batches) =Rs 900,000

Pollution Charge per M^3 Received in the Form of Water Bills = Rs 4
Pollution Charges Received by KTWMA in the Form of Water Bills = Rs 2.400,000 * 4 = 9,600,000

There are overall seven parameters that are controlled by KTWMA by overall pre-treatment. If it is assumed that the charges received for Chromium per annum are one seventh of the total charges received, the benefit in this context may be as given below. These have been assumed not to change in future and thus will be in the form of constant annual cash flows.

2.3.3.2. *Revenue Received by KTWMA vs. Chromium Recovery* **=** Rs 9, 600,000/7 =

Rs 1,371, 429

Total Benefits in 2000-2001 = Rs (900,000 + 1,371, 429) = Rs 2,271,429
Scrap Value of the Machinery and Equipment = Rs 554,700

2.3.4. *Total Expenditure and Total Returns Discounted to the Base Year*

2.3.4.1. *Present Value of Expenditure*

The calculations of present values of expenditure and returns are done by applying the relationship:
Expenditure: Initial Fixed Investment +Operating Cost
Present Value of Operating Cost = Rs 20,754,726 (Table 4)
Present Value of Cash Outlays (Cost) = Rs (20,754,726 + 8,065,700) = Rs 28,820,426

2.3.4.2. *Present Value of Revenue Returns*

Present Value of Returns = Rs 13, 956,954
Present Value of Scrap = Rs 554,700*0.385543=Rs 213,861
Present Value of Cash Flows (Benefits) =Rs (13,956,954 + 213,861) =
Rs 14,170,815

$$\text{Benefit / Cost (B/C) Ratio} = \frac{\text{Present Value of Benefits}}{\text{Present Value Cost}} =$$

$$\frac{14{,}170{,}815}{28{,}820{,}426} = 0.5 \text{ (After rounding off)}$$

Net Present Value = Rs (- 28,820,826 + 14,170,815) = – Rs 14,650,011

Table 4

Present Value of Expenditures Discounted Top the Base Year

Initial Fixed Investment = Rs 8,066,100 Operating Cost-Year 1999-2000 = Nil

	Future Costs	Discount Factor	PV
2000-2001	2,646,100	0.909091	2,405,546
2001-2002	2,772,440	0.826446	2,291,272
2002-2003	2,911,414	0.751315	2,187,389
2003-2004	3,188,485	0.683013	2,177, 777
2004-2005	3,356,644	0.620921	2,084,211
2005-2006	3,541,618	0.564474	1,999,151
2006-2007	3,887,920	0.513158	1,995,117
2007-2008	4,111,739	0.466507	1,918,155
2008-2009	4,357,940	0.466507	1,848,194
2009-2010	4,793,016	0.385543	1,847,914

Total Rs 20,754,726

2.3.4.3. *Costing by the Application of Payback Period Method (PBP)*

The data requisite for computation of PBP is as follows:

Initial fixed investment = Rs 8.066,000

Cost of Land and Building = 1,545,000

Initial price of Machinery, Equipment and Generators =

Initial Fixed Investment—Cost of Land and Building = 8,066,000–1,545,000 = Rs 5,547,000.

Cost of land and building was not considered towards total investment as in our environment, these components fall into permanent assets of entrepreneur which rather appreciate with passage of time.

Annual Return = Total Benefits /Annum–Operating Cost /Annum–Scrap Value of Machinery and Equipment or

Annual Return = Rs (2,271,429–2,646,100–554,000) = Rs 180.029

The PBP was calculated by applying the following formula:

$$\text{Payback Period} = \frac{\text{Total Investment}}{\text{Annual Return}} = \frac{6{,}521{,}000}{1\ 80{,}029} = 36 \text{ (Rounded figure)}$$

Thus, the Payback Period will be 36 Years.

3. RESULTS AND DISCUSSION

The results are presented in two parts. The first part is purely descriptive research that presents our observations on the setup, technology, and functioning of the plant and the second presents the results of the data processed above.

3.1. Chromium Recovery Plant at Kasur

The Chromium Recovery Plant installed at Kasur is a pilot plant installed on experimental basis. It is in operation since December 2000 and is equipped with the capacity of processing $20M^3$ of the effluent per day. This has been a successful experience as it caters the need of 35 to 40 small tanneries. The chromium recovery is claimed as 99 percent and the cost of recovered chromium is 50 percent of the prevailing market price of basic chromium sulfate. The tanners of Pakistan have been motivated by installation of this plant and are planning to install such plants in the individual tanneries.

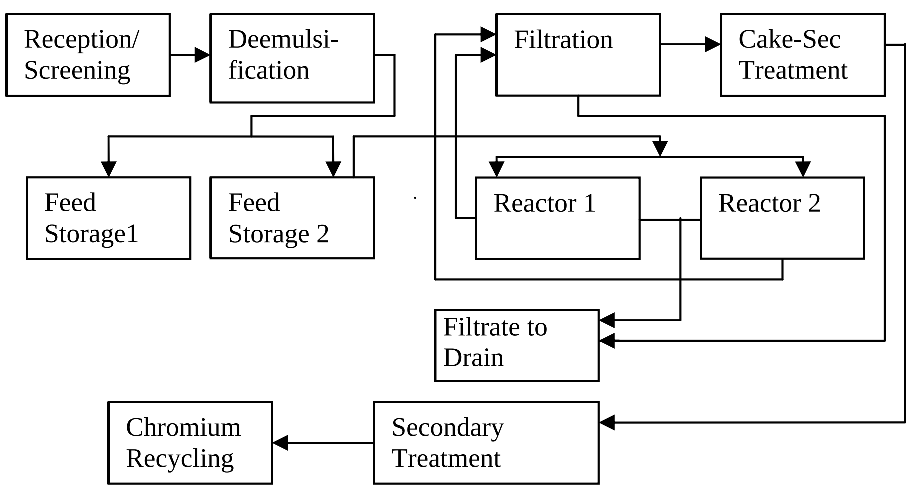
3.1.1. *Principle and Processes*

The Chromium Recovery Method is based on the principle that the chromium is present in the effluent in its trivalent form, and thus is generally insoluble at a pH of 8 to 12. It reacts with an alkali such as Ca O, Mg O, etc., and precipitates as chromium hydroxide [Cr $(OH)_3$]. The precipitate, after separation by filtration yields chrome sludge that when treated with sulfuric acid, forms soluble chromium sulfate, which can be reused after alkalification, as it is turned again into basic chromium sulfate.

3.1.2. Operations and Sub-processes

The operations and sub-processes involved in the Process of Chromium Recovery are self-explanatory as shown in Fig. 1.

Fig. 1. Chromium Recovery Plant Flow Sheet.



3.2. Benefit-Cost Ratio and NPV

Benefit to Cost Ratio is one of the important criteria for grading a project as non-profitable, profitable or socially acceptable. The decision rule is that if it is more than 1, the project is profitable and thus acceptable depending upon the expectation of the amount of profit by the investor. If it is less than one, it is non- profitable and thus not acceptable if it does not fall in the category of social obligations. In general, one can say that all such projects meant to produce salable goods for competing in a specific market must be rejected if the B/C ratio is less than1.

Let us see the situation in the light of the other criterion that is Net Present Value or NPV of the Project. The decision rule is that the project is acceptable if NPV is positive depending upon how much is the expectation of the entrepreneur. If it is negative, then project is rejected provided it does not fall in the category of social obligations. Usually, the projects meant to produce products for sale for competing in the market are straight away rejected if the NPV is negative. Of course, these may be considered for acceptance if their social cost is high and that is in terms of general social benefits such as cleanliness of environment, response to a community need if no other appropriate source is available, creation of employment opportunities, etc.

The cost analysis has led us to the B/C Ratio 0.5 and a negative NPV of Rs 14, 170,815. Both indices are far below the criteria for decision to accept the project. We see here that both indices deviate from the required values, roughly, by 50 percent. Thus, it may be clearly concluded that the installation is neither financially nor economically viable.

As the project falls in the social obligations of the tanners as they are required to process the effluent for elimination of chromium to meet the NEQS standards, they have to do it, even if, they have to make investment without expectation of any return. Thus, the study advises them to invest from their own resources without the expectation of any financial benefits.

We have not yet come across any study carried out on chromium recovery in Pakistan by the application of the Technique of Discounted Cash Flow. Thus, we cannot compare our results with any one with this reference.

3.3. Payback Period Results

The results of some studies have recently appeared either on internet or on the brochures of the suppliers of the chrome recovery plant machinery. These studies claim the payback period, five months to one year. That means that the initial investment is recoverable in less than a year. Thus it was considered to carry out cost analysis by Payback Period Method also.

Our calculation of payback period has led to alarming results. What to think of payback less than one year, here the payback is 36 years if the calculations are done without taking into consideration the fluctuating scrap values of plant and equipment. Why there is such an abnormal difference? Our observations and indications are as discussed below.

(1) Some workers have calculated the benefits of chrome recovery without consideration of all the cost elements. Some, unfortunately, have just matched

the cost of chromium recovered with the cost of chemicals and other consumables used. They have not considered the costs of land, building, plant itself and labour that go into millions (Here, more the Rs 7 million).

(2) As told by the General Manager KTWMA Project, the chromium recovery plant installed at Kasur is a pilot plant that was imported from Italy. It is exactly the same as one currently operating in Florence, Italy. Its cost is very high (Rs 4 million). This study indicates that its cost is the major factor in rendering recovery of initial fixed investment difficult. Pakistan Tanners Association, of course, has advertised in a brochure, titled "Chrome Recovery and Reuse" that presents some plants with capital costs varying from Rs 0.4 to 2.0 million depending on the size of production per day by the individual tanneries and nature of the skins and hides to be tanned. As the plant under study caters the needs of 30 to 40 tanneries, its equivalent can be a bigger plant. Those bearing price below Rs 1 million don't make the sense in context of the choice. If we choose midway between one to two million, say 1.5 million as the capital cost by changing machinery suppliers, still with this reduction in the capital cost, a payback of one year cannot be thought of.

(3) The plant under study, in spite of being under the control of KTWMA, is installed almost independently at a separate site in its own building. Its initial fixed investment also includes the cost of land and building (about Rs 1.6 million). It is also one of the important factors that contribute towards irrecoverable increase in the initial fixed investment. If such a plant is installed as a part of the tannery on one to one basis, it is possible that there may not be an investment on purchase of land and construction of building.

(4) Apart from above factors, another important factor is the labour that can be either shared between the main set up and the auxiliary set up or may be deputed from the former to the latter. For example, Supervisor of the main laboratory can look after the mini-lab of the chrome recovery plant. Similarly, the surplus unskilled labour and the semi-skilled labour, if available, can be deployed in the recovery plant on temporary or permanent basis. Thus the labour cost may be, significantly, reduced by integrating the recovery plant with main set up. There is the likelihood that the claimants of one year payback may be talking about such like integrated set ups. The Plant Supervisor at Kasur also hinted us about the lower cost of these set ups.

(5) Another important factor is the nature of technology and its choice. There are different options for making appropriate choices. The most general choice is the "Core Technology" purchased either on 'turn key' basis or installed through a contactor on commissioning basis. An alternative choice is "Synthetic Technology" that involves the break up of the core process into the sub-processes and purchase of machinery at sub-process level from local or foreign market and its installation by the local experts, by foreign experts or by local and foreign experts as a team. The substitution of imported components by the local components may reduce the cost of machinery dramatically.

(6) Finally, the plant installed at Kasur, is running on single shift basis. Thus, it is operating far below its capacity. If it is run on double shift basis, other cost factors being the same, the annual cash flow may be double as a result of which, the payback may be halved (18 instead of 36). Similarly, if it operates on three shit basis, the payback may reduce to one third (12). The question, here, will be whether there is so much effluent to cater the plant on two or three shift basis or not?

In the light of the results presented and discussed above, it may be concluded without any doubt that the Chromium Recovery Plant installed by KTWMA is not viable both financially and economically. Its installation, being a social and legal requirement, it is socio-economically justified even if it involves the tanner's own investment. To make it financially and economically viable, this piece of work should be extended to search the ways to bring its installation and operating costs down as narrated under the recommendations.

To extend the work reported in this study, we propose the following research projects to be carried out to make the installation both financially and economically viable:

- Down-costing of installation of chromium recovery plants in the developing countries with special reference to Pakistan.
- Choice of technique in installation of chromium recovery plants in the developing countries with special reference to Pakistan.
- Social analysis of the plants to assess its benefits in terms of reductions in mortality and morbidity and labour days lost. The results of social analysis may significantly pull the installation towards economic viability by increasing BCR and NPV.

It is appreciated that some critics pointed out that the social link is missing. The social analysis is one of the important aspects and its conduct has been recommended above. The problem is that focus all over the world mostly is on assessing the benefits of elimination of air pollutants from the atmosphere. The author has successfully applied World Bank Model for assessment of the benefits of banning two-stroke rickshaws in Lahore, currently in process for publication in *The Pakistan Development Review*. Unfortunately, no standardised method of assessment of disposal of liquid effluents and solid waste has been encountered yet. The only way to monetise it to identify the diseases, quantification how much effluent or solid waste will cause how many cases of morbidity and mortality and finally monetisation by calculating cost of recovery from the diseases and deaths . This is a difficult local exercise which is very difficult to carry out. Even this methodology may be applied to monetise the social costs of Kasur Tannery Waste Water Pre-treatment Plant, yet monetisation of the benefits of chromium recovery plant will not be possible because, it forms a part of overall activity. Moreover, chromium is partly recovered and partly disposed of in the pre-treatment plant. Thus checking of hospital records will further confuse the situation. The only thing that sounds helpful is the monetisation on the basis of amount of chromium recovered per annum. The assumption will be that if it was not recovered and remained in tannery waste then how many deaths it would have caused and how many cases of morbidity will be there. This may be accomplished by using dose response curves as templates if some studies on liquid effluents and solid waste have been carried out in advanced countries like USA, UK, Canada, etc. If not, the researchers with this aim will have no other alternative except to wait. The investigator of the work being reported is also after it to cover this dimension at a later stage.

Lack of social analysis does not mean that this study based on financial analysis loses anything in value. It carries significantly high value on the basis of reasons given below:

- The industrialist evaluates his projects on profit and loss basis by application of financial analysis. He is carefree about the social aspects. Had he been so conscious, he would have not polluted the environment to the state encountered today.
- There are a number of dimensions that may be enquired as highlighted while concluding results and discussion by applying financial analysis techniques and author's group has gone far in this enquiry. The results are expected to conclude with BCR many-fold of 1, the standard criterion and payback period and with miraculous reduction in the payback period. This evidence when brought to light will be sufficient to convince the tanners to install chromium recovery plants in their tanneries for disposal of chromium free waste water in environment.

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