POLLUTION CONTROL AND WASTE MINIMIZATION OF CHEMICAL PRODUCTS INDUSTRY
A Case Study of Polymers Production Industry

M. Nazih[1], Walid Abdel-Halim[1], Hisham S. A. Halim[2], and Sohair Abo Elaa[3]

[1] Housing and Building National Research Center, HBNRC, Egypt
E-mail: mohnazih@gmail.com
[2] Civil Engineering Department, Faculty of Engineering, Cairo University, Egypt
[3] National Research Center, NRC, Egypt

ABSTRACT

A bench scale model and treatability study was developed for chemical product "Polymers" industry to study the analysis of waste discharge. The main objective of this study is management and control of liquid and solid wastes in the industry in order to protect the environment and to gain benefits as much as possible from the wasted materials and identify opportunities for introducing pollution prevention measures and best method for waste minimization as cleaner production system. The study is taking into account all types of waste production including wastewater and solid waste during the production processes activities. The main raw materials used in the industry are naphthalene, Conc. Sulfuric acid, Formaldehyde, Sodium Hydroxide, Calcium Oxide, Sodium meta Bisulfate, oil. The main product of the industry is sulfated naphthalene formaldehyde which used as a super plasticizer material to achieve improved concrete properties. The chemicals used during the manufacturing processes are very toxic, hazardous and has severe impact on the environment and health of the workers. The liquid waste was found to be extremely soluble in water and very hardly biodegraded; accordingly it is very difficult to treat. It was found that the pH is varied between very acidic (1.9) to very alkaline (11.5).This may be attributed to the spill and leakage of raw materials such as H2SO4 or Ca(OH)2. Also, the COD and BOD values were as high as 27900 and 3000 mgO2/l, respectively. The average COD and BOD reached 20937 mgO2/l and 2613 mgO2/l, respectively. The oil and grease concentration reached 607 mg/l, the total residue amounted to 20695 mg/l. Also, total suspended solids, which exist in colloidal form, reached 1815 mg/l. Treatment Procedure is conducted through treatability study using physical and chemical treatment techniques. The Physical treatment eliminates the amount of CODcr from (13 to 22 %), BOD from (37 to57%) and oil and grease from (70 – 100%). The Chemical treatment eliminates the amount of CODcr from (45 to 81 %), BOD from (57 to85%) and oil and grease from (69 – 100%). Also, Cleaner Production Options is conducted to reduce the raw material leakages and improvement the operation and housekeeping activities in the industry. The Cost Estimation and Economical Assessment lead that annual saved money (Total Benefits) is about LE 43,070 /year and the payback period of capital investment is about 3.8 months.

1. INTRODUCTION AND BACKGROUND

Due to increasing environmental concerns associated with industrial processes, pollution prevention can be defined as any action which reduces or eliminates the creation of pollutants or waste at the source using the cleaner production and pollution prevention approaches which may occur due to inefficiencies in the manufacturing processes, operational practices, improperly designed or utilized equipment. Adopting pollution prevention program is a way of doing business which can provide a number of significant benefits to industry. Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment; it describes a preventative approach to environmental management. Cleaner Production refers to a mentality of how goods and services are produced with the minimum environmental impact under present technological and economic limits. Cleaner Production focuses on minimizing resource use and avoiding the creation of pollutants, rather than trying to manage pollutants after they have been created. Cleaner Production can reduce operating costs, improve profitability, worker safety and reduce the environmental impact of your business.

For production processes, Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process. The Cleaner Production assessment is most often divided in five phases "as shown in the following chart":

- Planning and Organization Phase
- Assessment Procedure
- Feasibility Analysis Phase
- Implementation and Continuation Phase

The industry produces 2500 ton liquid / month or 1100 ton powder / month of sulfated naphthalene formaldehyde. The raw materials used in the industry are naphthalene, Conc. Sulfuric acid, Formaldehyde, Sodium Hydroxide, Calcium Oxide, Sodium Meta- Bisulfate, oil. The main product of the industry is sulfated naphthalene formaldehyde which used as a super plasticizer which is a synthetic organic compound used in modern concrete construction technology and it is used to increase the amount of concrete admixtures. Wastewater produced from the manufacturing processes is discharged into a bond inside the industry& the wastewater produced from sanitary purposes is discharged into public sewerage network. There are two types of wastes produced due to the manufacturing process; liquid wastewater and solid waste. Based on the field visits and wastewater discharge analysis, environmental audit and analysis of the end-of-pipe it was found that the quality of the wastewater generated and solid waste produced are violating the environmental regulations.

2. STATEMENT OF ENVIRONMENTAL PROBLEMS

The chemicals used during the manufacturing processes are very toxic, hazardous and has severe impact on the environment and health of the workers. As a result of the manufacturing processes, different types of wastes are produced mainly liquid and solid wastes. The liquid waste was found to be extremely soluble in water and very hardly biodegraded; accordingly it is very difficult to treat. It was noticed that there are many bad housekeeping behaviors. Furthermore, the industry lacks the sufficient maintenance in general. All these factors increase the magnitude of the environmental problem.

3. STUDY OBJECTIVES

The main objective of this study is management and control of liquid and solid wastes in the industry in order to protect the environment and identify opportunities for introducing pollution prevention measure.
The main objective is achieved via verifying some of sub-objectives such as following:

- Reduce pollution load in terms of volume and concentration of wastewater through point source treatment and process modifications and recommend possible low cost pollution prevention measures, waste minimization, and cleaner production options.
- Improve the industry's operational efficiency through the application of waste minimization and cleaner production technology.
- Identify and provide information on any improvement measures with low costs and short pay-back periods in order to reduce waste at the source.

4. STUDY METHODOLOGY

Due to the great variation in the quality and quantity of wastewater produced, a continuous monitoring program was carried out to identify the quality and quantity of

wastewater discharged. Samples have taken from the process and end-of-pipe industrial wastewater and other point of industrial wastewaters discharge during the process activities to perform a preliminary assessment of the environmental status of the facility.

To achieve the required objectives, the study is conducted following some steps and approaches as following:

- Evaluate the current environmental conditions in the production and service units to determine the industry required to upgrade these units in order to reduce pollution load in the final effluent.
- Data collection including the collection of information relevant to the different activities in the industry including qualitative and quantitative estimation of solid and liquid wastes.
- Collecting composite wastewater samples from the end-of-pipe industrial effluent. The samples were analyzed by specialized laboratory and the results are used for selection of the most appropriate alternative schemes.
- Check on the compliance with National Environmental regulation and legislation and description of the existing environmental situation in the industry.
- Studying the different approaches for pollution prevention and waste minimization in the industry and Suggesting possible alternative remedial integrated schemes including in-process, in-plant modifications and end-of-pipe treatment modules.
- Suggesting possible alternative remedial integrated schemes including in-process, in-plant modifications and end-of-pipe treatment modules.
- Conducting technical and economical cost benefit analyses to select the preferred integrated scheme (PIS).

4.1 Waste Sources

The sources of wastes in the industry are generated from different sources as shown in Table (1).

Table (1): Sources and Quantities of Wastewater discharged into the Existing Pond

Sources	**Discharge Quantities** (m^3/day)
Retained water in the filter press	6
Cooling water of high pressure pump	24
Leakage of raw material	0.01
Leakage of product	0.02
Leakage of feeding pump	2
Floor washing	2
Washing of reactors	75 m^3/45day
Chemical and performance laboratory	1
Water softener regenerator	2
Total	**40**

4.1.1 Retained Water Discharge in Filter Press

The quantity of retained water discharged is 6 m^3/day. This wastewater is currently discharged to the floor under the filter press and then to the wastewater collection pond via collection gutters. This water is contaminated with chemicals used during the manufacturing processes which are very toxic, hazardous and it increases the pollution load in wastewater violating the National standards and limits set by Ministerial decree 44/2000.

4.1.2 Washing Water of Reaction Vessels (reactors)

The total amount of washing water is estimated to be 75 m^3/45 days. This washing water represents a major environmental problem in the industry since it contains raw materials and product.

4.1.3 Cooling System for the High Pressure Pump

The high pressure pump is used for spray drying of the product to change it from liquid to powder "option". This water is estimated to be 24 m^3/day. The cooling process is an open cycle and the cooling water discharged directly to the pond via collection channel. Also, the temperature of this water is too high which violate the standards and the limits set by the Ministerial Decree 44/2000.

4.1.4 Leakage of raw material and products, and water

The raw, process and feeding pumps suffer from martial leakage. These materials discharged to the drain and then to the pond. Also, the pumps used in spray dryer suffer from clean water leakage. This water is contaminated with chemicals which used during the manufacturing processes and products materials which are very toxic, hazardous and has severe bad impact and increase the pollutant in the wastewater.

<u>The main sources of the leakage are as the following:</u>

- Escape of products from the existing 9 pumps. This discharged to the drain and then to the pond. This represents a major problem for the contamination of the floor and then to the end-of-pipe. It is estimated to be 0.02 m^3/day.
- Leakage of raw materials from the feeding pumps, Naphthalene, Concentrated Sulfuric acid, Formaldehyde, Sodium Hydroxide, and Castor-Oil pumps. It is estimated to be 0.01 m^3/day.
- Leakage of water from feeding pumps of spray dryers; it is almost 2 m^3/day.

4.1.5 The Solid Waste (Cake) Disposal

As a result of the manufacture process, a semi solid waste (Cake) has been produced during the separation of the final product from the mother liquor using a filter press. The weight of the cake is almost 15 t/day. This cake is daily discharged to a dumping site. Laboratory analysis indicated that the cake contains 21% as final product, CaSO4 salts, water, and traces of sodium salts. Therefore, the main purpose of this part of the study is to utilize the entrapped products (21%) and the residual solid which is CaSO4. Pendent on the industrial audit and the analysis of the liquid and solid wastes in the industry it can be seen that there are many factors aggravate the high contamination and pollution load in the industry among these factors are the bad house keeping; leakage of raw materials, and product from the pumps auxiliaries storage tanks, spills

of the cake which is highly contaminated with product. Also, floor washing contribute greatly to the organic and inorganic loads in the final effluent.

As a general, the industry also lacks sufficient maintenance. All these factors aggravate the environmental problems and it can be overcome by introducing the pollution prevention and waste minimization measure.

Figure 1 illustrates Process Flow Diagram of the Existing Filter Press Water Streams and Solid Waste (Cakes) Disposal.

4.2 Waste's Samples Collection and Analyses

The purpose of this section is to quantify the major pollutants (Temperature, pH, BOD, COD, TSS, TDS, Settleable matter and oil & grease) of the final effluent discharged to the public sewer system. Wastewater from the end-of-pipe as well as the sludge cake from filter press were collected and analyzed. The monitoring program had focused on measuring the flow rate of the final discharge effluent during 48 hours started during daily shifts. Also, the monitoring program had focused on the quality of final wastewater discharged into a public sewer system. The collected sample was analyzed for Temperature (T), pH, Total suspended solids (TSS), Biological Oxygen Demand (BOD^5), Chemical Oxygen Demand (COD_{cr}), Oil & Grease, and total dissolved Solids (TDS) and Settleable matter. T and pH were considered as field measurements, while the rest items are considered as laboratory analysis.

Wastewater from the end-of-pipe as well as the sludge cake from filter press were collected and analyzed. Composite samples from the end-of-pipe were collected during the working shifts and subjected to physico-chemical analysis. The analysis included pH, total residue (T.R), Total suspended Solids (TSS), Total Dissolved Solids (TDS), Settleable Solids, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Phosphorous (T.P), Total Kjeldahl Nitrogen (T.K.N), Phenol, Formaldehyde, Oil & Grease and Soluble Sulfite. Furthermore, Calcium (Ca+2) and Sodium (Na+) concentrations were measured using Atomic Absorption Spectrometer, Varian SpectrAA (220) with graphite furnace accessory and equipped with deuterium arc background corrector. In addition, Sulfate (SO4--) were measured using turbidimetric method (APHA, 1998), using UV spectrophotometer, Shimdzu 2401 PC. The wastewater discharges are compared with the required limits of the law no 93 at year 1962, as modified by decree no 44 at year 2000 concerning the discharge final effluent to public sewer system. The quality of the final industrial water effluent to the public sewer system results of field and laboratory measurements shows that all tested parameter are comply with law no 93 for year 1962 and its decree no 44 for year 2000, except high amount of the BOD^5, and COD_{cr} in all examined samples than the permissible limit or it was so much near to the action limit. Also the amount of oil and grease, BOD & COD for septic tank sample is exceed than the permissible limit of law no. 93 for year 1962 and its decree no. 44 for year 2000. The applied analytical procedures are in accordance with the Standards of the United States Environmental Protection Agency (USEPA) and the Standard Methods for the Water & Wastewater Analysis(SM).

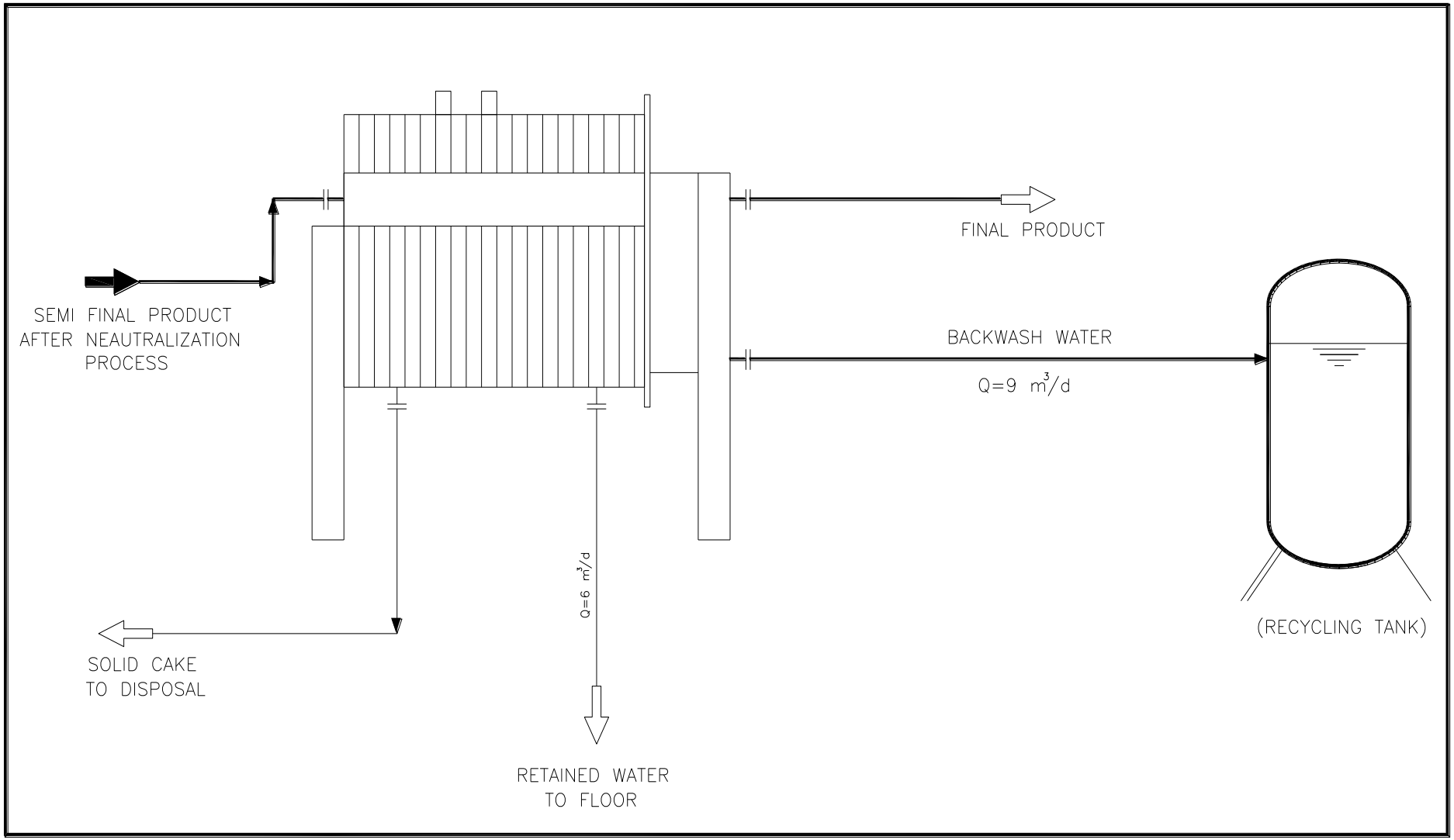


Figure (1): Process Flow Diagram of the Existing Filter Press Water Streams and Solid Waste (Cakes) Disposal

4.2.1 Characterization of Liquid Waste

Analyses of the end-of-pipe are recorded in following Tables 2, 3 and 4. The results obtained indicating that the effluent is highly contaminated with organic as well as inorganic pollutants. The quality of the effluent produced is not complying at all with the National Regulatory Standards concerned with wastewater discharge into public sewage network. It was found that the pH is varied between very acidic (1.9) to very alkaline (11.5). Also, the COD and BOD values were as high as 27900 and 3000 mgO2/l, respectively. The average COD and BOD reached 20937 mgO2/l and 2613 mgO2/l, respectively. The oil and grease concentration reached 607 mg/l. The total residue amounted to 20695 mg/l which is expected due to the presence of high content of salts such as sodium and calcium salts. Also, total suspended solids, which exist in colloidal form, reached 1815 mg/l. During the period of this study, it was found that a great spill, leakage and deficiencies in operation occurred. This was indicated by the analysis of the end-of-pipe which showed a great deterioration of the quality of the wastewater. The COD reached 57000 mgO2/l while the pH is increased to 11.7.

4.2.2 Characterization of Cooling Water of High Pressure Pump

Analysis of cooling water of high pressure pump shows that it contains only around 4 mg/l oil and grease. This indicates that the water can be recycled again. Through changing from open circuit to a closed one will greatly reduce the hydraulic load in the final effluent the water.

4.2.3 Characterization of Solid Waste

A solid waste (cake) is produced from the filter press. The analysis of the sludge cakes include the Water Content, Sulfate concentration, Sodium, Calcium, and the residual product entrapped in the cake. This cake is analyzed to identify its components as shown in Table 4.

The Cakes are discharged on daily bases by car to a dumping site. It is obvious from the analysis that there is a great loss in the product (20%) which can be utilized.

4.4 Treatment Procedure "*Lab Scale*"

4.4.1 Physical Treatment – Gravity separation

Acidified Sample (>2 pH) pour in a separate funnel and live withstand for 73 hrs then supernatant are taken for check the considered pollutants.

4.4.2 Chemical Treatment – Chemical Coagulants

Pour 500 ml sample in a 1000 ml beaker and agitate for 10 min, neutralize sample's pH by adding 0.4 gram NaOH, then agitate again for 10min. Add 100 ml Ferrous Sulfate (FeSO4.7H2O – 100 ppm Fe), then agitate again for 10 min and. leaved withstand for 15 min to precipitate coagulant, then supernatant are taken for check the considered pollutants.

Table (2): Characterization of the End-of-Pipe Wastewater

Parameters	**units**	**Results**					**Ministerial Decree 44/2000**
		Sam. 1	Sam. 2	Sam. 3	Sam. 4	Average	
pH	-------	11.7	8.4	5.2	1.9		**6-9.5**
Sett. Solids 10'	ml/l	0.1	--------	--------	--------	--------	**8**
Sett. Solids 30'	ml/l	0.2	---------	---------	---------	---------	**15**
Chemical Oxygen Demand	mgO_2/l	16950	20625	18272	27900	20937	**1100**
Biological Oxygen Demand	mgO_2/l	2950	3000	2100	2400	2613	**600**
Total Kjeldhal Nitrogen	mg/l	16.8	20.5	21.3	27	21.4	**100**
Total Phosphorous	mg/l	344	100	41	94	144.7	**25**
Total Dissolved Solids	mg/l	--------	14630	12459	--------	--------	
Total Suspended Solids	mg/l	906	354	721	1815		**800**
Total Residue	mg/l	14437	14984	13280	20596		
Oil& Grease	mg/l	29.2	254	607	290		**100**
Soluble Sulfide	mg/l	N.D	4	N.D	0.8		**10**
Phenol	mg/l	0.14	0.2	0.1	0.2		**0.05**
Formaldehyde	mg/l	370	N.D	N.D	N.D		**nil**
Sulfate	mg/l	15000	3000	2800	6500		--------
Sodium	mg Na^{+2}/l	--------	1450	1600	1308		--------
Calcium	mg Ca^{+2} /l	--------	51.2	256	576		--------

Table (3): Characterization of the End-of-Pipe, *(Special Case)*

Parameters		Units	Results	Standards
pH		-------	7.5	**6-9.5**
Chemical Oxygen Demand		mgO_2/l	57100	**1100**
Soluble Chemical Oxygen Demand		mgO_2/l	52300	
Total Phosphorous		mg/l	95	**25**
Sett. Solids	10^o	ml/l	0.2	**8**
	30^o		0.5	**15**
Total Suspended Solids		mg/l	689	**800**
Total Kjeldhal Nitrogen		mg/l	22.4	**100**
Oil& Grease		mg/l	507	**100**
Soluble Sulfide		mg/l	2.6	**10**
Phenol		mg/l	0.08	**0.05**
Formaldehyde		mg/l	780	**nil**
Sulfate		mg/l	7000	----------

Table (4): Characterization of Solid Waste (Cake)

Parameters	Units	Results
Water Cont.	%	21
Solid content	%	79
Sulfate	mg/l	471
Calcium	g/kg	139
Sodium	g/kg	53
Product concentration	%	21.5

5. RESULTS AND DISCUSSION

5.1 Raw Wastes

The quality of the final industrial water effluent to the public sewer system results of field and laboratory measurements shows that all tested parameter are comply with law no. 93 for year 1962 and its decree no 44 for year 2000, except high amount of the BOD5, and CODcr in all examined samples than the permissible limit or it was so much near to the action limit.

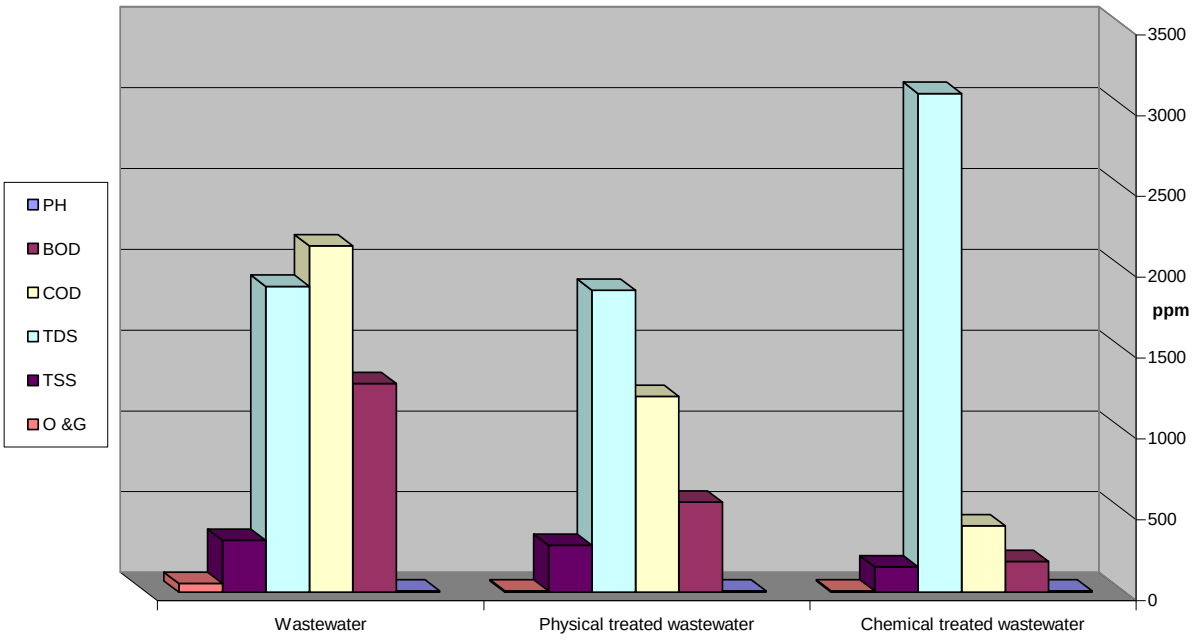
Also, the amount of oil and grease, BOD & COD for septic tank sample is exceed than the permissible limit of law no. 93 for year 1962 and its decree no 44 for year 2000.

5.2 Physical Treatment

The quality of the final industrial water effluent to the public sewer system results of laboratory measurements shows that the CODcr amount are not comply with law no 93 for year 1962 and its decree no 44 for year 2000. The Physical treatment eliminates the amount of CODcr from (13 to 22 %), BOD from (37 to57%) and oil and grease from (70 – 100%).

5.3 Chemical Treatment

The quality of the final industrial water effluent to the public sewer system results of laboratory measurements shows that COD_{cr} amount are not comply with law no 93 for year 1962 and its decree no 44 for year 2000. The Chemical treatment eliminates the amount of COD_{cr} from (45 to 81 %), BOD from (57 to85%) and oil and grease from (69 – 100%). This elimination recovery percent can be enhanced by studying the pH value effect and studying the effect of adding cationic and anionic polymer. Figure 2 shows comparison of the wastewater pollutants before and after physical and chemical treatment.



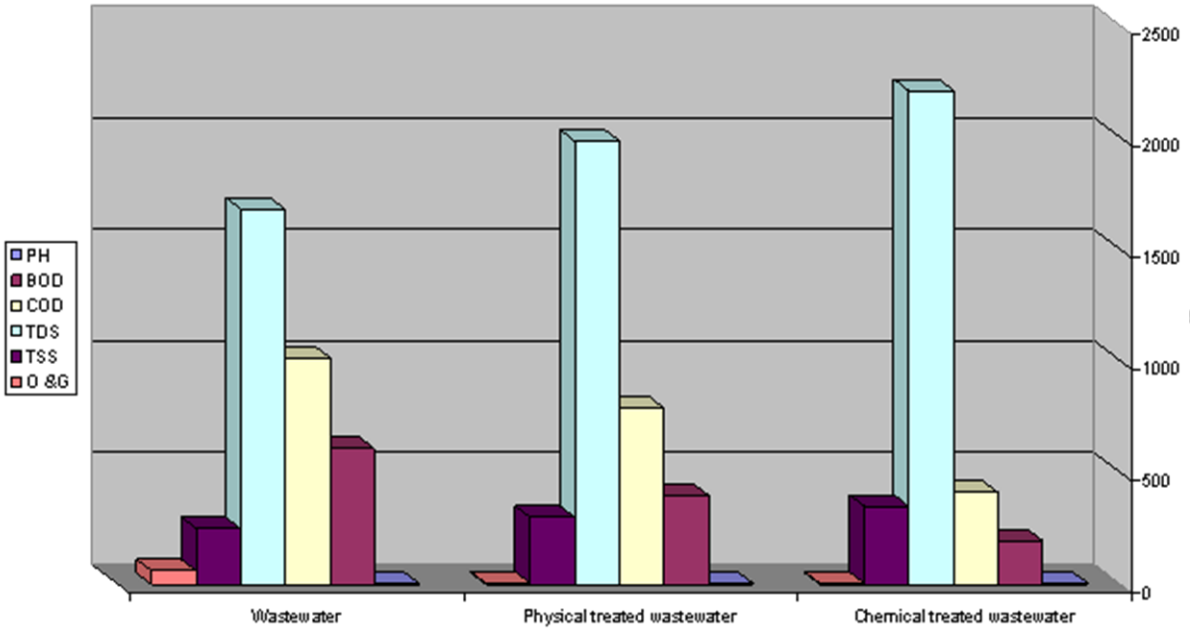


Figure 2: Comparison of Wastewater Pollutants before and after Physical and Chemical Treatment

5.4 Possible Modules for Remedial Measures and Cost estimation

Environmental performance can be improved by implementation of some pollution abatement measures. These proposed measures will reduce the pollutants load in the final effluent discharged to the existing pond inside the industry. The implementation of these measures depends largely on the availability of the financial resources.
All the proposed measures are used for the followings purposes:

- Minimization and elimination of environmental pollution at the source.
- Saving of product.
- Saving in raw material.
- Saving in water.

5.5 Cleaner Production Options

5.5.1 Recycling of Retained Water Discharge in Filter Press

Proposed Measures:

To avoid spreading of the retained water on the floor, it is suggested to have mobile collection containers underneath the filter press. These containers will be specially manufactured to fit the dimensions of the existing filter press and the available clearance. However, it is strongly recommended to raise the filter press elevation for proper collection for such water and dry cake. Two mobile containers equipped with a drain pipe ended by a coupling will be used. The collected water is assumed to be pumped by a skid mounted pump to the existing recycling tanks and then to the reaction vessels.

Figure (3) illustrates the process flow diagram of the filter press proposed measure.

The main components of the proposed system are:

- Re-install the filter press by raising the bottom elevation by one meter.
- Two polyethylene collection tanks (0.6 m^3/ each).
- Mobile skid mounted lifting pump.
- Piping System / flexible for connections between the units "collection tanks, pumps, reaction vessel"
- Using this proposed measure we can get the following benefits:
- Minimization and elimination of environmental pollution at the source.
- Saving in product amounted at 0.75 ton/day; refer to sec c.

Cost Estimation and Economical Assessment:

Capital Cost:

The capital cost for install the recycling of retained water discharge in filter press system	LE 40000

Annual Operation and Maintenance Cost

Annual operation and maintenance cost of the recycling of retained water discharge in filter press system	LE 250 / month * 12 = LE 30,000 / year

Expected Cost Benefits

Volume of recycled water	6 m^3/day
Percentage of product in recycled water	12%
Quantity of recycled product	6% * 6 = 0.36 t/day
Price of one ton of product	LE 2200
Total daily saved money	2200*0.36 = LE 792 /day
Annual saved money (total benefits)	792 * 365 = LE 289,080 /year

Pay Back Period

Capital cost	LE 40,000
Annual operation and maintenance cost	LE 30,000
Annual saved money (Total Benefits)	LE 289,080
Net benefits = (Total Benefits – Operation and Maintenance cost)	289,080 – 30,000 = LE 259,080
The pay back period = (Capital Cost / Net Benefits)	(40,000/259,080) * 365 = 56 days

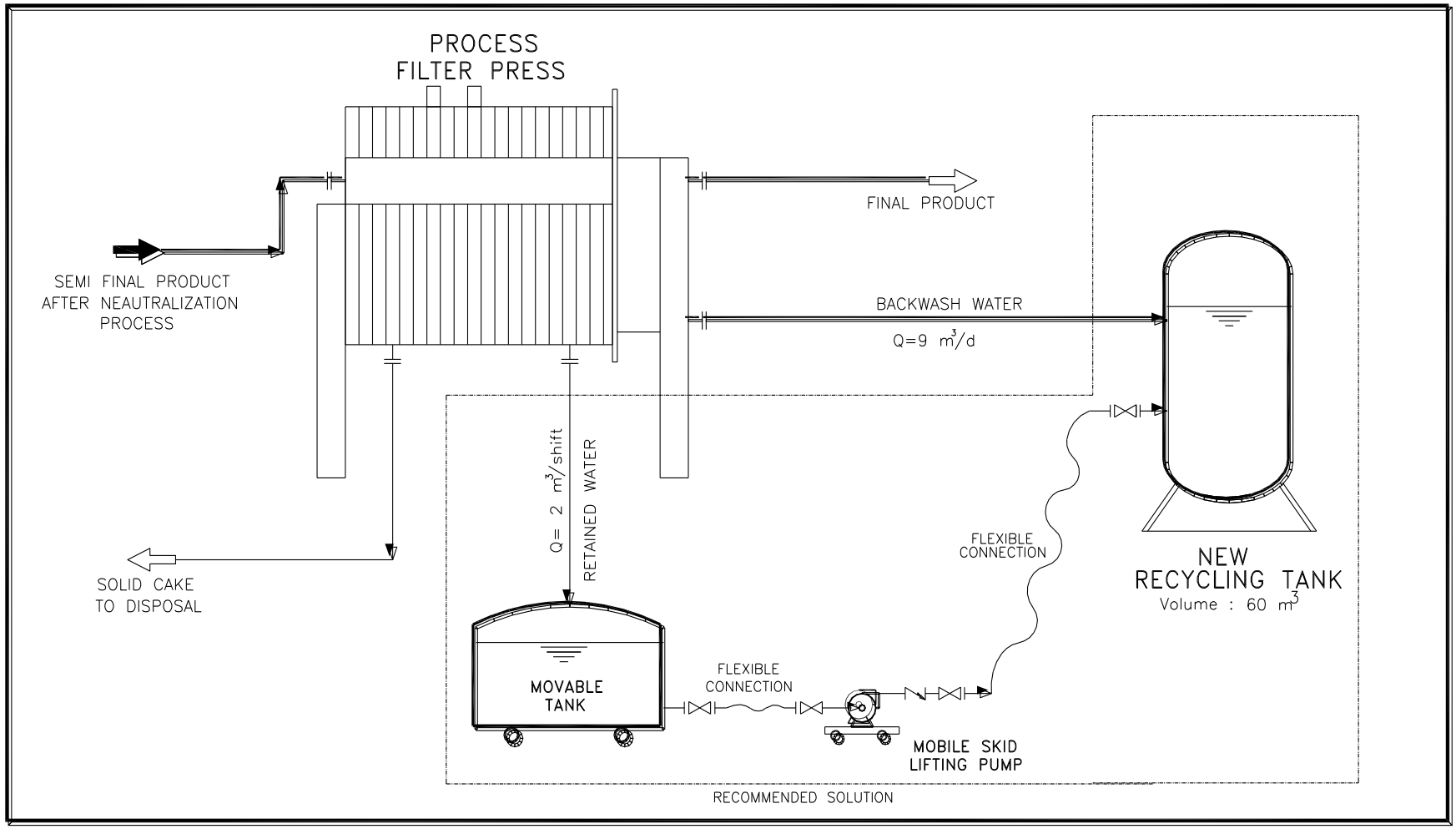


Figure (3): Process Flow Diagram of the Filter Press Proposed Measure

5.5.2 Recycling of Washing Water of Reaction Vessels (reactors)

Proposed Measures:

To avoid disposal of the washing water on the floor, it is suggested to recycle the washing water by discharging it to a special collection tank of a total capacity equals 15 m^3. There is an existing scrapping water tank of total volume equals 12 m^3, this tank is needed to be re-filled by water "make-up water" twice per day. Accordingly, the collection tank could be used as a storage tank to provide the scrapper water tank by water "make-up water" to use it for washing the reactors.

Figure (4) illustrates the process flow diagram for the proposed measure.

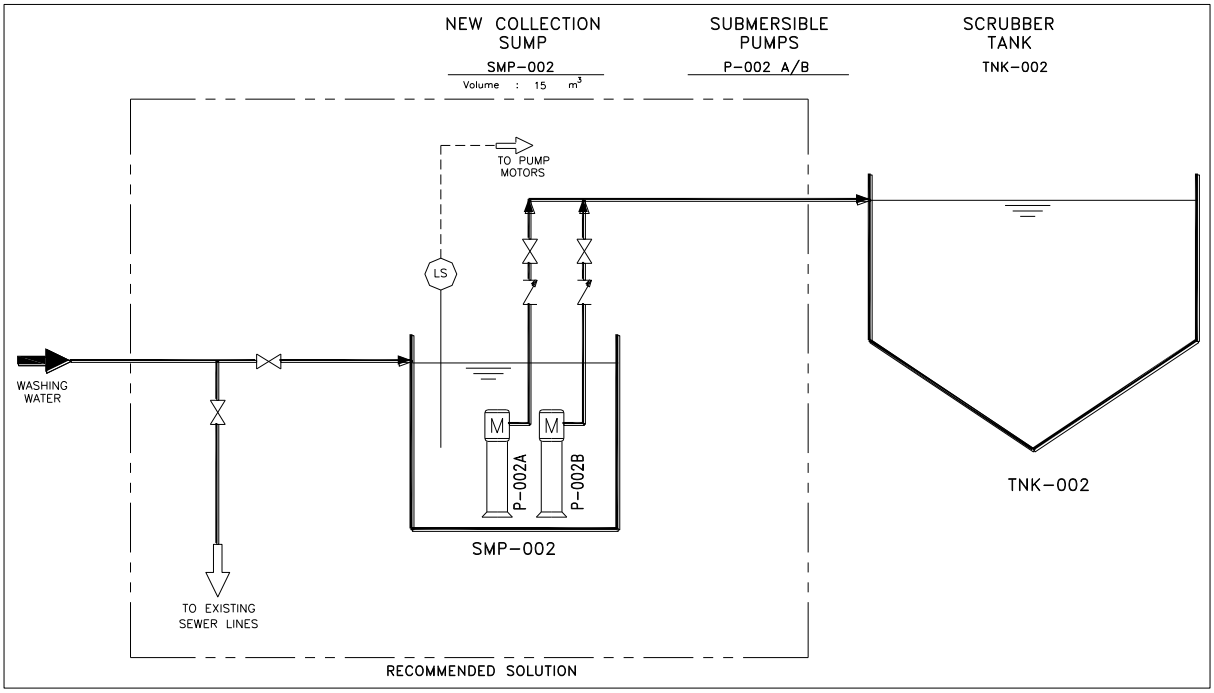


Figure (4): The process flow diagram for the Recycling of Washing Water of Reaction Vessels

The main components of the proposed system are:

- One Polyethylene or Galvanized Steel Storage Tank of volume 15m^3.
- Piping system for connections between the units "reactors, storage tank and scrapper water tank"

Using this proposed measure the following benefits can be obtained:

- Minimization and elimination of environmental pollution at the source.
- Saving in water amounted to 50 m^3/month

Cost Estimation and Economic Assessment:

Capital Cost:

The capital cost for installing Recycling of Washing Water for reaction vessels (reactors) system	LE 50000

Annual Operation and Maintenance Cost

Annual operation and maintenance cost for recycling of washing water for reaction vessels (reactors) system	LE 250 / month * 12 = LE 30,000 / year

Expected Cost Benefits

Daily water volume washing one reactor	15 m^3
Total number of reactors	5
Period of washing process	every 45 days
Total monthly volume of saved water	(15*5/45)*30 = 50=3/month
Annual volume of saved water	50 * 12= 600 m^3/year
Price of water	LE 1.75 / m^3
Annual saved money (Total Benefits)	1.75 * 600 = LE 1050 /year

5.5.3 Closed Circuit Cooling System for the High Pressure Pump

Proposed Measures:

It is suggested to recycle the cooling water by using a Chiller Closed Cooling system. Figure (5) illustrates the process flow diagram for the Chiller Closed Circuit Cooling system.

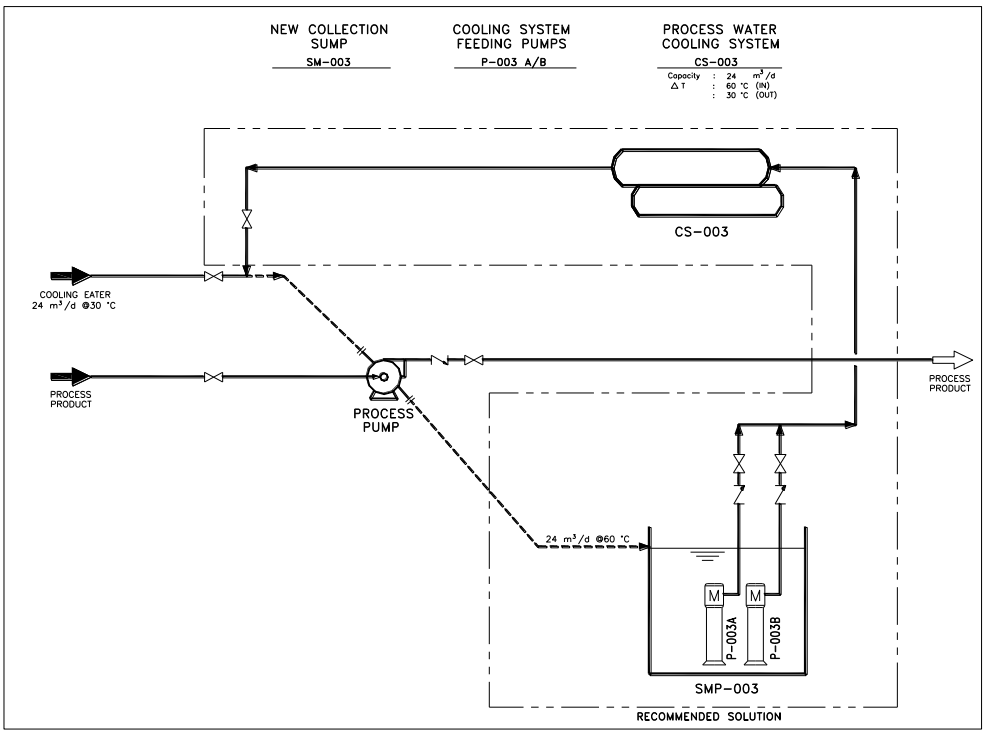


Figure (5): The process flow diagram for the Chiller closed circuit cooling system

Using this proposed measure we can get the following can be achieved:
- Saving in water amounted to 24 m^3/day.
- Reduce the final hydraulic load of the wastewater discharge to be equal (40 – 24) 16 m^3/day.

Cost Estimation and Economical Assessment:

Capital Cost:

The capital cost for Cooling System for the High Pressure Pump	LE 150000

Annual Operation and Maintenance Cost

Annual operation and maintenance cost for cooling system for the high pressure pump	LE 1000 / month *12 = LE 12000 / year

Expected Cost Benefits

Daily volume of saved water	24 m^3/day
Total monthly volume of saved water	24 * 30 = 720 m^3/month
Annual volume of saved water	720 * 12= 8640 m3/year
Price of water	LE 1.75 / m^3
Annual saved money (Total Benefits)	1.75 * 8640 = LE 15,120 /year

5.5.4 Leakage of raw material and products, and water

Proposed Measures:

The suggested solution of pollution prevention is to restructure the housekeeping and workers behaviors. Also, the industry needs to apply good maintenance in general. Also, all existing pumps need proper maintenance and rehabilitation.
It is expected that the proposed measures for good housekeeping will keep about 0.8% of the leaked material.

Using this proposed measure the following can be achieved:
- Minimization and elimination of environmental pollution at the source.
- Saving in product amounted at 0.016 ton/day.
- Saving in raw material amounted at 0.008 ton/day.
- Saving in water amounted at 2 m^3/day.

Cost Estimation and Economical Assessment:

Capital Cost:

Maintenance of raw material feeding, product, spray of dry powder pumps.	LE 6000

Annual Operation and Maintenance Cost

Annual operation and maintenance cost for raw material feeding, product, spray of dry powder pumps.	LE 2000 / month * 12 = LE 24000 /year

Expected Cost Benefits

Expected efficiency of pumps after maintenance	80 %
Volume of product leakage	0.02 t/day
Daily volume of saved product	80% * 0.02 = 0.016 t/day
Annual volume of saved product	0.016 * 365= 5.84 t/year

Price of one ton of product	LE 2200 /ton
Volume of raw material leakage	0.01 t/day
Daily volume of saved raw material leakage	80% * 0.01= 0.008 t/day
Annual volume of saved raw material leakage	0.008 * 365= 2.92 t/year
Price of one ton of raw material	LE 10000 /ton
Daily volume of leaked water	2 m^3/day
Daily volume of saved water	80% * 2 = 1.6 m^3/day
Annual volume of saved water	1.6 * 365 = 584 m^3/year
Price of water	LE 1.75 / m^3
Annual saved money (Total Benefits)	(5.84 * 2200)+(2.92*10000)+(584*1.75) = LE 43,070 /year

Pay Back Period

Capital Cost	LE 6,000
Annual operation and maintenance cost	LE 24,000
Annual saved money (Total Benefits)	LE 43,070 /year
Net benefits = (Total Benefits – Operation and Maintenance cost)	43,070 – 24,000 = LE 19,070
The payback period = (Capital Cost / Net Benefits)	(6000/19070) * 365 =115 days(3.8 months)

5.5.5 Utilization of the Residual Product from the Solid Waste (Cake)

Proposed Measures:

To avoid a greet lose in the product due to daily discharge of the solid waste (Cake) by car to a dumping site, it is suggested to utilize the solid waste (Cake) using a special type of filter press (Chamber Press) to separate the product from the waste sludge. The solid material (CaSO4) after removal of the entrapped product can be utilized also, and may be sell as a by-product. Analysis of the cake indicated that the dry CaSO4 produced is almost 40% of the total weight.

Figure (6) illustrates the process flow diagram for the solid waste (Cake) utilization system and producing a dry CaSO4 as a by-product.

The main components of the proposed system for utilization of the product and Producing of a by-product which is CaSO4 are:

- Stirrer Tank of total volume 9 m^3
- Chamber Press system for 15 t/day solid waste (cake) to separate the product from the waste sludge.
- Dryer to produce a dry $CaSO_4$

Using this proposed measure we can get the following:

- Minimization and elimination of environmental pollution at the source.
- Saving in product amounted at 3.15 t/day; refer to sec c.
- Production of a by-product which is $CaSO_4$ amounted to 6 t/day as a by-product.

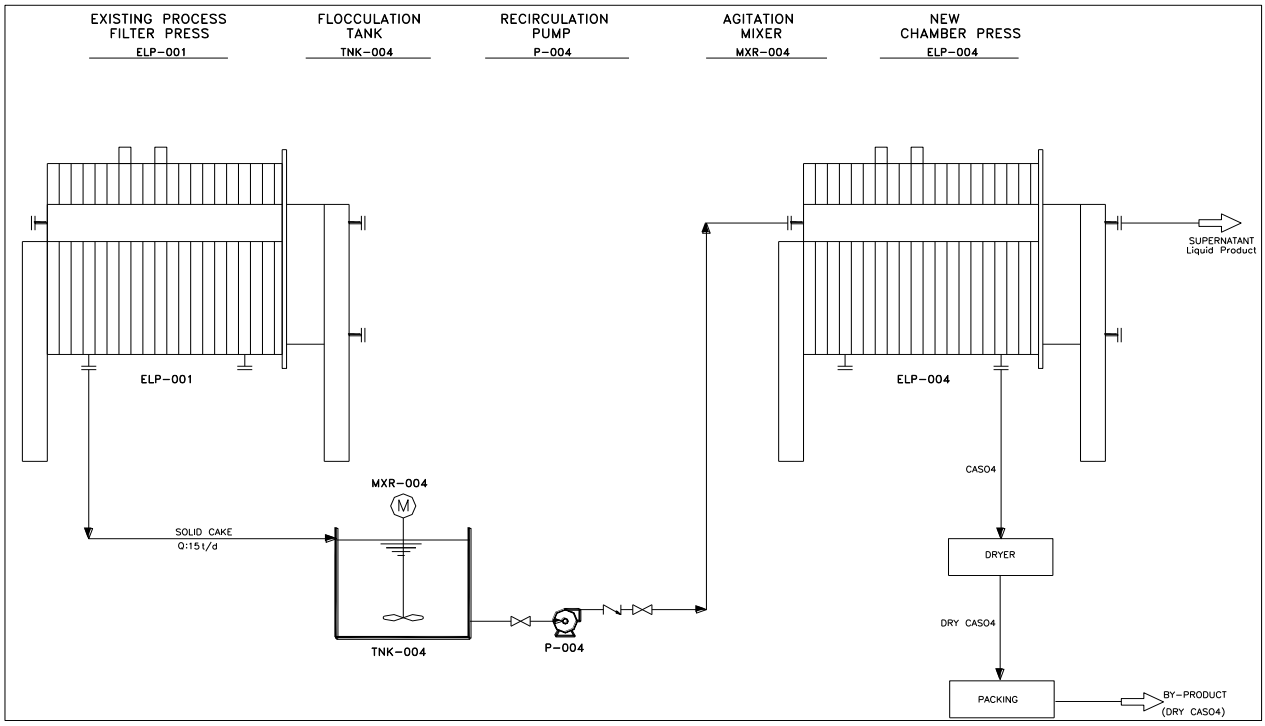


Figure (6): The process flow diagram for the solid waste (Cake) utilization system and producing a dry CaSO4 as a by-product

Cost Estimation and Economical Assessment:

Capital Cost:

- Utilization system for the utilization of residual product from the solid waste (cake) and production of dry CaSO4	LE 700000

Annual Operation and Maintenance Cost

- Annual operation and maintenance cost for utilization of the residual product from the solid waste (cake).	LE 1000 /month * 12 = LE 12,000 /year

Expected Cost Benefits

- Volume of recycled cake	15 t /day
- Percentage of product in recycled cake	21%
- Volume of recycled product	21% * 15 = 3.15 t/day
- Price of one ton of Product	LE 2200 /ton
- Total daily saved money	2200*3.15= LE 6930 /day
- Annual profit of recycled product	6930 * 365 = LE 2,529,450 /year
- Percentage of dry CaSO4 in recycled cake	40%
- Volume of produced dry CaSO4	40% * 15 = 6 t/day
- Price of one ton of dry CaSO4	LE 750 /ton
- Total daily saved money of dry CaSO4	750*6= LE 4500 /day
- Annual profit of dry CaSO4	4500* 365 = LE 1,642,500 /year
- Annual profit (Total Benefits)	2,529,450 + 1,642,500 = LE 4,171,950 /year

Pay Back Period

- Capital cost	LE 700,000
- Annual operation and maintenance cost	LE 12,000
- Annual profit (Total Benefits)	LE 4,171,950 /year
- Net benefits = (Total Benefits – Operation and Maintenance cost)	LE 4,171,950 /year – 12,000 = LE 4,159,950
- The payback period = (Capital Cost / Net Benefits)	(700,000/4,159,950) * 365 = 61.5 days (2 months)

5.6 Cost Estimation and Economic Assessment of the Proposed Remedial Scheme

A cost estimate and assessment for all equipment schemes is made based on tentative market survey. The economical assessment will be based on the expected capital cost for each propped solution considering the operation and maintenance costs for the different components. The expected benefits will be quantified and valuated in terms of money to perform the cost benefit analyses. The following section will investigate the cost for each components based on the different integrated schemes suggested in section 4. The capital cost is estimated based on the current prevailing prices for year 2005. The running cost covers both operation and maintenance cost. The operation was calculated only for power consumption and man power salary. Due to the simplicity of the proposed systems, it is assumed that the proposed system will be operated by the stuff already available at the industry.

Accordingly, the cost of personnel was not included for calculations of the operation cost. The cost benefits analyses were applied for the following schemes:

- Recycling of Retained Water Discharge in the Chamber Press
- Recycling of Washing Water of Reaction Vessels (reactors)
- Closing Circuit Cooling System for the High Pressure Pump
- Maintenance of the Existed Defected pumps
- Utilization of the Residual Product from the Solid Waste (Cake) and Producing of dry $CaSO_4$ as a by-Product

5.6.1 Actual Benefits of all proposed measures

- Total Capital Cost	LE 946,000 /year
- Total Benefits	LE 4,520,270 /year
- Total Operation and Maintenance cost	LE 108,000 /year
- Total Net Benefits = (Total Benefits – Operation and Maintenance cost)	4,520,270 – 108,000 = LE 4412270 /year

5.6.2 Pay Back Period of the Project

The payback period (Capital Cost / Net Benefits)

= (946,000 / 4412270)*365

= 78.25 days equal to 2.6 months

6. CONCLUSIONS AND RECOMMENDATIONS

The liquid wastes produced from the industry are extremely soluble in water and very hardly biodegraded; accordingly it is very difficult to treat. It was found that the pH is varied between very acidic (1.9) to very alkaline (11.5).This may be attributed to the spill and leakage of raw materials such as H2SO4 or Ca(OH)2. Also, the COD and BOD values were as high as 27900 and 3000 mgO2/l, respectively. The average COD and BOD reached 20937 mgO2/l and 2613 mgO2/l, respectively. The oil and grease concentration reached 607 mg/l, the total residue amounted to 20695 mg/l. Also, total suspended solids, which exist in colloidal form, reached 1815 mg/l. Treatment Procedure is conducted through treatability study using physical and chemical treatment techniques. Also, Cleaner Production Options is conducted to reduce the raw material leakages and improvement the operation and housekeeping activities in the industry. The Cost Estimation and Economical Assessment lead that annual saved money (Total Benefits) is about LE 43,070 /year and the payback period of capital investment is about 3.8 months.

REFERENCES

- A comparative analysis of three companies' efforts to develop environmentally responsible corporate cultures, International Society for Industrial Ecology Meeting “The Science & Culture of Industrial Ecology”, Leiden, 12-14 November.
- Bohne, R.A. and Brattebø, H. (2002): Future C&D waste recycling in Norway - Learning from Danish experience? Proceedings Sustainable Building 2002. Sustainable Building 2002, Oslo, Norway, 23-25 September.
- Bohne, R.A. and H. Brattebø (2003): "Eco-efficiency in Norwegian C&D waste recycling systems". Proceedings ILCEDES 2003, Integrated Lifetime Engineering of Buildings and Civil Infrastructure Proceedings, Kuopio, Finland, 1-3 December.
- Bohne, R.A., Røine, K. and H. Opoku (2003): Book review: Handbook of Industrial Ecology. Journal of Industrial Ecology. 7(2), pp. 125-126.
- Brattebø, H. (2001): Waste reduction in an industrial ecology perspective, Conference Proceedings from 1st Polish-Norwegian Seminar: Selected Research Issues at the Polish and Norwegian Universities, Technical University Warsaw, 18-20 October.
- Eik, A., Steinmo, S., Solem, H., Brattebø, H. and Saugen, B. (2001): Indicators for eco-efficiency in recycling systems, International Society for Industrial Ecology Meeting “The Science & Culture of Industrial Ecology”, Leiden, 12-14 November.
- Fet, Annik Magerholm (2002): Environmental Management Tools and their Application – A Review with References to Case Studies, Chapter 19 in Knowledge for Inclusive Development, Quorum Books, Greenwood Publishing Group, USA.

- Hanssen, O.J., Olsen, A. & Møller, H. (2003): National Indicators for Material Efficiency and Waste Minimization for the Norwegian Packaging Sector 1995-2001. Resources, Conservation and Recycling, Volume 38, pp. 123-137.
- Hertwich, E.G., D. Pennington and J. Bare (2002). Introduction. In: Life Cycle Impact Assessment: Striving towards Best Practice, edited by H. A. Udo de Haes et al. Pensacola: Society of Environmental Toxicology and Chemistry.
- Klang, A., Vikman, P.-Å and Brattebø, H. (2003): Sustainable management of demolition waste an integrated model for the evaluation of environmental, economic and social aspects, Resources, Conservation & Recycling, Volume 38, pp. 317-334.
- Klang, A.G. (2001): Framework for sustainable waste management – examples from the building sector, Proceedings from the Workshop on System Studies for Integrated Waste Management, Johannesberg Castle, Uppsala, Sweden, 2-3 April.
- Opoku, H. and Eik, A. (2001): Policy Design for Material Recovery Systems: A Case Study of Policy and Technology Based Obstacles for Eco-efficiency for Recycling Systems of Plastic Packaging from Households in Trondheim, Norway, International Society for Industrial Ecology Meeting "The Science & Culture of Industrial Ecology", Leiden, 12-14 November.
- Potting, B. Steen, eds. (2002). Life Cycle Impact Assessment: Striving towards Best Practice. 272 pp. Pensacola: Society of Environmental Toxicology and Chemistry. ISBN 1-880661-46-6. Book was awarded the APEX publication award.
- Røine, K and Brattebø, H. (2003): Towards a methodology for assessing effectiveness of recovery systems – A process system approach. Perspectives on Industrial Ecology. pp. 101-111, Greenleaf Publishing, ISBN: 1-874719-46-2.
- Solem, K. E. and Brattebø, H. (2002): Industrial Ecology as a Strategic Instrument for Sustainability. The International Journal for Manufacturing Science and Production 4(2): 2002. ISSN 0793-6648.