TIME - DEPENDENT FLOW BEHAVIOUR OF FIG JAM PUREE

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ABSTRACT

The rheological properties of Fig Jam puree were studied over the range 20-90 °C, concentrations 40-65% and speed of spindle 10-50 rpm. Shear stress- Shear rate data indicate that the puree behaves as a non-Newtonian Bingham plastic fluid with yield stress. The yield stress decreases with increasing temperature except for the samples that have solid concentrations from 60-65% wt. due to pectin formation. Also, the yield stress increases with increase in solid concentration (at all temperatures investigated). Fig jam puree exhibits a thixotropic behaviour in which, the apparent viscosity of the material decreases with time of shearing at constant shear rate. Two models were applied to simulate thixotropic behaviour. The first model is the Tiu and Boger model which characterise shear and time-dependent viscosity behaviour in foods by using a Herschel-Bulkley model modified to include a structural parameter λ to account for time-dependent effects. The other model is the Weltmann model, where an exponential shear stress decay is obtained at different time of shearing and different concentrations.

keywords: Rheology - Jam - Thixotropy - Flow behaviour

1. INTRODUCTION

Fruit and vegetable purees present special problems in flow and heat transfer applications because of their non-Newtonian nature. In some materials, the property of thixotropy becomes important. A thixotropic fluid is one for which the shear stress is a function of time as well as shear rate, (Harper, 1960). Three factors will influence its apparent viscosity excluding its chemical composition: temperature, shear rate and time. For example, the behaviour of stirred yoghurt depends upon its thermal and mechanical history. This is consistent with a thixotropic fluid which follows the definition given by Barnes, et al., (1989): a material is thixotropic when there is a decrease in viscosity with time under constant shear stress or shear rate, followed by a gradual recovery when the stress or shear is removed. Chinnan, et al., (1985) employed a capillary viscometer to obtain shear stress-shear rate data of two types of cow pea pastes. A power law model was established in the form:

$$\tau = k\,\gamma^{n} \qquad (1)$$

where, τ is the shear stress, Pa, k is the consistency index, γ is the shear rate, sec^{-1} and n is the flow behaviour index.

These authors found that the flow behaviour of the pastes showed two consistency indeces of 77.45 and 59.02, and flow behaviour indeces of 0.456 and 0.458.

Carbonell et al., (1991) studied eight samples of jam that were sheared to destroy gel structure and their flow behaviour was analysed in a concentric cylinder viscometer. Jams were prepared from 4 different fruits- strawberry, peach, plum, and apricot at 50% and 30% fruit content approximately. Flow of sheared jam showed time dependence, which could be quantified by the Weltmann model Eq. (2):

$$\tau = A - B \ln t \qquad (2)$$

Where, A and B values were obtained from linear regression between τ and ln t, t is the time, sec, τ is the shear stress, Pa.

Casson yield stress values were obtained at two ranges of shear rates 0.08-1.01 s^{-1} (τ_{01}) and 2.58-387.3 s^{-1} (τ_{02}), τ_{02} values were about double the τ_{01} values.
Flow could be adequately described by Herschel-Bulkley model, introducing either of the yield stress values (τ_{01} or τ_{02}). Significant differences were found for some of the rheological parameters studied (Weltmann A and B constants, τ_{01}, τ_{01} , k_1 and n_1) between samples containing 50% and 30% fruit.

These results demonstrate the role played by fruit particles in the rheological behaviour of this type of product and suggest the possibility of using rheological parameters as an indication of the fruit content of jams.

Butler and O'Donnell, (1999) found that the viscosity of buttermilk exhibits shear and time-dependent behaviour at different constant shear rates. The authors found that the viscosity decreased dramatically with increasing shear rate. At all levels of shear, the viscosity decreased significantly with time. Abu-Jdayil, (2003) stated that the characterization of time-dependent rheological properties of food systems is important to establish relationships between structure and flow and to correlate physical parameters with sensory evaluation. The author stated that many food products exhibited the thixotropic behaviour, in which the apparent viscosity of material decreases with time of shearing at constant shear rate. The structural kinetic model (SKM) was used to characterise the thixotropic behaviour of three different kinds of food products, they include milled sesame, concentrated yogurt and mayonnaise. The (SKM) postulates that the change in the rheological behaviour is associated with shear induced breakdown of the internal structure of the food product.

2. EXPERIMENTAL TECHNIQUE

2.1. Materials and Method

Six samples of Fig Jam puree with different solid concentrations (40, 45, 50, 55, 60, 65 wt%) were taken during the processing of the jam.

Fig puree jam is obtained from fresh Fig fruits which have been cleaned by a special washer then passed through a bucket elevator that transfer the fig fruit to a refiner which separates the pulp from fiber, the pulp is then packed in a container.

The Fig puree is then manufactured using the following procedure:-

1- The fig puree is transferred to a vacuum pan with suction and, if needed, a little treated water is added to rinse out the last of the material.

2- Addition of sugar to the pulp with weight ratio 1:1 fig pulp to sugar, and citric acid 2.6 gm per kilogram pulp.

3- The vacuum pan is heated to 80-90°C with stirring until the puree reaches the required concentration.

4- The puree jam is then pumped to the filler where it is packed.

2.2. Rheological Properties:

Flow properties (shear stress, shear rate, and apparent viscosity) of Fig jam puree were measured directly with Brookfield Digital Rheometer, Model DV-III (Brookfield Engineering Laboratories INC). The puree was placed in a small sample adapter, the SC4-25 spindle was selected for the sample measurement. A thermostatic water bath provided with the instrument was used to regulate the sample temperature. The rheological parameters for Fig jam puree were studied in the temperature range 20-90°C, speed of spindle between 10-50 rpm and at different concentrations of Fig jam puree 45-65% for plotting shear stress - shear rate data. For studying thixotropic behaviour, a sample of Fig jam puree at 65% solid concentration was measured at room temperature (20°C), in the time range 1-10 minutes and spindle speed between 10 and 50 rpm.

3. RESULTS AND DISCUSSION

3.1. Shear stress-Shear rate behaviour

Shear stress and shear rate values are plotted in Fig.1 for 65% solid concentration of Fig jam puree at different temperatures (20, 40, 50, 60, 70, 80, 90°C). The same trend was observed at solid concentrations (40, 45, 50, 55, 60 wt %) of Fig jam puree.

The results show that all the samples exhibited non-Newtonian Bingham plastic behaviour at all the studied temperatures and concentrations, in which the stress is a linear function of shear rate.

The stress-strain rate data obtained fitted well to the constitutive Eq. (3) :

$$\tau = k\gamma + \tau_y \qquad (3)$$

Where, τ is the shear stress, Pa, k is the plastic viscosity (consistency index) and γ is the shear rate, sec^{-1}, τ_y is the yield stress, Pa.

A plot of yield stress versus temperature at different concentrations is shown in Fig. 2. This figure shows that, in general, the yield stress decreases with increasing temperature except for the samples that have solid concentrations from (60-65%) of Fig jam puree where, yield stress exhibit an increase at temperatures between 50 and 70°C. This may be explained by the formation of high methoxyl pectin that forms a gel between 50 and 60%, solids.

It was observed that this sudden increase in yield stress disappears at lower concentrations 40-50%, This is in accordance with the work of Imeson, (1992) who noticed that high methoxyl pectin does not form at such low concentrations of solids.

Fig. 3 shows that the plastic viscosity (k) decreases with increase in temperature at different solid concentrations (40, 45, 50, 55, 60, 65 %) of Fig jam puree. On the other hand, it is noticed that the fluctuations in (k) decrease at higher concentrations (60-65%) this may be explained by the fact that the pectin set is completely formed at concentrations 60-65%.

Fig. 4 shows the variation of yield stress with concentration at different temperatures, over the concentration range studied (40-65%). All data could be fitted by one simple relation in the form:

$$\tau_y = A(C-35)^n \qquad (4)$$

Where, τ_y is the yield stress, Pa ,and A, n are empirical values related to temperature, C is the concentration, wt. %.

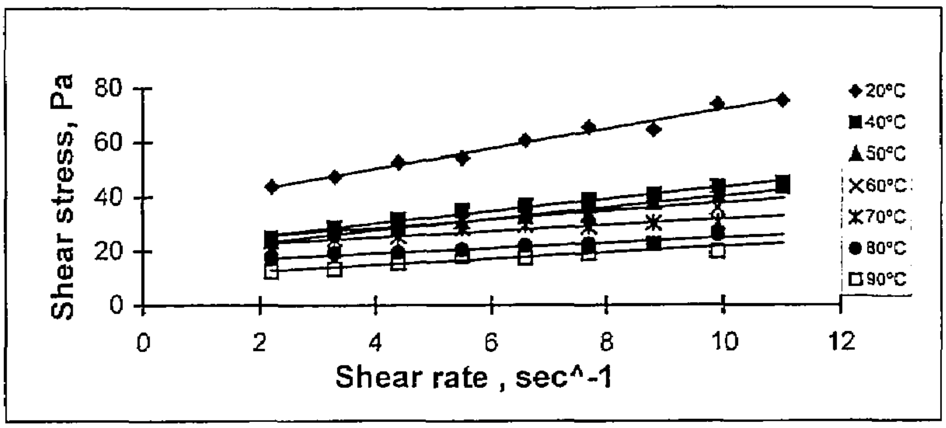

Fig. 1. Relationship between shear stess and shear rate at different temperatures, 65% solid concentration of Fig jam puree.

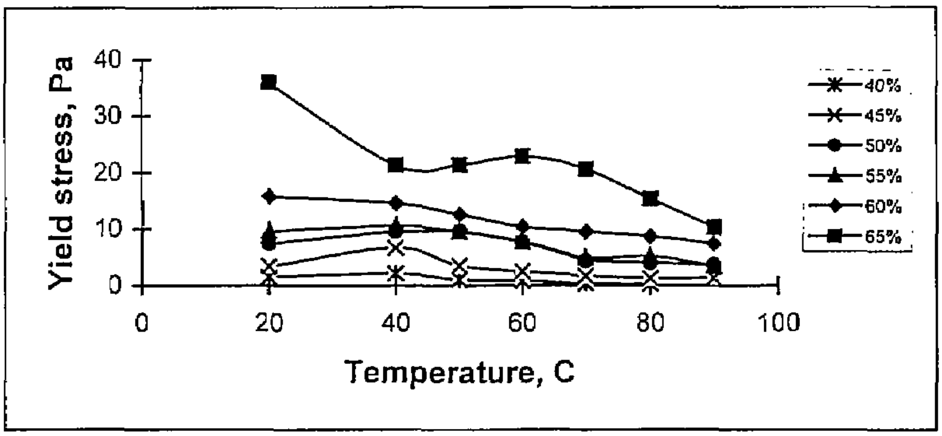

Fig. 2. Relationship between yield stress and temperature at different concentrations of Fig jam puree.

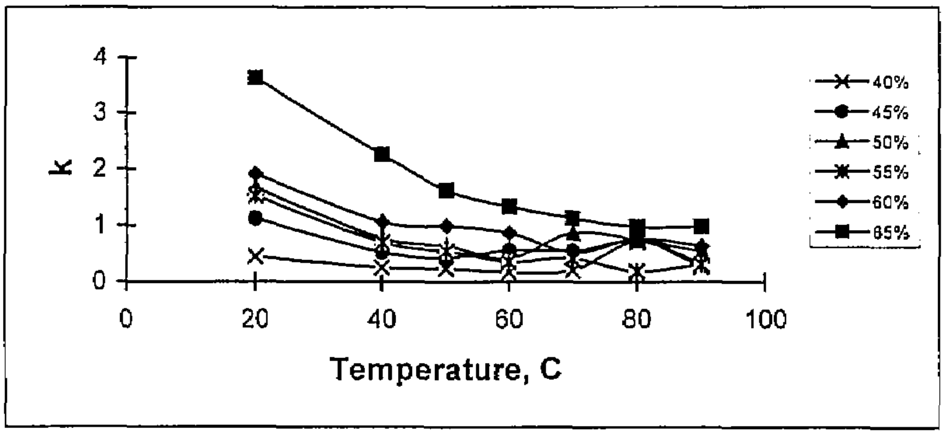

Fig. 3. Relation ship between k and temperature at different concentrations

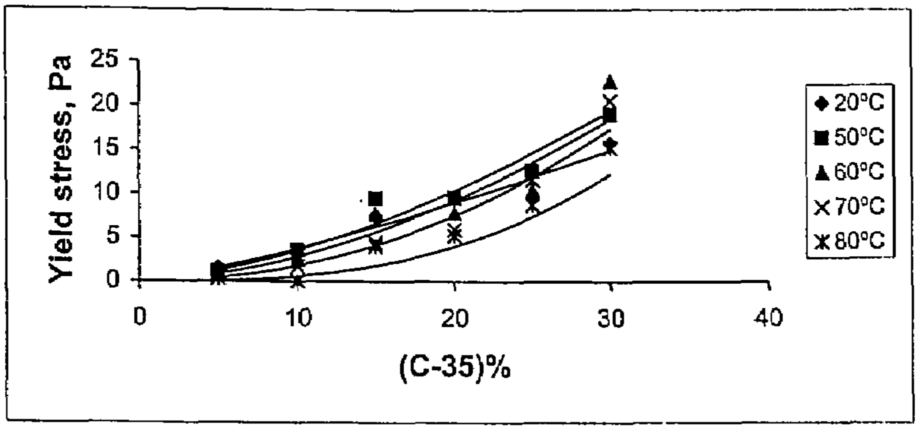

Fig. 4. Relationship between yield stress and solid concentration of Fig jam puree at different temperatures.

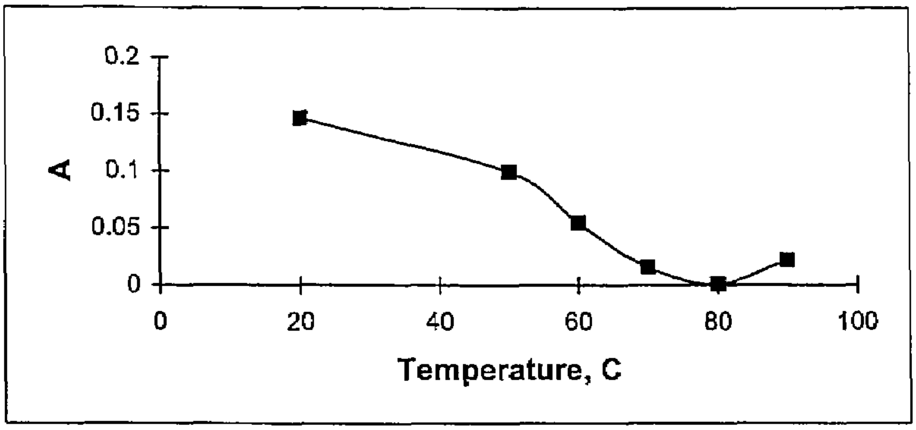

Fig. 5. Relationship between constant A and temperature.

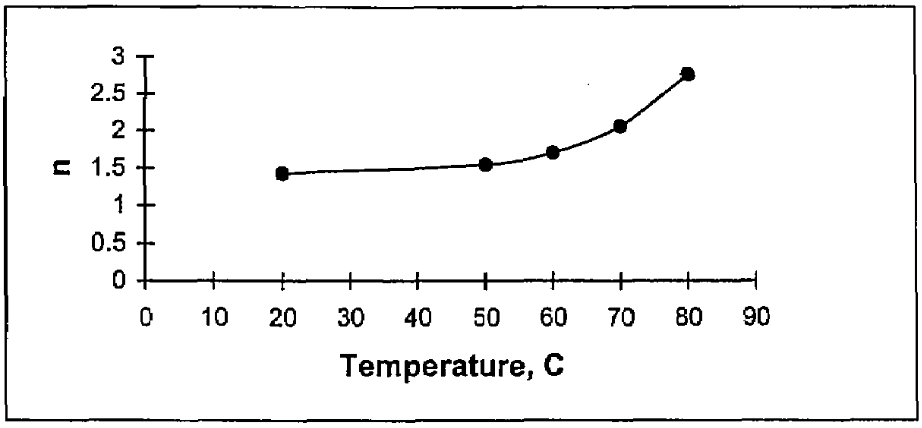

Fig. 6. Relationship between constant n and temperature.

As concentration increases the yield stress increases and this is the same trend for all temperatures investigated.

The value of the constant A, steadily decreases with temperatures up to 80°C, Fig. 5.

On the other hand, the values of the exponent (n) in Eq. 4 remain almost the same at 20°C and 50°C then begin to increase as temperature is increased from 50°C to 90°C, Fig. 6., Table 1.

Table 1

Values of empirical constants of Eq.4 at different temperatures.

T, °C	A	n
20	0.094	1.63
50	0.099	1.55
60	0.055	1.71
70	0.015	2.07
80	0.011	2.1
90	0.0016	2.66

3.2. Time dependent behaviour

Thixotropic behaviour is observed in some shear-thinning fluids in which no equilibrium is established between the structural breakdown and reformation processes, such that the number of structural interactions decreases continuously with time and the material suffers a permanent change as a result of shearing for examples include, starch paste, gelatins and mayonnaise, (Rielly, 1997).

A thixotropic fluid exhibits an increase in shear rate with increasing shear stress. If now, the shear rate is decreased, the material needs some time to rebuild its original structure. Hence, a hysteresis loop is obtained. Such a loop is typical of a thixotropic material for a test in which the shear rate is ramped up then ramped down over the same period of time (30 sec) for 65% concentration of Fig jam puree as shown in Fig. 7.

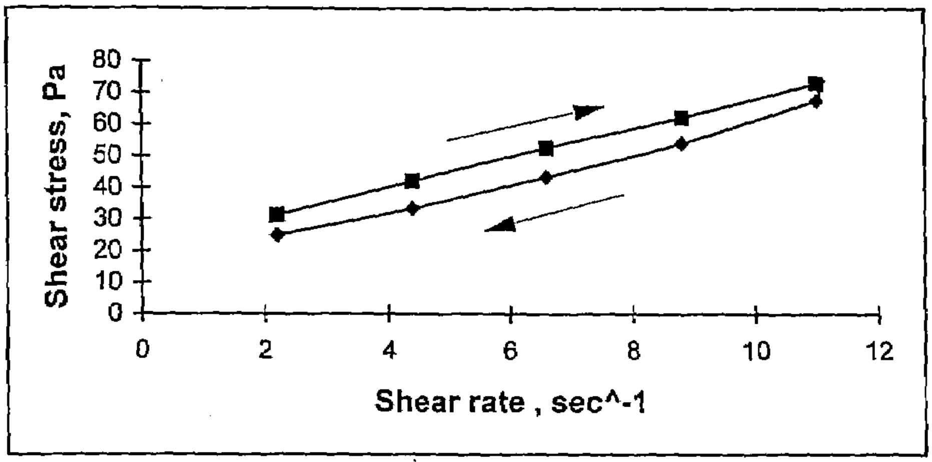

Fig. 7. Thixotropic effect at 65% solid concentration of fig jam puree, 20°C.

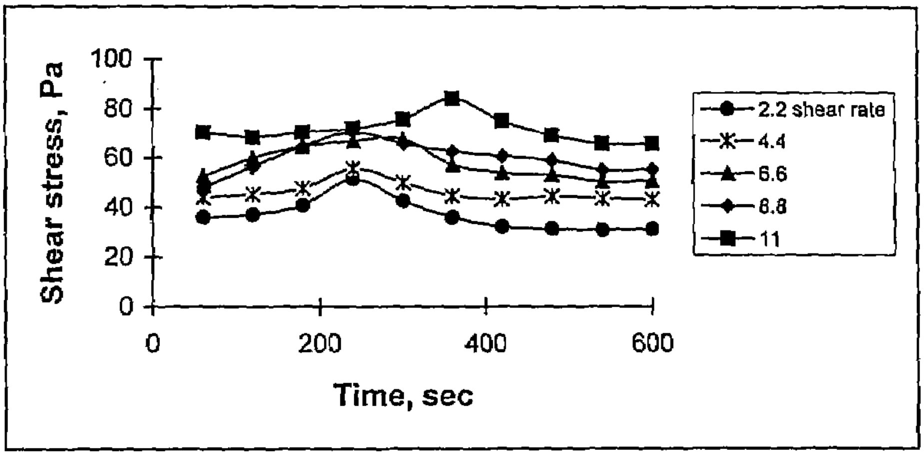

Fig. 8. Relationship between shear stress and time at different shear rates, 20°C, 65% solid concentration of Fig jam puree.

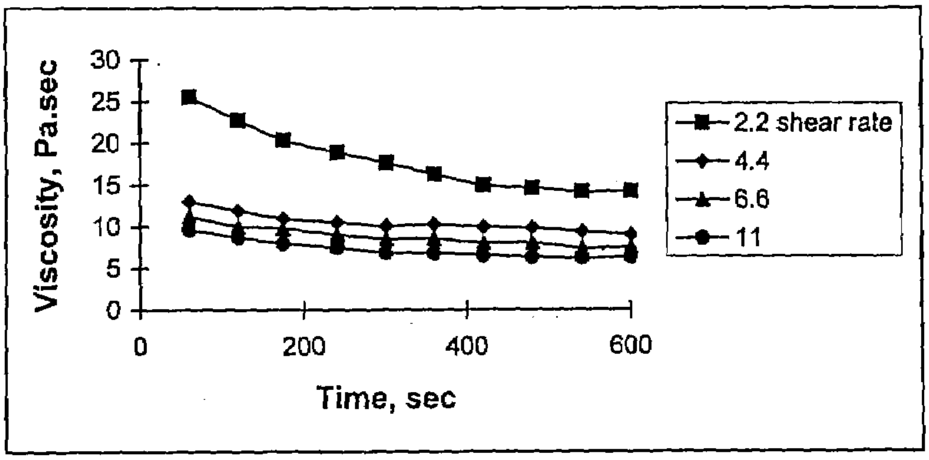

Fig. 9. Effect of time on viscosity at different shear rates, 20°C, 65% solid concentration of Fig jam puree.

On the other hand, if the shear rate is kept constant at a certain value, the shear stress drops with time to reach a certain minimum value, then it remains constant with time. It was observed, however, when studying the behaviour of Fig jam puree at 20°C, that the shear stress generally tends to increase with time, as the shear rate is constant, then it decreases to reach values lower than the original values. Fig. 8, shows such behaviour.

Fig. 9, shows that because the material is both shear thinning and time dependent, the viscosity decreases continously with time at all shear rates.

Constitutive models such as the Herschel-Bulkley equation may be adapted to allow for thixotropic effects by introducing a structural parameter λ, This method was described by Tiu and Boger, (1974) on the study of thixotropic behaviour of mayonnaise. If the behaviour is of the Bingham type, then a structural parameter λ can be defined so as to obtain the time dependent modified equation.

$$\tau = \lambda\,(\tau_y + k\,\gamma)\text{, where, } \lambda = \lambda(t) \qquad (5)$$

λ has a value of 1 at t=0 and may be described by a first order decay equation :

$$\frac{d\lambda}{dt} = -k_1\,(\lambda - \lambda_e) \text{ for } (\lambda > \lambda_e) \qquad (6)$$

Where, λe is the final value for complete breakdown of structure and k_1 is a rate constant depends on the shear rate.

Integerating this equation, we get :

$$\ln(\lambda - \lambda_e) = -\,k_1\,(t - t_0) + C \qquad (7)$$

Where, t_0 = time at which the shear stress starts to decrease.

It is therefore clear that λ is a decreasing function of time. Referring to Eq. 5, and dividing by γ, we get :

$$\mu = \lambda\,(\tau_y / \gamma + k) \qquad (8)$$

Where, μ is the viscosity, Pa.s and τ_y is the yield stress, Pa.

Hence, at constant shear rate, the viscosity should decrease with time. This can be shown in Fig. 9, where the effect of thixotropy is much more pronounced at low shear rates. In practice, this means that, if the jam is stirred at low velocity, then its viscosity will steadily decrease with time. A high agitation speed will not affect the viscosity in the same way.

The following table shows the variation of constants k_1 , C with shear rate.

Table 2

Empirical constants k_1, C of Eq. 7

Shear rate, (γ) sec^{-1}	k_1	C
2.2	0.0209	4.5718
4.4	0.0112	1.0539
6.6	0.0107	1.024
8.8	0.0061	0.079
11	0.0138	1.828

Figure 10 shows the relation between ln (λ - λe) and time at different shear rates (2.2, 4.4, 6.6, 8.8, 11).

Another model for time dependent effect is Weltmann model: Shear stress decay data were obtained at different time values for and at concentrations, (40, 50, 60, 65%), 20°C. The variation of shear stress with time of shearing was fitted to Weltmann model Eq. (9).

$$\tau = A - B\ \ln t \qquad (9)$$

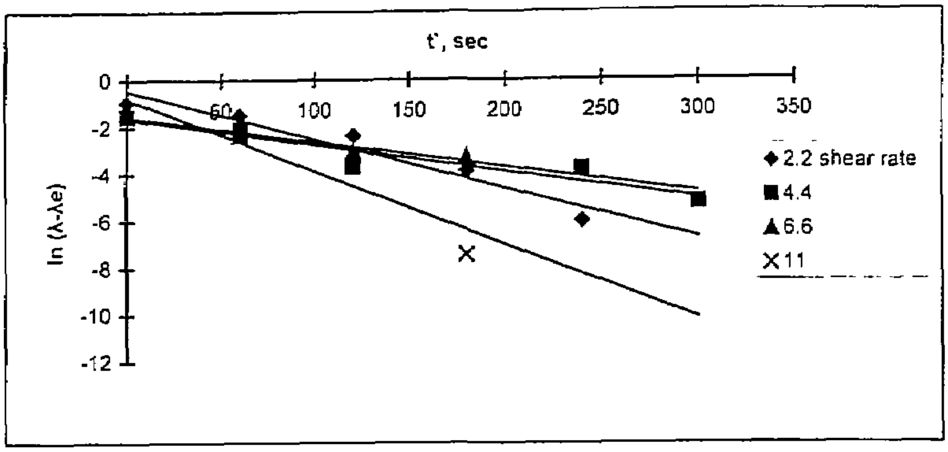

Fig. 10. Shows the relation between ln (λ-λe) and t' (time, sec) at different shear rates, 65% solid concentration of Fig jam puree and 20°C.

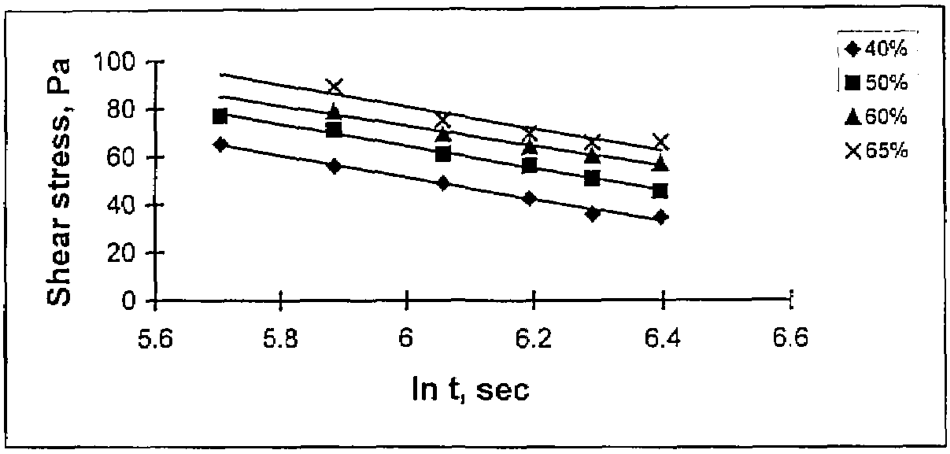

Fig.11. Relationship between shear stress and lnt at different solid concentrations of Fig jam puree, shear rate =11 sec^-1, 20°C.

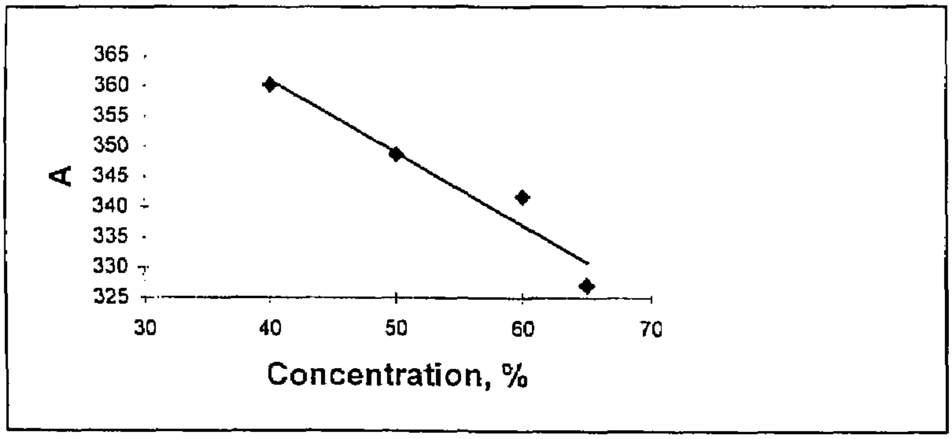

Fig.12. Relationship between constant A and solid concentration of Fig jam puree.

Where, τ is the shear stress, Pa and t is the time, sec

In Fig. 11 the shear stress variation with time was well fitted by Weltmann model for different concentrations at a sample shear rate 11 sec^{-1} according to Eq. 9. The lines are almost parallel having a constant slope of $B \cong 45$.

The relation between constant A in Eq. 9. and concentration, Fig.12., was fitted well by the following constitutive equation:

$$A = 410.53 - 1.2279\ C \qquad (10)$$

Where, C is the solid concentration of Fig jam puree.

4. CONCLUSION

Fig jam puree behaves as a non-Newtonian Bingham fluid. The yield stress decreases with increasing temperature except for the samples that have solid concentrations from (60 to 65%) of Fig jam puree because of the formation of pectin gel at these concentrations. Also, as the solid concentration of Fig jam puree increases, yield stress increases at all the temperatures investigated.

The time dependent flow behaviour of Fig jam puree possessing thixotropic behaviour was simulated using two models. The first model is Tiu and Boger model which characterise shear and time-dependent viscosity behaviour in foods by using a modified Herschel-Bulkley model to include a structural parameter λ to account for time-dependent effects. The other model is Weltmann model where shear stress decay is obtained at different values of shearing time and for different concentrations. Such models are helpful in prediction of both flow and thixotropic behaviour in the range of solid concentrations and temperatures investigated.

NOTATION

τ	Shear stress, Pa
k	Consistency index.
γ	Shear rate, sec^{-1}.
n	Flow behaviour index.
A and B	Constants in Weltmann model equation.
t	Time, sec.
τ_y	Yield stress, Pa.
·	Structural parameter in Tiu and Boger model in the thixotropic behaviour.
λ_e	Final value for complete break down of structure.
k_1	Rate constant depends on shear rate.

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TREATABILITY STUDY FOR AN INDUSTRIAL TEXTILE WASTEWATER

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ABSTRACT

Textile wet processing is a major source of water consumption and wastewater pollution. There are many wastewater treatment processes for reducing textile wastewater pollution including physical, chemical and biological. This paper studies treatability of industrial wastewater of a large fabric textile plant, known as Misr Company for Spinning and Weaving, El-Mahalla El-Kobra, Egypt. The rate of industrial water usage in the company is reported to be 330 m^3 of water per ton produced, which is higher than the international range. The company discharges about 1750 m^3/hr to agricultural drain. Treatment of the end-of pipe effluent was carried out using batch laboratory setup. Settlability study indicates that the settling could reduce COD, BOD, and TSS with removal efficiency of 47, 48 and 56 % respectively. Meanwhile biological activated sludge process with 6 hrs aeration residence time could reduce the COD and BOD to the regulation limits. Sand and activated carbon filters are proposed for further removal of suspended solids and color.

KEY WORDS:

Textile wastewater, treatability study, biological treatment, industrial pollutant removal.

INTRODUCTION:

The role of wastewater treatment is becoming more and more important, as both the effluent quality and quantity are subject to more stringent regulations. In Egypt, textile industry has played an important role in economic development since early last century. Water demands of textile industries has a wide range according to the process, with a typical international water consumption rate of 30 to 300 m^3 per metric ton produced (Tchobanoglous and Burton, 1991). Meanwhile Germirli *et al.* (1998,1999) have reported a low range of water usage from 20 to 100 m^3 per ton of fabric processed. Technological advancement in processing to minimize the use of water may help reducing effluent quantity, where cost-effective wastewater treatment can be adopted to reduce pollutant concentration to an acceptable limits.

Traditionally there are three types of wastewater treatment: physical such as sedimentation, filtration, adsorption; chemical such as oxidation, reduction and ion exchange and biological such as activated sludge, trickling filter, rotating biological reactor, and lagoons. Due to the inability of a single treatment method to meet effluent quality standards in certain industries, a number of recent researches attempted to explore the combination of two or more methods to achieve the desired degree of treatment, and the results are encouraging.

The choice of the correct system must be carried out considering several factors, including technical and economical consideration. In several cases, specific experimental tests are required in order to assess actual efficiency and proper treatment condition. Scott and Ollis (1996) and Esplugas and Ollis (1997) described the advantages of combined wastewater treatment as: protection of biological culture from inhibitory or toxic compound by pretreatment; reduction of cost by the usage of cost-effective biological treatment; flexibility in relative residence time as a result of broad maximum efficiency plateau; and cost-effective while achieving complete pollutant minimization.

Ozone treatments were efficiently used in a pilot plant with membrane in treating textile wastewater for reuse (Lepoz et al., 1998, Ciardelli et al. 2000, Bes-Pia et al. 2003)). Moreover, Lee et al. (2001) used membrane nano-filtration, oxidation and biological treatment processes as successful textile wastewater treatment for reuse of treated water in the textile manufacture processes. Also adding hydrogen peroxide solution in the presence of ferrous coagulant salts has a significant effect on the increase in efficiency of organic pollutant removal of textile wastewater (Meric, et al. 1999 and Perkowski and Kos 2002).

This paper outlines treatability studies on industrial wastewater pollution control for a large fabric textile plant, emphasizing waste minimization and compliance with regulation limits for disposal into neighbor water body.

PLANTS DESCRIPTION:

The wastewater of the treatability study was collected from Misr Company for Spinning and Weaving, El-Mahalla El-Kobra, Egypt. Misr Company is a public Egyptian company, and one of the largest Textile Companies in the Middle East. It was established in 1927 on an area of about 600 acres (250 hectare) and has about 28700 employees working 3 shifts a day, 7 days a week, 330 days a year. The company has an average annual production of 48,000 ton, of which approximately 50% is internationally exported. The company produces cotton yarn, wool yarn, clothes, downy textile, pieces of garments, wool clothes, blankets, surgical cotton, weaved silk-polyester and bleached clothes.

The factory consumes 53000 m3 water per day of which about 20% is underground well water and 80% is treated surface water. About 85% of the treated water are used in the manufacturing process applications while the rest is used for domestic applications in the administration and labor houses. The rate of industrial water usage in the factory is reported to be 330 m3 water per ton produced, which is much higher than the international range.

The company discharges about 1750 m3/hr to its wastewater treatment plant including both industrial and domestic wastewater. The effluent from the wastewater treatment plant is discharged to the public drain number 5, at the North of the site. The existing wastewater treatment has lower hydraulic and treatment capacities than that needed for handling the wastewater received. Therefore, the effluent violates pertinent environmental law.

LABORATORY ANALYSIS:

The physico-chemical characteristics investigated and covered the following parameters: pH value, total solids (at 105°C & 550° C) total suspended solids (TSS), settleable solids, total phosphate, CODtot, BOD, ammonia, total kjeldahl nitrogen (TKN) and oil & grease. Moreover sludge analysis including, sludge volume and sludge weight were also carried out.The analysis, unless specified, were carried out according to the American Standard Methods devised by APHA methods (1998).

TEXTILE WASTEWATER CHARACTERIZATION:

As stated above in order to reduce the pollutant parameters such as COD, BOD TSS TKN to the allowable regulation level, it is necessary to identify the wastewater characteristics so that the treatment objective can be determined. A review by Correia et al. (1994) provides a general but comprehensive study on textile wastewater characterization. It is, however, necessary to conduct a series of analyses to identify the actual parameter for local textile factory. Samples from the final mixture raw wastewater from the factory were obtained. Characteristics of the final raw wastewater are shown in Table (1).

The characteristics of the raw textile wastewater are similar to the characteristics of the strong domestic wastewater except for the high concentration of phosphate and total suspended solids (TSS). Although the final raw wastewater characteristics of TDS, TKN, oil and grease are within regulation limits, the other wastewater characteristics should be adjusted to comply with regulatory standards for disposal into the neighboring non-fresh water body (agricultural drain).

TREATABILITY TECHNIQUE:

There are various treatment techniques to remove textile wastewater pollutants. The aerobic biological treatment of textile wastewater is the most commonly used method all over the world. Orhon et al. (2001) indicated that more than 80 % of the textile wastewater COD is of soluble nature and activated sludge system is used for treatment. their results reflected a textile character with a biodegradable COD ratio of around 75%, a readily biodegradable COD ratio of 10%, the same level normally encountered in domestic sewage. Vives et al. (2003) used activated sludge and SBR at step-feed strategy to reduce the effluent biodegradable matter presented in textile.

Table (1) Raw wastewater Characteristics and regulation limits for disposal.

Parameter	Unit	Raw WW	Regulation
Daily flow rate	m3/d	72,000	
Hourly flow rate	m3/hr	3,000	
pH	value	7 - 12	6-9
COD	mg/L	740	100
BOD	mg/L	400	60
TSS	mg/L	900	50
TDS	mg/L	2000	2000
Oil & grease	mg/L	10	10
Phosphate	mg/L	18 - 90	10
Total Nitrogen	mg/L	4.6 – 9.4	45
Total heavy metal	mg/L	1.5	1

The suggested end of pipe wastewater treatment for this study was included one or more of the following treatment techniques: sedimentation, biological treatment via activated sludge and filtration.

Sedimentation; To study the settleability of the suspended solids, wastewater samples were subjected to gravity sedimentation in an imhoff cone for two hours. Samples from the settled sewage were taken at different time intervals for analysis.

Biological treatment: Nitrogen and Phosphorous concentrations of the wastewater were adjusted to satisfy the ratio BOD (100): N (5): P (1), by the addition of ammonium dihydrogen phosphate. Biological treatment of the end-of pipe effluent was carried out using batch laboratory experiment. To develop sludge which is acclimatized on the waste under consideration, activated sludge from a nearby municipal wastewater treatment facility was fed twice a day with a mixture of domestic and industrial wastewater. This was followed by using only industrial wastewater. The sludge weight ranged from 3-4 gm/L and the aeration time ranged from 1 to 24 hours. Dissolved oxygen concentration was adjusted to maintain a minimum concentration of 2.0 mg O_2/L. The characteristics of the biologically treated effluent, as indicated by COD and TSS were determined after 60 minutes settlement. Sludge analysis was also carried out.

RESULTS AND DISCUSSIONS:

Sedimentation: Results of the preliminary investigations indicated that the optimum sedimentation time is 45 minutes with the addition of Alum as coagulant with a dosage of 400mg/l of waste stream (Orhon, D. *et al.* (2001). Available data presented in Table (2) and Figure (1) indicates that BOD, COD and TSS removal values were 47%, 48% and 56% respectively.

Biological treatment: Aeration periods of 2,3,4,5,6, and 24 hours were examined. The results of the biological treatment of the settled industrial waste are presented in Table (3). Available data indicates 70 % reduction in COD after two hours. By increasing the aeration period to three hours, the removal efficiency increased to 72%, 91% and 95% for COD, BOD and TSS respectively. Corresponding residual values were 89 mg/L, 16 mg/L and 13 mg/L, respectively. The quality of the treated waste is complying with the standard given by the Egyptian law (48/1982).

Table (2) Characterization of wastewater after settling

Parameter	Raw W.W.	After 30 min.		After 45 min.		After 1 hr.	
		mg/l	%Remove	mg/l	%Remove	mg/l	%Remove
COD(mgO_2/l)	600	400	33	318	47	312	48
BOD(mgO_2/l)	330	210	36	172	48	165	50
TSS(mg/l)	570	320	44	251	56	245	57

Microscopic examination of the sludge indicated the presence of many colonies of protozoa, especially staked ciliates such as Vorticella and Opercularia. Paramoecium and Rotatoria were frequently observed.

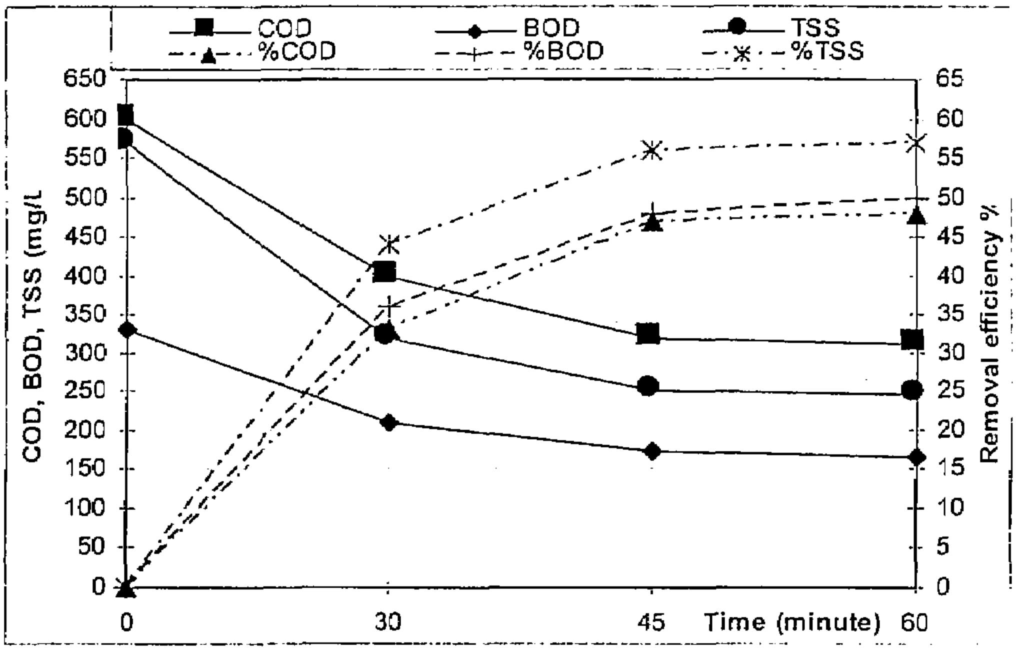

Fig.(1) Removal pollutant in sedimentation treatability study

Biological treatment: Aeration periods of 2,3,4,5,6, and 24 hours were examined. The results of the biological treatment of the settled industrial waste are presented in table (3).

Table (3) Biological treatment of the end pipe after settling via activated sludge

Parameters	Raw	Settled Sample	Detention period (hours)					
			2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	24 hrs.
PH value	10.5	10.5	8.3	8.4	8.26	8.0	8.1	8.0
COD mgO_2/l	600	318	95.4	89	16	3.0	1.5	3.0
%Removed	-	47	70	72	95	99	99.5	99
BOD mgO_2/l	330	172	-	16	-	-	3.5	-
%Removed	-	48	-	91	-	-	99.0	-
TKN mg/l	6.5	10	-	6	-	-	1.5	-
TSS	570	251	15	13	N.D.	N.D.	N.D.	N.D.
%Removed	-	56	94	95	100	100	100	100
<u>Sludge analysis</u>								
SVI ml/l	-	-	60	65	70	80	85	82
MLSS g/l	-	-	0.642	0.696	0.749	0.856	0.9	0.88

REMEDAL PROPOSED ACTION:

Reduction of water consumption; It is shown that the water consumption in industry by the company is almost three times higher than the international standards norms. Therefore attention should be given to the methods of reducing and controlling the industrial water consumption in the company.

From field visits and study; flow rate reduction can be accomplished using one or more of the following options: i- Using automatic shut off valves in the continuous process units, ii- Adjust amount of water depending on the fabric width, iii- Maintenance of level indicators in adiabatic saturation chambers (Air conditioning units) to adjust the relation between relative humidity of air and amount of water consumed in units, iv- Install automatic steam regulators and meters to adjust and hold a constant flow over a range of pressures, v- Collection and reuse of condensed steam, vi- Recycling of final washing water to the first step of bleaching stage, vii- Reuse of slightly contaminated wastewater such as: discharged fire extinguishing water and blow down water from cooling towers, boilers, and swimming pool, viii- Recovery water from filters and clarifiers wastewater in the water treatment plants, ix- Install flow meters on all streams entering plants, and x- Inspection of the water distribution network for any suspected leakage especially in valves and chambers.

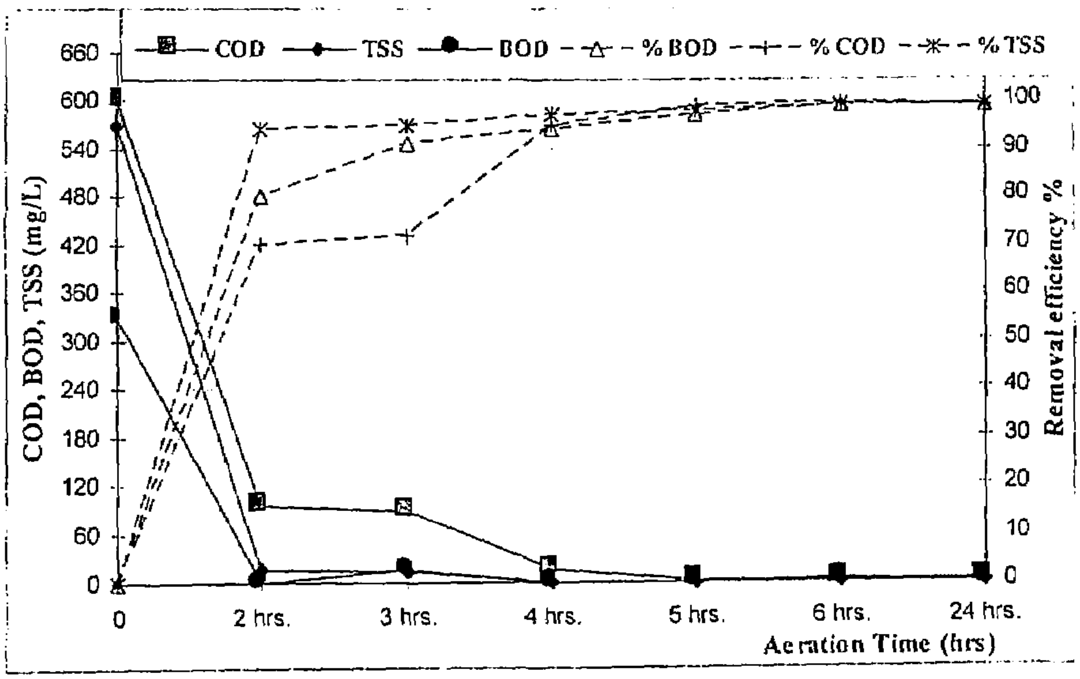

Fig.(2) Removal of pollutant in activated sludge process

Wastewater Treatment Process Description; The industrial and domestic wastewater of the factory is proposed to be treated in a plant according to the characteristics of the raw wastewater and regulation (Table 1), and according to results of the treatability study mentioned above (Tables 2 & 3 and Figures 1 & 2). The proposed treatment units can absorb disturbances limits ± 15% of the levels mentioned in the basis of design. The steps of the treatment are described blow (Fig. 3).

Primary treatment; The influent wastewater passes through three manual and automatic screens. Then raw wastewater is directed to the grit, oil and grease removal tanks as shown in Fig. (3). The treated effluent from grit chambers passes to a conditioning units where sulphuric acid is added to adjust the pH to enhance the separation of suspended solids.

The wastewater then enters the primary sedimentation tanks after addition of the selected coagulant for partial removal of suspended solids and organic load before biological treatment. The settled sludge is pumped to thickening units.

Secondary Treatment; Partially treated wastewater is then passed to the aeration tanks for biological treatment. The air required for biological treatment and mixing is provided by surface aerators. The mixed liquor from the aeration zones is then moved for settlement in secondary sedimentation tanks. The settled sludge is continuously re-circulated to the aeration tanks to maintain the optimum MLSS and F/M ratio in the aeration tanks. Excess sludge is pumped to the thickeners on intermittent basis. The effluent from the secondary sedimentation tanks is directed to disinfection chlorination units. This unit is used to disinfect the effluent prior to disposal to the drain.

Tertiary Treatment; The clarified effluent from the final sedimentation tanks is directed to sand filters for further removal of suspended solids. Upon limiting head loss the pressure filters is manually backwashed using the filter feed/backwash pumps. Activated carbon filters should be used to adsorb color by using activated charcoal. The adsorbent agent is proposed to be placed in the cylindrical shell in the form of beds. After exhausting of any bed, the bed will be replaced by another fresh one.

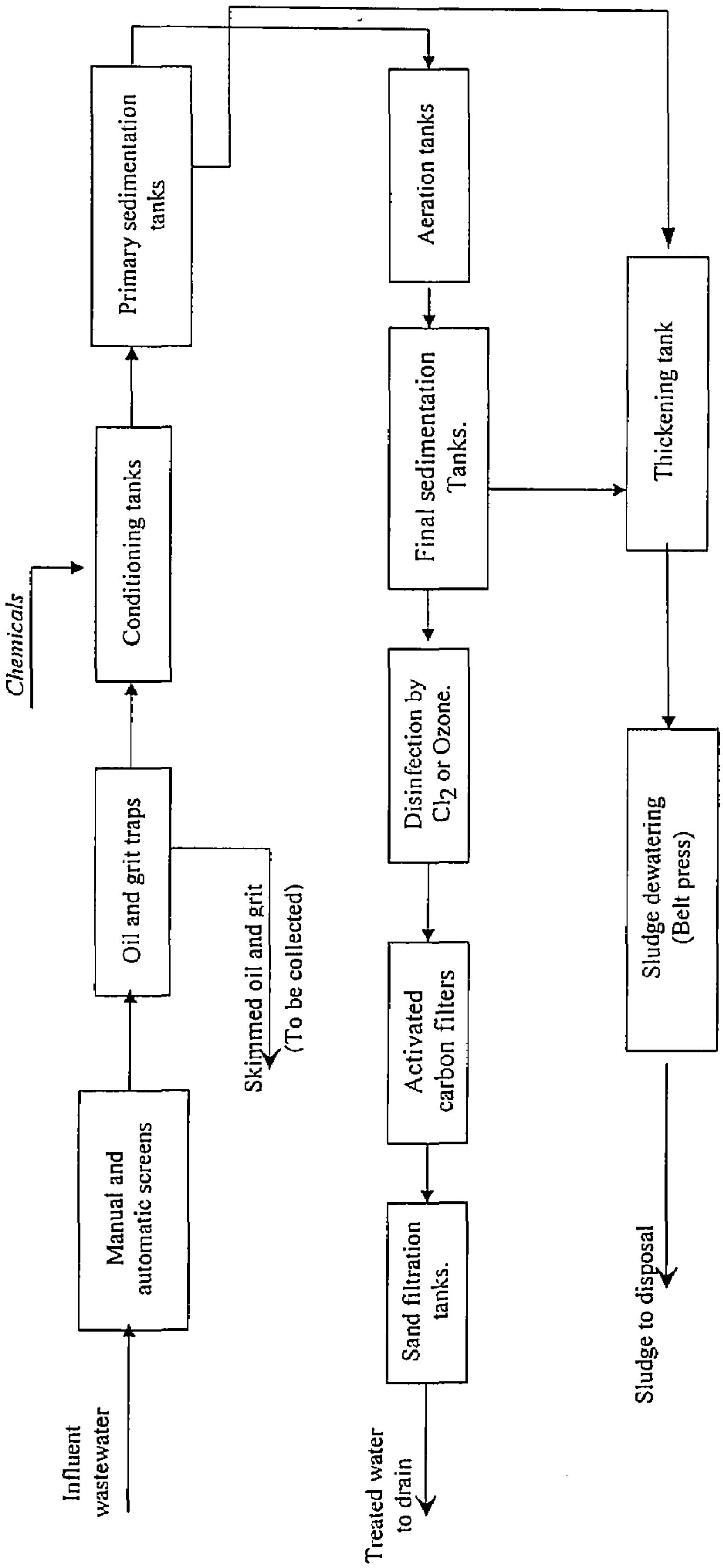

Fig. (3) Block Diagram for the Proposed Treatment Plant.

9

Sludge Treatment; After thickening of the sludge in the gravity sludge thickeners, thickened sludge is pressurized by thickened sludge pumps to the sludge belt press for further dewatering. The sludge is dosed by polyelectrolyte before entering the belt press to ensure efficient dewatering. The sludge cake is then delivered to trucks for disposal offsite as solid wastes.

Preliminary Design of the treatment unit; The results of sizing of the main equipments to treat 72,000m^3/day are as follows:

- **Lift Station Sump**

Quantity	: Three
Length	: 8.5 m
Width	: 6.0 m
Side wall depth	: 4.0 m

- **Manual and automatic screen chambers**

Quantity	: Three
Length	: 4.0 m
Width	: 1.0 m
Side wall depth	: 0.7 m

- **Grit & Grease Traps**

Quantity	: Six Channels
Length	: 12.0 m
Width	: 2.0 m
Side wall depth	: 1.9 m

- **Conditioning Tanks**

Quantity	: Three
Length	: 16.0 m
Width	: 8.0 m
Side wall depth	: 4.0 m

- **Primary Sedimentation Tanks**

Quantity	: Three
Diameter	: 20.0 m
Side wall depth	: 4.5 m
Liquor depth	: 4.0 m
Working volume	: 804.0 m^3

- **Primary Sludge Collection sump**

Quantity	: One
Length	: 5.0 m
Width	: 5.0 m
Depth	: 4.0 m

- **Aeration Tanks**

Quantity	: Four
Length	: 50 m
Width	: 20 m
Side wall depth	: 4.4 m
Liquor depth	: 4.2 m

- **Final Sedimentation Tanks**

Quantity	: Four
Diameter	: 25.0 m
Side wall depth	: 4.5 m
Liquor depth	: 4.0 m
Working volume	: 486 m^3

- **Excess/Return Sludge Collection sump**

Quantity	: One
Length	: 10.0 m
Width	: 6.0 m
Depth	: 6.0 m

- **Sludge Thickening Tanks**

Quantity	: Four
Diameter	: 14.0 m
Side wall depth	: 4.5 m
Liquor depth	: 4.0 m

- **Gravity Sand Filters**

Quantity	: Ten
Length	: 10.0 m
Width	: 6.0 m
Side wall depth	: 5.0 m

Liquor depth : 4.2 m

CONCLUSION:

The feasibility and treatability study implemented on the industrial wastewater of Misr Company for Spinning and Weaving, El-Mahalla El-Kobra, Egypt, indicated that the consumed water per ton produced is higher than the international range. Many options and scenarios have been suggested for reduction of water used in production in order to minimize the wastewater flow rate. From the treatability study, the physical sedimentation and biological treatment followed by filtration and disinfection is the best technique for treatment. Biological activated sludge treatment has given 99% removal of BOD and COD concentrations with 6 hrs aeration period. Activated carbon filters are proposed for further removal of color. Further studies should be done in order to reuse the lightly contaminated textile wastewater in the manufacturing processes.

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