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Integration between Engineering and Knowledge Systems: Evaluation of Performance of a Wastewater Treatment Plant in a Textile Company

Mohammed A. Ahmed Al-Dujaili[1], Haitham Remdhan Abed Ali[2] and Ahamed Noori Obeed[3]

1. School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester M13 9PL, UK

2. Mechanical Engineering Department, College of Engineering, Babylon University, Babil, Iraq

3. Textile Company, Babil, Iraq

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Abstract: The integration between engineering and knowledge systems (KS) in a manufacturing environment in a network of industrial enterprises was investigated. The drivers for this application of engineering design to infrastructure in an industrial setting where cost and time to market are vital were to spread best practice, and to gain experience in dealing with the regulatory authorities according to ISO 14000. Therefore, the aim of this study was to evaluate the performance of the industrial wastewater treatment plant of the Hilla Textile Factories, to find an appropriate method of treating the industrial wastewater so as to render it fit for reuse or safe to be disposed of as stipulated by the Iraqi laws on effluent disposal. The removal efficiencies of the different parameters used to describe water quality was low. It was found that the removal efficiency of COD (Chemical Oxygen Demand) was 20-21%, that of BOD (Biochemical Oxygen Demand) was 17-30% and that of TSS (Total Suspended Solids) was 27-31%. The quality of the effluent was not in line with those of either the Iraqi or American standards.

Key words: Source of water, knowledge systems, water quality, water pollution, activated carbon adsorption, granular activated carbon.

1. Introduction

The wastewater treatment works (WTW) may be considered as an asset management system. This is because it holds structural information about the plant in terms of an asset register. It also has the capacity to supply different consumers with access to current and historic data [1].

Subsequent to this, the perceptions of the role of human intervention in economic transactions have changed. The appreciation of an individual's physical labor and ability to regulate and co-ordinate has given way to an emphasis on potential contribution to the production and application of knowledge. Accordingly, the paper is organized as follows: Section 2 proposes knowledge systems; section 3 presents water quality; section introduces 4 plant description; section 5 talks about water supply and distribution description; section 6 is the productive sections; section 7 explains the industrial wastewater treatment plant description; section 8 presents results and discussion; section 9 gives conclusions; section 10 presents future work.

2. Knowledge Systems

The ability to collect information, generate new knowledge, disseminate and apply this knowledge to

Haitham Remdhan Abed Ali, assistant professor, Ph.D., research field: applied mechanics.

Ahamed Noori Obeed, engineer, research field: general mechanics.

Corresponding author: Mohammed A. Ahmed Al-Dujaili, assistant professor, Ph.D. student, research fields: quality control, and knowledge systems. Email: Mohammed.Al-Dujaili@postgrad.manchester.ac.uk, mhammed aldujaili@yahoo.co.uk.

achieve improvement and innovation is vital in an organization which promotes knowledge productivity. Therefore, knowledge productivity will remain the dominant economic factor in a knowledge society, making a flexible and competent workforce even more important. On this premise, creating powerful learning environments is crucial [2].

Fig. 1 explains the relationship model between a Knowledge Management Systems (KMS) and Total Quality Management (TQM). On this premise, it could be inferred that management support processes are combined with TQM activities and the companies' lifecycle procedure are composed of the KM activities. As a result, both companies and support processes exploit techniques of KMS to maneuver according to the specification. Tests, checks and management revisions are supporting processes that implement improvement actions to correct or prevent non-conformities as contained in the techniques of the KMS. The techniques of the KMS help to solve problems using things such as (brainstorming, communities of practice, face-to-face interaction and training). However, many non-conforming products are corrected during the previous stages, the level of customer satisfaction has changed and the obligations of TQM have brought forward a system of improvement.

On this premise, KM has become an effective tool, and many companies aim to gain competitive advantage via the efficient and effective management of their knowledge assets. Therefore, the companies can create a link between the two systems, to enable a KMS which benefits from TQM experiences because of the importance of their common attributes. This is because, individuals encouraged to brainstorm can support the transfer of individual knowledge to organisational knowledge, thereby meeting also specific performance targets (such as increased productivity, improved quality) and also increasing employee satisfaction, development and personal growth [4].

3. Water Quality

3.1 Source of Water

With the future need to safeguard the quality of fresh water supplies and reduce fresh water usage by the introduction of reclamation schemes, the control of industrial discharges will become of great importance. In many instances the wastes that industry discharges to the sewers are detrimental to the production of a high quality reclaimed water [5].

There are many sources of water. Most individuals and industry in U.S.A obtain their water from surface waters (streams, rivers, lakes, reservoirs) and groundwater. However, in other parts of the world (e.g., the Middle East), construction of desalination plants has allowed the use of seawater as a source of drinking water. Reclaimed water is obtained from the treated effluent from a wastewater treatment plant. While it is technically feasible to pipe treated wastewater effluent into a drinking water treatment plant, most municipalities who utilize this option first discharge the treated wastewater effluent into a reservoir for a set period of time, after which the reservoir can then be used as a source of drinking water [6].

3.2 Water Pollution

Table 1 shows the types of wastewater contaminants produced from industry. Many of these pollutants resist degradation by the self-purification processes of the water environment as well as the controlled environment of the conventional biological treatment works and eventually find their way into potable water supplies.

Industries consume large quantities of water of different types. This water could be raw taken from natural sources like rivers or could be taken from drinking water nets. Whatever the sources are, its destination will be to the sewage nets or the sources of water. In both cases, these waters must be treated before disposal. Such treatments may take the form of different types due to the different pollutants. Such

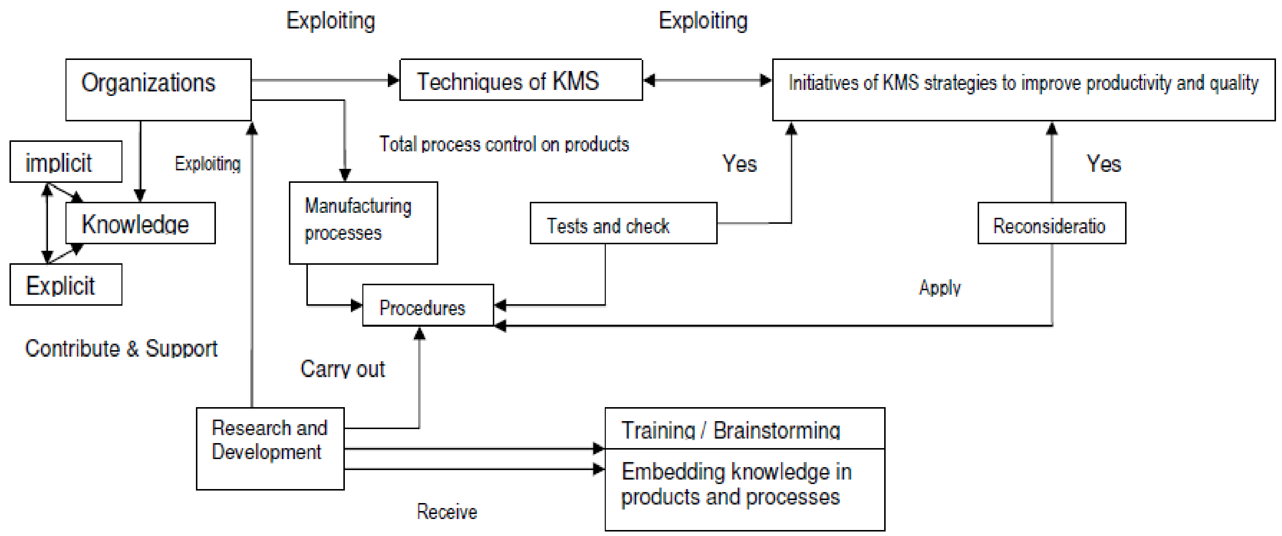

Fig. 1 Structure model of integration between KS & TQM [3].

Table 1 Effects of specific types of pollution in industrial waste discharges [5].

Water pollutants	Industries and industrial activities responsible	Adverse effects
Color	Pulp and paper, textiles, abattoirs, steel, dairy	Visually objectionable
Solids	Pulp and paper mills, textile factories, tanning, canning, breweries, steel mills, boiler-house operations, mining (drainage from mine dumps), abattoirs	Blockage of sewer lines and equipment, damage to rivers by deposit of solids and depletion of oxygen
Oil and grease	Abattoirs, wool-washers, tanneries, metal finishing, dairy plants, steel mills, oil refineries, railway workshops, locomotive, truck and aircraft washing, engineering works	Blockage of sewer lines and equipment, floating scum on water which prevents transfer of oxygen, anaerobic conditions, unpleasant smell and attraction of flies
Organic wastes	Pulp and paper, textiles, abattoirs, tanneries, canning, brewery, starch and yeast factories	Overloading of conventional sewage treatment plants, depletion of oxygen in rivers.
Insecticides, pesticides	Chemical, food and textile factories	Toxic to bacterial and aquatic life; puts sewage treatment works out of action
Heavy metals cyanide	Pickling, plating, metal finishing, plating, coking, refineries	
Chemical wastes	Coking, synthetic dyes, chemicals, plastics, solvents, textile finishing, Kraft and Sulphite pulp	Unpleasant taste and odor; toxic to aquatic life
Acids (mineral and organic)	Steel pickling, chemicals, food processing, acid mine drainage	Corrosion of concrete structures
Alkalis, sodium	Metal finishing, plating, textile and pulp mills, tanneries, water softening, ion-exchange installations	Toxic to fish, rendering water unsuitable for irrigation by causing brackish conditions due to imbalance of ions
Nitrogen, phosphorus	Fertilizer plants, synthetic detergents	Rapid growth of aquatic organisms, algae, Sphaerotilns natans
Carbohydrates	Fruit and vegetable canning, sugar milling	
Heat	Cooling, all physical and chemical processes	Stimulates organic growth and reduces oxygen in water
Detergents	Textiles , metal finishing	Foaming
Pathogens, viruses, worm	Hospitals, abattoirs	Spreading of disease

different pollutants are always accompanied with high cost for the treatment process. Recycle and reuse of water will minimize the consumption of water, saving some water that could be used for drinking.

However, wastewater is treated to remove and decompose substances that are harmful to the natural environment. The substances are either directly decomposed or first separated and then decomposed, by using or promoting the natural purification processes. In other words, a treatment plant is built on separation and decomposition technologies as shown in Fig. 2. The processes of treating wastewater are usually divisible into many principal sections. The divisions according to Refs. [7-8] are:

3.2.1 Activated Carbon Adsorption

Activated carbon comes in two forms: powdered activated carbon (PAC), and granular activated carbon (GAC). Both forms effect removal by physically adsorbing compounds. In the past, (PAC) was employed more frequently, primarily for color, taste and odor control. (PAC) was reportedly first used in the United States in 1929. However, both (PAC) and (GAC) are generally viewed as a reliable last recourse for removal of color, taste and odors particularly from industrial sources.

The adsorption process by activated carbon is able to remove color, odor, and taste. It is also capable of removal of dissolved organic materials, detergent, grease, oil, phenols and hydro carbonate. The value of BOD is changed from 200 mg/l to 1 mg/l whereas the value of COD is changed from 200 mg/l to 20 mg/l by using activated carbon [9].

The removal efficiency by activated carbon compared with other treatments is tabulated in Table 2 [10].

Overall, Table 2 highlights that the removal efficiency of activated carbon is very high, but the industrial waste must first be treated by chemical and Biological treatment and then the remainders of the pollutants are removed by activated carbon [10].

3.2.2 Granular Activated Carbon (GAC)

The contact system for granular activated carbon (GAC) consists of a cylindrical tank which contains a bed of the material. The water is passed through the bed with sufficient residence time to allow for completion of the adsorption process. The system may be operated in either a fixed-bed or moving-bed mode. Fixed-bed systems are batch operations that are taken off line when the adsorptive capacity of the carbon is used up [11].

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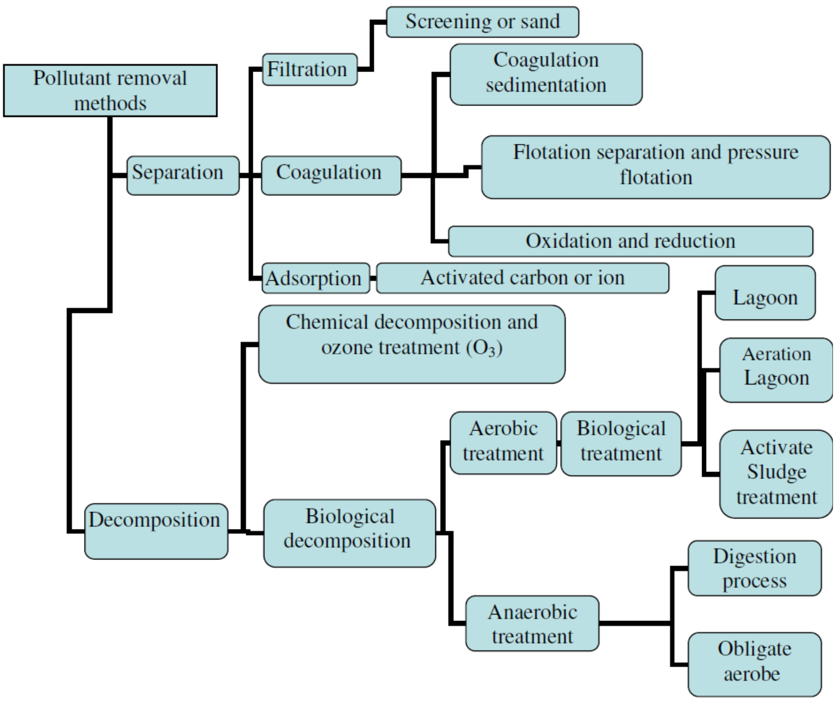

Fig. 2 Pollutant removal methods.

Table 2 Efficiency of activated carbon compared with other treatments [10].

Pollutant (mg/l)	Chemical treatment (%)	Biological treatment (%)	Activated carbon (%)
BOD_5	50-70	70-95	60-95
COD	50-70	30-70	60-95
TSS	80-98	30-90	60-90
Color	80-90	10-80	80-98
Alkalinity	0-20	10-20	5

The design of granular-activated-carbon systems is based on flow rates and contact times. Flow rates of 0.08 to 0.4 n^3/m^2.min and contact times of 10 to 50 min are based on empty-tank cross section and volume, form a common practice.

The effectiveness of GAC in removing color, taste and odor can be expressed using Eq. (1) [11].

$$Ln[(C_0 / C_e) - 1] = Ln(e^{KN0D/V_-} - 1) - KC_0 t \qquad (1)$$

3.2.3 Powdered Activated Carbon (PAC)

Powdered activated carbon (PAC) cannot be used in a fixed-bed arrangement because of the tiny size of its particles and subsequent high head loss that would result from passing water through it. Powdered activated carbon is contacted with the water in open vessels where it is maintained in suspension for the necessary contact time and then removed by conventional solids-removal processes.

Powdered activated carbon is much more difficult to regenerate than granular. In wastewater treatment, powdered activated carbon is added to the aeration basin and removed with the biological solids in the secondary clarifiers. In this case, both refractory and biodegradable organics are adsorbed [11]. Carbon dosages may vary from 20 to 200 mg/l depending on the results desired [12].

The Freundlich equation is expressed by Eq. (2) [13].

$$X / M = KKC^{(1/n)} \qquad (2)$$

It was found that the removal efficiency of COD was 20-21%, that of BOD was 17-30% and that of TSS was 27-31%. The quality of the effluent was not in line with those of either the Iraqi or American standards.

4. Plant Description

The Hilla textile factories of the State Company for Textile Industries have been taken as the case study in this research. The factories produce the following fabrics: (1) cotton fabric and blending; (2) velvet and Jacquard; (3) synthetic fabric for special uses as a blanket base. The complex comprises of several productive, technical, and administrative sections, and as follows: (1) the spinning, (2) the preparation, (3) the textile weaving, (4) the finishing, (5) the velvet and jacquard section.

Those which have a bearing on the quality, use, and consumption of water, and consequently on the subject of this research, are briefly discussed hereafter.

5. Water Supply and Distribution Description

The total daily water consumption in Hilla Complex is nearly 3500 m^3/day. Of this, about 1500 m^3/day is used for industrial purposes, and the remainder is for drinking and sanitary services, as shown in Fig. 3. The soft water (influent) and industrial wastewater (effluent) limits are summarized in Tables 3-4, respectively. However, the capacity of the existing treatment plant is 438 m^3 per working shift 7 hours.

6. The Productive Sections

Finishing Section (Factory No. 1)

This section is the one that uses the largest quantity of water among all the sections, and represents about 55%, of the water used in production. Moreover, it is the one that produces the most polluted effluent. The finishing process constitutes the following sub-processes.

6.1 Scouring and Bleaching

Scouring with hot alkali removes the natural waxes and pectins from the cotton together with spinning oils. Bleaching with hydrogen peroxide is used to whiten the fabric. Many chemicals are used in this stage, such as sodium hydroxide and sodium silicate. Steam is used to raise the temperature and increase moisture.

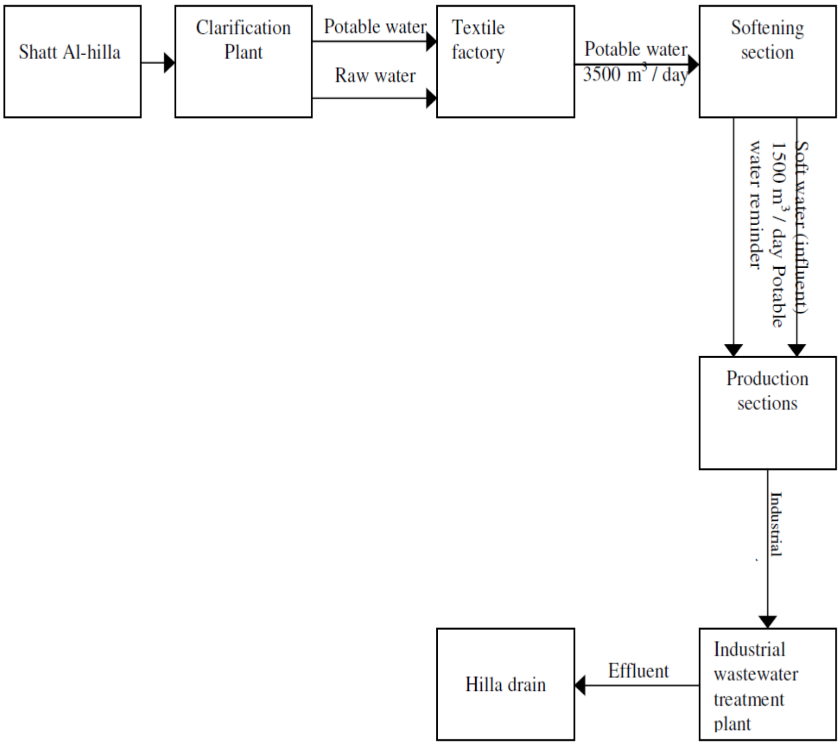

Fig. 3 Schematic illustration of water supply and distribution of Hilla factories of the state company for textile industries [14].

Table 3 The standard influent limits for soft water in the textile industry [14].

Parameter	Limit
pH	7.5-8.5
Cl^{-1}	600 mg/l
SO_4^{-2}	400 mg/l
Hardness	(0-1mg/l)
Conductivity	(1000-1500 ms/cm)
TDS	(500-1000 mg/l)

Table 4 The standard effluent limits for industrial water in the textile industry [14].

Parameter	Limit
pH	6-9.5
Cl^{-1}	600 mg/l
SO_4^{-2}	400 mg/l
TSS s	60 mg/l
BOD	40 mg/l
COD	100 mg/l
Fe	0.5 mg/l
Mn	0.1 mg/l
Zn	1.0 mg/l

6.2 Dyeing and Printing

Cloth is colored to customers' requirements by either dyeing or printing. Final finishing in the form of easy care or handle finish is often carried out prior to the sale of the cloth. Chemical materials in different doses are used in this process. The pollutants produced in this section are as follows:

- Colors

Colors are caused by different kinds of dyes such as direct, disperse and reactive dyes;

- Suspended solids (TSS)

Such a contaminant results from cleaning machines, the remainder of fabric and sludge;

- Oil and grease

These are produced because of the use of oil in industrial operations. Grease is used in the maintenance of machines. It is used continually;

- High alkalinity and pH

This is the result of using chemical materials like sodium hydroxide, which is used in large amounts in the industrial processes;

- High level of organic materials

This is the result of removing the starch and the use of organic colors. These materials cause an increase in the biochemical oxygen demand (BOD_5);

- Small amounts of chlorides and sulfates

This is the result of using some materials that contain chloride ion and sulfates like sodium chloride and colors that contain sulfates;

- Large amounts of soaps, bleach and detergents

They are used extensively in this section before and after the processes of dyeing and in the processes of coloring.

Finishing Section (Factory No. 1)

This section contains three units:

- Preparation: No industrial water is utilized;
- Textile: No industrial water is utilized;
- Finishing: This operation forms the principal user of the industrial water in the velvet and jacquard section. As for pollution, this section uses about 60 m^3 of water per day. Its pollution is less than the processing section (Factory No. l). However, pollution in this section is the result of using alkaline colors and chemical materials as used in the bleaching processes; H_2O_2 and NaOH are used with pH equal to 9.

7. The Industrial Wastewater Treatment Plant Description

The industrial wastewater that is produced from the productive sections is collected through a pipe network that ends in a special treatment plant. The treatment plant comprises the following basic units: the primary mixing tank, the sedimentation tank, the biological treatment tank, filters, the final sedimentation tank, and the final mixing tank, as shown in Fig. 4. A brief discussion of each unit is given.

7.1 The Primary Mixing Tank

This tank is the first stage of the treatment. The process of receiving industrial water here may be considered as an equalization process. The tank has a square cross-section with 4 m length, 2 m width and 2 m depth. Water entering this tank contains salts, dyes, grease and other suspended and dissolved organic materials. The tank is preceded by screens to screeroot, laree matter, Grease, fats and oil are partially removed

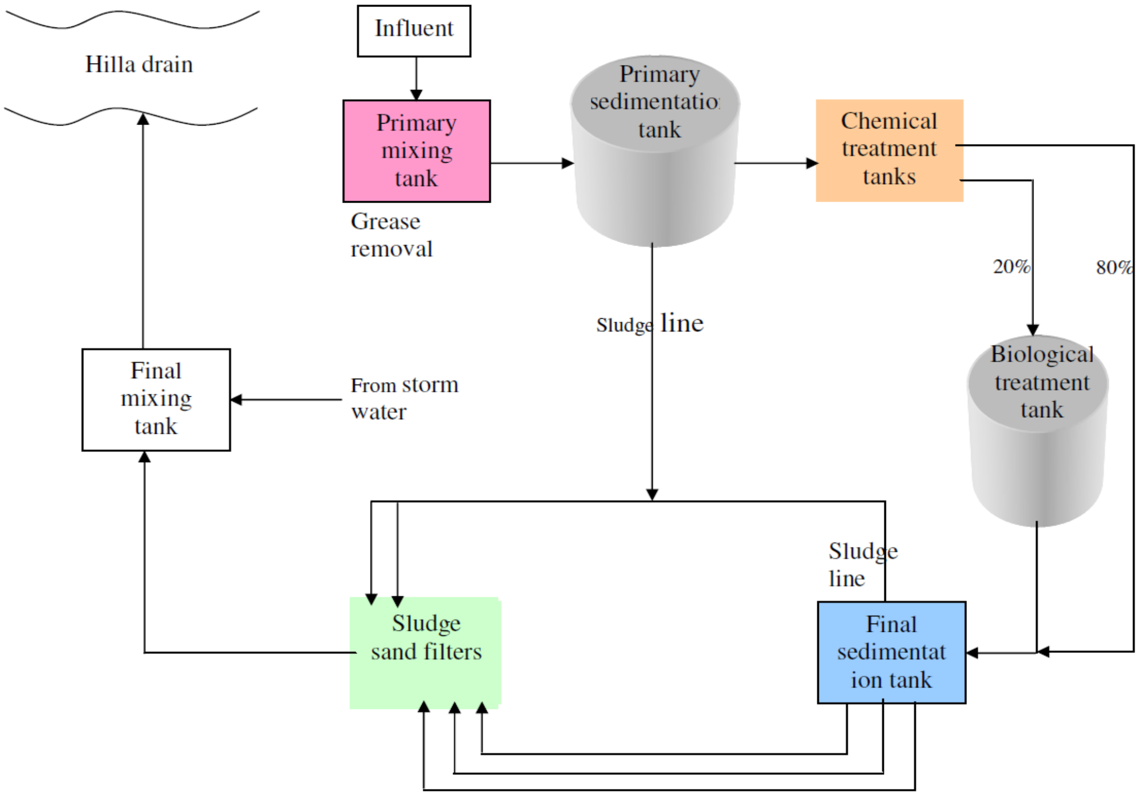

Fig. 4 Industrial water treatment plant unit of the Hilla textile factory.

in this tank. The wastewater in this tank is then pumped by a set of submersible pumps to the primary sedimentation tank.

7.2 The Primary Sedimentation Tank

The circular tank of diameter 25 m and depths 1.6 m, has a capacity of about 700 m^3. The tank is used as a sedimentation tank. It is equipped with a revolving bridge with a scraper mechanism at the bottom that removes sludge from the lower part of the tank. Sludge is pumped from there to the sludge drying beds. Water then flows by gravity to the chemical treatment tanks.

7.3 The Chemical Treatment Tank

These are five tanks. Alum and lime are added in the tanks. Each tank has a square cross-section 2 × 2 m and a length of 2.5 m. Residual grease is removed here. 20% of the flow is then sent to the biological treatment units, while the rest is sent directly to the final sedimentation tank.

7.4 The Biological Treatment Tank

The tank has an oval- circular shape. Its capacity is 200-250 m^3 Mechanical brushes are used to aerate the wastewater in this tank.

7.5 The Final Sedimentation Tank

The tank is 20 m long, 9.5 m wide and has a depth of between 1 to 3.5 m. The tank is equipped with a revolving bridge with a scraper mechanism. Sludge is pumped from this tank to the sludge drying beds.

7.6 Filters

The plant involves five Filters. Two of these are used to dry the primary sludge, while the other three are used to filter the combined effluent from the final sedimentation lank. The dimensions of each filter are 20 × 10 × 1.5 m. A cross-section through a filter shows a layer of 35 cm of sand resting on a layer of gravel of 35 cm in which the gravel is 5-18 mm in size. At the bottom, a final; layer of gravel of 20 cm in height is placed on a drainage system of perforated pipes. The gravel in this layer has a size of 18-50 mm. The drainage water from these filters is pumped by 3 pumps to the Hilla drain.

7.7 The Final Mixing Tank

The tank is 4 m long, 8 m wide and 6.5 m deep. Final disposal of industrial wastewater effluent is pumped from this tank to the Hilla drain.

8. Results and Discussion

To evaluate the performance of the treatment plant, ten samples were taken from the primary and the final mixing tanks as indicated in Table 5. The samples were tested for pH, TSS, SO_4^{-2}, BOD_5, COD, hardness, and alkalinity according to Ref. [15]. The results of the tests are summarized in Table 6. The results indicate that the different units were not operating efficiently compared with Ref. [10] specification (as given in Table 2) as seen by the individual removal efficiency of each parameter, e.g., TSS, BOD_5, and COD. This is believed to be due to lack of maintenance and overloading of the treatment plant.

A comparison between the measured parameters in Tables 5-6 (which were measured in the chemical department in the college of science/Babylon University) with standard parameters in Tables 3-4 indicates that:

- The existing wastewater treatment plant is not working efficiently. The removal efficiencies of the respective quality parameters were

TSS = 27-31%, BOD_5 = 17-30% and COD = 20-21%

The values of TSS, BOD_5 and COD are very high because of the small added amount of activated carbon throughout the treatment processes.

- The applied physio-chemical treatment which involved neutralization, addition of alum and polyelectrolyte achieved a COD removal efficiency of around 50%.

Table 5 Sampling for the evolution of performance of the existing treatment plant.

Location	Sample No.	Date of sampling
The primary mixing tank before treatment	B	12/2/2010
	2-B	16/4/2010
The final mixing tank after treatment	A	12/2/2010
	2-A	16/4/2010

Table 6 Quality of the industrial water of Hilla textile factories before and after treatment (sample No. 1, 2).

sample	tests	pH	TSS	SO_4^{-2}	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Fe	Mn)	Zn
1	1-B	8	450	333	130	320	220	607	2.8	0.28	0.7
	1-A	9	310	532*	91	252	165	310	0.9	0.12	0.4
	Efficiency		31%		30%	21%					
2	2-B	9.5	110	280	90	225	225	320	3.0	0.3	0.8
	2-A	10	80	310*	75	180	180	292	1.2	0.14	0.3
	Efficiency		27%		17%	20%					

- According to the tests that were done, it was found that the quality of the water is not sufficiently good to be reused in industry or to be discharged into the river, this is because the removal efficiencies are less than that required, and some values are in excess of permitted values.
- For sample No. 1 the small increment in efficiency occurred because of the addition of soft water to the wastewater in the final mixing tank (after treatment).
- Increase of SO_4^{-2} after treatment is due to residual Alum (which contains SO_4^{-2}).
- It may be seen that the high amount of Fe and Mn are due to the nature of the manufacturing processes in a Textile Company.
- The values of pH and Zn are typically in the permitted range.

9. Conclusions

This paper was undertaken to design integration between engineering and knowledge systems, and evaluation of performance of wastewater treatment plant in the textile company. The results indicate that the different units were not operating efficiently compared with Ref. [10] specification (as given in Table 2) as seen by the individual removal efficiency of each parameter, e.g., TSS, BOD_5, and COD, Table 7 is explaining the symbols that have used in the research. This is believed to be due to lack of maintenance and overloading of the treatment plant. In conclusion, it was found that the quality of the water is not sufficiently good to be reused in industry or to be discharged into the river; this is because the removal efficiencies are less than that required, and some values are in excess of permitted values.

10. Future Work

This preliminary study is not detailed enough to be deemed completely reliable. In view of that, it is required that further data that can be used essentially as

Table 7 The symbols have used in the research.

Symbol	Definition
AICE	American Institute of Chemical Engineers
AWWA	American Water Work Association
BOD_5	Biochemical oxygen demand at 5days
C	Final or equilibrium concentration of the adsorbate (mg/l)
COD	Chemical oxygen demand
C_e	Allowable effluent concentration (mg/l)
C_0	Influent concentration (mg/l)
C_i	Initial concentration of adsorbate (mg/l)
D	Depth of bed (m)
EPA	Environmental protection agency
GAC	Granular activated carbon
k	Constant rate (m^3/kg.hr)
kk	Empirical constant
n	Inverse constant
N_0	Adsorptive capacity (kg solute/m^3 carbon)
M	Carbon dose (mg/l)
PAC	Powdered activated carbon
pH	Hydrogen number
SCTI	State Company of Textile Industries
SS	Suspended solids
v	Linear flow rate (m/hr)
t	Service time (hr.)
TDS	Total dissolved solids
TSS	Total suspended solids
X	adsorbate actually adsorbed by carbon (mg/l) ($X = C_i - C$)
KMS	Knowledge management systems
KS	Knowledge systems
TQM	Total quality management

the basis of the main investigation is provided. On this premise, this case study could be implemented in other Industrial companies and with bigger sampling regimes. The aim, WWTP efficiency reduction caused by microbiological problems (death of some species or proliferation of filamentous bacteria—bulking) can cause problems in solids concentration, organic matter and turbidity, so that the effluent does not achieve established quality patterns required as legal standards.

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