In-plant control for water minimization and wastewater reuse: a case study in pasta plants of Alexandria Flour Mills and Bakeries Company, Egypt

Magda Magdy Abd El-Salam a,b,*, Hesham Mahmoud El-Naggar c

aPublic Health Sciences, Biology Department, College of Education, Alkhair University, Kingdom of Saudi Arabia
bEnvironmental Chemistry and Biology, Environmental Health Department, High Institute of Public Health, Alexandria University, Egypt
cEnvironmental Engineering, Environmental Health Department, High Institute of Public Health, Alexandria University, Egypt

1. Introduction

As Egypt is currently facing water scarcity problems and water resources show signs of water quality deterioration, there is growing interest for the benefits of wastewater reuse, this will led to minimize the potential impact of effluent on the environment (Abdel-Shafy and Raouf, 2002; Feng and Chu, 2004). According to the National Water Resources Plan, total water consumption for Egyptian industries was 3.6 billion cubic meter (BCM) per year at the year 2000 and is estimated to reach 5.6 BCM/year by the year 2017 (El-Gohary, 2002). Major opportunities for wastewater reuse exist in industry because most water is used for processing activities (washing, rinsing, etc.). In recent years, various systematic design approaches to wastewater reuse across complex manufacturing operations have been developed (Feng and Chu, 2004). Water minimization and exploration of the potential for wastewater reuse are priority issues of industrial wastewater management especially in industries that are consuming high amounts of water. In-plant control implementation is the preferred option not only for decreasing waste output and minimizing water consumption but also alleviating costs (Dulkadiroglu et al., 2002).

Like many developing countries, Egypt strives to increase its export and cope with the globalization movement (RAC/CP, 2001). In recent years, the Egyptian Ministry of Industry has set the “Modernization of the Industry” as one of its top priority themes (Hamed and El Mahgary, 2004). Therefore, Egyptian industries are being faced additional constraints to modernization in terms of raw water availability and limitations on wastewater discharge. This, in turn, means that in-plant water conservation efforts are becoming necessary to reduce the volume of effluents discharged (Miner and Unwin, 1991). However, some companies are failing to apply in-plant modifications in practice due to improper end-of-pipe treatment of the generated wastes, difficulties in monitoring emissions and enforcing environmental regulations, lack of expertise for management of remediation systems, inadequate provision of budget allocation, and lack of machinery for strategic planning for waste minimization and integration of cleaner production in production process (Hamza, 2005).

Environmental problems associated with pasta manufacturing processes had provided the material of this study. In the present study, the mean of wastewater produced from the two pasta manufacturing processes amounted to 2215.6 m3/month was discharged into the municipal sewerage system without any treatment and it was highly contaminated with suspended solids and organic pollutants as well. The different processes in the plant were operated in an open circuit manner. Figs. 1–3 show the manufacturing processes, water usage and wastewater discharged.
The objectives of this study were to examine the water usage in the pasta manufacturing processes, to determine the characteristics of wastewater generated, and to introduce in-plant control measures such as installation of water flow meters, spring valves on water hoses, and design of a steam condensate recovery system in order to reduce water consumption and wastewater generation then conduct a cost benefit analysis to estimate the savings achieved from applying in-plant modifications.

2. Material and methods

The study design was adopted in three stages as following: (1) assessment of the pre-in-plant situation in the two selected pasta plants of Alexandria Flour Mills and Bakeries Company (AFMCO), (2) implementation of envisaged in-plant control measures, and (3) cost benefit analysis for the post-in-plant control stage.

A survey of the two plants was carried out through reviewing their records and by using a predesigned questionnaire to collect information about processing, raw materials, energy consumption, water consumption, wastewater flow, sources of waste generation, methods of handling, storage and transportation of products, methods of waste discharge, and locations of sampling points. Wastewater samples were collected fortnightly for six months giving a total of 12 samples for each plant. Wastewater samples were collected, preserved, and analyzed according to the Standard Methods for the Examination of Water and Wastewater (Eatons et al., 1995).

Air samples were taken once in a month from each plant for a period of six months. They were collected from the: (1) flour sieving area using calibrated air flow personal air pumps and weighed filters were used to determine the particulate matters and respirable suspended particulates according to the method described by Zimmerman et al. (1987), and (2) chimneystack
boilers on a fiberglass filter to determine the total particulates gravimetrically. Samples were taken isokinetically perpendicular to the flow in the chimney (Davis, 1972) while gaseous contaminants such as carbon monoxide (CO), sulfur dioxide (SO₂), and nitrogen oxides (NOₓ) were determined by a direct reading combustion analyzer/environmental monitor Bacharach Model 300. Also, solid waste collection, segregation and weighing were carried out to determine its quantity and generation rate. Then in-plant control measures were implemented to save water and energy as well as to minimize air pollution and waste quantities. Data were analyzed using Statistical Package for Social Sciences (SPSS) version 11.0 computer software package (Forthofer and Lee, 1995).

3. Background information

3.1. General company information

AFMCO is one of the subsidiary companies of the Holding Company for Food Industries in Egypt. The company consists of 15 production units for several activities as shown in Table 1. From this table, it is evident that the main activity of the company is the wheat milling with a total capacity of 593,000 tons annually to produce wheat flour 72% extraction (deluxe flour) and wheat flour 82% extraction. Nearly 15% of deluxe flour is used for the production of the various types of pasta and the remaining percentage of 85% is distributed to wholesale, shops, and bakeries. Moreover, biscuit products, tin-plates, painting tin-plates, and products’ transportation using heavy trucks are considered as supplementary activities of the company. Also, cooling and freezing processes take place in refrigerators with a capacity of 12,000 tons. Additionally, wheat bran (Radda) is a flour milling by-products.

Pasta plants were selected to conduct this study that is representing 13.3% of company’s units. They included: (1) Pasta Mina plant located in Mohram Bek/Middle district which is consisting of one output line only for producing nearly 3646 tons/year as a short-type of macaroni, and (2) Pasta Mina plant located in El-Ras El-Soda/East district which is equipped with seven production lines providing four different shapes of outputs; three for long-type (Spaghetti, Vermicelli, Noodles, etc) and four lines supplying short-type of macaroni. The last plant is serving current yearly output of 7807 tons.

3.2. Description of the industrial process

The semolina wheat is automatically discharged from the trucks by jacks onto two receiving lines; 250 tons/h for each one. The factory comprises approximately 10 wheat silos with a storing capacity ranging between 2500 and 10,500 tons per silo. The total grain storage capacity is 35,000 tons/cycle. Distribution of product is carried out directly from the existing 10 mills to the wholesale and retail traders, bakeries and industrial companies. Fig. 1 shows a process diagram for pasta production. It consists of three stages: the first one includes kneading and extrusion. The second stage is the drying process which comes to lower the moisture content of the pasta dough from 31% to 12% so that the finished product is hard, retains its shape, and can be stored without spoiling. According to different shapes of macaroni and macaroni type, the...
Table 1
Mean production size (tons/year) from different activities in Alexandria Flour Mills and Bakeries Company.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Production size (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat milling</td>
<td>593,000</td>
</tr>
<tr>
<td>Wheat flour (82%)</td>
<td>508,000(85)*</td>
</tr>
<tr>
<td>Deluxe flour (72%)</td>
<td>85,000(15)*</td>
</tr>
<tr>
<td>Pasta products and Cuscus</td>
<td>17,000</td>
</tr>
<tr>
<td>Bread</td>
<td>5250</td>
</tr>
<tr>
<td>Complementary and supplementary</td>
<td>50 tin-plates, 1000 tin-</td>
</tr>
<tr>
<td></td>
<td>manufacturers</td>
</tr>
<tr>
<td>Refrigerator storage</td>
<td>12,000</td>
</tr>
</tbody>
</table>

* Percentage from wheat milling production size.

3.3. Air emissions

Air emissions may arise from a variety of sources in pasta manufacturing. Particulate matter (PM) emissions result mainly from solids handling and mixing. For pasta manufacturing, PM emissions occur during the wheat milling process, as the raw ingredients are mixed, and also during packaging. Emission sources associated with wheat milling include grain receiving, pre-cleaning/ handling, cleaning house, milling, and bulk loading (U.S. Environmental Protection Agency, 1995).

Volatile organic compound (VOC) emissions may potentially occur at almost any stage in the production of pasta, but most usually are associated with thermal processing steps, such as pasta extruding or drying (U.S. Environmental Protection Agency, 1995).

Low-pressure boiler is a steam boiler that operates below 15 Pounds per Square Inch (psi) pressure, or a hot water boiler that operates below 160 psi or 250 °F (Ministry of State for Environmental Affairs and EEEA, 2002). The fire-tube boiler operates at low pressure and is the most prevailing boiler used for heating purposes in the studied plants.

The survey revealed that Mohram Bek plant is equipped with two fire-tube boilers for drying process which utilize low pressure hot water system (operating pressure ranged between 22.5 and 30 psi) while El-Ras El-Soda plant is supplied by eight fire-tube boilers; 2 of them are utilizing low pressure steam system (with mean operating pressure of 11 psi) for cuscus line production and the rest are utilizing low pressure hot water system. The available boilers’ capacity in Mohram Bek plant is 1.0 or 0.5 tons/h while all those of El-Ras El-Soda plant are 0.5 tons/h.

Diesel is used in plants’ boilers as a source of fuel. The exhaust gases from fuel burning contain primarily PM, sulfur oxides (SOx), NOx, CO, and VOC (EEAA, 2002). There are several problems associated with using diesel in boilers and are encountered during the present survey. Among these problems, products of diesel combustion generate acidic oxides such as SOx and NOx causing corrosion of fuel pipelines and consequently increasing maintenance cost. United Nations Framework Convention on Climate Change (UNFCCC, 2006) recorded that the yearly default value for the emission coefficient of carbon dioxide (CO2) for diesel fuel is 3.08137 kg CO2 per kg of diesel fuel. Based on this coefficient, it is expected that the amount of emitted CO2/year in Mohram Bek plant is 460,933 kg while in El-Ras El-Soda plant is 1,178,688 kg giving a total CO2 amount of 1,639,621 kg as presented in Table 2. Moreover, the probability of leakage from fuel storage tanks or fuel distribution system is very high which requires continuous follow-up and also increases maintenance cost. Additionally, the high cost of diesel fuel that is representing 6.7% relative weight from production cost in Mohram Bek plant where it is consuming 178,080 L diesel fuel/year (48.9 L/ton product) and 6.6% relative weight from production cost in El-Ras El-Soda plant that is utilizing 455,380 L diesel fuel/year (58.3 L/ton product).

The gaseous emissions generated by boilers are typical to those from combustion processes. On the other hand, workplace air quality is affected by PM generated from flour sieving, and dough preparation. PM smaller than 10 μm (PM10) penetrate most deeply into the lungs, causing a large spectrum of illnesses (e.g. asthma attack, cough, bronchitis) (EEAA, 2002). Even though, it has been suggested that the risk of developing respiratory symptoms due to flour dust exposure has decreased, flour was recognized in Quebec and the U.K. as one of the major causes of occupational asthma. A fatality due to baker’s asthma has been reported (Burstyn et al., 1997).

3.4. Water usages and distribution

Water in pasta industry is used as process water, as rinse water for equipment and floor, as boiler feed water, as cooling water and for domestic purposes. Boiler grade water is pretreated in softeners to prevent scale formation. Water is supplied from municipal distribution system.

3.5. Waste effluents sources and characteristics

Figs. 2 and 3 show that waste effluent is mainly wash water, boiler and cooling tower blow downs, and steam condensate. In addition, flour particles that settle on the floor due to poor housekeeping practices are washed to the sewer. Accordingly, it is expected that the waste effluent contains organic matter and suspended solids. Floor and equipment washing and sanitation are additional sources of wastewater containing organic matter, and traces of the chemicals used for sanitation.

Table 2
Yearly default values for the emission coefficient for diesel fuel in pasta plants

<table>
<thead>
<tr>
<th>Plants</th>
<th>Fuel consumption (L/year)</th>
<th>Fuel consumption (kg/year)</th>
<th>Amount of emitted air pollutants/ amount of fuel used (kg pollutants/kg fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 kg of diesel</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>Mohram Bek</td>
<td>178,080</td>
<td>149,587</td>
<td>3.08137</td>
</tr>
<tr>
<td>El-Ras El-Soda</td>
<td>455,380</td>
<td>382,519</td>
<td>460,933</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>633,460</td>
<td>1,178,688</td>
</tr>
</tbody>
</table>

Diesel density – 0.84 kg/L.
Gross calorific value – 46 MJ/kg.
Table 3
Mean air pollutants emissions concentrations collected from smokestack boilers of the pasta plants in Alexandria Flour Mills and Bakeries Company.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Unit</th>
<th>Plasta Plants</th>
<th>Mohram Bek Before</th>
<th>After</th>
<th>El-Ras El-Soda Before</th>
<th>After</th>
<th>%a</th>
<th>Law No.4/1994 (Ministry of Housing and Utilities, 1997)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide mg/m³</td>
<td>320</td>
<td>160</td>
<td>400</td>
<td>200</td>
<td>50</td>
<td>2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide mg/m³</td>
<td>150</td>
<td>75</td>
<td>180</td>
<td>108</td>
<td>40</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides mg/m³</td>
<td>120</td>
<td>72</td>
<td>180</td>
<td>108</td>
<td>40</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total particulates mg/m³</td>
<td>100</td>
<td>65</td>
<td>120</td>
<td>78</td>
<td>35</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Reduction percentage.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Results and discussion

4.1. Environmental survey

4.1.1. Air emissions

Table 3 shows air emissions from smokestack of boilers. From this table, it is evident that El-Ras El-Soda plant had the highest mean air emission concentrations. Among air emissions, CO had constituted the highest concentration in each of Mohram Bek and El-Ras El-Soda plants, respectively. The results presented in Table 6 reveal that the average water consumption is 1695.5 m³/month and 6575 m³/month in Mohram Bek and El-Ras El-Soda plants, respectively. The generation rate of solid waste per tons of final product was considerably large ranging from 1.99 kg in Mohram Bek plant to 2.0 kg in El-Ras El-Soda plant as given in Table 6.

4.1.2. Water usages and energy consumption

Table 5 shows the distribution of water usage in Mohram Bek and El-Ras El-Soda plants. Table 5 and Figs. 2 and 3 indicate that washing and cleaning operations consume about 34% and 36% of total monthly water consumption in Mohram Bek and El-Ras El-Soda plants, respectively. In the present study, in-plant control measures were focused on saving water and energy consumption, reducing raw materials losses and reducing the volume of the discharged effluent to reduce hydraulic load on the wastewater treatment plant. In many cases, the adoption of in-plant control can eliminate the need for end-of-pipe treatment (EEAA, 2002).

4.1.4. Solid waste

Flour was bought in large sacs of about 50 kg weight, which were carried on the back of the workers to the processing area. A hook was used to facilitate their handling tearing the sack and causing loss of flour. In addition, solid waste was mainly composed of out-of-spec products that were dumped. The quantity of solid waste generated from the pasta plants was considerably large ranging from 607 to 1301 kg/month in Mohram Bek and El-Ras El-Soda plants, respectively. It was classified into fabrics and organic materials, in a form of weaved sacs and flour remnants, respectively. The generation rate of solid waste per tons of final product ranged from 1.99 kg in Mohram Bek plant to 2.0 kg in El-Ras El-Soda plant as given in Table 6.

4.2. In-plant modifications

In the present study, in-plant control measures were focused on saving water and energy consumption, reducing raw materials losses and reducing the volume of the discharged effluent to reduce hydraulic load on the wastewater treatment plant. In many cases, the adoption of in-plant control can eliminate the need for end-of-pipe treatment (EEAA, 2002).
4.2.1. Water saving

Water saving was calculated as percentage reduction in total monthly water consumption as shown in Table 6. The change of water flow rate or water quantity in one unit process was determined by water flow meters. Figs. 4 and 5 clarify water usage and wastewater reuse in Mohram Bek and El-Ras El-Soda plants, respectively, after in-plant control. The following measures were implemented to control and reduce water consumption as indicated for each measure.

1. Installation of water flow meters to monitor and control water consumption in all activities. Water saving was about 5%.
2. Minimize spills on the floor minimized floor washing. Water saving was about 5%.
3. Installation of spring valves on water hoses used for machines and floor washing. Water saving was about 5%.
4. Recycle and reuse of wash water. Water saving was about 30%.
5. Collection of dry flour remnants before cleaning operations to reduce water consumption, wastewater discharge quantity and its organic load, suspended solids and biodegradable matter presented as high BOD and COD. Water saving was about 5%.
6. Repair leaks. Water saving was about 5%.

4.2.2. Energy and water conservation

4.2.2.1. Recovery of steam condensate. Steam condensate was about 190 m³/month and 802 m³/month in Mohram Bek and El-Ras El-Soda plants, respectively. It was discharged to sewer at temperature of 75–80 °C. So, collection and recycle of hot steam condensate as boiler feed water recovered both energy and clean water.

4.2.2.2. Energy and water saving. Energy saving was about 237,000 L diesel fuel/year. As for fuel consumption, saving of about 37% was achieved from collection and recycle of hot steam condensate as boiler feed water. Fuel saving was calculated as percentage from the total yearly fuel consumption (633,460 L diesel fuel/year) as given in Table 2.

Water saving was about 12% of total water consumption. Water saving was calculated as percentage from the total monthly water consumption (8270 m³/month) after recycling of hot steam condensate (992 m³/month) as boiler feed water.

Therefore, the in-plant modifications had proved to save more than 50% of the total water consumption besides, the great energy saving obtained from the condensate recovery.

4.2.3. Energy saving

The following measures were implemented to reduce the energy consumption.

- Insulation of steam lines.
- Installation of steam traps.
- Repairing or replacing steam valves.
- Maximize boilers efficiency.
- Install pressure regulators on steam lines.

4.2.4. Air pollution

The following measures were implemented to minimize air pollution from flue (exhaust) gases.

4.2.4.1. Flue gases

1. Regulate the fuel to air ratio for an optimum excess air that had ensured complete combustion of CO to CO₂. The effect of complete combustion on CO and SO₂ emissions is shown in Table 3.
2. Keep the combustion temperature at a moderate value to minimize particulate matter and NO\textsubscript{x}. Table 3 shows that a reduction of about 35% was achieved for particulate matter. Further, for the case of NO\textsubscript{x}, a reduction of about 40% was achieved.

### 4.2.4.2. Dust.

1. Cyclones were installed for dust elimination from stack emissions.

2. Flour sieving area was equipped with dust collectors.

### 4.2.5. Housekeeping

Housekeeping practices comprised the following.

1. Provide adequate awareness to the cleaning workers in pasta plants to collect any residual or spilled product from equipment in a solid form rather than washing them with water.

2. Diminish flour losses by sweeping its remnants of about 200–300 kg/month before cleaning operations and selling them as valuable animal feeds, or in other non-food industries.

3. Apply regular maintenance program to minimize any leaks.

4. Apply the housekeeping procedures of the open areas and roads in the factory and quick removal of any solid waste.

5. Reuse of all woven wheat sacs in plant or by selling them for outsiders.

6. Adopt good working practices, with correct use of local exhaust ventilation to reduce particulate matters (flour and dust particles).

### 4.3. Economic evaluation of in-plant interventions

The cost benefit analysis of a pollution reduction program for an industry is a crucial step in the study. The cost of organizing a study and implementing a proposed change must be weighted against the benefits of lower water bills, reduced sewer charges, reduced treatment costs, and increased by-product recovery. The cost benefit analysis must be carried out for several coming years. The uncertainty of future costs for raw water and wastewater treatment

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Pasta Plants</th>
<th>Mohram Bek</th>
<th>El-Ras El-Soda</th>
<th>Limits of decree No.44/2000 regarding discharge into sewerage system (Minister of Reconstruction, New Communities, Housing and Services, 2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>Min</td>
<td>25.5</td>
<td>37.6</td>
<td>32.3</td>
</tr>
<tr>
<td>PH</td>
<td>-</td>
<td>Max</td>
<td>7.8</td>
<td>8.18</td>
<td>7.6</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>Min</td>
<td>402</td>
<td>690</td>
<td>499</td>
</tr>
<tr>
<td>Total Solids</td>
<td>mg/L</td>
<td>Max</td>
<td>528</td>
<td>930</td>
<td>620</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>mg/L</td>
<td>Mean</td>
<td>382</td>
<td>531</td>
<td>429</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>mg/L</td>
<td>Mean</td>
<td>146</td>
<td>359</td>
<td>191</td>
</tr>
<tr>
<td>Total Volatile Solids</td>
<td>mg/L</td>
<td>Mean</td>
<td>241</td>
<td>322</td>
<td>279</td>
</tr>
<tr>
<td>Dissolved Volatile Solids</td>
<td>mg/L</td>
<td>Mean</td>
<td>200</td>
<td>290</td>
<td>260</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand</td>
<td>mg/L</td>
<td>Mean</td>
<td>50.7</td>
<td>70.8</td>
<td>61.5</td>
</tr>
<tr>
<td>Oil &amp; grease</td>
<td>mg/L</td>
<td>Mean</td>
<td>38</td>
<td>50</td>
<td>42</td>
</tr>
<tr>
<td>Phosphates</td>
<td>mg/L</td>
<td>Mean</td>
<td>0.63</td>
<td>1.25</td>
<td>0.532</td>
</tr>
<tr>
<td>Sulphates</td>
<td>mg/L</td>
<td>Mean</td>
<td>38.5</td>
<td>44.5</td>
<td>42.3</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>Mean</td>
<td>55</td>
<td>60</td>
<td>59</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>mg/L</td>
<td>Mean</td>
<td>110</td>
<td>120</td>
<td>125</td>
</tr>
<tr>
<td>Magnesium hardness</td>
<td>mg/L</td>
<td>Mean</td>
<td>100</td>
<td>105</td>
<td>103</td>
</tr>
<tr>
<td>Total alkalinity</td>
<td>mg/L</td>
<td>Mean</td>
<td>50</td>
<td>95</td>
<td>75</td>
</tr>
<tr>
<td>Nitrates</td>
<td>mg/L</td>
<td>Mean</td>
<td>0.3</td>
<td>0.8</td>
<td>0.63</td>
</tr>
<tr>
<td>Ammonia</td>
<td>mg/L</td>
<td>Mean</td>
<td>0.12</td>
<td>0.34</td>
<td>0.22</td>
</tr>
<tr>
<td>Total organic nitrogen</td>
<td>mg/L</td>
<td>Mean</td>
<td>8.55</td>
<td>10</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Table 7: Physical and chemical analyses of wastewater samples collected from pasta plants of Alexandria Flour Mills and Bakeries Company

Fig. 4. Water usage and wastewater reuse in Mohram Bek plant after in-plant control.
make the analysis very difficult and require careful judgment by the industry (Dencker et al., 1985).

Simple treatment options (sedimentation, filtration, etc) were provided to allow wastewater to be reused as boiler feed water. Also, sodium resin softeners were used to reduce hardness as given in Table 8 and Fig. 6.

In the Philippines, industrial technology development institute applied in-plant control at central macaroni company and revealed nearly similar results to the present study where the reduction of BOD loading to the wastewater treatment plant was by 3.8 tons/year and reduction of product loss with total saving of 1.39 million dollars (Philippine Council for Industry and Energy Research and Development, 2002). Moreover, Oktay et al. (2007) showed that in-plant control improved the management of wastewater in beverage industry where when reuse practices were not employed a wastewater having an organic content of 33,000 mg/L of COD must be treated. Whereas if wastewater originating from filter cleaning operations were segregated from other wastewater sources and passed through a suitable system such as a membrane process, a valuable sugar by-product can be obtained and the rest of the wastewater did not require any type of treatment to meet the discharge standards as they contain only 250 mg/L of COD. Erdogan et al. (2004) studied the feasibility of water minimization and wastewater reuse for a wool finishing textile mill by application of in-plant control measures, they had proved a potential for 34% reduction in water consumption and for 23% of wastewater recovery for reuse. This finding confirmed the results of the present study where reuse of wastewater as boiler feed water resulted in reduction of water consumption/month in Moharam Bek and El-Ras El-Soda plants that amounted to 49.2% and 52.6% saving in water consumption, respectively, as shown in Table 6. This consequently reduced both rates of water consumption and wastewater discharge per amount of final products. Additionally, in Iraq, the application of in-plant waste control and water reuse proved to be considered the most effective and economic approaches to solve the problem of industrial waste discharge to domestic sewer or directly into water resources where a 30% of water consumption can be economized with recirculation of wash water to manufacturing operations in tanning factory (Hamad, 2004). The results of this study were in agreement with those expected by Abou-Elela et al. (2008) who proved that the management of environmental pollution problems caused by recycling waste paper at a board paper mill through the application of in-plant control measures such as reduction of freshwater consumption was found to be very cost effective and saved $49,440/year with a payback period of 3 days.

4.4. Cost benefit analysis of in-plant modification

Table 9 summarizes the economic savings achieved by implementing in-plant control modifications. It is evident from this table that an economic cost benefit analysis was conducted based on the
criteria of capital cost, total annual benefit, and payback period. From this table, it is noticed that the application of in-plant control is very cost effective with annual saving of $228,245.

5. Conclusion

From this study it is apparent that the implementation of in-plant control measures such as installation of water flow meters, spring valves on water hoses and design of a steam condensate recovery system proved to be very efficient in reducing water and energy consumption throughout the pasta industry in addition to reduction of the hydraulic load on the wastewater treatment plant. An estimated annual benefit of $228,245 could be achieved. Cost benefit analysis for the implemented environmental improvements had proved to be very economic with a short payback period and resulted in great savings. Therefore, it is recommended to apply in-plant control measures in pasta industry which consumes significant quantities of freshwater and generates significant quantities of wastewater to reduce these financial burdens.

6. Recommendations

6.1. Recommendations for actions to steer sustainable industrial development

- Pasta industry in Egypt should implement in-plant control interventions which could be energy saving, water saving, labor-intensive and less-polluting technologies in order to achieve modernization of the state-owned facilities, and decentralize industry to ease the pollution burden on urban centres.

- The pasta industry should invest in new low-waste processing technologies through provision of financial and technical support as it will pay back through eliminating the increasing levied taxes for the discharge of volumes of wastewater with high loads of organic wastes as generated by their current technologies.

- Pasta industry tends to be carried in Egypt in small-scale industries which need the government research institutions’ interventions to reduce their raw materials’ losses as well as energy dissipation and low efficiency manufacturing processes where water is consumed lavishly with low efficiency of cleaning. The industry needs to develop the mechanisms and institutions to extend financial and technical assistance to the informal manufacturing sector is necessary.

- Newly constructed plants should conduct a full-fledged EIA in order to reduce future processing delays and non-controlled sources of pollution non-compliance with environmental law and their closure.

- Building human skills and mainstreaming new technologies and management approaches should be emphasized in formal technical and business education.

- Mechanism for information concerning legislation, emission standards, cleaner technologies and waste minimization of the industry will be very helpful for similar industrial plants to use. Emphasis should be laid on improving performance of existing information channels, in terms of relevance and user-friendliness to industry and other stakeholders.

Acknowledgements

The authors gratefully acknowledge the three anonymous referees whose comments have helped to improve the quality of this manuscript, Prof. Dr. Donald Huisingh editor of the journal for his assistance and support, and Khalil El-Robi director of quality control and environmental affairs in AFMCO for his assistance and support during the course of this research.

References


References

Regional Activity Centre for Cleaner Production (RAC/CP), 2001. State of Cleaner Production in the Mediterranean Action Plan Countries. RAC/CP.

