Smart Water Fund

Final Report

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"Removing Effluent Colour by Advanced Treatment"

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Executive Summary

Examination of the major sources of colour to the ETP indicated that one industrial plant contributed approximately 20% of the total colour load, and given the processes conducted at that plant, this was probably due to melanoidins that contribute a dark brown colour and high organic load to effluents.

The objectives of this work were to investigate the feasibility of and to compare coagulation, ozonation and UV/H_2O_2 treatment separately or in sequence as appropriate, for the removal of colour from the wastewater before and after anaerobic treatment.

The key findings obtained from this work are summarised below.

- There was a large variation in the colour of the wastewater between sample batches, consequently the optimum conditions for physico-chemical treatment of the wastewater varied.

- Although there was no apparent colour reduction, anaerobic treatment of the wastewater reduced the DOC and COD levels by 66% and 53%, respectively.

- Colour removal by coagulation with ACH/LT410 was 40% for wastewater and 46% for anaerobically treated wastewater.

- UV/H_2O_2 treatment after coagulation increased colour removal from raw wastewater by more than 45% and from anaerobically treated wastewater by 23-27%. This resulted in overall colour removals of 60% for wastewater and 75-85% for anaerobically treated wastewater. The extent of colour removal, the high doses of peroxide and the high energy requirements would militate against the use of this process for this application.

- Ozone treatment removed 86% of the colour from wastewater while the sequence of anaerobic treatment and ozonation treatment of the wastewater removed 95% of the colour. Ozonation led to significant reductions in colour, COD and UVA_{254} in both wastewater and anaerobically treated wastewater.

- Coagulation with ACH/LT410 prior to ozone treatment assisted the reduction of UVA_{254} for both wastewater and anaerobically treated wastewater, but only marginally increased the reductions in colour and DOC for these samples. As coagulation led to the production of a significant amount of sludge and so would involve another unit operation for sludge removal, coagulation prior to ozone treatment of the wastewater is not recommended.

- Ultrafiltration with 30 kDa MWCO membrane gave 66% and 51% removal of colour from raw and anaerobically treated wastewater, however, the flux was extremely low. Although pre-treatment with ACH/LT410 greatly improved the flux, it was still low and the overall colour removal from anaerobically treated wastewater was not significantly increased (60%). Membrane fouling due to the high concentration of organic matter in the feed make this process a less favourable option for this application.

The results obtained from this work demonstrated that anaerobic treatment followed by ozonation may be suitable for the treatment of wastewater from the targeted industry. However, this is dependent on the consistency of the chromophoric properties of the wastewater and further trials need to be undertaken to determine the range of characteristics of the wastewater and anaerobically treated wastewater, whether coagulation is necessary, and the ozone dosages required for consistent colour removal. Further investigation is required into the nature (e.g., toxicity, BOD and DBP formation potential) of the oxidised products and residual ozone with regard to the subsequent fate of the treated water. Larger scale ozonation trials on the wastewater and anaerobically treated wastewater are recommended.

Table of Contents

1. Background

Investigation of the sources of colour to Eastern Treatment Plant (ETP) by South East Water Limited (SEWL) showed that a relatively small number of industrial plants contribute a large proportion of the brownish colour to the secondary effluent. Examination of the major sources of colour to the ETP indicated that one industrial plant contributes approximately 20% of the total colour load, and given the processes conducted at that plant, this is probably due to melanoidins. Melanoidins are high molecular weight polymers that contribute a dark brown colour and high organic load to effluents (González et al., 1999). The formation of melanoidins is via a series of consecutive and parallel chemical reactions between amino compounds and carbohydrates during the Maillard reaction (Kim et al., 1985; Cämmerer and Kroh, 1995). The chemical properties of melanoidin are similar to those of humic substances, being acidic, polymeric and highly dispersed colloids which are negatively charged due to the dissociation of carboxylic and phenolic groups (Migo et al., 1993). The colour, nitrogen content and carbon content are determined by the degree of polymerisation (Motai, 1976), aromaticity and saturation (Cammerer and Kroh, 1995) that occurs as a result of the reaction conditions (i.e., temperature and formation time). Melanoidins are resistant to biodegradation (Zhou et al., 2008) thus the brown colour is not readily removed by conventional biological treatment and can even increase due to polymerisation (Peña et al., 2003). The structure and characteristics of the melanoidins are still not fully understood and this has consequently hindered the development of an appropriate process for their removal (Satyawali and Balkrishnan, 2008).

Methods which have been used to remove and/or decolourise humic-like matter and melanoidins include biological treatment with specific microorganisms, or consortia of microorganisms, and physico-chemical treatment. Biological treatment comprises both aerobic and anaerobic processes (Nandy et al., 2002; Jiménez et al., 2004). Physico-chemical treatment includes activated carbon adsorption (Mall and Kumar, 1997; Bernardo et al., 1997); coagulation and flocculation (Migo et al., 1993; Zhou et al., 2008); oxidation using ozone (Kim et al., 1985; Peña et al., 2003), UV/H_2O_2 or UV/H_2O_2/Fe (II) (Çatalkaya et al., 2006) and membrane treatment (Mutlu et al., 2002). The original concentration of colour and the molecular size, and the net charge of the coloured molecules, plus the characteristics and concentration of the other species present will greatly influence the effectiveness of the colour removal process. There has been very little consistency in the types of samples investigated and the methods used for measurement of colour concentration, and frequently the degree of colour removal is given in percentage terms with no initial values given. Consequently, no consistently effective method is apparent from examination of the literature.

2. Description of Project

The objectives of this project were to investigate the feasibility of and to compare coagulation, ozonation and UV/H_2O_2 treatment separately or in sequence, as appropriate, for the removal of colour from the wastewater before and after anaerobic treatment.

3. Samples and Methods

3.1 Samples

Samples of wastewater and anaerobically treated wastewater collected from the target industry were delivered to RMIT University on 2nd June, 7th, 17th July and 11th August 2009. According to the company, the wastewater discharged to sewer comprised 40% first pass (i.e., process supernatant) and 60% of second pass (washings) wastewater streams. Samples were stored at 4°C on receipt and analysed as soon as possible. The samples were filtered (0.45 µm membrane) prior to the measurement of absorbance, DOC, true colour and fluorescence.

3.2. Materials and Test Procedures

- **Chemicals:** ACH (aluminium chlorohydrate), sold as Megapac 23 (40% w/w), was supplied by Omega Chemicals. Poly(diallyldimethylammonium chloride) (poly DADMAC) was supplied as Magnafloc LT410 by Ciba Specialty Chemicals Pty, Ltd. Ferric chloride ($FeCl_3$) was supplied by BDH by Pty Ltd.

- **Anaerobic treatment of the raw wastewater:** Anaerobic treatment of the raw wastewater was conducted in a commercial laboratory using a lab-scale unit and the treated effluent was supplied for further physico- chemical treatments.

- **Coagulation:** Coagulation trials were conducted using a laboratory jar tester (Phipps and Bird, PB-700) with rapid mixing for 2 minutes at 250 rpm followed by slow mixing for 20 minutes at 30 rpm. The coagulated water was settled for 2 hours and the supernatant was then collected for measuring colour.

  For alum (or ACH)/polyDADMAC (LT410) sequence treatment, alum (or ACH) was added to the wastewater and mixed at 250 rpm for 2 minutes. PolyDADMAC (LT410) was then added to the solution and mixed at 250 rpm for a further minute, followed by slow mixing at 30 rpm for 20 minutes. Doses were as noted in the text. ACH dosages in this report are recorded in terms of pure ACH.

- **Ultrafiltration:** Ultrafiltration was conducted using 100 kDa (PES, Amicon, PBHK) or 30 kDa MWCO (PDVF, GE Sepa CF) disc membranes in a stirred cell (Amicon 8050) at a trans-membrane pressure of 220 kPa and stirring speed of 430 rpm.

- **Ozone treatment:** Ozone treatment of wastewater was carried out in a 250 mL glass column using a lab-scale ozone generator (Ozomatic LAB 802) at room temperature (~20^{o}C) in a fume cupboard. Ozone gas was produced from pure oxygen and the inlet gas flow rate was 0.33 L min^{-1}. The volume of wastewater was 100 mL and the ozone concentration was 7 mg L^{-1}. The reaction time was 45 minutes for all samples.

- **AOP treatment of the coagulated wastewater sample:** The wastewater was coagulated with ACH/LT410 and settled for 2 hours, the supernatant was then filtered (filter paper 5 µm; Advantec No.2). UV/H_2O_2 treatment of the filtered coagulated wastewater was then conducted in the annular reactor detailed by Thomson et al. (2004). The average fluence value of the UV-lamp was 12.95 mJ s^{-1} and the H_2O_2 dosage was 5.3 g L^{-1}. The dose of hydrogen peroxide was chosen after consideration of the colour degradation effect reported in the literature, the residual mass and the cost of the peroxide (Dwyer et al., 2008)

3.3 Analytical methods

- **Colour:** The true colour (i.e., after filtration, 0.45 µm) of the samples was measured in Pt-Co units at 455 nm using a Hach DR/4000U spectrophotometer. Error is cited as ± 5%.

- **Dissolved Organic Carbon (DOC):** DOC was measured with a total organic carbon analyser (Sievers 820).

- **pH:** pH was measured with a Hach Sension 156 pH/conductivity meter.

- **UV Absorbance:** The UV absorbance at 254 nm was determined using a double beam scanning spectrophotometer (Unicam UV2, 1 cm pathlength).

- **Chemical oxygen demand (COD):** COD was measured according to Hach method 8000 and a Hach DR/4000U spectrophotometer.

- **Excitation Emission Matrices (EEMs):** Fluorescent EEMs were obtained with a Perkin Elmer Luminescence Spectrometer LS 55 and reported in arbitrary units (AU). Excitation and emission wavelength ranges were 200-550 nm. Samples were filtered (0.45 µm cellulose acetate membrane) to remove any suspended particulates.

4. Key Activities Completed

4.1 Characterisation of the raw and anaerobically treated wastewater

- The raw and anaerobically treated wastewater was characterised in terms of pH, colour, DOC, COD, UVA_{254}.

4.2 Physico-chemical treatments of the raw and anaerobically treated wastewater

- Coagulation with a range of coagulants (lime,$FeCl_3$, alum, ACH and poly DADMAC)
- UV/H_2O_2 treatment
- Ozone treatment.

4.3 Evaluation the performance of the treatment processes

- Evaluation of the performance of physico-chemical treatment of the raw and anaerobically treated wastewater in terms of decolourisation efficiency and characteristics of the dissolved organics.

5. Results Achieved

5.1 Treatment of raw wastewater

5.1.1 Characteristics of raw wastewater

The water quality characteristics in terms of pH, colour, DOC, SUVA of the raw and anaerobically treated wastewater collected over the period of June - August 2009, are shown in Table 1. The raw wastewater had a very high colour and there was marked variation in the colour concentrations of samples for different batches. Anaerobic treatment resulted in a significant decrease of COD and DOC level but a slight increase in the true colour of the raw wastewater.

Table 1. Characteristics of raw and anaerobically treated wastewater

Parameter	Raw Wastewater	Anaerobically treated wastewater
pH	5.6-6.0	7.7-8.5
True colour (mg Pt-Co L^{-1})	30,000-35,500	32,000-36,000
DOC (mg L^{-1})	8,200-12,000	3,200-3,900
COD (mg L^{-1})	18,000-30,000	6,000-14,000
UVA_{254} (cm^{-1}, 1:1000 dilution)	0.1-0.15	0.13-0.16

5.1.2 Colour removal of raw wastewater by coagulation

The colour removal by various coagulation treatments of the wastewater sample collected on 2/6/09 is shown in Figure 1. The best result was obtained with lime treatment at the dosage of 20 g CaO L^{-1} (60% colour removal), however, a significant amount of sludge was produced and the pH increased markedly from 5 to more than 12 which would necessitate adjustment prior to discharge as Trade Waste.

At the same dosage of 200 mg Al^{3+} L^{-1}, colour removal with alum was better than with ACH, however, the amount of sludge produced after treatment by alum was slightly higher than for ACH treatment.

Treatment of the wastewater stream with low molecular weight polyDADMAC (LT410) at the optimum dosage of 1.2 g L^{-1} (Milestone 3 Report) resulted in 30% colour removal. Sequential treatment by alum and LT410 did not increase colour removal although sequential treatment by ACH and LT410 removed a further 10% (overall colour removal of 40%).

Coagulation with $FeCl_3$ removed 20% of colour, however the pH decreased markedly, from 5.9 to 2.7, and the wet volume of the sludge in the $FeCl_3$-treated water was about 6-7 times higher than that for the ACH/PolyDADMAC LT410 treated wastewater. The results indicate that the sequence ACH/polyDADMAC may be a suitable coagulation treatment for the wastewater.

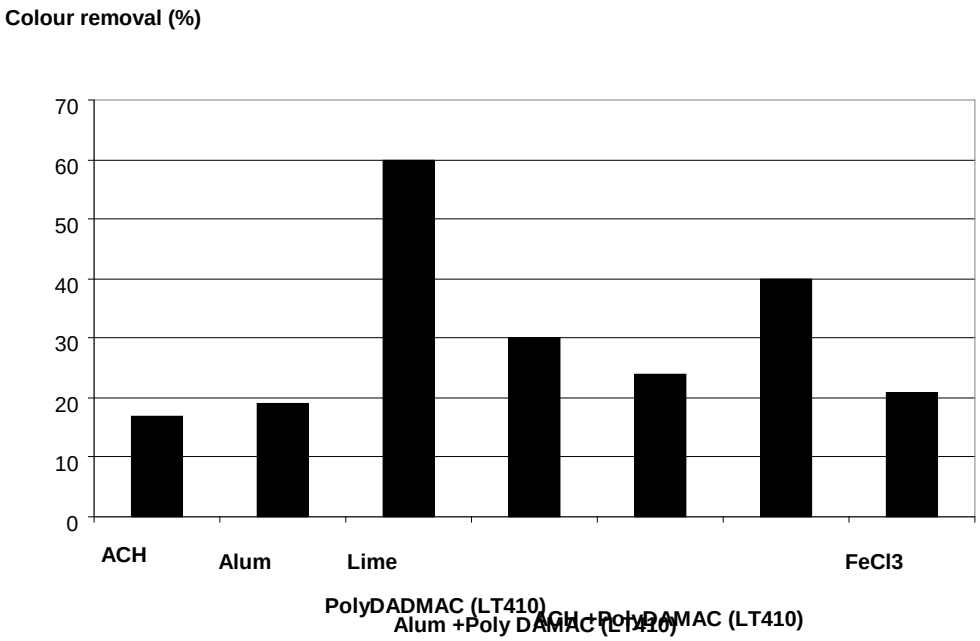

Figure 1. Colour removal from raw wastewater collected on 2/6/09 by different coagulation treatments (Milestone 2 Report)

5.1.3 Colour removal from raw wastewater by coagulation with ACH/LT10 followed by UV/H_2O_2 treatment

Colour removal by coagulation with ACH/LT410, and coagulation followed by UV/H_2O_2 treatment of the wastewater sample is shown in Figure 2. At the optimum dosage of 0.96 g L^{-1} for ACH and 1.2 g L^{-1} for LT410 (Milestone 2 report), coagulation removed only 40% of the

colour. Subsequent treatment of the coagulated wastewater with UV/H_2O_2 for 60 minutes removed a further 19% (overall removal of 59%), and treatment for up to 120 minutes gave only a marginal increase in colour removal. Although this suggests that the peroxide concentration may have become limiting for hydroxyl radical production and thus oxidation of the melanoidins, measurement of residual peroxide after 2 h irradiation gave concentrations in excess of 250 mg L^{-1}. The peroxide dose was not optimised for this waste as uneconomically large doses were indicated.

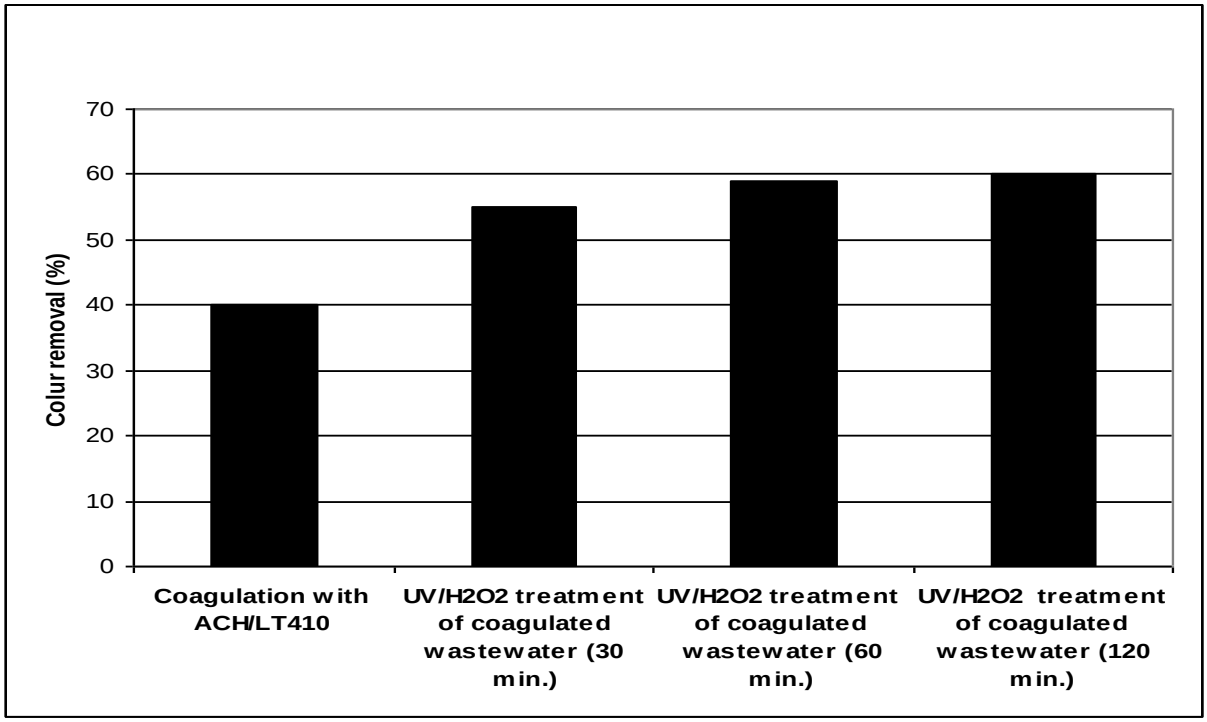

Figure 2. Colour removal by coagulation and oxidative treatment of raw wastewater collected on 2/6/09 (Milestone 3 Report)

Although treatment of melanoidin-containing water and wastewater with UV/H_2O_2 has been shown to be feasible by Çatalkaya. and Sengül (2006), Dwyer et al. (2008) and Dwyer and Lant (2008), it was not so for this highly coloured sample. As anticipated, the high colour concentration (leading to “inner filter” effects, i.e., the high concentration of chromophores absorbs the incident radiation and so reduces the amount of radiation available to be absorbed by the target molecules and consequent photooxidation) and the high DOC level of the waste meant that colour removal was limited. Taken overall, the extent of colour removal, the high doses of peroxide and the high energy requirements militate against the use of this process for this application.

5.1.4 Colour removal from raw wastewater by ozone treatment

The reductions in colour, DOC, COD and A_{254} after ozonation of the wastewater collected on 2/6/09 are shown in Table 2. Ozone treatment increased the colour, DOC and COD removals from the coagulated wastewater by 47%, 60% and 43%, respectively. However, coagulation with ACH/LT410 prior to ozone treatment did not improve the reductions in COD, DOC or colour. Coagulation decreased the UVA_{254} of the wastewater by 30%, while ozonation decreased it by 28%, and the sequence of coagulation and ozonation decreased it by 43%.

Table 2. Reductions in colour, DOC, COD and UVA_{254} after coagulation with ACH/LT410 and ozone treatments of the raw wastewater collected on 2/6/09 (Milestone 3 Report).

	Colour removal (%)	DOC removal (%)	COD removal (%)	Decrease in UVA_{254} (%)
After coagulation	40	12	8	30
After ozonation	86	71	51	28
After coagulation + ozonation	87	72	51	43

An interesting observation was that white particulate matter which could be settled out formed in the ozonated wastewater, whether or not the wastewater had been pre-treated by coagulation. If ozonation were implemented for this wastewater, this material would need to be taken into account and may require the inclusion of a further unit operation for its removal.

5.1.5 Characteristics of dissolved organics in the treated wastewater

The characteristics of the organic matter in the untreated and treated wastewater were investigated using three-dimensional fluorescence excitation emission matrices (EEMs). EEMs provide 3-dimensional plots of the intensity of molecular excitation and emission in the UV-visible wavelength range that can be used for providing a “fingerprint” of fluorescent dissolved organic compounds in water. The EEM spectra were divided into five regions: regions I and II contain peaks at shorter excitation and emission wavelengths which are related to simple aromatic proteins (Determann et al., 1994). Region III comprises peaks which are associated with fulvic acid-like materials (Nguyen et al., 2005). Region IV consists of peaks which are related to soluble microbial product (SMP) materials (Sheng and Wu, 2006). Region V includes peaks which are associated with humic acid-like organics (Mounier et al., 1999).

The spectra show that coagulation with ACH/LT410 removed only a small proportion of the fulvic acid-like (region III) and humic acid-like materials (region V) from the wastewater. Ozonation almost completely degraded the SMPs (region IV) and most fulvic acid-like (region III) and humic acid-like materials (region V). Ozonation after coagulation led to almost complete destruction of all the fluorophores. These data are consistent with the reductions in colour and UVA_{254} in Table 3. Thus these results demonstrate that ozonation is very effective for breaking down these chromophores and thus reducing the colour of the wastewater. Hence ozonation appears to be a very promising treatment for the removal of colour from this coloured industrial effluent.

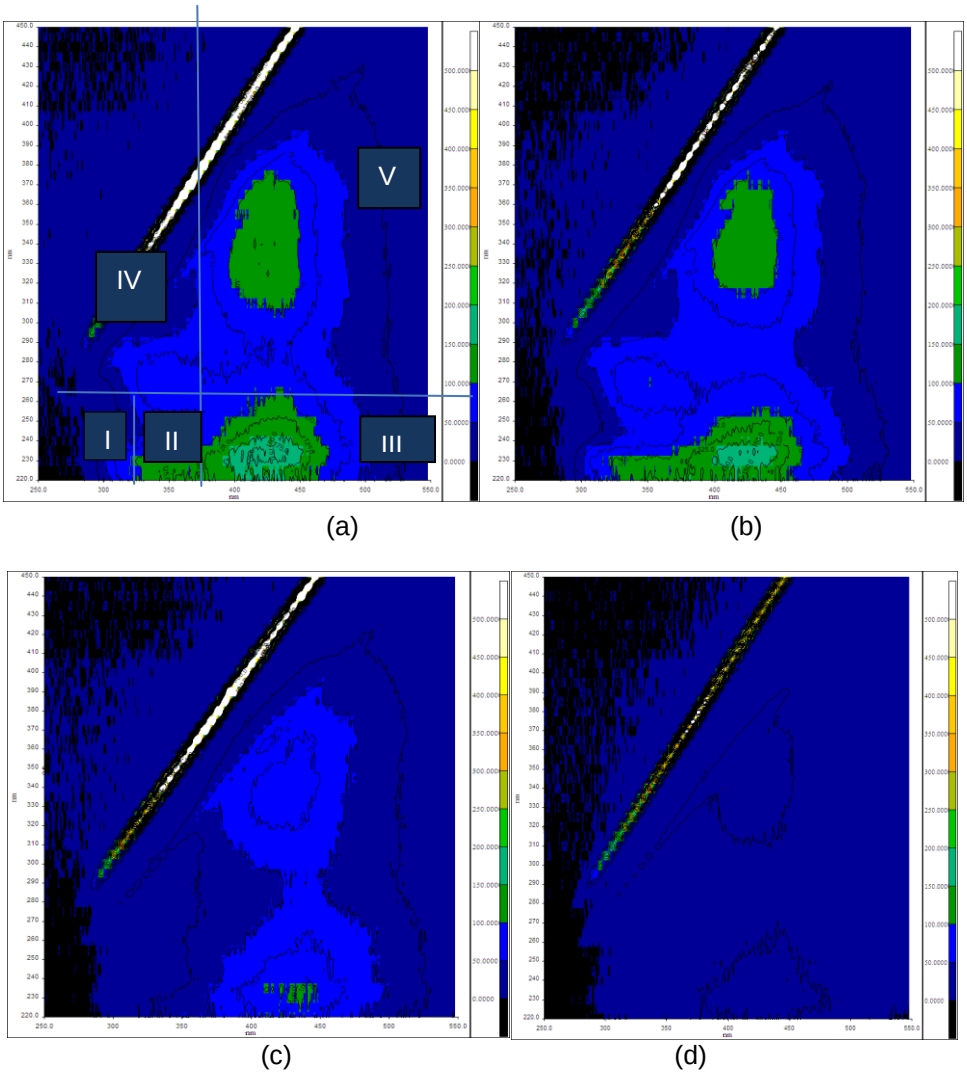

Figure 3. EEM spectra of (a) untreated wastewater; (b) wastewater after coagulation; (c) wastewater after ozone treatment and (d) wastewater after coagulation and ozone treatment with similar DOC level (3.2 ± 0.1 mg L^{-1})

5.2 Treatment of the anaerobically treated wastewater

5.2.1 Colour removal from the anaerobically treated wastewater by coagulation with ACH/LT10

Colour removal by coagulation of anaerobically treated wastewater samples collected on 17/7/09 and 11/8/09 with ACH/LT410 is shown in Table 3. Although the colour levels were fairly similar and the same coagulant dosages (0.96 g L^{-1} for ACH and 1.4 g L^{-1} for LT410) were used, the colour removal from the sample collected on 17/7/09 was markedly higher than for the sample collected on 11/8/09 (62% and 46%, respectively). This indicates that either the chemical characteristics of the wastewater matrix and/or the characteristics of the chromophores (e.g., molecular size) were markedly different for the two samples. This may be due to the differing nature of the composition of the feed which may be used in the industrial process.

Table 3. Colour removal by coagulation with ACH/LT410 for anaerobically treated wastewater collected on 17/7/09 and 11/8/09 (Milestone 3 report).

	Colour (Pt-Co units)	Total colour removed (Pt-Co units)	Colour removal (%)
17/7/09 raw sample	33,500		
After coagulation	12,750	20,750	62
11/8/09 raw sample	34,750		
After coagulation	18,750	16,000	46

5.2.2 Colour removal from the anaerobically treated wastewater by ultrafiltration

Colour removal from the anaerobically treated sample collected on 2/6/09 by ultrafiltration with a 30 kDa membrane was 51% (Table 4). The greater removal of colour for the raw wastewater compared with the anaerobically treated wastewater indicated that some breakdown of the chromophores occurred in the anaerobic process. Pretreatment of the anaerobically treated wastewater with ACH/LT410 at 0.96 g L^{-1} for ACH and 1.2 g L^{-1} for LT410 before ultrafiltration gave a total colour removal of 60%. Although pre-treatment with ACH/LT410 greatly improved the flux for anaerobically treated wastewater, it was still low and the overall colour removal was not significantly increased (60%). Use of a cross-flow membrane system would probably further improve the flux, although membrane fouling would be likely due to the high concentration of organic matter remaining after coagulation

Table 4. Colour removal from anaerobically treated wastewater collected on 2/6/09 by ultrafiltration using 30 kDa membrane (Milestone 2 Report)

	% colour removal
Raw wastewater + UF	66
Anaerobically treated wastewater + UF	51
Anaerobically treated wastewater + coagulation +UF	60

5.2.3 Colour removal from the anaerobically treated wastewater by ACH/LT10 followed by UV/H_2O_2 treatment

UV/H_2O_2 treatment for 60 min after coagulation with ACH/LT410 (0.96 g L^{-1} for ACH and 1.4 g L^{-1} for LT410) increased the colour removal by 20-26% (Table 5). Further oxidative treatment led to only a marginal increase in colour removal, even though concentrations of peroxide in excess of 250 mg L^{-1} remained. Colour removal after coagulation and UV/H_2O_2 treatment of the anaerobically treated wastewater varied between sample batches: for the sample collected on 17/7/09 it was 85% (to 5,025 Pt-Co units) whereas for the sample collected on 11/8/09 it was 73% (to 8,375 Pt-Co units), again reflecting the heterogeneity of the composition of the wastewater. The greater removal of colour for the anaerobically treated wastewater compared with the wastewater reflects the negative influence of the higher DOC level of the latter (Table 1) on the removal of the colour. It would be more feasible to consider UV/H_2O_2 treatment for the anaerobically treated wastewater, although the high colour levels and associated inner filter effect mean that the process would not occur at maximum efficiency.

Table 5. Colour removal at each stage of the coagulation-UV/H_2O_2 sequence for anaerobically treated wastewater (Milestone 3 Report).

	True colour (Pt-Co units)	Total colour removed (Pt-Co units)	Colour removal (%)
17/7/09 sample			
Anaerobically treated wastewater	33,500		
After coagulation	12,750	20,750	62
After coagulation + UV/H_2O_2 (30 min)	6,000	27,500	82
After coagulation + UV/H_2O_2 (60 min)	5,250	28,250	84
After coagulation + UV/H_2O_2 (120 min)	5,000	28,500	85
11/8/09 sample			
Anaerobically treated wastewater	34,750		
After coagulation	18,750	16,000	46
After coagulation + UV/H_2O_2 (30 min)	10,000	24,750	71
After coagulation + UV/H_2O_2 (60 min)	9,500	25,250	72
After coagulation + UV/H_2O_2 (120 min)	9,250	25,500	73

5.2.4 Colour removal from the anaerobically treated wastewater by ozone treatment

Reductions in colour, DOC, COD and UVA_{254} after ozone treatment of the anaerobically treated wastewater are shown in Table 6. Coagulation with ACH/LT410 reduced the colour by 46% and the UVA_{254} by 22%. However, the DOC and COD removal was only 10% and 3%, respectively. Ozone treatment removed 95% of the colour, 33% of DOC and 46% of COD, and decreased the A_{254} by 49%. Coagulation of the anaerobically treated wastewater by ACH/LT410 prior to ozone treatment led to only marginally greater reductions in colour (by 3%) but a greater reduction in UVA_{254} (by 12%).

These results differed from those for another anaerobically treated sample collected on 19/09/09 for which the reduction in the original colour of 31,000 Pt-Co units was greater (68%) after coagulation, but only 73% after ozonation and 93% after the sequence of coagulation plus ozonation. There was a much greater decrease in UVA_{254} for this sample, being 51%, 67% and 81% for coagulation, ozonation, and the sequence of coagulation and ozonation, respectively. This again demonstrates the heterogeneity of the coloured organic content within the wastewater samples. It should be noted that the results for the ozonation treatment for the two samples may not be directly comparable since a different ozone generator system was used in this trial, however, the colour-reducing potential of ozonation was clearly demonstrated.

Unlike the wastewater, ozone treatment of the anaerobically treated wastewater did not lead to the production of particulate matter.

Table 6. Reductions in colour, DOC, COD, UVA_{254} after coagulation and ozonation of the anaerobically treated wastewater sample collected on 11/8/09 (Milestone 3 Report).

11/08/09 sample	Colour removal (%)	DOC removal (%)	COD removal (%)	Decrease in UVA_{254} (%)*
After coagulation	46	10	3	22
After ozonation	95	33	46	49
After coagulation + ozone treatment	98	33	46	61

(*) compared with the raw sample (diluted 1:1000)

When the initial DOC and COD levels of the raw wastewater were taken into account, anaerobic treatment of raw wastewater removed 66% of DOC and 53% of COD from raw wastewater (Table 7). The total DOC and COD removal by anaerobic and ozone treatment of the wastewater were greater than 99%. Coagulation of the anaerobically treated wastewater with ACH/LT410 prior to ozone treatment did not significantly increase the total DOC and COD removal (less than 1%). Total DOC and COD removal from anaerobic and coagulation with ACH/LT410 were 76% and 56%, respectively and subsequent treatment of the coagulated wastewater with H_2O_2/UV increased the total DOC and COD removal by 21% and 42%, respectively. The results indicated that anaerobic treatment followed by ozonation would be suitable for colour removal from the raw wastewater.

Table 7. DOC and COD removals by various sequences of treatments of raw wastewater (Milestone 3 Report)

Treatment	DOC removal (%)	COD removal (%)
Anaerobic	65.7	53.5
Anaerobic + Ozonation	99.2	99.6
Anaerobic + ACH/LT410 + Ozonation	99.4	99.9
Anaerobic + ACH/LT410	75.7	56.4
Anaerobic + ACH/LT410 + H_2O_2/UV	96.7	98.5

5.2.5 Characteristics of dissolved organics in the anaerobically treated wastewater before and after physico-chemical treatment

EEM spectra for the anaerobically treated wastewater before and after ozone treatment are shown in Figure 4. Coagulation with ACH/LT410 led to only a small reduction in the peak for humic acid-like materials (peak V, Figure 4b) whereas ozonation led to the destruction of almost all the fluorescent organics with or without coagulation pre-treatment. (Figure 4c and 4d).

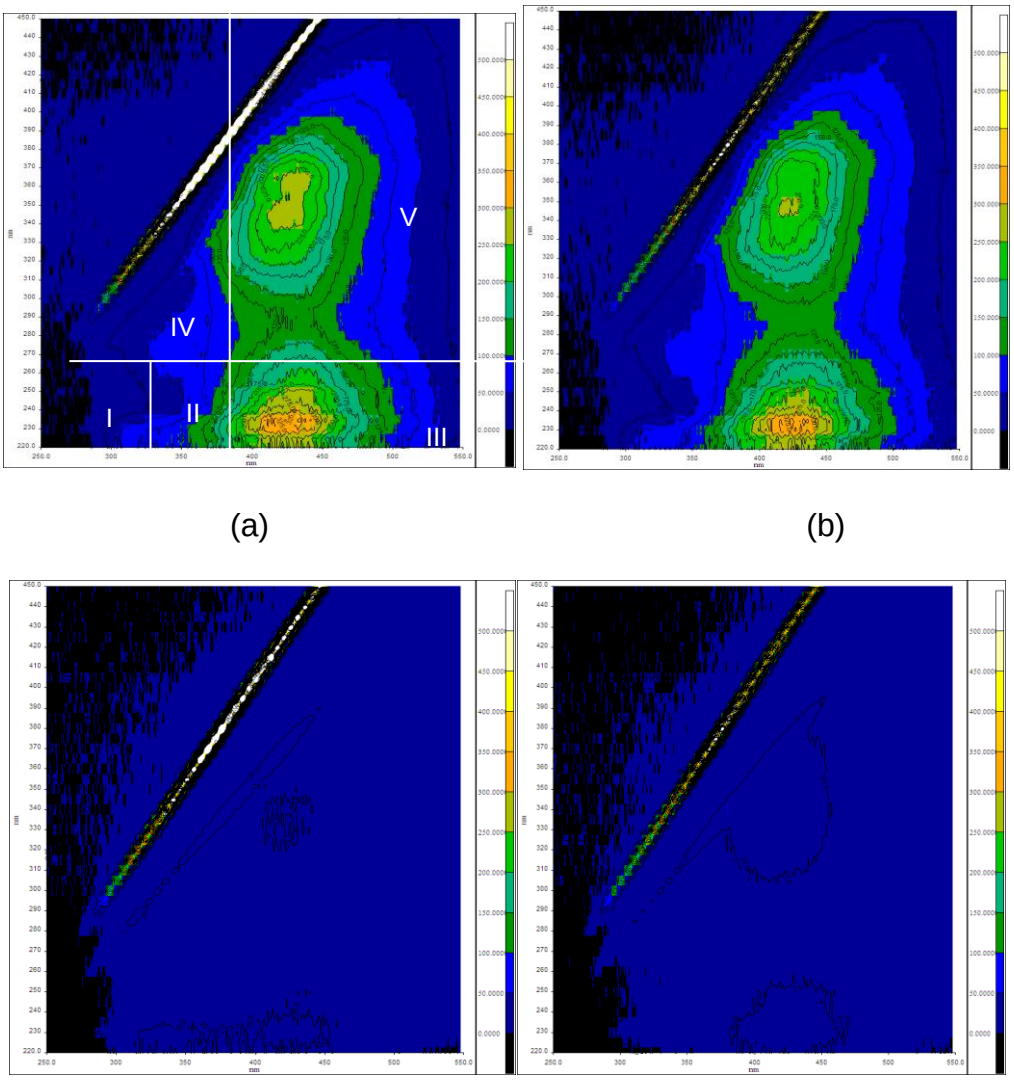

Figure 4. EEM spectra of (a) anaerobically treated wastewater (DOC = 3.9 mgL^{-1}); (b) anaerobically treated wastewater after coagulation (DOC = 3.5 mgL^{-1}) and (c) anaerobically treated wastewater after ozone treatment (DOC = 3.5 mg L^{-1}) and (d) anaerobically treated wastewater after coagulation and ozone treatment (DOC = 3.3 mg L^{-1})

6. Issues Arising

- There was a large variation in the colour components of the raw wastewater between sample batches therefore the optimum conditions for physico-chemical treatment of the wastewater varied.
  Should the plant continue to produce a heterogeneous waste stream, then further testing of samples is necessary to determine whether the sequence of anaerobic biological treatment, coagulation and ozonation is required to ensure that a robust system capable of producing an effluent of consistently high quality is in place. Should the plant operators standardise their process, i.e., use a feed with consistent properties and a consistent washing procedure, then it may be possible to simplify the wastewater treatment process to anaerobic treatment followed by ozonation.

- The nature (e.g., toxicity, BOD and DBP formation potential) of by-products from the treatment processes with regard to subsequent use of the treated water should be considered, particularly if an oxidation process is to be used as a polishing treatment after coagulation.

- The transfer of technology from laboratory scale to industrial scale requires further study.

7. Conclusions

The effectiveness of physico-chemical treatment on colour removal from the raw and anaerobically treated wastewater from an industrial plant was investigated. As there was a large variation in the chromophoric properties of the water between samples, the efficiency and optimum treatment conditions varied, and this would need to be taken into account when implementing a treatment process at the industrial plant.

The results showed that anaerobic treatment followed by ozonation would be suitable for the treatment of the wastewater. However, this is dependent on the consistency of the chromophoric properties of the wastewater and further trials need to be undertaken to determine the range of characteristics of the wastewater and anaerobically treated wastewater, whether coagulation is necessary, and the ozone dosages required for consistent colour removal. Furthermore, the formation and nature (e.g., toxicity, biodegradability) of the products, and depending on the subsequent use of the treated water, the disinfection by-product formation potential of the products, from the treatment process require further investigation.

8. References

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9. Publication and Dissemination of the Project Findings

Conference presentations

- Nguyen T., Fan L. and Roddick F. A. (2010) Removal of melanoidins from an industrial wastewater, in Proceedings of OzWater 10 Conference, 8-10 March, Brisbane, Australia
- Fan L., Nguyen T. and Roddick F.A. (2011) Decolourisation of high-strength molasses wastewater by coagulation, the 4th International Water Association ASPIRE Conference, 2-6 October, 2011, Tokyo, Japan

Journal publication

- Fan,L., Nguyen,T. and Roddick, F. A. (2011). Characterisation of the impact of coagulation and anaerobic bio-treatment on the removal of chromophores from molasses wastewater, Water Research, 45, 3933-3940.