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MEASURING COLOUR IN TRADE WASTE

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ABSTRACT

Colour is emerging as a critical quality parameter of trade waste which needs to be managed by Water Authorities, but is currently not well understood. Colour can present aesthetic or technical barriers to water reuse, interfere with treatment processes, and contribute to the appearance of plumes when outfall effluent discharges mix into receiving water bodies.

This paper provides a discussion on how colour is defined, how it can be measured, and what colour is deemed acceptable for potable water supply, recycled water supply, and trade waste discharges. Common laboratory tests for colour discussed in this paper are Apparent Colour, True Colour, Adams-Nickerson Colour, ADMI Colour, and Biodegradable Colour.

KEY WORDS

Trade Waste –Colour – True - Apparent – Adams-Nickerson – ADMI - Biodegradable Colour

1.0 INTRODUCTION

The Hatlar Group has been working with South East Water Limited (SEWL), a retail water authority located in eastern Melbourne, to improve its understanding of the colour discharged in trade waste by its major customers and to identify opportunities for source reduction. These investigations are driven by the fact that Melbourne Water and the retail water authorities have identified colour as an emerging critical quality parameter, especially for water reuse.

In SEWL's region, recycled water is supplied by Melbourne Water through the Eastern Irrigation Scheme which recycles ~3.5% of the treated effluent from the Eastern Treatment Plant (ETP). Reclaimed water is treated with ultra-filtration to meet Class A irrigation quality, then distributed as recycled water to over 60 locations for horticulture, recreational, industrial and non-potable residential use. SEWL also supplies reclaimed water from its own treatment plants, treated to Class C quality, for uses including agriculture and irrigation of a golf course.

Unfortunately, some customers receiving recycled water have complained about its quality, especially the staining of toilet bowls which are flushed with recycled water. Whilst such complaints may appear trivial, especially when water resources are becoming increasingly constrained, these customers are likely to stop using the recycled water entirely. In this way, colour can present an aesthetic barrier to customer acceptance, and failure to address colour issues may compromise the success of projects which reuse or recycle water.

Colour in recycled water obviously arises from the wastewater received and how it is treated; but the contribution of individual trade waste customers and domestic customers to the resultant water quality is not well understood. More work needs to be done to investigate sources of colour, downstream impacts, and options for colour removal or amelioration; all of which are complex tasks. Currently the Water Industry lacks a common method for measuring colour and a common acceptance standard for colour in trade waste.

2.0 DISCUSSION

2.1 What is Colour?

Colour can be described by the three properties: hue, chroma, and value.

- *Hue* is the “colour”, for example blue or red;
- *Chroma* is the intensity, brightness, or dullness of colour; and
- *Value* is the amount, or lightness or darkness, of colour.

For water and other liquids, distinction is made between *true colour* and *apparent colour*.

- True colour is caused by the absorption of specific wavelengths of light by coloured substances; and
- Apparent colour is caused by the scattering of light by particles or suspended matter.

In practice, an apparent colour test will be applied prior to filtration and a true colour test will be applied after filtration. In this way “apparent colour” tests measure all the colour in a sample, irrespective of how it is caused. Even a slight turbidity causes the measured colour to be noticeably higher (or different) than the same sample without turbidity.

The colour value of water can be pH-dependent and invariably increases as the pH of the water is raised. For this reason, samples submitted for analysis are often pH adjusted (usually to a more neutral pH) prior to colour analysis. Alternatively, some tests report the colour value at the natural pH of the sample and at a standard adjusted pH.

Additionally, liquids are typically contained in some type of vessel and the perception of colour may be influenced by the background colour of the containing surface. The perception of colour against a white background can be quite different than against a black background. Colour interpretations can also be complicated by how different people perceive colour.

Common contributions to colour in wastewater are coloured minerals and dyes, humic substances, and iron.

- Coloured minerals and dyes can be found in any colour of the rainbow and in trade waste arise from many sources including product losses and the use of various coloured chemicals.
- Humic substances are ubiquitous in nature and originate from the breakdown of organic matter. They comprise two main fractions: humic acids and fulvic acids. Humic acids are dark brown to black in colour and fulvic acids are light yellow to yellow-brown in colour. Humic acids are typically associated with wastewater from the pulp and paper industry.
- Iron can be present in various interchangeable forms: oxidised (“red water” iron), soluble (“clear water” iron), colloidal, or organic-bound. Iron in water supply is well known for causing reddish-brown staining at concentrations above 0.3 mg/L. Iron bacteria, which cause reddish-brown slimes, often colonise biofilms when waters contain high concentrations of iron. Iron in trade waste can arise from iron-based flocculants used in water and wastewater treatment.

Other metals known to cause colour staining include copper (blue-green) and manganese (brownish-black). Manganese bacteria can also produce black-brown slime. Stains are not normally removed by soaps and detergents, and the use of chlorine bleach and alkaline builders can also intensify such stains.

2.2 What are the Water Supply Standards for Colour?

Colour in supply water is often due to humic substances and metals such as iron and manganese. The Australian Drinking Water Guidelines (ADWG) (2004) provides an aesthetic guideline value for true colour to not exceed 15 Hazen Units (HU), but also advises that up to 25 HU may be acceptable if the turbidity is low. A guideline value based on health has been deemed “not necessary”. The ADWG advises that consumer complaints regarding water colour are often due to variations in water colour rather than the absolute water colour. Melbourne Water prefers to specify apparent colour rather than true colour, and water supplies for Melbourne are found to rarely exceed 15 Pt-Co units (1 Pt-Co is equivalent to 1 HU).

There is usually no specification or guideline value for colour in recycled water. Treated effluent leaving ETP typically has colour which varies from 40 - 160 Pt-Co units and has a median measured colour of 90 Pt-Co units. This means that even after further treatment, the colour of recycled water delivered in the Eastern Treatment Scheme is likely to be variable and to far exceed the colour of most drinking water supplies.

2.3 What are the Trade Waste Standards for Colour?

Unlike many trade waste quality parameters, colour discharges do not present a risk to the safety of sewer works or to the integrity of sewer assets. This may partly explain why there is no consistent compliance standard for colour in trade waste. Trade waste standards for colour are distinguished by the diversity of methods used to measure colour, additionally it is often not specified whether the colour is to be measured on a grab sample or a composite sample. (It would appear reasonable to use a composite sample because the colour impacts will be flow balanced.) Acceptance standards applied by Water Authorities in Australia include:

- “The Customer must not discharge trade waste containing Colour greater than 9 Adams-Nickerson (42) units, determined from the most pronounced Colour obtained from a sample adjusted to a pH of not less than 7.0 and no greater and than 8.0 following biological treatment by an activated sludge process.” [SEWL]
- “No visible colour when the waste is diluted to the equivalent dilution afforded by domestic sewage flow.” [Various NSW Shire Councils, e.g. Bega Valley, Wyong]
- “No colour visible after 100 dilutions; Colour must be biodegradable” [Power and Water, Northern Territory]
- “The colour is not to exceed, at a pH of 8.0, 300 platinum/cobalt units or 9 Adams-Nickerson units, or the equivalent per cent light transmission as determined by a procedure acceptable to the Engineer” [City of Devonport, Tasmania]
- “The assessment of colour in a trade waste shall be on a filtered sample of waste discharged to the sewer; and the trade waste shall have a colour not exceeding 300 True Colour units.” [Goulburn Valley Water, Victoria]
- “The limit for Colour shall be 300 ADMI units within the range of 6.0 to 10.0 relative to distilled water; and all determinations of the Colour of a waste shall be made after the sample of such waste has been adjusted to a pH that gives the most pronounced Colour within the pH range of 7.0 to 8.0.” [North East Region Water Authority, Victoria]
- “The Colour of the wastes when measured on the Platinum Cobalt scale shall not exceed 1000.” [Gippsland Water, Victoria]

Other acceptance standards for trade waste colour are based on how the colour discharged may impact on the operation of the receiving wastewater treatment plant:

- "Limited such as not to give any discernible colour in treatment works discharge." [Cairns Water]
- "No waste shall have colour or colouring substance that causes the discharge to be coloured to the extent that it impairs wastewater treatment processes or compromises the final effluent discharge consent." [Wellington City Council, NZ]

The author is unaware of any Water Authority which charges its customers for the colour discharged. Additionally, whilst colour may be regularly monitored, it is rarely managed as a compliance issue. Some exceptions to this may be major customers known to discharge significant non-biodegradable colour such as the pulp and paper industry (e.g. colour from lignosulphonates in black liquors) and the textile dyeing industry.

2.4 How is Colour Measured?

There are a wide variety of colour analysis techniques available, but as demonstrated by the diversity of acceptance standards used, there is no universal method to classify coloured wastewaters. There are two recognised approaches to measuring colour:
- ***Visual Comparison methods*** – The colour of a sample is determined by comparison to a standard colour. The standard is typically either a colour wheel or a set of calibrated concentrations of a known substance. These methods can be used for true colour and apparent colour.
- ***Spectrophotometric methods*** – these methods are usually only suitable for true colour measurements as the presence of turbidity interferes with the analysis. A spectrophotometer is used to measure how much light is transmitted through the sample at a number of known wavelengths of light. The results are then used as inputs into various algorithms, which should be defined in the test method.

An alternative approach may measure other parameters which can be correlated to a colour in particular applications, for example humic acid in trade waste from a pulp mill.

Ecowise Environmental provide the following colour analysis services:
Visual Comparison Methods:
- "Apparent Colour", Platinum Cobalt Units (Pt/Co) [low cost]
- "True Colour", Platinum Cobalt Units (Pt/Co) [low cost]

Spectrophotometric Methods
- "ADMI Colour", ADMI Units [medium cost]
- "Adams-Nickerson Colour", Adams-Nickerson Units (ANU) [medium cost]
- "Colour, Bio-degradability", Adams-Nickerson Units (ANU) [high cost]

ALS Laboratory Group provide similar services but do not provide a Colour, Bio-degradability test. For the ADMI Colour, ALS reports the results measured at both the natural pH and at an adjusted condition of pH 7.6.

Note that the Platinum-Cobalt scale is often referred to as APHA Colour or Hazen Colour and can be reported in either Pt/Co or HU. APHA is the American Public Health Association, which publishes the standard methods on this test. Dr A Hazen is credited with originally describing this test in 1892. ADMI is the abbreviation for American Dye Manufacturers' Institute Colour, which developed this standard test.

Apparent Colour Test
The sample is not filtered prior to analysis. Colour is determined by visual comparison of the sample with known dilutions of a coloured Platinum-Cobalt stock solution, and the results are reported in Pt/Co units.

This test is most suited to water samples which are clear to light yellow liquids, and is especially suited to sources of potable water supply. This test is used extensively in the water industry but is also used for clear oils, chemicals and petrochemicals such as glycerine, plasticisers, solvents, carbon tetrachloride and petroleum spirits.

Trade waste samples often contain colouration from a variety of other sources, and test may not be well suited. The presence of turbidity also makes it harder to see through the sample to make the visual comparison. For these reasons, *Ecowise Environmental* are often unable to apply this test to trade waste samples.

True Colour Test

For the true colour test, the sample is filtered, using a 0.45 micron filter, to remove suspended matter contributing to apparent colour (*ALS Laboratory Group* use the same filter size). The test is then carried out in the same manner as the apparent colour test.

Ecowise Environmental use a reading range of 0 – 80 units (*ALS Laboratory Group* use 0–100 units and some test kits used in industry can range up to 250 units). However, reported results can often be above 80 units, which means that the sample has been diluted prior to analysis, and then the reported colour has been estimated with consideration to the dilution factor. The dilution factor may be as much as 0.5 mL per 100 mL. The option to dilute samples also means that many samples with colours different from yellow can often be tested by using a sufficiently diluted (low colour) sample. However, the results should be interpreted with caution, especially if the original sample was not suitable for the apparent colour test.

It is usual that true colour measured will be less than apparent colour. However, some recent results from *Ecowise Environmental* showed the opposite. The laboratory confirmed the results and explained that when samples have a cloudy appearance to them, this can in effect add a “whiteness” to the colour which can cause a lessening of the apparent colour. Such “unexpected” results may be more likely to occur with trade waste samples, which can contain different types of colours than supply waters.

ADMI Colour Test and AN42 Colour Test

For these true colour tests, the sample is filtered using a 0.45 micron filter. The transmittance values are measured using a spectrophotomer at 10 different known wavelengths (the standard tests recommend using either 10 or 30 wavelengths). The transmittance values are used to calculate tristimulus (X,Y, Z ordinates) values – these values should be the same for both the ADMI and the AN42 test. A factor conversion method is then used to calculate a “colour difference value”. The factor conversion method used for ADMI colour is similar but different to that used for AN42 colour.

The tristimulus values could be used to assess the dominant hue or other information about the sample, but usually only the colour difference value is reported. The colour difference value calculated is independent of chroma and hue - when two colours ‘A’ and ‘B’ are considered to be different from colourless to the same degree, the calculated colour difference will be the same.

According to samples results obtained from *Ecowise Environmental*, the ADMI colour value obtained is typically ~26 times the reported AN42 value. (*ALS Laboratory Group* use a standard relationship to check equipment calibration, and at 300 ADMI, the ADMI colour value obtained is ~34 times the AN42 value). A relationship between the two methods exists, but is non-linear.

These tests overcome the limitations of the Pt-Co colour range because they are based on a large number of wavelengths across the visible light spectrum. These types of colour tests are often used in manufacturing to check that a consistent product quality is being made, for example that the colour of orange juice has not varied outside a specified quality range. However, interpreting the results for trade waste can become more difficult because the colour difference value only reports one type of colour information. There may be significant variation within and between trade waste discharges, and other mixing and chemical interactions which influence colour value.

Colour Biodegradability Test

The colour biodegradability test attempts to simulate the type of biological degradation which would occur during standard treatment at the receiving wastewater treatment plant. After filtration and pH adjustment, the sample is incubated with a sample sewerage sludge for a period of time, then colour tested using the Adams-Nickerson method. The resultant value should be the same or less than the value originally measured, as some of the sources of colour are likely to be removed by degradation. This test is particularly useful to indicate the likely impact of colour resulting from a trade waste source, after the trade waste has been treated.

It is often assumed that colour discharges from industries such as food manufacturing are likely to comprise mostly biodegradable colour. This type of test can check whether such assumptions are valid.

3.0 CONCLUSIONS

There is currently no consistent method used in the Water Industry for measuring colour in trade waste and there is no recognised standard for what colour is acceptable in trade waste discharges or in recycled water. Generally there is a lack of consistent information available on colour in trade waste, which makes it problematic to attempt to manage the colour discharges from individual trade waste customers. Whilst colour does not necessarily present a risk to health and safety, there is an emerging need for Water Authorities to manage colour, especially when customers are supplied with recycled water. Potentially, the costs of managing colour could be recovered, but not unless colour is better understood.

Many customers supplied with recycled water are likely to judge its quality based on aesthetic consideration such as colour. Failure to address colour issues may compromise the success of projects which reuse or recycle water Tackling this issue will require both the technical management of colour (e.g. source reduction, colour removal and amelioration) and community engagement to develop realistic acceptance standards.

4.0 ACKNOWLEDGEMENTS

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5.0 REFERENCES

Standard methods for colour analysis are described in:

American Public Health Association, American Water Works Association, Water Environment Federation (2005) *Standard Methods for the Examination of Water & Wastewater 21st Edition*. Part 2120.