INDUSTRIAL WATER MANAGEMENT

WASTE MEASUREMENT AND MINIMISATION

Richard Hill
Whitewater Ltd, UK
Water Audit

- Mass Balance principles
- The manufacturing process
- Evaporation and blowdown losses
- Results
- Reducing water use
- Reducing contamination of water
- Re-using water
- Recycling water
Mass Balance Principles

“When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, your knowledge is of a meagre and unsatisfactory kind.”

William Kelvin, 1894
Mass Balance Principles

- Mass and heat balances based on
  - conservation of matter
  - conservation of energy
- What goes in comes out unless it stays there
- For a system: $\Sigma$ mass in = $\Sigma$ mass out
Mass Balance Principles

- **Water Audit**
  - Mass balance on water
  - May also need to consider concentrations of specific contaminants
  - May identify leakage losses
The Manufacturing Process

- identify the unit operations used in the manufacturing process
- prepare a process flow diagram showing operating temperatures and pressures
- identify the water quality required for each unit operation
The Manufacturing Process

- characterise water and wastewater streams for each unit operation (quality and quantity)
- generate a mass balance for each part of the process showing raw materials in and products out including water
- prepare a plot plan and identify drains
The Manufacturing Process

- remember that water is exported in the product:
  - Soft drinks and beverages >99%
  - Pharmaceutical liquid products >95%
  - Wet products - eg cosmetics >50%
  - “Dry” products (paper, salt) ~10%
The Manufacturing Process

- review the chemical inventory
- review historical data
  - what quantities of chemicals have been purchased in previous years?
  - how much water has been purchased?
  - how much wastewater discharge has been assessed by the receiving authority?
- identify the discharge criteria
Evaporation & Blowdown

- Steam from boiler
- Fate of condensate
- Boiler blowdown
- Cooling tower evaporation
- Cooling tower blowdown
- Cooling tower windage
Evaporation & Blowdown

Condensate
C kg/h
0 mg/l

Export Steam
S-C kg/h
0 mg/l

Steam
S kg/h
0 mg/l

Make-up
M kg/h
m mg/l

Feed
F kg/h
f mg/l

Boiler

 Blowdown
B kg/h
b mg/l
Evaporation & Blowdown

Boiler blowdown calculation by mass balance

\[
\frac{B}{S} = (1 - r) \times \frac{m}{(b - m)}
\]

B = blowdown
S = steam rate
b = boiler water concentration
m = make-up water concentration
r = fractional condensate return
Evaporation & Blowdown

- **Evaporation**
  - \( E \) m³/h
  - 0 mg/l

- **Make Up**
  - \( M \) m³/h
  - \( m \) mg/l

- **Bleed Flow**
  - \( B \) m³/h
  - \( b \) mg/l

- **Windage**
  - \( W \) m³/h
  - \( b \) mg/l

- **Flow**
  - \( T_1 {}^\circ C \)

- **Return**
  - \( T_2 {}^\circ C \)
  - \( C \) m³/h
  - \( b \) mg/l
Evaporation & Blowdown

Cooling Tower Losses

MASS BALANCE

\[ M = E + B + W \]
\[ Mm = Bb + Wb \]
\[ \therefore M = (B + W)CF \]
\[ \therefore E = (B + W)(CF - 1) \]
\[ \therefore B + W = E/(CF - 1) \]
\[ \therefore M = E.CF/(CF - 1) \]

HEAT BALANCE

\[ C \times 4.2 \times T_1 = C \times 4.2 \times T_2 + E \times 2450 \]
\[ \therefore C \times 4.2 \times \Delta C = E \times 2450 \]
\[ \therefore E/\Delta C = C \times 0.0017 \]
Results

- Identify any unaccounted water losses
- Identify potential water reduction measures
- Identify potential opportunities for re-use and recycling
Results

- Assess water consumption per unit of product and compare with industry benchmarks
- Assess whether water consumption can be reduced
Results

A water audit on a cellophane factory identified 500m³/day of mains water (8% of the factory’s water intake) which could not be accounted for. A subsequent leak survey found a major pipe leak. The leak was costing the company about £100,000 per annum.
Reducing Water Use

- **Unnecessary use including**
  - pipe leaks
  - uncontrolled steam losses
  - leaking or open valves

- **Necessary but excessive use**
  - over-rinsing
  - over-bleeding systems to control TDS
Reducing Water Use

A laboratory stored bottled samples prior to analysis at below ambient temperature. This was achieved by standing the bottles in a bath through which mains water continuously ran to sewer. The total volume was about 0.5m³/h. Since the water was never turned off it ran for 24 hours per day, 365 days per year at a cost of £4000 per annum for water and discharge.

A laboratory sample cooler was installed at a cost of £2000 with a payback of six months.
Reducing Water Use

A 6000kW cooling tower has an evaporation loss of about 10m³/h when operating at full load. A factory set a manual valve to give a blowdown flow of 3m³/h that is equivalent to a concentration factor of 4.

During winter the tower load was lower and evaporation reduced to 6m³/h corresponding to a blowdown of 2m³/h.

Installing a £2000 automatic conductivity controlled blowdown valve saved 4000m³pa of water and reduced costs by £2,400pa giving a payback of less than 1 year.
Reducing Contamination of Water

- Preventing a contaminant from entering the wastewater means:
  - it will not be present in the final discharge
  - it does not have to be removed
- Often preventing contamination is very simple and cheap
Reducing Contamination of Water

A resin factory uses product filters. When a filter was opened at the end of a batch for cleaning there was a spillage of solvent onto the floor and this was washed to the drain where it contributed most of the 2000mg/l of COD in the discharge to sewer.
Drip trays were fitted to the filters at a cost of £100 per filter. Catching the solvent in the drip tray and disposing of it off site reduced the effluent COD to 500mg/l and reduced the discharge cost by £3000 per annum.
Re-using Water

- Often the wastewater from one unit operation is of good enough quality to use as feed to another.
- Lower grade uses can usually be found - e.g., concentrate from reverse osmosis systems can be re-used for WC flushing or floor washdown.
A plating factory operated a process in which workpieces were dipped into a series of baths. Each of three rinse baths was continuously fed with mains water at 0.4 m³/h giving a total usage of 1.2 m³/h or 2400 m³ per annum.
Re-using Water

A simple modification costing £500 allowed a counter current rinse system to be adopted with mains water flowing only into Rinse 3 and discharge only from Rinse 1. Water consumption reduced by 1400 m$^3$/pa with cost reduced by £1500 pa.
Recycling Water

Where wastewater has to be treated for discharge, it is often economically attractive to treat to a higher standard suitable for use either in the same process or in a different one.
Recycling Water

- Think of wastewater as a resource
- Treatment for recycling may be cheaper than treating raw water
- Rain water has a low cost (storage) and usually requires very little treatment
A cadmium plater used mains water “once through” to rinse product and treated by precipitation to meet 0.2mg/l Cd. New legislation required zero discharge of cadmium.
Recycling Water

A deionisation plant which removed the cadmium, and other ions, from the rinse water producing a high purity water which was recycled. The cadmium was concentrated into a small volume of waste regenerant which was taken off site.
Recycling Water

Capital cost of the ion exchange plant: £100,000
Reduction in mains water: £15,000pa
Reduction in sewer discharge costs: £33,500pa
Reduction in chemicals costs: £4,000pa
Increase in off-site disposal costs: £3,500
Net savings: £49,000pa
Payback: <2 years

The cadmium discharge problem was solved and the product was improved by the use of deionised rinse water.
WATER LOSSES COST MONEY !!!