INDUSTRIAL WATER MANAGEMENT

WATER AND WASTEWATER IN INDUSTRY

Richard Hill

Whitewater Ltd, UK

UNESCO-IHE
Institute for Water Education

Whitewater Limited
Consulting Engineers & Scientists

Industrial Water Quality

- *Industrial Water Quality*
  - *Utilities Water*
  - *Manufacturing Process Water*
  - *Water for Food and Drink*
  - *Pharmaceuticals*
- *Industrial Wastewater*
  - *Manufacturing wastewater*
  - *Utilities wastewater*
  - *Disposal of liquid wastes*

Definition of Water Quality

Water quality criteria

Class:	3	4	5	6	7	8	9
Type:	Softened	Dealkalised	Deionised	Purified	Apyrogenic	High Purity	Ultrapure
Conductivity, µS/cm			20	5	5	0.1	0.06
Resistivity, MΩ.cm			0.05	0.2	0.2	10	18
TDS, mg/l			<10	<1	<1	0.5	0.005
pH			5.0 - 9.5	6.0 - 8.5	6.0 - 8.5	6.5 - 7.5	
LSI	-1 to +1	-1 to +1					
Hardness, mg/l $CaCO_3$	<20		0.1	<0.1	<0.1		0.001
Alkalinity, mg/l $CaCO_3$		<30					0.001
Ions, mg/l							0.001
Silica, mg/l			0.5	0.1	0.1	<0.01	0.002
TSS, mg/l			<0.1	<0.1	<0.1	<0.1	ND
Turbidity, NTU			<0.5				
SDI			<5	<3	<3	<1	<0.5
Particle count, No/ml				1	1	1	0.1
COD, mg/l				<0.1	<0.1		
TOC, mg/l							0.05
Microorganisms, cfu/ml				<10	<1	<1	<1
Pyrogens, EU/ml					<0.25		<0.25

Definition of Water Quality

USE	INDUSTRY	APPLICATION	QUALITY
Fire Fighting	All		1 (natural)
Irrigation	Agriculture		1
Domestic	Offices	Drinking water	2 (potable)
	Hotels/Catering	Down services	2/3
	Healthcare	Laundries	3
Steam Raising	Process industries	Heating	3/4
		Steam stripping	3/4
		High pressure steam	5
	Power generation	Turbine drive	8
Heat transfer	Manufacturing	Closed heating and cooling systems	3/4
	Process industries	Open recirculatory cooling systems	3/4
	Offices	Air conditioning	5
	Hotels/Catering		
	Healthcare		
Process water	Heavy chemicals	Product washing	2/3
	Fine chemicals	Solvent	4
	Food/soft drinks	Bottle/container washing	5
	Brewing	Cleaning in place (CIP)	2
	Pharmaceuticals		6/7
	Metal finishing		5
	Photographic		5
	Laboratories		8
	Semiconductor	“ultrapure water”	9
Product	Food/soft drinks	Product quality	4
	Brewing	Shelf life	2/4
	Pharmaceuticals	Parenterals	7
	Cosmetics	lotions/liquids/topicals	5/6

Utilities Water

BOILER WATER TREATMENT

Thermal efficiency - scale/corrosion
Waste minimisation - blowdown
Condensate line protection
Safety - boiler explosions
Safety - turbine failures

Utilities Water

BS2486:1978 Table 2

Table 2. Recommended water characteristics for shell boilers

For pressures up to 25 bar*

The letters in parentheses in the final column refer to comments in 8.2.2.

Total hardness in feed water, mg/l in terms of $CaCO_3$ max.	2	20	40	(a)
Feed water				
pH value	7.5 to 9.5	7.5 to 9.5	7.5 to 9.5	–
Oxygen	†	†	†	(b)
Total solids, alkalinity, silica	†	†	†	(c)
Organic matter	†	†	†	(d)
Boiler water				
Total hardness, mg/l in terms of $CaCO_3$ max.	ND‡	ND	ND	–
Sodium phosphate, mg/l as Na_3PO_4 §	50 to 100	50 to 100	50 to 100	(e)
Caustic alkalinity, mg/l in terms of $CaCO_3$ min.	350	300	200	–
Total alkalinity, mg/l in terms of $CaCO_3$ max.	1200	700	700	–
Silica, mg/l as SiO_2 max.	Less than 0.4 of the caustic alkalinity			
Sodium sulphite, mg/l as Na_2SO_3	30 to 70	30 to 70	30 to 70	(b)
or				
Hydrazine, mg/l as N_2H_4	0.1 to 1.0	0.1 to 1.0	0.1 to 1.0	(b)
Suspended solids, mg/l max.	50	200	300	(f)
Dissolved solids, mg/1 max.	3500	3000	2000	–

Utilities Water

BS2486:1978 Table 3

	Boiler water							
Sodium phosphate, mg/l as Na_3PO_4 §	50 to 100	30 to 70	20 to 50	10 to 40	5 to 20	3 to 10	†	(f)
Caustic alkalinity, mg/l in terms of $CaCO_3$ min.	300	150	60	30	10	5	2	(a)
Total alkalinity, mg/l in terms of $CaCO_3$ max.	700	500	300	200	100	40	10	(g)
Silica†, mg/l as SiO_2 max.	Less than 0.4 of the caustic alkalinity		20	10	†	†	†	(h)
Sodium sulphite, mg/l as Na_2SO_3 or	30 to 50	20 to 40	15 to 30	10 to 20	†	†	–	(b)
Hydrazine, mg/l as N_2H_4	0.1 to 1.0	0.1 to 0.5	0.05 to 0.3	0.05 to 0.1	†	†	†	(b)
Suspended solids, mg/l max.	200	50	–	–	–	–	–	(g)
Dissolved solids, mg/l max.	3000	2000	1200	700	350	100	15	(g)
Chloride, mg/l as Cl^- max.	–	–	–	–	10	5	1	–

Utilities Water

COOLING TOWER TREATMENT

scale
corrosion
Langelier Saturation Index
bio-fouling
public health (Legionella etc)
waste (blowdown) minimisation

Manufacturing Process Water

- *Company standards apply to:*
  - *plastics/synthetic organics manufacture*
  - *concrete production*
  - *metal finishing*

Manufacturing Process Water

US COMPANY'S INTERNATIONAL STANDARDS FOR AUTOMOBILES

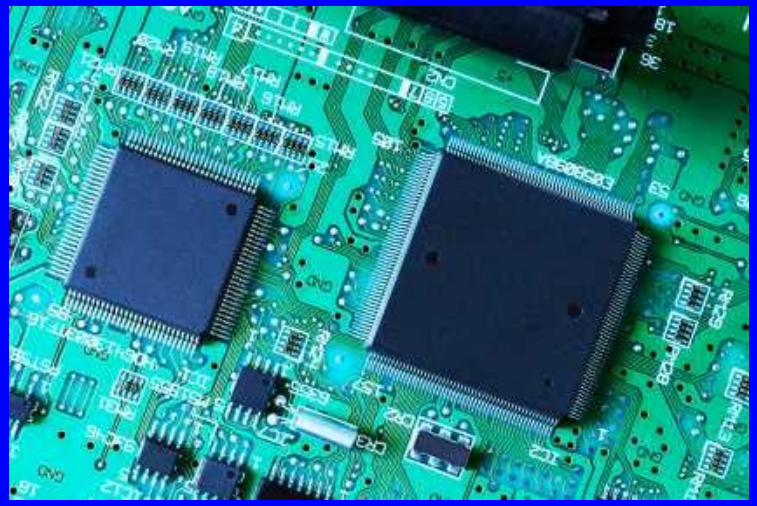
	Chloride ASTM D512	Sulphate ASTM D516	Total Solids ASTM D1069	Conductivity ASTM D1125	pH ASTM E70
Final rinse after phosphating			1	20	5 – 7.5
Phosphating stages other than above	165	200	1050	1000	5 – 8
Clarified water for wet sanding	165	200	1050	1000	5 – 8
Final rinse after sanding			1	20	5 – 7.5
Water for electrocoating primers and other water thinnable paints			1	20	5 – 7.5
Final electrocoat rinse prior to subsequent painting			1	20	5 – 7.5

Manufacturing Process Water

WIMPEY CONSTRUCTION STANDARD FOR CONCRETING WATER

Chloride content, max	mg/l Cl	500
Sulphate content, max	mg/l SO_3	1000
Inorganic impurities max	mg/l	2000
pH value at 25°C		6.6 – 9.2
Organic impurities		If present refer to BS3148

Manufacturing Process Water



SEMICONDUCTOR RINSE

ASTM Type E1 water

Resistivity >18.2MΩ.cm
Inorganic contaminants ng/l
TOC <5µg/l
TVC < 1 cfu /l
particles < 0.1/ml >0.03µm

Manufacturing Process Water

- *Semiconductor systems*
  - *Pre-treatment*
  - *RO*
  - *MB ion exchange*
  - *UV 254nm*
  - *UV 185nm*
  - *Polishing MB*
  - *Polishing UF*
  - *PVDF pipework*

Water for Food & Drinks

- *Product Quality Standards*
  - *legislative*
  - *industry*
  - *company*
- *Public Health*
  - *nitrates*

Water for Food & Drinks

1) All water used in the factory for food ingredient, food washing or cleaning purposes must comply with the EC Drinking Water Directive 80/778/EEC.

2) The water supplier must be notified that the site is a food manufacturing operation. Emergency notification and contact arrangements must be agreed.

3) A nominated member of the senior management team must be responsible for water quality and crisis management.

4) There must be a good understanding of the source of the water supply and the on site storage and distribution system.

5) A documented risk assessment must be carried out and appropriate control measures implemented so that water continues to meet the specification required to ensure the quality and safety of St Michael food products.

These control measures must include:

- As necessary, water treatment systems to ensure the continued quality and safety of finished products.
- An appropriate water sampling and testing programme.
- A hygiene maintenance programme for the water system including storage tanks.

6) Membrane filtration to 1μ (absolute standard) or less must be in place to remove any protozoan oocysts (e.g. cryptosporidium) which may be present in the water except where there is adequate heat treatment in place for the finished product.

7) Where water is found not to comply with the EC Drinking Water Directive standard, or the factory has received a Boil Water Notice from the Water Company, a Marks & Spencer Food or Hygiene Technologist must be informed immediately by telephone.

FOOD INDUSTRY

Code of Practice for Water Quality and Safety at Marks & Spencer Food Suppliers

Water for Food & Drinks

- *Brewing and soft drinks*
  - *Water Supply (Water Quality) Regulations*
  - *international licence specifications*
  - *multi-product production*
  - *Cryptosporidium*

Water for Food & Drinks

		Melbourne	Pilsen	Pittsburgh	Munich	London	Vienna	Burton
Sodium	mg/l Na^{+}	5	3	20	1	24	8	30
Calcium	mg/l Ca^{++}	2	7	32	80	90	200	268
Magnesium	mg/l Mg^{++}	0.8	1	6	19	4	60	62
Bicarbonate	mg/l HCO_3^{-}	3.5	9	45	164	123	125	141
Chloride	mg/l Cl^{-}	6.5	5	31	1	18	12	36
Nitrate	mg/l NO_3^{-}	0.2	0	0	3	3	1	31
Sulphate	mg/l SO_4^{--}	1	6	72	5	58	120	638
TDS	mg/l	19	31	206	273	320	526	1206

Water for Food & Drinks

INTERNATIONAL SOFT DRINKS MANUFACTURER

Constituent	Treated water maximum allowable concentration*
Appearance	Clear
Organic matter	None
Taste	None
Odor	None
Color, ppm	5.0
Turbidity, ppm	1.0
Total dissolved solids, ppm	500.0
Chlorides, ppm Cl	250.0
Sulphates, ppm SO_4	250.0
Iron, ppm Fe	0.1
Total alkalinity, ppm $CaCO_3$	50.0
Total hardness, ppm $CaCO_3$	Not applicable
Free chlorine, ppm ClO	0.0
Nitrates, ppm NO_3	25.0 *
Fluoride, ppm F	1.0
Manganese, ppm Mn	0.05
Zinc, ppm Zn	5.0
Copper, ppm Cu	0.05

*Use local standards for drinking water if more stringent than the above. Nitrate concentration must be reduced to 5 ppm if water will be used for canning.

Water for Food & Drinks

- *Bottled water*
  - *mineral water regulations*
  - *table water*

Water for Food & Drinks

The current legislation on Mineral Waters forbids:

"any treatment or other addition other than:

a) the separation of unstable elements, such as iron and sulphur compounds, by filtration or decanting possibly preceded by oxygenation insofar as this treatment does not alter the composition of the water as regards the essential constituents which give it its properties

b) the total or partial elimination of free carbon dioxide by exclusively physical method

c) the introduction or re-introduction of carbon dioxide"

Bottled Water and its Treatment

- *Table Water/Bottled Water*
- *Cannot be labelled "Mineral Water" or "Spring Water"*
- *Covered by The Food Safety (General Food Hygiene) Regulations 1995*
- *Has to comply with EU Water Quality Directive*
- *Can be (and usually is) treated*
  - *Filtration*
  - *Iron removal*
  - *Arsenic removal*
  - *GAC*
  - *RO*
  - *Ozonation*
  - *UV*

Pharmaceuticals

- *Pharmaceuticals*
  - *Patient safety*
  - *Drug efficacy*
  - *USP and FDA inspection*

Pharmaceuticals

PHARMACEUTICAL AND HEALTHCARE

BP
Ph Eur
JP XIII
USP26
FDA inspection

Criteria:

Patient safety
Drug standards

Pharmaceuticals & Healthcare

- *Purified Water USP24*
  - *conductivity <1.3µS/cm at POU*
  - *TOC <100 µg/l*
  - *pH 5 - 7*
  - *TVC <100 cfu/ml*
  - *Treatment usually RO/EDI*
- *Water for Injection*
  - *TVC <10cfu/ml*
  - *pyrogens <0.25EU/ml*
  - *treatment by distillation or RO*

Origins of Wastewaters

- *All manufacturing processes produce waste (3rd law of thermodynamics)*
- *Evaporation losses leave a concentrated solution behind*
- *The treatment of wastes may recover water and/or other materials but there will still remain a waste for disposal*

Origins of Wastewaters

- *Wastes arise from:*
  - *Manufacturing processes*
  - *Utilities*
  - *Water treatment processes*
- *Manufacturing processes vary so every industrial wastewater is different*

Manufacturing Wastewaters

- *Inorganic contaminants*
  - *Metal finishing (plating and painting etc)*
  - *Automotive*
  - *Tanning*
  - *Chemical manufacture*
  - *Semiconductors*

Manufacturing Wastewaters

- *Soft COD (biodegradable)*
  - *tanning*
  - *abattoir*
  - *soft drinks*
  - *brewing*
  - *papermaking*
  - *oil refining*

Manufacturing Wastewaters

- *Hard COD (non-biodegradable)*
  - *pharmaceuticals*
  - *organic chemicals*
  - *plastics*
  - *oil/petrochemicals*
  - *timber treatment*

Wastes from Utilities

- *Boiler blowdown*
  - *steam boilers produce steam which leaves a concentrated "boiler water"*
  - *condensate recovery minimises the effect*
  - *"blowdown" limits the concentration*
  - *high pH*
  - *low oxygen*
  - *conditioning chemicals*
  - *high temperature (carbon footprint)*

Wastes from Utilities

- *Cooling tower blowdown*
  - *cooling towers work by evaporation*
  - *wastewaters are concentrated*
  - *high TDS*
  - *possible scaling potential (heat transfer)*
  - *biocides*
  - *corrosion inhibitors*
  - *scale inhibitors*

Wastes from Utilities

- *Water treatment process liquid wastes*
  - *Oil separator wastes*
  - *Reverse osmosis - high TDS*
  - *Softening - highly saline*
  - *Deionisation - acid/alkaline*
  - *Evaporator residues - highly saline*

Disposal of Liquid Wastes

- *Discharge to natural watercourse*
  - *may have environmental impact on receiving water*
- *Discharge to sewer*
  - *may increase load on sewage treatment works*
  - *may be toxic to activated sludge bacteria*
  - *may be beneficial to STW operation*

Disposal of Liquid Wastes

Typical discharge standards

		SEWER	SURFACE WATER
pH		6 - 10	6 - 10
sulphides	mg/l	1	
Fats, oils and grease	mg/l	100	10
sulphate	mg/l	1000	
toxic metals, total	mg/l	10	0.5
cyanide	mg/l	0.1	
suspended solids	mg/l	400	35
BOD	mg/l		25
COD	mg/l		125
Total nitrogen	mg/l		15
Total phosphorus	mg/l		2

Disposal of Liquid Wastes

- *Discharge to natural watercourse*
  - *standards set to protect the environment*
  - *dispersion and dilution in high river flows*
  - *dispersion and dilution in estuaries*
  - *offshore operations*

Disposal of Liquid Wastes

- *Discharge to sewer*
  - *charge by composition reflecting impact on sewage treatment works*
  - *UK has developed the Mogden formula for charging*

Disposal of Liquid Wastes

The Mogden Formula

$$C = R + V + B\frac{O_t}{O_s} + S\frac{S_t}{S_s}$$

Where C = effluent charge p/m^3
R = a reception charge to cover sewer costs
V = a charge to cover costs of preliminary treatment
B = average cost of biological treatment
O_t = COD of effluent
O_s = average COD of sewage
S = average cost of primary treatment
S_t = suspended solids of effluent
S_s = average suspended solids of sewage

Disposal of Liquid Wastes

- *Cost of sewer discharge allows the economics of on-site treatment to be assessed:*
  - *partial treatment to reduce COD will reduce sewer discharge costs*
  - *full treatment to surface water discharge standards eliminates sewer discharge costs*

Industrial Wastewaters

RECYCLING INDUSTRIAL WASTEWATER

SAVES MONEY !!!