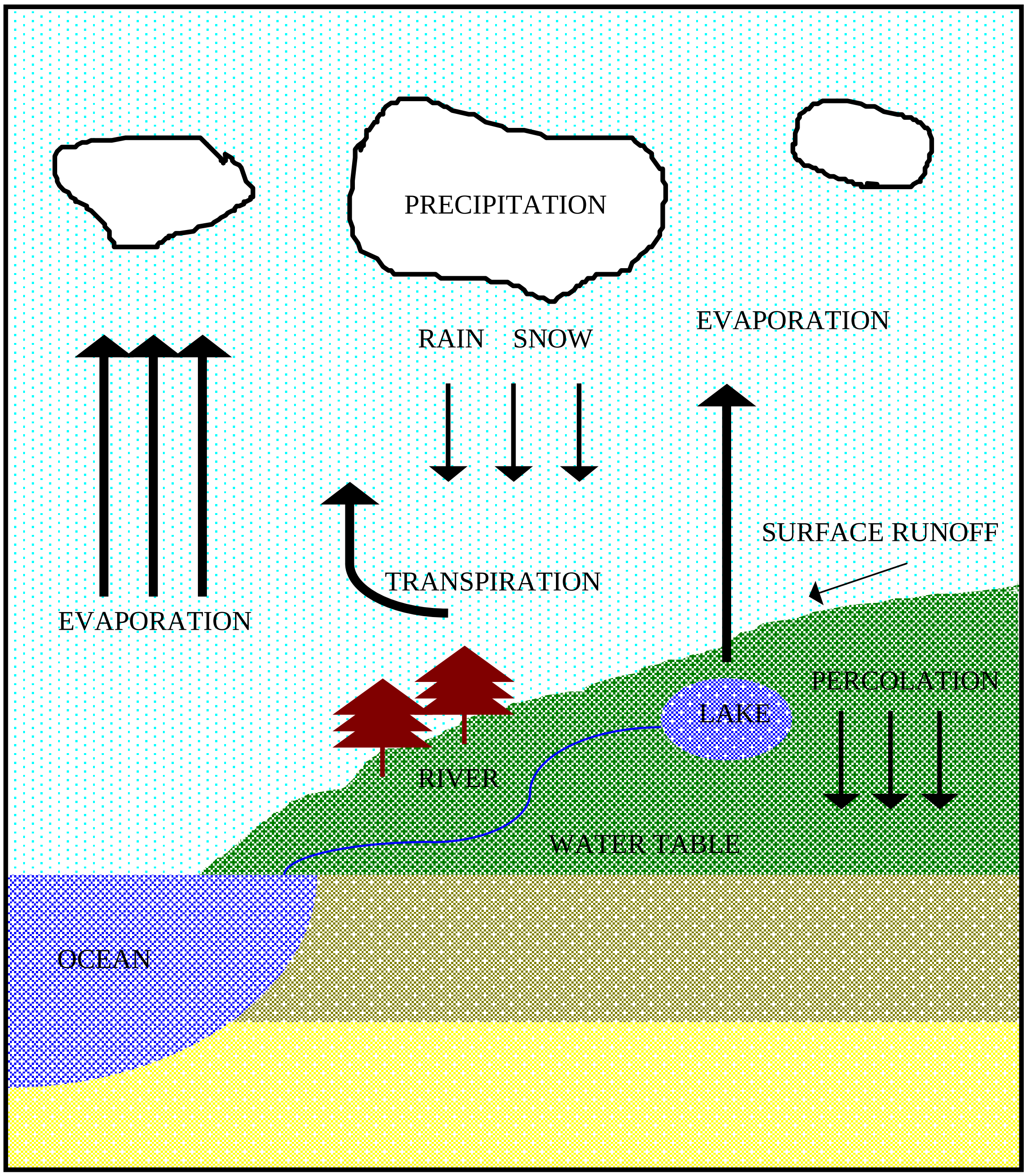
IMPURITIES IN WATER

Water is in continuous recirculation between the earth's surface and the atmosphere through various processes which are collectively bound under the heading 'The Hydrological Cycle'. The diagram below explains the cycle which maintains the balance of the world's water. (Figure 1)

Figure 1: **THE HYDROLOGICAL CYCLE**



Water is lost to the atmosphere by evaporation from surface supplies and transpiration from vegetation. Water vapour then condenses in the cooler air, eventually returning to the earth's surface as precipitation, i.e. rain, sleet or snow. During its passage through the atmosphere, the water dissolves a range of gases. These include oxygen and carbon dioxide, together with oxides of sulphur and nitrogen, and carbon monoxide. In addition, as it nears the ground, the water picks up other contaminants such as airborne particulates, spores and bacteria.

Once water has fallen on the earth as rain, it will either start to penetrate the soil, remain on the surface in puddles, or run off into rivers or lakes - depending largely on the type of rock strata found immediately below the earth's surface. Therefore, the main source of impurities is the mineral and organic constituents which make up the upper layers of the earth's crust, and which are dissolved or held in suspension by the water.

Water supplies in the UK are drawn from three principal sources - groundwater, upland surface water and lowland surface water - each with its own set of characteristics. If raw water comes from underground sources - such as deep wells, boreholes or springs - it is likely to be rich in minerals, and to have high total dissolved solids (TDS) and hardness levels. The organic content, however, is generally low as most of the organic matter will have been filtered out as the water percolated down through the rock strata.

Waters taken from upland streams and lakes usually have a meagre mineral content and low TDS and hardness levels. However, they are rich in natural organic matter - especially humic and fulvic acids - which tend to give them a yellowish tinge. Surface water derived from lowland sources sometimes originates from springs and so has the same general characteristics as groundwater. River and canal waters, especially in industrial areas, tend to accumulate man-made pollutants, while recycled river water normally has high TDS levels. Table 1 shows the TDS content of raw waters in different parts of the country. The figures provide only a general guide to contamination levels, as there are often local variations in raw water quality.

Table 1:

FEEDWATER TOTAL DISSOLVED SOLIDS (TDS) IN MILLIGRAMS PER LITRE POST CODE AREAS OF GREAT BRITAIN

Post Code	Area	TDS
AB	Aberdeen	<100
AL	St Albans	300-500
B	Birmingham	100
BA	Bath	400
BB	Blackburn	50
BD	Bradford	100
BH	Bournemouth	400
BL	Bolton	50
BN	Brighton	400
BR	Bromley	400
BS	Bristol	500
CA	Carlisle	150
CB	Cambridge	400-700
CF	Cardiff	100-400
CH	Chester	150-300
CM	Chelmsford	400->500
CO	Colchester	400->500
CR	Croydon	400
CT	Canterbury	400
CV	Coventry	200->500
CW	Crewe	200
DA	Dartford	400-500
DD	Dundee	70
DE	Derby	200
DG	Dumfries	70
DH	Durham	100
DL	Darlington	100
DN	Doncaster	400-500
DT	Dorchester	400
DY	Dudley	200-350
EH	Edinburgh	70
EN	Enfield	300-500
EX	Exeter	150
FK	Falkirk	100
FY	Blackpool	100
G	Glasgow	50
GL	Gloucester	500
GU	Guildford	300-400
HA	Harrow	400-500
HD	Huddersfield	100-200
HG	Harrogate	100-200
HP	Hemel Hempstead	300-400
HR	Hereford	100
HU	Hull	400-500
HX	Halifax	100-200
IG	Ilford	>500
IP	Ipswich	>500
IV	Inverness	70
KA	Kilmarnock	70
KT	Kingston	400-500
KW	Kirkwall	70
KY	Kirkcaldy	70
L	Liverpool	200-400
LA	Lancaster	100
LD	Llandrindodd Wells	40
LE	Leicester	500
LN	Lincoln	400-500
LS	Leeds	200-300
	London	400-500
LU	Luton	500
M	Manchester	70
ME	Medway	400-500
MK	Milton Keynes	>500
ML	Motherwell	70
NE	Newcastle	150-300
NG	Nottingham	400
NN	Northampton	300->500
NP	Newport	200
NR	Norwich	500
OL	Oldham	100-300
OX	Oxford	400
PA	Paisley	70
PE	Peterborough	400-500
PH	Perth	70
PL	Plymouth	100
PO	Portsmouth	400
PR	Preston	150
RG	Reading	400-500
RH	Redhill	300
RM	Romford	500
S	Sheffield	200-300
SA	Swansea	100
SG	Stevenage	500
SK	Stockport	100
SL	Slough	500
SM	Sutton	500
SN	Swindon	400-500
SO	Southampton	400
SP	Salisbury	400
SR	Sunderland	100-400
SS	Southend	300-500
ST	Stoke-On-Trent	300-500
SY	Shrewsbury	150-300
TA	Taunton	300
TD	Galashiels	70
TF	Telford	300-500
TN	Tonbridge	400
TQ	Torquay	100
TR	Truro	300
TS	Cleveland	200-900
TW	Twickenham	500
UB	Southall	500
WA	Warrington	100-300
WD	Watford	500
WF	Wakefield	200
WN	Wigan	100-300
WR	Worcester	200-400
WS	Walsall	200-400
WV	Wolverhamp-ton	200->500
YO	York	300-400

Surface waters are especially prone to seasonal changes in quality caused mainly by varying levels of organic contaminants. For instance, during the autumn and winter months, dead leaves and decaying plants release large quantities of organic matter into streams, lakes and reservoirs. As a result, the degree of organic contamination reaches a peak in January and February, falling to a minimum in July and August.

Water has been called both ‘the matrix of life’ and ‘the universal solvent’. So in addition to providing a life-support system for a broad range of living organisms, it can dissolve virtually every chemical compound, though not necessarily to a detectable degree. However, mains water is still purer than bulk commercial chemicals; it normally contains < 500 mg/l TDS - equivalent to a purity of 99.95%. Even so, minute quantities of impurities can have a profound effect on industrial and laboratory processes - hence the need for purification.

The impurities present in raw waters can be classified as follows:

<u>DISSOLVED</u>

- Inorganic salts
  - Calcium (Ca^{2+}), Magnesium (Mg^{2+})
  - Chloride (Cl^{-}), Nitrate (NO_3^{-})
  - Sulphate (SO_4^{2-})
- Organic Matter
  - Humic and Fulvic Acids
  - Pesticides, Detergents, etc.

<u>SUSPENDED</u>

- Colloidal (Organic and Inorganic) - Clays, Peat Acids
- Inorganic - Sand Particles
- Organic - Industrial, Domestic by-products

<u>LIVING MATTER</u>

- Micro-Organisms (Bacteria, Algae, Viruses, etc.)
- Macro-Organisms (Fish, Shrimps, Worms, Larvae, etc.)

See Table 2 ‘Classification and Origin of Impurities Found in Water’ for more details.

Table 2

CLASSIFICATION AND ORIGIN OF IMPURITIES FOUND IN WATER

Class of Impurity			**Typical Impurities and their origins**	
1. DISSOLVED	1.1	**Inorganic Salts**	1.1.1	Leaching of minerals and pick-up of atmospheric CO_2, leads to hardness, alkalinity and other mineral impurities.
			1.1.2	Fertiliser run-off, mostly phosphate (PO^{3-}_4), nitrate (NO_3^-) and sulphate (SO_4^{2-}).
			1.1.3	Proportion of inorganic salts in domestic waste returned to the water cycle, mostly sodium (Na^+), chloride (Cl^-) and phosphate (PO^{3-}_4).
			1.1.4	Industrial discharges of all kinds, especially from metal finishing trade.
			1.1.5	Salinity (principally chlorides) from sea water or saline groundwater intrusion.
			1.1.6	Breakdown products of organic nitrogen (N_2) yielding ammonium compounds and nitrates (NO_3^-).
	1.2	**Dissolved Organic Matter**	1.2.1	Natural impurities from decay of vegetable and animal matter, leading to colouring material and humic and fulvic acids.
			1.2.2	Domestic waste: general biological debris and decay products, soap, detergents.
			1.2.3	Industrial discharges from e.g. food processing and intensive agriculture, papermaking, organic chemical industry. Includes fats, oils and solvents.
			1.2.4	Residues of pesticides, herbicides etc.
2. SUSPENDED	2.1	**Colloids (Organic and Inorganic)**	2.1.1	Inorganic Colloids such as clay, and iron (Fe) or manganese (Mn) oxides.
			2.1.2	Natural organic macro-molecules and particles (cf 1.2.1).
			2.1.3	Industrial wastes from e.g. china, clay or paper processing.
			2.1.4	A component of sewage solids.
	2.2	**Suspended Inorganic Matter**	2.2.1	Natural materials, mostly sand.
			2.2.2	Industrial materials from coal washings, mining waste, lime and other sludges, oxide dust, fly ash, flue washings etc.
	2.3	**Suspended Organic Matter**	2.3.1	Plant and animal particles (cf 1.2.1)
			2.3.2	Industrial and Domestic products (cf 1.2.3 and 2.1.4)
3.	3.1	**Micro Organisms**	3.1.1	Algae, viruses, bacteria, protozoa,

L I V I N G M A T T			 3.1.2 3.1.3	microfungi, etc. occur in all natural waters and some fraction at least remains behind unless it is specifically removed. Occurrence is promoted by nutrients (cf esp. 1.1.2) and favourable breeding grounds e.g. domestic sewage. Exposure to light promotes algae growth. Iron (Fe) bacteria in ferruginous wells and iron pipes. Sulphur (S) bacteria (in anaerobic conditions).
E R	3.2	**Larger Life Forms**	3.2.1 3.2.2	Fish, newts, worms, crustacea, insect larvae, water lice etc. breed in large numbers where food is plentiful. Aquatic plants, floating and rooted.
4. **G** **A** **S** **E** **S**	4.	**Gases**		O_2 and CO_2 occurs in all natural waters. Some underground sources contain high CO_2, a few contain H_2S. NH_3 can result from biological decay or from industrial discharge. Cooling towers pick up CO_2 and, in some industrial sites, SO_2. Cl_2 is often used deliberately. Algal growth removes CO_2 and may raise O_2 to super-saturation in daytime, with some reversal at night.

3. WHAT IS HARD WATER?

All natural water contains dissolved mineral salts which leave deposits in pipes and plant, particularly when the water is heated. The commonest salts are calcium and magnesium and their concentration in water is expressed either in parts per million (ppm) or in ‘degrees hardness’ which vary from country to country. The following tables form a ready reckoner for converting the figures involved.

Table 3:

	American Degree	English Degree	French Degree	German Degree	ppm ($CaCO_3$)
American Degree	1.00	1.20	1.71	0.96	17.10
English Degree	0.83	1.00	1.43	0.80	14.30
French Degree	0.58	0.70	1.00	0.56	10.00
German Degree	1.04	1.24	1.79	1.00	17.85
ppm ($CaCO_3$)	0.06	0.07	0.10	0.06	1.00

1 American Degree = 1 grain $CaCO_3$ per US gallon
1 English Degree = 1 grain $CaCO_3$ per Imperial gallon
1 French Degree = 1 part $CaCO_3$ per 10^5 parts water
1 German Degree = 1 part $CaCO_3$ per 5.6×10^4 parts water

Normally accepted classifications for water are as follows:
Table 4:

	English Degrees	ppm ($CaCO_3$)
Soft	0 - 3.5	0 - 50
Moderately soft	3.5 - 7.0	50 - 100
Slightly hard	7.0 - 10.5	100 - 150
Moderately hard	10.5 - 14.0	150 - 200
Hard	14.0 - 21.0	200 - 300
Very hard	over 21.0	over 300

ppm	=	mg/l (milligrams per litre)
1°Clark	=	one English degree