Water resource management

Water resources were managed on an individual basis, with little coherent policy in terms of how water bodies interacted with each other, or how land-based activities affected them. The concept of catchment management emerged in the 1970s and led to the formation of catchment-based water authorities in the UK. This allowed improved management of water resources, especially the regulation of flow in major rivers. Water resources in Europe are effectively protected from all land-based sources of pollution for the first time, pre- venting hazardous substances from being lost into the marine environment.

The objective of river management is to balance the interests of users with the development of the resource, while at the same time improving and preserving environmental quality. The ideal situation is the optimal utilization of resources without deterioration of their natural quality. Uses can be classified as either consumptive (e.g. irrigation, water supply, waste disposal, fishery production, etc.) or non-consumptive (e.g. aesthetic, ecological, scientific, etc.).

Owing to the growth in population, climate change effects and the increasing demand for water, many of the impacts from anthropogenic activities affecting freshwater systems are increasing.

Water quality describes the conditions of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or swimming.

For example, distilled water is extremely pure chemically and so its quality can be considered as being high as it contains no toxicants or pollutants, yet it is unsuitable for potable use and it lacks the trace elements necessary for freshwater biota. Water quality can only be defined in relation to some potential use for which the limiting concentrations of various parameters can be identified. This approach makes particular sense as concern for quality is normally related to some practical need (e.g. drinking, fishing, agriculture, etc.). **It is measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), or the amount of material suspended in the water (turbidity). In some bodies of**

water, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality.

There are a variety of uses for water each requiring their own set of specific quality requirements (criteria). These can be categorized into simple groups, such as:

I) those requiring water of highest quality and free of pathogens; uses include: drinking water supply, fishery, swimming and certain industrial processes such as food processing;
II) those requiring water of lesser quality but still free from toxins and a high level of pathogens; uses include: coarse fishery, amenity and recreation such as boating, also agricultural irrigation and certain industries;
(III) where quality is unimportant, just quantity; uses include: cooling water and navigation.
This classification system was originally proposed by the World Health Organization.

In water management, decisions are based on the comparison of water quality data with criteria and standards. Criteria are scientific requirements on which a decision or judgment may be based concerning the suitability of water quality to support a designated use; that is, the determination of the basic water quality requirements for a particular use. Sets of criteria exist for five categories of specific water use:

1. Raw water sources for drinking, supply.
2. Public recreational waters, aesthetics.
3. Agricultural supply.
4. Industrial supply.
5. Preservation of freshwater, estuarine and marine ecosystems.

Standards are legally prescribed limits for discharges adopted by governments or other legal authorities. These have been based on technical feasibility and cost–benefit and risk–benefit analyses. Standards are used to achieve objectives which in turn are based on the critical assessment of national priorities, such as cost, population trends, present and projected water usage, industrialization and economic resources. Water quality standards have been set by various organizations including the WHO, the EU and the US Environmental Protection Agency (USEPA).

Water quality Management Plans

Water quality management plans (WQMP) provide a legal framework which defines management objectives and sets water quality objectives and standards. The primary aim of a WQMP is to ensure that water quality is maintained in a satisfactory condition and where necessary improved,

The aim of WQMP

1) Safeguarding public health;
2) Catering for the abstraction of increasing quantities of water for domestic, industrial and agricultural purposes;
3) Catering for the needs of commercial, game and coarse fish (as appropriate); and
4) Catering for the relevant water-based amenities and recreational requirements. Such plans normally cover a period of 20 years and are reviewed and, where necessary, revised at least every 5 years.

There are seven major stages in the development of a WQMP for a river catchment:

1. To decide on the uses of a particular river (i.e. group designation).
2. To establish hydrological, chemical and biological status of the catchment.
3. To decide on the water quality conditions necessary in the river to support the uses decided at stage 1 (i.e. water quality criteria).
4. To assess the effect of existing discharges on a river and to attempt a forecast of future effluents.
5. To decide upon the standards that is required for each effluent discharge in order to leave a river with the necessary quality (i.e. water quality objectives).
6. To produce consent (discharge) conditions which will include the standards decided under stage 5.
7. To initiate a sampling programme which will both ensure that discharges comply with the above standards and also indicate from the river water quality whether revised effluent standards are necessary.

Water pollution

The effect of pollutants on river communities depends;

(a) The type of pollutant;
(b) Its concentration in the water;
(c) The length of exposure to the community.

These effects can be summarized according to their physico-chemical or biological nature as:
(a) The addition of toxic substances;
(b) The addition of suspended solids;
(c) Deoxygenation;
(d) The addition of non-toxic salts;
(e) Heating the water;
(f) The effect on the buffering system;
(g) The addition of human, animal and plant pathogens.

The concentration of a pollutant reaching a particular organism or site is dependent on a number of factors.

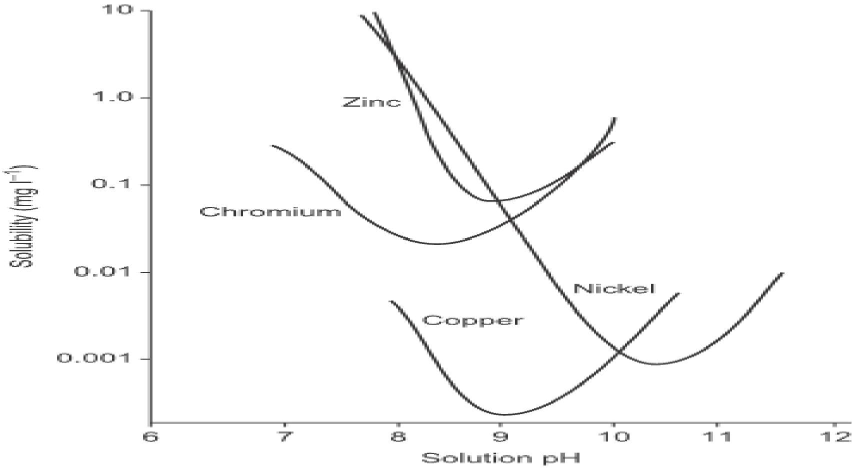
(i) The rate of emission of the pollutant from its source – this may be intermittent or continuous and will be variable in concentration or constant.
(ii) The rate of transport through the system which depends on the dispersion characteristics of both the pollutant (e.g. density, solubility, diffusion coefficient, etc.) and the medium (e.g. current direction, rate of fow, rate of mixing, adsorption properties, etc.).
(iii) The rate of removal, which depends on the dilution, sedimentation, and both chemical and biological transformations. Removal may or may not be permanent. For example, filter feeders may remove pollutants from the

water and break them down or alternatively bio-accumulate them as long-lasting residues.

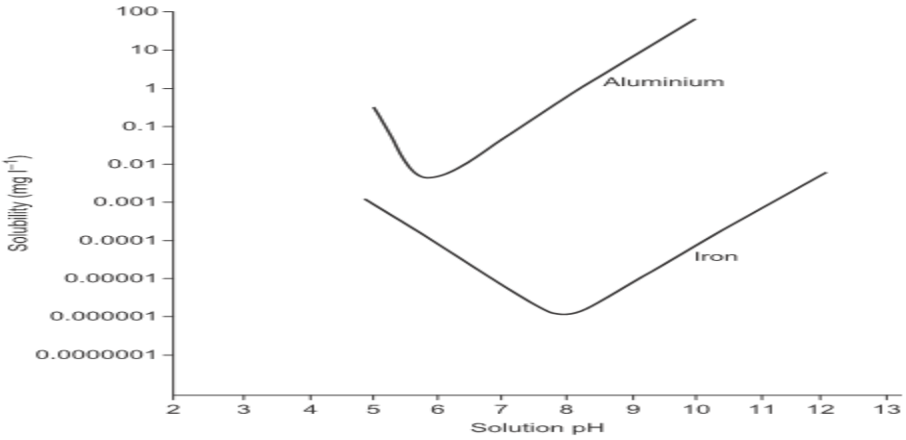
Toxic Substance:

Which include heavy metals and trace organics, decrease in concentration downstream after discharge due to dilution and removal by precipitation and adsorption. Metals are lost from solution by precipitation as the pH changes.

Most metals are highly soluble in circumneutral waters with the exception of iron and aluminum which are least soluble between pH 6.5 and 7.5.



Solubility curves for
Common metals in freshwater with pH



Solubility curves for
Aluminum and iron with pH

Aluminum is particularly toxic to freshwater organisms which become increasingly

Vulnerable as the metal is solubilized due to either acidity or eutrophication causing extreme alkaline conditions. Many organic poisons are degraded, while some harmless organics are broken down to produce toxic substances, such as ammonia and sulphides, resulting in an increase in toxicity and a reduction in dissolved oxygen further downstream. Other toxic material is adsorbed onto suspended and other particulate matter, and eventually settles out of suspension. The toxicity of heavy metals can be listed in order of decreasing toxicity as Hg >Cd > Cu > Zn > Ni > Pb > Cr > Al > Co, although this is only approximate as the vulnerability of species to individual metals varies. Toxicity also varies according to environmental conditions that control the chemical speciation of the metals.

Adsorption is primarily controlled by the surface area of particles; also the finest sediments are the richest in trace elements. Pollutants and nutrients associated with particulate matter can be partitioned into different phases or forms (speciation).

The major forms in which pollutants and nutrients occur in particulate matter are, in terms of the most to least reactive:

(a) Adsorbed (electrostatically or specifically) onto mineral particles;
(b) Bound to the organic matter (e.g. organic debris and humic substances); (c) bound to carbonates;
(d) Bound to sulphides;
(e) Occluded in Fe and Mn oxides which occur commonly as coatings on particles; (f) within a mineral lattice (e.g. calcium phosphate, copper oxide or sulphide);
(g) In silicates and other non-alterable minerals.

Particulate organic matter has a very high surface area and so a very high adsorption capacity. Therefore, the concentration of pollutants in sediments is often proportional to the amount of organic matter present or to the amount of carbon adsorbed onto mineral surfaces.

Toxicity of metals is reduced in waters rich in humic acids (humic and fulvic acids) as they become bound to the organic compounds, a process known as chelation.

While these organic compounds remain in solution the metals are essentially unavailable biologically. Metals can also react with organic compounds to form toxic organo-metal complexes (e.g. methyl-mercury and butyl-tin). Hardness also plays an important part in metal toxicity, which varies depending on the concentration of calcium in the water. For example, the higher the concentration of Ca^{+2}, the lower the toxicity of Hg, Pb, Cu and Zn.

Toxic compounds are rarely present on their own so that the response of organisms to individual pollutants is often different when other pollutants or compounds are present.

Pollutants, especially metals and pesticides, are readily accumulated in organisms. Biomagnifcation is where pollutants increase in concentration through the food chain with maximum concentrations found in the top carnivores (e.g. mercury and organochlorine pesticides.

Pollutants can be taken up via food or water, and this varies according to the pollutant and the organism. Bioaccumulation and bio magnification of metals can affect the whole food chain resulting in high concentrations in shellfish or fish that could be eaten by humans. The mercury originated from wastewater containing mercuric sulphate, which was used as a catalyst in the production of polyvinyl chloride (PVC) at a local factory. Mercury also is usually discharged in its inorganic form Hg to the highly toxic methyl mercury ($Hg(CH_3)2$) by microbial action. It is the methyl form that is more readily absorbed by tissues and dissolves in fat**.** Each species shows a different tolerance to different toxic compounds, while indirect effects can also be significant.