NF 2008

الجمهورية اللبنانية
مكتب وزير الدولة لشؤون التنمية الإدارية
مركز مشاريع ودراسات القطاع العام

MINISTRY OF ENVIRONMENT

Republic of Lebanon
Office of the Minister of State for Administrative Reform
Center for Public Sector Projects and Studies
(C.P.S.P.S.)

RIVER WATER POLLUTION IN LEBANON

Dany Abla
September, 1998

TABLE OF CONTENTS

Introduction

The total amount of water on earth has been estimated as 10^{15} acre-feet. Of this 97% is ocean and therefore nonpotable and only 3% or 33×10^{12} acre-feet are fresh water.

Of the fresh water, 89% is not readily available for

75% is ice in glaciers or polar ice

14% is ground water at depths between 2500 and 12,000 ft

11% is ground water at depths less than 2500 ft

0.03% is in lakes

0.03% is in rivers

0.06% is present as soil moisture

0.035% is present in the atmosphere at any given time

The annual distribution of moisture available through the atmosphere is shown in figure 1.

Water pollution is any detrimental change resulting from human conduct in the natural composition, content or quality of the waters of an international area. Water pollution is significant only when it influences living or biological systems either directly or indirectly. In a broad sense, it can be depicted as a normal consequence of the growth of organisms including man in or near the aquatic habitat.

River pollution can have two meanings: the act of polluting or fouling the stream and the actual impurity or contamination introduced into the water course.

Uses of river water

A- For drinking purposes

Water is pure and wholesome if it is free from visible suspended matter, color, odor and taste, from all objectionable bacteria indicative of the presence of disease-producing organisms, and contains no dissolved matter of mineral or organic origin which in quality or quantity would render it dangerous to health, and will not dissolve substances injurious to health. It is desirable that drinking-water should not have a 'flat' taste and should be reasonably soft.

Rivers are being used to an increasing extent as sources of drinking-water and, particularly if polluted, may require quite elaborate methods to render the water suitable for the purpose. The following methods are generally used for the treatment of water required for drinking purposes.

1- Storage of raw water

Storage in large reservoirs for 2-3 weeks effects quite a marked purification and somewhat reduces the bacterial content. It is an important means of ensuring reduction or even elimination of pathogenic bacteria of sewage origin in river water containing sewage effluents.

2- Screening and straining

These processes remove coarse solid materials and also small particles of suspended matter. Micro-stainers are now being used to an increasing extent in water treatment for removing finely-divided suspended matter.

3- Coagulation with chemicals

Aluminum sulfate (alum) sodium aluminate, and ferrous sulfate are commonly used as flocculating agents to remove color, fine particles of suspended matter, turbidity, etc. More recently, activated silica (prepared by partial neutralization of sodium silicate with acid, chlorine, $NaHCO_3$, $(NH_4)_2SO_4$, alum, or carbon dioxide, followed by aging for a short time) has been used in conjunction with aluminum sulfate as a coagulation aid. The use of activated silica reduces not only the alum dose but also the volume of sludge produced.

Much sludge is produced when water is coagulated with chemicals and this has to be disposed of, e.g. on drying beds, and by tipping, lagooning, vacuum filtration, etc

4- Sand filtration

Slow sand filters were formerly relied upon for complete treatment of water, but with the advent of modern methods of sterilization rapid sand filters either of the pressure or gravity type and dealing with greatly increased volumes are now more utilized.

5- Disinfection

Chlorine and chloramines are used to remove bacteria from water. Ozone and chlorine dioxide also find limited application as sterilizing agents and sometimes have the advantage over chlorine of removing, in addition, tastes and odors.

Copper sulfate, chlorine, and other chemicals are used, if necessary, to control growths of algae and other undesirable micro-organisms in water. Any slight excess of residual chlorine in water can easily be removes with sulfur dioxide or with sodium thiosulfate.

6- Aeration

Followed by sedimentation and filtration, aeration is used to remove iron and manganese which are oxidized to form insoluble hydroxides containing the metal in a higher valency state. Iron is easily removed in this way at pH 7-7.5. Manganese requires a higher pH value.

Aeration is also used to remove volatile gases such as H_2S and CO_2.

7- Activated carbon

Sometimes used in quantities of the order of a few p.p.m. to remove tastes, odors and occasionally color. It is stated that activated carbon will remove 99.5% of the radioactivity of water; thus the remaining 0.5% can be removed by ion-exchange methods.

8- Softening

This is carried out when considered desirable in hard waters either by the older lime-soda process, which usually reduces the hardness to about 20-40 p.p.m. (as CaCO3); or, by the more modern methods using ion-exchangers which can give water of zero hardness and can be used for complete demineralization of water in special cases.

9- Nitrifying filters

These have occasionally been used in the treatment of very polluted river waters high in ammoniacal nitrogen in order to oxidize ammonia to nitrate biologically and thus prevent any subsequent interference with chlorination. A high content of ammonia in river water used as a source of domestic water supplies is undesirable because ammonia reacts with chlorine to produce chloramines which are much less active as bactericidal agents than chlorine. The destruction of ammonia by chlorine to leave a residual of free chlorine requires a ratio of nearly 10 parts of chlorine to 1 part of ammoniacal nitrogen and in the presence of much organic matter even more chlorine would be required.

10- Chemical treatment to reduce corrosiveness

A water which is capable of depositing a very thin protective film of calcium carbonate on the interior of metal pipes is regarded as non-corrosive. When waters are corrosive (i.e. do not deposit this thin protective film), it is necessary to add certain chemicals to control the corrosive tendency, for instance 'Calgon' (sodium hexametaphosphate).

The use of Calgon (usually 1-2 p.p.m.) has other advantages. First, it prevents the scale formation in pipes and boilers by forming soluble complexes with Ca and Mg compounds. Second, it prevents the formation of 'red water', a condition caused by precipitation of trivalent iron compounds; since only divalent iron is sequestered by Calgon, the latter should be added before chlorination and aeration. Finally, it stabilizes manganese.

B- For recharge of ground water

The artificial replenishment of ground water supplies - generally called 'artificial recharge'- is now carried out to an increasing extent to augment the decreasing supplies of ground water. Factors limiting the use of the method are the nature of the geological conditions and the availability of suitable and sufficient water. River waters, even when polluted, can be used, and sewage effluents can also be utilized for this purpose. Before using polluted river water, a preliminary investigation should be made, in order to avoid serious clogging or any deterioration in the quality of the ground water. In addition, the character of soil and subsoil are of great importance; thus sand and gravel soils are highly permeable to water whereas clay soils are almost impermeable. In most cases where artificial recharge is practiced, unconsolidated sands and gravels are used which have lead down on more or less impermeable bedrock.

C- For industrial uses

River water is used in large quantities by industry for steam-raising (boiler feed water), cooling purposes, process work, and water power. Consequently, when a site is chosen for a new factory, much consideration should be given to the quality as well as to the quantity of the available water. The quantity depends upon the purpose for which the water is required, and may range from polluted water to drinking or even better quality water. Among the largest industry users or consumers of water are the chemical industry, steel plants, textile industries, tanneries, oil refineries, paper and pulp mills, power stations and atomic energy plants. While much of this water comes from rivers, other sources are also used, such as underground water from wells, sea-water and water reclaimed from sewage effluents or industrial wastes. Much water can often be saved in an industry by the adoption of proper water conservation measures.

1- Boiler feed water

In general, river water used for steam-raising requires some treatment for the following reasons:

a- To avoid corrosion of the boiler plates and fittings. Corrosion may be due to the presence of acidic substances, dissolved gases (oxygen and carbon dioxide), calcium and magnesium, chlorides and nitrates, and iron and aluminum sulfates. Dissolved corrosive gases may be removed by de-aeration.

b- To prevent the deposition of hard scale on the boiler plates. This condition is caused by the presence of such scale-forming substances as calcium and magnesium bicarbonates and sulfates, and silica. Scale is harmful because it tends to hinder free interchange of heat, thus causing fuel wastage, and may also lead to serious local overheating of the boiler. Softening of the water is necessary to remove scale-forming substances.

c- To minimize as far as possible the condition known as 'priming' or 'foaming'. In this case, froth is produced in such large quantities that bubbles are carried over into the steam pipes. The presence of finely divided suspended matter, mineral or organic, tends to aggravate this condition. Foam production is usually considerably lessened by softening the water. Foaming can be controlled by adding to the water small quantities of solid synthetic polyamides.

In order to prevent too great a concentration of soluble salts, or an objectionable accumulation of sludge at the bottom of a boiler, it is customary to open the blow-off cock occasionally, a practice often referred to as 'blowing-off' or 'blowing-down' the boiler. It is customary to discharge the blow-off water, which may be alkaline to phenolphthalein and high in suspended matter, to a stream, but the volume is small and generally causes little pollution.

2- Cooling water

Cooling water is essential for many industrial processes and the quantities required are often very considerable. At electricity generating stations of the thermal type, where superheated steam drives the turbines and is condensed back again to water, enormous volumes of cooling water are needed in the condensers and the amounts will increase as new stations are brought into operation or existing stations are enlarged. Most of this water abstracted in this way is subsequently returned to the watercourse. Where the amount of river water is likely to be insufficient to meet the needs of the power station, 'cooling towers' are erected; the water leaving the condensers is cooled in these towers and recirculated, thus making the amount of river water required only a fraction of that needed for a 'once through' system. Owing to the fact that some stations make use of direct cooling and others of cooling towers, it is not possible to give any general rule for equating the number of units generated with the maximum water abstraction.

While it may be agreed that the most important requirements of cooling water are that a large volume should be available at a reasonable cost and at as low a temperature as possible, nevertheless the quality of the water cannot be altogether ignored. In fact, the usefulness of water for cooling can be impaired if it contains slime-forming microorganisms and if appreciable amounts of scale-forming constituents, suspended solids, dissolved corrosive gases, acids, oil, and organic matter are present. The efficiency of condensers decreases considerably when the tubes become coated with solid material, oil, bacterial slimes, etc. Hence, the turbidity, hardness, and suspended solids content of the rive water should be low. Chlorination is usually used to control growths of undesirable microorganisms. The amount of chlorine required naturally depends upon the quality of the river water and sufficient should be applied to ensure a small residual in the water leaving the condensers.

Ideally, cooling water, other than suffering a rise of temperature, should not receive any additional forms of pollution and consequently should have undergone little alteration in chemical composition when discharged to a watercourse. Some purification of the water, however, does occur by passage through cooling towers due to the biochemical action of bacteria thus causing some reduction in B.O.D. and ammoniacal nitrogen. On the other hand, cooling water can be somewhat polluted by leaks and additions of other effluents. Moreover, if the water is from a vacuum evaporation plant where it can come into direct contact with polluting gases, vapors and the organic materials, for instance in the jet condensers of a multiple-effect vacuum evaporator, the condenser water can acquire quite a considerable B.O.D.

3- Process work

Each industry requires for its processes a water having certain desirable and distinctive qualities but in many cases it must be remembered that local factors are of considerable importance. For instance, the amount of space available for a water treatment plant, the amount, quality and extent of the pollution of the sources of water at the disposal of the particular industry, and the cost of the treatment al have an important bearing on the choice of treatment.

In general, it is desirable to give river water some treatment before it can be used for process work and the methods used are similar to those employed for drinking-water. The purity requirements of water used for process work in particular industries varies considerably according to the nature of the industry.

4- Power

In various parts of the world, especially where a high head of water is available vast hydro-electric power stations are set up. The scheme is a multiple purpose one involving the use of water for power, irrigation, navigation, domestic supplies, afforestation, flood prevention and provision of natural parks.

Hydro-electric power stations can be used to relieve the conventional thermal power stations of peak loads and they have the further advantages that the fuel is gratis and the life of the plant long.

D- For agricultural uses

1- Watering of cattle and other livestock

Although the drinking-water for human consumption by most civilized countries is of a high standard of quality, much less attention is usually given to the sanitary quality of streams used for watering cattle and other domestic animals. Cattle drinking polluted waters can contract anthrax and bovine tuberculosis and the presence of pathogenic bacteria in the water in which cattle wade can easily lead to the contamination of the milk. In addition, excessive salt concentrations in drinking-water can be harmful to animals. Furthermore, cases are on record of domestic animals being poisoned or killed by drinking water containing blooms of certain blue-green algae. Death of the animals appears to be caused by some toxic substances produced by the algae.

2- Water for irrigation

Water is being more widely used for irrigation in temperate climates to increase crop yields. Irrigation is usually administered in the morning or evening to decrease the evaporation rate.

E- Fisheries

It is common knowledge that water satisfactory for industrial purposes or navigation does not necessarily support fish life. Again, water unsafe for drinking purposes owing to bacterial contamination might yet be suitable for the support of fish. Various species of fish, and even individual fishes, showed marked differences in their degree of resistance or tolerance to external influences, and so conditions which may be satisfactory for coarse fish will not necessarily ensure the survival of game fish. Since, quite short periods of adverse conditions can easily prove fatal to fish, it is emphasized that high temperature and low flow and under maximum conditions of pollution. The main requirements desirable for the maintenance of good fish faunae in inland streams can be summarized as follows:

1- Dissolved oxygen

The minimum dissolved oxygen content of water for maintaining fish in healthy condition is 5 p.p.m. at 20 °C or about 57% of saturation. Water becomes hazardous or lethal to fish when the dissolved oxygen falls to about 3 p.p.m. or less, though it must be remembered that the oxygen requirements of fish depend upon a number of factors (e.g. species and age of fish, temperature, composition of water, presence of toxic substances, etc.).

2- Temperature

It is generally agreed that salmon, trout and other game fish thrive best in cool water (temperature about 13-19 °C) and they are less numerous at somewhat higher temperatures (19-22 °C) while at water temperature above about 23 °C they are rarely or never observed. Coarse fish are able to withstand much higher temperatures.

3- pH range

Acidic or alkaline conditions in a stream are harmful to fish. Freshwater fish usually thrive in waters having a pH value between 5 and 8.5 or 6.7 and 8.6. It is stated, however, that many poorly dissociated acids and bases (e.g. ammonia) can be toxic quite apart from any effect they may have upon pH value, and consequently should not be judged merely upon the basis of pH but also by their own toxicity as determined by bio-assay methods.

A good reserve of natural bicarbonate alkalinity is desirable in a river as a safeguard and so as to prevent any sudden discharges of acid or alkali from causing a marked fall or rise in pH.

4- Free carbon dioxide

Free CO2 in any considerable amount is lethal to fish and their eggs. It might be produced by the oxidation of organic matter or by the action of acid discharges on bicarbonates.

5- Ammonia

Unpolluted natural waters have a very low content of ammonia but pollution by sewage and other nitrogenous organic wastes and by many chemical waste waters can increase the ammonia content to dangerous levels. Ammonia should not exceed about 2.5 p.p.m. It has been shown, however, that pH has a marked influence on the toxicity of ammonia to fish and that the concentration of unionized ammonia rather than total ammonia, is the important factor.

6- Freedom from toxic substances

A river water can have a satisfactory pH range and a high concentration of dissolved oxygen, and yet be unsuitable for the maintenance of fish owing to the presence of one or more substances toxic to fish. Therefore, toxic substances should be absent from a fishing stream.

7- Dissolved salts

Brackish water is, in general, not favorable for the maintenance of freshwater fish and freshwater weeds.

8- Freedom from excessive suspended matter

Fish can apparently live, though somewhat precariously, in a good sewage effluent. Thus, it has been shown that considerable number of fish occurred during spring and summer in an effluent channel containing sewage effluent from a works treating domestic sewage with about 20% by volume of trade wastes. Mortality took place from time to time due mainly to low concentrations of dissolved oxygen.

F- Means of disposal of waste waters

Rivers not only act as channels in the transportation to the sea of surface run-off in wet weather but also play a vital part as conduits for the reception and removal of various liquid wastes such as sewage effluents and effluents from industrial processes. These wastes are not only diluted but also, if of an organic nature, undergo oxidation by bacteria and other microorganisms. Disposal to rivers is a very ancient method of dealing with unwanted wastes but care has to be taken that the organic load is not greater than the amount the river can carry. In general, such wastes should receive the best practicable and reasonably available pre-treatment to prevent overloading the river and destroying its self-purifying capacity.

G- Recreational activities

Water for recreational use (boating and bathing) should not only be free from color, odor, or anything visible of an objectionable nature (such as sludge banks, suspended matter, floating material and oil) but also should not contain anything injurious to public health. Many rivers are polluted by sewage and may be unsuitable for bathing unless a bacteriological analysis has shown them reasonably safe.

Conservation of water resources

The water in our rivers is derived in the first place from rain, or less frequently, hail, snow and sleet. Part of this rain is absorbed by the soil and is utilized for the growth of plant life; part percolates through the soil and subsoil to be stored as ground water and to form springs and underground streams which feed our rivers. A portion of the residual rainfall will find its way directly to existing river systems and so further augment the discharge of the rivers, but a greater portion will thus increase the river flow when ground conditions have been saturated by previous rainfall. Subsequent evaporation leads to the transference of part of the water to the vapor phase from which rain is again produced by a process of condensation, and the whole cycle begins again.

Rivers and lakes, being formed from water which has percolated through the surface soil will contain dissolved salts, traces of organic matter, suspended matter, and such dissolved gases as oxygen, nitrogen and carbon dioxide. The activities of man, however, may lead to quite marked alterations in the natural composition of river water.

The average consumption of water taken over the whole world for drinking, washing and domestic uses is about 10-15 gallons per person per day. In some industrial cities, especially in the USA, the per capita daily water consumption may be as much as 100 gallons or more. Whereas, in backward, rural or desert areas, where piped water supplies and the water carriage system of sanitation are in most cases non-existent, the figure may be as low as 5 gallons.

However, water quality is of equal importance. Thus, the pollution of many rivers represent the problem of first magnitude and a wasteful misuse of water, for, in view of the rising consumption of water and of the diminishing amounts available from underground sources owing to demand exceedingly supply, more use will undoubtedly have to be made of rivers in the future -even polluted reaches of rivers- as sources of supply for drinking and other purposes. Water ought to be considered as a valuable raw material and thus each person has a duty to conserve as far as practicable the water resources of his area. Some of the ways in which water resources might well be conserved can briefly be summarized as follows:

A- Reduction of run-off

The construction of more and larger reservoirs would do much to conserve water which is at present wasted and frequently causes unnecessary flooding.

B- Reduction of evaporation

Much water in reservoirs is lost by natural evaporation during the summer and warm climates. The loss of evaporation from the surface of the earth amounts to no less than 13 cubic miles every day. The use of higher fatty alcohols (e.g. cetyl alcohol) has been proposed to minimize this loss

C- Better utilization of existing supplies

There would be less waste of water if supplies were metered and customers had to pay for what they use. Moreover, efficient waste detection services and modifications in the design of domestic fittings could go far towards preventing leaks and wastage of water. For example, considerable economy in the use of water for flushing toilets will be secured when the present type of flushing cistern (delivering 2-3 gallons of water) is replaced by a new type of dual flush cistern delivering 1 gallon of water in the first place, and then only a second gallon if desired.

D- Reclamation and re-use of sewage effluents and trade effluents

In creased attention should be directed towards the use of sewage effluents for various purposes e.g. by industry for cooling purposes. Sewage effluents can also be utilized for the recharge of ground water supplies.

E- Treatment of brackish and saline waters

The treatment of brackish and saline waters to produce fresh water has been used for a long time on ocean-going ships and in lands where no other water is available, but has only comparatively recently become a reasonably economic proposition elsewhere because improvements in plant design have lowered the cost.

Several methods are now available commercially:

1- Electrodialysis

This method is suitable for brackish waters (containing up to about 15,000 p.p.m. of dissolved salts) but it is too expensive for the sea water as the cost increases with increase in salinity. It involves passage of the brackish water through an electrolytic cell formed by two ion-exchange membranes, one permeable to negative ions (e.g. Cl, SO_4) and the other to positive ions (e.g. Na, K, Mg, Ca). A small electric current passes through the cell between two electrodes and the negative and positive ions so produced pass through the respective membranes and are discarded.

2- Freezing

Sea water can be almost completely demineralized by freezing, 1,000 liters (containing 32 salt/l.) giving in this way about 193 liters of fresh water containing about 500 mg/l. of salt.

3- Solar distillation

The utilization of the sun's heat can be carried out for evaporation saline water but is restricted to suitable places having abundant and reliable hot sunshine.

F- Reduction of pollution

Much water is rendered unfit for use by unnecessary pollution. A growing proportion of the population is drawing water supplies from polluted rivers and this entail additional and expensive treatment of the water at a waterworks. Certain types of industrial pollution may render the subsequent treatment financially impracticable. The reduction of pollution is, therefore, of major importance in the conservation of water.

G- Control of water abstractions

Uncontrolled abstractions of water from rivers by industry and agriculture are already adversely affecting the water resources. Thus the chemical quality of the water may deteriorate because the amount of clean water available for diluting effluents has been reduced. In addition, the abstraction may reduce the flow in the stream so that the requirements of navigation, industry, and other interests are insufficient.

Surface water capacity in Lebanon

In Lebanon we have three major rivers in the internal region and sixteen coastal rivers. Some of the coastal rivers are dried during the summer such as the Beirut river. The average seasonal and annual levels of river waters are shown in table 5 (Tables 1a&1b).

Kinds of Pollution

Pollution may be solid or liquid and if liquid may contain dissolved material or suspended matter as well as dissolved gases of a polluting character.

Solid pollution may consist of any kind of solid material, such as sand, gravel, soil, ashes, cinders, clinkers; sweeping from any factory, mine, quarry, or house; any sludge or solid sewage matter; any vegetable or other garbage; offal or parts of the carcass of any animal; rubber, wood, paraffin wax, gelatin, straw, paper or paper pulp.

The most common form of pollution causing the most trouble to river waters is liquid and is generally caused by the discharge of sewage and industrial wastes into rivers.

The different kinds of pollution are classified into the Four categories: chemical, physical, physiological and biological. (Table 2)

A- Chemical

1- Organic

This form of pollution is due to the presence of proteins, fats, carbohydrates and other organic substances and materials found in sewage and trade wastes.

The trade wastes containing proteins are food processing and canning wastes, gelatin and size manufacturing wastes, slaughterhouse wastes, dairy and tannery wastes. The polluting character of all these, is due to a large degree to their protein content.

Fats occur in sewage and in such industrial wastes as wool scouring wastes, edible oil and fat refining wastes, wastes from soap manufacture and laundry wastes. Soaps -water-soluble sodium and potassium salts- are found in sewage, sewage sludge, laundry wastes and textiles wastes. Calcium soaps present in sewage and sewage sludge are formed by the action of hard water, containing calcium salts, on sodium and potassium soaps used for washing and cleaning purposes. Waxes -esters of higher fatty acids- are present in waste waters from the scouring of wool and in certain paper and textile wastes.

Carbohydrates include a wide variety of compounds. Resins are introduced through the wastes of paint manufacture, textile industries and the preparation of lacquers. Rubber is found in wastes from rubber manufacture and processing and from the waxing of paper. Coal is present in effluents from coal-washing plants. Oil may come from barges, tankers, and boats on rivers or canals, or may be derived from industrial wastes, metallurgical industries, engineering works, garages, or any trade premises using lubricating oils or fuel oils.

Tar is produced by the destructive distillation of coal, peat, wood, bituminous shale and other naturally occurring organic materials. It is also produced as an unwanted by-product in the synthesis and preparation of many organic compounds.

Dyes are intensely colored synthetic organic compounds capable of fixing themselves permanently to various materials, i.e. not removed by washing. Dyes are usually present only in small amounts in textile waste waters but may be objectionable because of their color.

Synthetic detergents are derived from the ordinary household detergents used for washing and laundry.

There are many other organic compounds prepared and used industrially and so may be present in waste waters from chemical and other factories. These compounds may be objectionable because they are toxic or because of their tendency to undergo fermentation.

Many trade wastes contain poisonous organic compounds such as phenols, tar bases, cyanide and DDT. These wastes are derived from the manufacture of coal gas, organic chemicals and insecticides.

2- Inorganic

Many industrial wastes contain corrosive inorganic acids or alkalis. Many of the alkaline wastes have pH values up to 12 or even higher while the acid wastes frequently go down to pH 1 or less (Table 3). The industries producing the largest volumes of acid wastes are: iron pickling, and the manufacture of titanium dioxide, viscose rayon and transparent paper (cellophane).

The most common types of toxic inorganic substances are free chlorine, chloramines, ammonia, hydrogen sulfide and soluble sulfides, and salts of heavy metals (e.g. copper, zinc, lead, nickel, chromium, cadmium, silver, mercury, uranium, vanadium, thorium, etc.). These substances are introduced to river waters from many industrial effluents discharged into the rivers (Table 4).

B- Physical

1- Color

Many trade wastes discharging to a river have a pronounced color which they impart to the water. The color is due in most cases to organic dyes but there are some highly colored substances of mineral origin, especially compounds of iron and chromium. A However, the color of a waste water is not necessarily a safe guide to its polluting power.

2- Turbidity

Turbidity is caused by the presence of colloidal matter or finely divided suspended matter which settles only with difficulty. As a rule, the more pronounced the turbidity, the stronger is the sewage or trade waste and the worse is the effect on the river. However, a river water might be somewhat turbid owing to the presence of small amounts of some inert and relatively harmless material, and yet be satisfactory as a fishing stream and for most other purposes. Moreover, the clearest water might be well contaminated with acids or toxic metals which do not cause turbidity.

3- Temperature

The temperature of a watercourse can very diurnally as well as seasonally and also be markedly affected by the discharge of heated effluents. The discharge of heated trade effluents from factories and mills and of large volumes of warm 'cooling water' from electricity generating stations may easily cause a temperature rise of several degrees in a river or canal.

4- Suspended matter

Insoluble matter in suspension is one of the most common forms of pollution, being present in sewage and in most industrial waste waters. All river waters, even those, which are relatively unpolluted, contain suspended matter consisting of natural silt, sand, etc. derived from the stream bed and banks. Suspended matter can be mainly inorganic or 'mineral' in character, predominantly organic or 'volatile', or, as is commonly the case, partly organic and partly inorganic. The suspended matter in sewage effluents, dairy wastes and many coal washery effluents is largely organic in nature. On the other hand, wastes from sand-washing and stone quarrying contain chiefly inorganic suspended solids.

5- Foam or Froth

Foam consists of a suspension or dispersion of gas bubbles (usually air) in a liquid medium (usually water). Many substances are known to cause in water, for instance soaps and other detergents, fish glue and saponins. Scum and froth on the surface of rivers have been known for a considerable time, being especially noticeable in streams containing untreated alkaline organic discharges from paper mills making pulp from straw and other similar raw materials. Nevertheless, the present widespread complaints of masses of foam on rivers and at the sewage treatment plants are mainly due to the increase in the use of synthetic detergents. Such detergents have good properties for domestic purposes as well as for industrial purposes. In fact, they have remarkable wetting, dispersing, and emulsifying powers in the leather, paper, textile, cosmetics, and rubber industries; in laundries; in photography; and for bottle washing in breweries and dairies. Much of the increasing popularity of synthetic detergents is due to the fact that, unlike soap, they are unaffected by hard water. In addition, they can be used in acid solutions

C- Physiological

1- Taste

Industrial wastes contain many chemical compounds which impart characteristic and unpleasant tastes to water; for instance, salts, iron, manganese, free chlorine, hydrogen sulfide, phenols and unsaturated hydrocarbons. Synthetic rubber waste contain taste-producing hydrocarbons and aldehydes; explosive factory waste waters contain traces of nitro derivatives of benzene and toluene which impart a 'bitter almond' flavor to fish; and oil refinery wastes give an objectionable taste to fish because of the presence of naphthenic acids. Peculiar tastes can be imparted to water by the decomposition of organic matter and algae, fungi and filamentous bacteria.

2- Odor

The odor of a river is often one of its most important characteristics. Odor may be caused by the presence of certain strong-smelling chemical compounds (e.g. ammonia, phenols, free chlorine, sulfides, and cyanides) which can easily be identified and estimated. Moreover, it may be associated with many organic materials (e.g. essential oils), with algae and other vegetable organisms, and with decomposing and putrescent organic matter. Many kinds of odor (e.g. grassy, earthy, musty, moldy, vegetable) may be caused by minute traces of substances which cannot easily be identified by chemical analysis. Certain micro-organisms have been shown responsible for odors in water supplies. For example, the protozoa Dinobryon and Uroglena and the alga Volvox impart a fishy smell to water; the algae Oscillatoria and Rivularia, a moldy odor; and the alga Anabaena, a strong grassy odor. It is suggested that these odors are caused by the liberation of traces of essential oils.

Most unpleasant smells associated with polluted rivers are due to the presence of inorganic and organic compounds of nitrogen, sulfur and phosphorous and arise from the putrefaction of proteins and other organic materials present in sewage and in trade wastes. Some of the very worst smells are caused by compounds of sulfur, such as hydrogen sulfide (H_2S) and the mercaptans. The Royal Commission on Sewage Disposal classified smells arising from polluted rivers as follows:

a- Putrid smell (due mainly to H_2S).

b- Fishy smell (due probably to organic amines).

c- Wormy smell (due possibly to phosphorous compounds).

d- Earthy smell (due to humus).

Many industrial wastes contain organic substances having characteristic odors. Examples are wastes containing alcohols, phenols, esters, ketones, aldehydes, organic acids, sulfur compounds, hydrocarbons, and cyanides.

Food processing wastes, which contain high concentrations of nitrogenous organic matter, develop extremely unpleasant smells when stale owing to anaerobic decomposition.

Nuisance due to bad smells arising from a polluted stream must be carefully distinguished from atmospheric pollution in the vicinity of the stream caused by smells from a particular industrial process. Moreover, objectionable odors, although unpleasant, are not in themselves known to be injurious to public health unless they arise from certain toxic chemical gases and vapors.

D- Biological

The biological kind of pollution include pathogenic bacteria, certain fungi, algae, viruses, pathogenic protozoa, parasitic worms and any plants or animals which for some reason either multiply excessively in a stream or are otherwise undesirable, harmful or injurious. Biological pollution is often a secondary result of pollution by sewage or trade wastes.

Causes of river pollution

A- Sewage

The discharge of crude or partially treated sewage into a river constitutes the most common form of pollution. The effects of domestic sewage on the environment are determined to some extent by the contents of the sewage. Organic material is the chief constituent but the mixture also contains nutrient salts, silt and other inert suspended solids, pathogenic bacteria and viruses.

B- Trade wastes

Trade wastes are discharged from trade premises into the rivers. It is possible to treat trade wastes to produce a reasonably satisfactory effluent, which, given sufficient dilution in the river, will not cause pollution. There are, however, many trade wastes for which no large-scale methods of treatment of proved reliability have been developed (e.g. gas liquor and kier liquor) or for which only methods of partial purification are available. Then the waste waters can be discharged to the public sewers, subject to certain conditions and safeguards, for biological treatment in admixture with sewage at the sewage disposal works. Among the many benefits of this method of disposal are the following:

- It is easier and less costly, as a rule, to purify a mixture of sewage and trade wastes separately.

- At a sewage works of sufficient capacity, it is usually possible to obtain from the mixed sewage and trade wastes a final effluent conforming to the standards whereas this is rarely possible by the separate treatment of industrial wastes.
- There is a reduction in the number of points of pollution on the river.
- There is skilled technical supervision at a sewage works of any size by staff especially trained for the job. Such expert supervision is unlikely to be obtained at any but the largest industrial plants.
- It eliminates the accidents that sometimes occur at a trade waste purification plants through carelessness, leakage, lack of adequate technical control of the processes, and the breakdown of pumps and other vital parts of the plant.

C- Natural pollution

Pollution of rivers may take place as a result of natural causes not necessarily associated with the activities of man. Pollution of this kind is generally small and intermittent, being often connected with adverse weather conditions (e.g. heavy rain, a sudden thaw, etc.). Thus it may consist of run-off from land carrying silt, vegetable extent and character of such pollution depend on the chemical and physical characteristics of the river bed and catchment area and on the type of vegetation present. Erosion of river blanks and valley slopes can lead to considerable natural pollution. The kinds of pollution commonly found in streams as a result of natural causes include organic, mineral and suspended matter, turbidity, color, odor, acidity and alkalinity. For instance, in limestone areas, the pollution may consist of 'temporary' (carbonate) hardness and the water may be somewhat alkaline. In areas where gypsum is present, there may be 'permanent' (non-carbonate) hardness due to presence of calcium sulfate. Rivers flowing through granite areas usually contain only traces of soluble calcium salts and therefore have a low hardness. In salt districts, the streams may contain considerable amounts of sodium chloride. In large amounts, this can cause decomposition of vegetation and so lead to fish mortality. Drainage from peaty areas is liable to contain much vegetable matter, color and organic acids.

In many rivers, especially the sluggish industrial sort, heavy rain with consequent higher river flows, produces a scouring effect, causing sludge on the bed and behind weirs, dams, etc., (which is often in a septic condition) to be stirred up. Samples of river water taken under these conditions have an abnormally high content of suspended solids.

Another peculiar kind of natural pollution has been known for a long time is the sudden appearance of excessive growths of algae. The various factors influencing the formation of algae blooms include climate, physical factors, prevailing winds and their intensity, and chemical factors such as pH, presence of $CO2$ and inorganic nutrients. Eventually, the algae undergo decomposition and so can cause damage to fisheries, presumably by depleting the water of its dissolved oxygen and possibly also by the formation of substances toxic to fish. Tastes and odors may also be imparted to the waters and this is particularly undesirable if the water is to be used for drinking purposes. Chemicals can be used to destroy such algae growths and copper sulfate and chlorine, separately or in combination, are commonly employed for this purpose.

Excessive growths of weeds and other vegetable life sometimes take place in rivers and they do not only cause an obstruction of the free flow of the river but when they die and decay can seriously deplete the river of its dissolved oxygen.

Care is needed in the application of these toxic chemicals since they may cause mortality among fish, and, of course, they are inapplicable if the water is to serve for drinking purposes. Nevertheless, chemical methods can be a useful adjunct to mechanical methods.

D- Use of toxic chemicals for agricultural and other purposes

The widespread and uncontrolled use of pesticides and weed-killers can cause pollution of streams and fish mortality, especially after rain. Some insecticides especially DDT and BHC are occasionally used at a sewage disposal works to control flies associated with biological filters. The amounts used are probably too small to affect fish in the stream receiving the sewage effluent but the position needs careful watching.

E- Miscellaneous causes of river pollution

1- Solid pollution

Pollution can be caused by the dumping of solid refuse, rubbish, or litter into a river, or by the placing of such solid matter so that it drains or passes into the river. The aesthetic value of a stream, especially in built-up and industrialized areas, is often much spoilt by the thoughtless actions of persons, including children, who throw rubbish of all kinds into the water, and by manufacturers who tip their sludge and other solid wastes on or near the river bank so that there is serious encroachment on to the river by the tip with the probable result that part of it may be carried into the water during wet weather. These practices, besides causing pollution, may lead to considerable erosion of the opposite bank as well as to shoal formation farther downstream.

2- Oil pollution

Oil pollution is usually occasional or intermittent, and the result of accidental discharges to watercourses from nearby garages, oil storage depots, engineering works, etc. It can also occur as a consequence of the use of watercourses by ships and barges for navigation. The increasing use of oil as a fuel and the tendency for pollution from this source to be more widespread make it desirable that legislation should be introduced to control the storage of diesel and other light fuel oils. Oil should be stored well away from watercourses, if possible, and in suitable containers which should be regularly inspected by a responsible person. The tanks or containers should be surrounded by impervious material so that the contents can be retained in case of a burst.

3- Tip drainage

Tips can consist of municipal refuse as well as miscellaneous solid waste products of little or no commercial value from coal mines, manufacturing processes, and trade effluent treatment plants. Drainage from municipal refuse tips may contain sulfide and organic matter having a high B.O.D. and by denuding a stream or other body of water of dissolved oxygen has been the cause of mortality among fish.

4- Pea vining drainage

In many agricultural areas, considerable pollution of streams is caused by drainage and washing liquors from farms or factories adopting mechanical methods of removing peas from pea vines. This is a seasonal problem mainly confined to a few weeks in the summer when the peas are ripe. The processing of the peas is chiefly, though not always, carried out at canning factories. The worst liquors, however, are those produced by drainage from pea haulm silage which ahs an extremely high content of putrescible vegetable matter and can be up to about 50 times as strong as domestic sewage. Since the drainage is comparatively small in volume and the trade is seasonal, normal methods of biological treatment are not practicable. If a sewer and suitable sewage works are not available, the avoid public nuisance, therefore, piggeries are usually sited in country districts, which, unfortunately, generally means that no sewers are available for the disposal of the wastes. The discharges are intermittent and, because of their strength, difficult to treat biologically.

Drainage from manured land may be washed into a stream during wet weather but, in general, pollution from this source is unlikely to be considerable since the flow in the stream should be well above normal.

7- Surface drainage

While discharges to foul water sewers pass to the sewage disposal works for treatment, those proceeding to surface water sewers may go straight to a stream. Pollution is liable to occur in this way from garages, trade premises, etc., situated close to the river, and can be due to

a- harmful liquors, oil, etc., spilled accidentally on the ground (for example by leakage or bursting of barrels, pipes, tanks, and so forth) as well as floor washing; and

b- Careless discharges of polluting materials.

In some cases, discharges are sent down surface drains in the mistaken belief that these drain to the foul sewers.

8- Road drainage

This may contain toxic substances derived from the tar used for spraying the road surface.

9- Boiler blow-off water

This occasional discharge from boilers using alkaline conditioning agents is alkaline to phenolphthalein and has a high content of suspended solids. Since the volume is small, the pollution caused is usually negligible and is only likely to be serious in a fishing stream or where the dilution is low.

10- Sheep washing

The washing of sheep in a small stream can cause pollution due to grease, dirt and chemicals, which may lead to mortality among fish. The washing should never be done in a river used for drinking purposes.

11- Sheep dipping

This is a process carried out in order to control various parasites which infest sheep, and may have to be repeated several times a year. The sheep are fully immersed (generally in a large wooden tub) in a fluid containing a toxic chemical preparation (e.g. arsenious acid, arsenic-sulfur compounds, phenolic preparations, lime-sulfur dips, and synthetic insecticides), hence the spent liquors are highly poisonous and grossly polluting. Methods of disposal include carting away to a disused mineshaft, putting into a soakway pit (i.e. a hole in the ground filled with broken stone or clinker and with a layer of soil on top), and discharging to a foul drain.

12- Watering of cattle

Pollution caused by excreta of cattle, sheep, etc., drinking stream water will, in general, be small, and is unlikely to be serious except in a very small watercourse or in a feeder stream to a reservoir of a water authority.

F- Indirect causes of river pollution

A number of factors can indirectly affect or aggravate river pollution and among the more important are the following:

1- Factors which reduce the amount of clean dilution water in the stream. These include:

a- Drought, which causes low river flows if prolonged

b- Reduction in the amount of 'compensation water' discharged by water undertakings who impound a river or its tributaries or feeders

c- The present unrestricted liberty to abstract river water for various purposes, particularly irrigation.

These factors all have the undesirable effect of adversely reducing the ratio of clean water to effluent in a stream, thus increasing the concentration of polluting materials.

2- Thermal pollution.

3- Lack of dissolved oxygen in deep reservoirs discharging compensation water to streams.

Effects of river pollution

A- General effects

1- synthetic detergents

Synthetic detergents tend even in small amounts to cause foam on rivers and at sewage plants. They also reduce the rate of re-aeration of river water, adversely affect the efficiency of sewage purification plants, may cause tastes in water supplies and are toxic to aquatic flora and fauna.

2- Organic compounds

Most of various organic compounds and materials can be broken down by micro-organisms present in river water, and dissolved oxygen is used up in these biochemical reactions. However, bacteria can become acclimatized to toxic substances. Such toxic organic wastes have the objectionable property of killing bacteria and so rendering the river sterile and unable to undergo self-purification, in addition, in quite low concentrations they can cause mortality amongst fish and other aquatic life. Moreover, a few organic compounds are very resistant to microbiological decomposition e.g. hydrocarbons, ethers, synthetic pesticides, lignin, peat and coal.

3- Toxic inorganic compounds

Any appreciable amounts of any toxic inorganic substance may hinder or even prevent self-purification of rivers and may kill fish and other aquatic life whether animal or vegetable.

Minute doses of copper sulfate can destroy many algae, trout fish, perch and black bass. Zinc is another heavy metal that is very toxic to fish. Metallic contamination in a stream, especially arsenic and lead, may constitute a danger to public health if the water is to be used subsequently for drinking purposes. The effect of toxic substances on fish food may be a vital factor in determining whether fish can flourish or survive in a polluted stream. In many cases the lower organisms upon which fish depend for food are even more susceptible to a particular poison than are the fish themselves.

4- Acids and alkalis

Acids are particularly objectionable in a stream because of the corrosion they may cause to metal or concrete structures and pumps especially if the pH value of the stream falls below about 5.0. They may also liberate evil-smelling hydrogen sulfide from sludge deposits and river mud. Acids and alkalis can destroy bacteria and other micro-organisms and so inhibit or even prevent self-purification of a stream; they are also lethal to fish and other forms of aquatic life.

5- Temperature

When a rise in temperature occurs in a stream polluted by organic matter, there is not only disappearance of dissolved oxygen, due to the lower solubility of oxygen at higher temperature, but also an increased rate of utilization of dissolved oxygen by biochemical reactions which proceed much faster at higher temperature. For these reasons many rivers may be satisfactory as regards dissolved oxygen content in the winter but may contain little or none during the summer. If the dissolved oxygen does fall to zero, putrefaction of organic matter will occur giving rise to bad smells and nuisance.

Another harmful consequence of a discharge of warm water is that it tends to encourage excessive growths of 'sewage fungus' and of water weeds which may in some cases interfere with stream flow and so cause flooding.

6- Suspended solids

Suspended solids are objectionable in streams for three reasons:

- They interfere with self-purification by diminishing photosynthesis and by smothering benthic organisms.
- They can damage fisheries, and
- They are unsightly and are a nuisance aesthetically

B- Harmful effects of sewage and trade waste

1- Fermentable organic matter will decompose and cause deoxygenation of the stream water. Fish may be asphyxiated and ultimately, when all dissolved oxygen has disappeared, there will be objectionable smells due to hydrogen sulfide, mercaptans, organic amines, etc.

2- Suspended matter will deposit on the rive bed, or behind weirs as sludge and cause silting up of the bed and possible flooding. If the suspended solids are largely organic in nature, putrefaction may occur, and solid matter buoyed up by gas may rise to the top, resulting in floating masses of evil-smelling and unsightly sludge. Suspended matter of any kind blankets the bottom of a stream, so interfering with the spawning of fish as well as reducing the number of animals which form the food of fish.

3- Corrosive substances (acids, alkalis) or toxic substances (e.g. cyanides, phenols, zinc, copper, etc.) may kill fish, bacteria, and other aquatic life, animal and vegetable. The resulting destruction of beneficial water bacteria may produce a sterile river which is unable to undergo natural self-purification. Such waters may prove dangerous to use for domestic purposes or for watering cattle.

4- Pathogenic micro-organisms may be discharged with sewage during epidemics. Trade wastes, as a rule, are free from pathogens, though anthrax bacilli may possibly occur in tannery wastes.

5- Certain undesirable physical effects caused by the discharge of sewage and trade wastes are turbidity, discoloration, foam and radioactivity. Heated effluents discharged to rivers (e.g. from power stations) may cause harmful rises in the temperature of the stream. This can lead to undesirable putrefaction in streams already polluted by organic matter, and may also cause destruction of fish in relatively unpolluted waters.

6- Substances causing tastes and odors in water may be present in certain trade wastes (e.g. phenols, oil refinery wastes) and may make the water either unfit for drinking purposes or else difficult and costly to purify by conventional water purification processes.

7- Undesirable biological effects may be observed due to disturbance of the biological balance by substances in sewage and trade wastes. Sewage and many organic trade wastes may cause excessive growths of sewage fungus or other objectionable growths in a stream. These may choke the river bed or even the screens of river users, and may give rise to objectionable odors when they decompose.

8- Certain mineral constituents (e.g. calcium and magnesium) can cause excessive hardness in a river water, making it difficult to use for certain manufacturing processes. Excessive amounts of salt discharged to a stream may be objectionable if the chloride content of the stream rises to a value which is deleterious to freshwater fish and vegetable.

C- Effect on fish

1- Organic load

If fish are present in a river receiving a heavy organic load, mortality may occur when the dissolved oxygen falls below a certain critical level (usually 5 p.p.m).

2- Cyanide

Cyanide can cause death to trout fish even in low concentrations, in smaller concentrations cyanide reduces the ability of trout to swim against a current by about 50%.

3- pH

Freshwater fish usually thrive in waters having pH values lying between 5.0 and 8.5, but certain species are affected by more acid or alkaline conditions. In particular, fish are liable to be adversely affected if suddenly transferred from an alkaline stream to an acid stream or vice versa.

4- Turbidity

Turbidity has no direct effect on fish and many of the best fishing streams in the world are turbid. However, turbidity, by cutting off some sunlight, does reduce the amount of plant life in a stream.

5- Temperature

Fish are affected by rise in temperature and there may be even mortality among those fish sensitive to temperature. Although fish can become acclimatized to high temperatures, at a certain point they will eventually die. Moreover, it is important to realize that a rapid change in temperature, or the sudden transference of fish to a warm water, may result in death at a temperature well below that regarded as lethal for the species. Furthermore, a temperature rise may have adverse effects on the hatching of the eggs of fish. A rise in temperature also has the unfortunate result of increasing the lethal effect of compounds toxic to fish. Although a rise in temperature lowers the dissolved oxygen content of a stream, the minimum critical concentration of dissolved oxygen for fish is unfortunately greater when the temperature increases. In addition, the oxygen consumption of aquatic fauna nearly doubles itself for each 10 °C rise in temperature. The conclusion seems to be that all these factors taken in the aggregate may mean that even a rise of a mere 1 °C might have marked bad effects on fish life.

6- Taste

River waters polluted by trade wastes often contain taste-producing substances which may damage the value of fisheries by imparting unpleasant tastes or 'taints' to fish. Phenols, nitrogenous organic compounds and hydrocarbons present in coal carbonization effluents are not only toxic to fish and fish food but also adversely affect the flavor of the fish, i.e. cause tainting of the flesh. The phenolic taste imparted by phenols can be removed by transferring the fish to clean water.

7- oxygen-reducing effluents

When sewage, milk washings and other effluents containing organic matter are discharged into rivers and streams much of the material they carry in suspension and solution is broken down by the microorganisms present in stream water, a process which involves using up the dissolved oxygen. If this is removed faster than it can be replaced by natural means the concentration of dissolved oxygen falls. Inorganic substances that are readily oxidized, such as sulfites and ferrous salts, can produce a similar effect. Normally, streams are kept well aerated by the movement of the water and the photosynthesis of the plants and a certain amount of organic pollution can be tolerated. In fact, some addition of organic matter can be beneficial as this can enrich the food supply, and many of the invertebrate animals of the stream-bed feed upon the mixture of mineral matter and amorphous organic matter called detritus, which accumulates on the bottom. A serious degree of organic pollution results in a depletion of the oxygen supply which is harmful or lethal to fish.

Fish are made restless by lack of oxygen and stimulated to move away to better aerated water.

8- Lead and zinc

Lead is present in effluents associated with the manufacture of accumulators, in lead paint wastes and wastes from the manufacture of pewter ware. Zinc is present in effluents associated with the manufacture of rubber and the processes of zinc-plating and galvanizing.

Control of river pollution

A- self- purification

If the organic pollution load is small and the dilution by well-oxygenated stream water is high, sufficient dissolved oxygen may be present to enable certain bacteria –aerobic bacteria– to break down the organic matter completely to relatively harmless, stable and odorless end-products. The river thus recovers naturally from the effects of pollution and is said to have undergone "self-purification". The oxidation reactions which occur are as follows:

Carbon, $C \rightarrow CO_2$ + carbonates and bicarbonates

Hydrogen, $H \rightarrow H_2O$

Nitrogen, $N \rightarrow NH_3 \rightarrow HNO_2 \rightarrow HNO_3$

Sulfur, $S \rightarrow H_2SO_4$

Phosphorus, $P \rightarrow H_3PO_4$

Massive pollution by organic matter causes exhaustion of the dissolved oxygen. The remaining organic matter is then broken down by a different set of bacteria –the anaerobic bacteria which do not require free oxygen but can utilize combined oxygen in the form of nitrates, sulfates, phosphates and organic compounds. Putrefaction then occurs, resulting in the breakdown of organic matter to a different set of end-products, some of which have objectionable odors and may be the cause of complaints. The anaerobic decomposition of organic matter requires the participation of at least two groups of anaerobic bacteria, namely acid- and methane-producing bacteria, resulting in the production of organic acids and methane, respectively, and new cells are also produced in the form of sludge. The oxidation and reduction reactions occurring in the anaerobic breakdown of organic matter are as follows:

Carbon, $C \rightarrow$ Organic acids (R-COOH)

$\downarrow$

$CH_4 + CO_2$

Nitrogen, $N \rightarrow$ amino acids $[R\text{-}(NH_2)\text{-}COOH]$

$\downarrow$

NH_3 + amines

Sulfur, $S \rightarrow H_2S$ + organic S compounds

Phosphorous, $P \rightarrow PH_3$ + organic P compounds

B- Treatment of waste water

When it is considered desirable to remove color from waste waters discharging to streams, this can often be achieved by coagulation with chemicals, thereby at the same time removing any finely divided suspended matter and colloidal organic matter, and reducing the oxygen demand of the waste. Activated carbon is often very effective in reducing or removing the color of a waste but large amounts are required, which makes its use expensive.

C- Agricultural uses of pesticides

1- Obtain more information on the nature, effect and origins of the chemicals in the watercourses.

2- Consider the siting of industries, especially those concerned with the manufacture of organic chemicals.

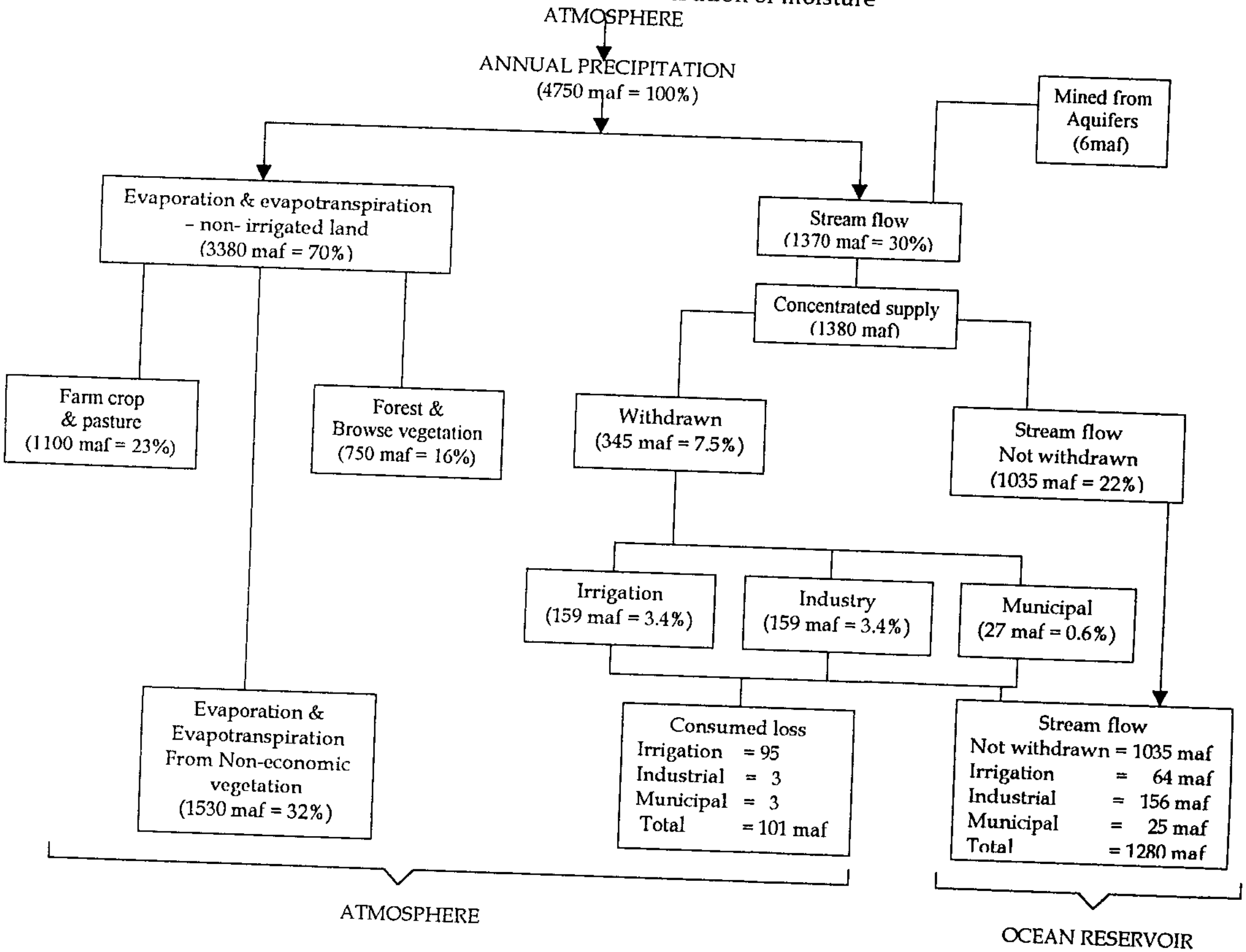
3- Devise more realistic financing arrangements so that there is a real incentive for effluents to be treated to a high standard before discharge.

4- The existing legislation must be brought into a more realistic relationship with the rate of change of development and technology, to deal with several issues. These are the control of waste disposal in the ground; the changes in agricultural practices; the causes and remedying of unintentional or negligent pollution; and, particularly the control of the manufacture of potentially dangerous new chemicals.

D- Joint efforts

First, there is the greatest need for a rapid increase in the research effort being devoted to basic and applied problems in ecology, oceanography and in the dynamics of the ocean-atmosphere system. Second, those who make decisions having effects on the environment must learn, or be taught, to foresee as many as possible of the consequences of such decisions. In other words, there is a need for a kind of ecological education for administrators, politicians, engineers and many others. Third, interdisciplinary studies are needed because they bring together the environmentalists, biologists, chemists, engineers and administrators when confronted with an ecological or pollution problem. In this way, not only will decision-makers be ecologically educated but ecologists will be enlightened with regard to the processes of administration and law. Finally, the social implications of pollution, its consequences and control need to be explained to the people at all age levels, with emphasis on the everyday problems and responsibilities as well as the sensational occurrences and possibilities.

Figure 1: The annual distribution of moisture



Appendix B

Table 1a: River water levels (internal region)

River	Source		Years	Winter level (m^3/s)	Summer level (m^3/s)	Average annual level (m^3/s)
Litani	Guelle		1964-68	1.20	0.78	0.99
	Ammik		1961-68	1.07	0.34	0.71
	Kab Elias		1961-68	1.02	0.34	0.68
	Jdita		1961-67	0.22	0.05	0.13
	Korayzat		1961-68	0.35	0.25	0.30
	-	Chita	1962-68	0.48	0.18	0.31
	-	Berdaouni	1952-68	2.25	0.57	1.41
	Chtaura		1961-68	0.58	0.34	0.46
	Anjar		1961-68	2.62	1.43	2.00
	Chamsine		1961-68	0.50	0.43	0.46
	Ras El Ain (terbol)		1963-68	0.33	0.11	0.22
	Faouar		1963-68	0.17	0.06	0.12
	Ain El Baida		1963-68	0.27	0.25	0.26
	Ain Zerka		1962-68	2.96	1.91	2.44
	-	Litani (Mansoura)	1938-68	14.20	4.46	9.34
	-	Litani (Karaoun)	1931-61	20.25	5.81	13.02
	-	Litani (Khardale)	1921-51	29.20	11.40	20.40
Hasbani	Hasbaiya		1963-68	1.75	0.48	1.12
	Sreid		1963-67	1.57	0.45	1.01
	Wazzani		1963-67	1.82	1.51	1.86
	-	Hasbani	1963-67	6.34	2.11	4.25
Nahr el Assi	Ras el Ain (Baalbeck)		1960-66	0.36	0.34	0.35
	Laboue		1960-68	0.88	1.12	1.00
	Yammoune		1967-68	2.08	3.54	2.82
		Assi (Hermel)	1931-68	12.97	14.30	13.63

Table 1b: River water levels (coastal region)

River	Source		Years	Winter level (m³/s)	Summer level (m³/s)	Average annual level (m³/s)
Kebir			1966-68	13.20	1.84	7.51
Ostouen			1966-68	3.16	0.98	2.04
Arka			1966-68	3012	1.01	2.06
Bared			1952-56	1.81	1.22	1.51
Abou Ali	Rachine		1960-68	1.26	0.94	1.10
	El Quadi		1960-68	0.41	0.33	0.37
		Abou Ali (Kousba)	1948-68	4.93	2.18	3.56
		Abou Ali (aBou Samra)	1966-68	21.20	8.92	15.10
Jaouze	Dalle		1966-68	2.82	1.04	1.93
		Jaouze (Beit Chlala)	1966-68	4.25	1.42	2.84
Ibrahim	Afka		1965-68	5.45	3.80	4.62
		Ibrahim	1966-68	19.45	11.60	15.52
Kelb	Jeita		1949-60	4.80	4.15	4.48
		Kelb	1949-60	11.45	4.30	7.88
Antelias	Antelias		1950-51	0.72	0.41	0.56
Beirut		Beirut	1948-62	5.94	0.51	3.24
Damour	Barouk		1945-68	1.23	0.81	1.03
	Safa		1929-55	1.62	1.23	1.43
		Damour (Jisr el Qadi)	1966-68	14.45	1.78	8.10
Awali		Bisri	1961-68	8.30	1.15	4.75
		Awali	1961-68	13.15	4.86	9.00
Saitanik		Saitanik (Wadi laimoun)	1963-68	0.46	0.04	0.25
		Saitanik (Tyr)	1966-68	0.63	0.02	0.33
Zahrani		Zahrani (Wadi	1963-68	1.79	0.21	1.00

		Akhdar)				
		Zahrani (Tyr)	1965-68	1.20	0.03	0.60
Litani		Kasmiye	1965-68	4.84	3.38	4.11
Ras el Ain (Tyr)	Ras el Ain (Tyr)		1959-68	0.93	0.83	0.88

Table 2: Types of pollution

Chemical	Physical	Physiological	Biological
➢ Organic ➢ Inorganic	➢ Color ➢ Turbidity ➢ Temperature ➢ Suspended matter ➢ Foam ➢ Radioactivity	➢ Taste ➢ Odor	➢ Bacteria (pathogenic) ➢ Viruses ➢ Animals ➢ Plants

Table 3: Some typical alkaline and acid waste waters

Alkaline Wastes		
Waste	pH	Alkali(s) present
Gas liquor	8-9	Ammonia
Kier liquor (kiering of cotton or straw)	12-14	Caustic soda, sodium carbonate, lime
Cotton mercerizing wastes	12-14	Caustic soda
Chemical manufacture wastes	Variable	Caustic soda, sodium carbonate, lime, ammonia
Tannery wastes	Up to 12	Lime
Wool scouring wastes (untreated)	9-10	Sodium carbonate
Acid Wastes		
Waste	pH	Acid(s) present
Mine water	2.5-6.5	H_2SO_4
Battery factory wastes	1.0 or less	H_2SO_4
Iron pickle liquor	Strongly acid	H_2SO_4 , sometimes HCl, Rarely H_3PO_4
Copper pickle liquor	Strongly acid	H_2SO_4
DDT waste	Very strongly acid	H_2SO_4
Viscose rayon Wastes	Strongly acid	H_2SO_4
Wood pulp spent sulfite liquor	2-4	H_2SO_3 Sulfurous acid
Chemical manufacturing wastes	Variable	H_2SO_4, HCl, HNO_3, H_3PO_4
Munition factory wastes	1-3	H_2SO_4, HNO_3
Wool scouring wastes (cracked with acid)	< 4	H_2SO_4

Table 4: Some chemical substances in industrial wastes

Substances	Present in waste waters from
Free chlorine	Laundries, paper mills, textile bleaching
Ammonia	Gas and coke manufacture, chemical manufacture
Fluorides	Scrubbing of flue gases, glass etching, atomic energy plants, fertilizer plants, metal refineries, ceramic plants, transistor factories
Cyanides	Gas manufacture, plating, case-hardening, metal cleaning
Sulfides	Sulfide dyeing of textiles, tanneries, gas manufacture, viscose rayon manufacture
Sulfites	Wood pulp processing, viscose film manufacture, bleaching
Mineral acids	Chemical manufacture, mines, iron and copper pickling, DDT manufacture, brewing, textiles, battery manufacture, photoengraving
Acetic acid	Pickle and beetroot manufacture, acetate rayon
Citric acid	Soft drinks and citrus fruits
Organic acids	Distilleries, fermentation plants
Tartaric acids	Dyeing, wine making, leather manufacture, chemical works
Alkalis	Cotton and straw kiering, wool scouring, cotton mercerizing, laundries
Chromium	Plating, aluminum anodizing, chrome tanning
Lead	Battery manufacture, lead mines, paint manufacture
Nickel	Plating
Cadmium	Plating
Zinc	Galvanizing, zinc-plating, viscose-rayon manufacture, rubber-processing
Copper	Copper-plating, copper pickling, cuprammonium rayon manufacture
Arsenic	Sheep-dipping, fellmongering
Silver	Plating, photography
Hydrogen peroxide	Peroxide bleaching of textiles, rocket motor testing
Sugars	Dairies, breweries, preserve manufacture, glucose and beet sugar factories, chocolate and sweet industries, wood processing
Starch	Food processing, textile industries, wall-paper manufacture
Fats, oils, and grease	Wool scouring, laundries, textile industries, petroleum refineries, engineering works
Phenols	Gas and coke manufacture, synthetic resin manufacture, textile industries, tanneries, tar distilleries, chemical plants, dye manufacture, sheep dipping

Formaldehyde	Synthetic resin manufacture, penicillin manufacture
Mercaptans	Oil refineries, pulp mills
Tannic acid	Tanning, sawmills
Nitro compounds	Explosives factories, chemical works
Hydrocarbons	Petro-chemical and synthetic rubber factories

REFERENCES

1. Dalu, Radwan (1978). Evaluation of waste water treatment in Lebanon. Beirut.
2. Dugan, Patrick R. (1972). Biochemical ecology of water pollution. Plenum press.
3. Eckenfelder, William Wesley (1968). Advances in water quality improvement. Texas: University of Texas press.
4. Economic and Social Commission for Western Asia (1996). Assessment of water quality in the ESCWA region. New York: UN.
5. Erichsen, J. R. (1964). Fish and river pollution. London: Butterworths.
6. FAO (1996). Control of water pollution from agriculture. Rome: FAO UN.
7. Hellawell, J. M. (1986). Biological indicators of fresh water pollution and environmental management. London: Elsevier Applied Sciences Publishers.
8. Hodson, Lord (1970). Water pollution as a world problem. London: Europa publications.
9. Iowa State University (1971). Agricultural practices and water quality. Iowa: Iowa State University Press.
10. Klein, Louis (1962). River pollution causes and effects. London: Butterworths.
11. Laws, Edward (1993). Aquatic pollution. John Wiley and Sons.
12. Muniruzzaman, Pathan (1977). Pollutional aspects of water resources in Lebanon. Beirut.
13. Plamer, Charles Mervin (1980). Algae and water pollution. London: Castle house publication.
14. Pankratz, Tom (1991). Dictionary of water and waste water treatment trade marks and brand names. Lewis publishers.
15. Tarzwell, Clarence M. (1962). Biological problems in water pollution, 3rd seminar. Ohio: Public Health Services.
16. Warren, Charles E. (1971). Biology and water pollution control. Saunders.
17. Wilber, Charles Grady (1969). Biological aspects of water pollution. Thomas: Silverdale, wash.