AIM AND SCOPE

The overall composition of natural water is influenced by many physical, chemical and biological processes. The major components include dissolved gases, dissolved organic and inorganic compounds and solid and colloidal materials of both organic and inorganic fractions. A greater emphasis has been on the organic pollution which was mainly due to the discharge of untreated or partially treated human waste into water courses. Until the middle of the present century population, urbanization and industrialization have been on the rise increased as a result of ever increasing quantities of human wastes that were generated along with the biodegradable substances.

The effect of pollution caused by the discharge of domestic, agricultural or industrial wastes in water bodies can be studied by physico-chemical and biological analysis. As the assessment of water quality lies in the delicate interface between physics, chemistry and biology, a knowledge of these three component becomes necessary for proper assessment, evaluation and abatement of pollution.

The present study aims at the evaluation of the physico-chemical parameters along the chosen stretch of the river Kaveri so as to assess the extent of pollution. River Kaveri is the river
par excellence which has contributed to the well being and prosperity of a large section of the people of our country. The indiscriminate use of the water resources of the riverine system has led to the undesirable changes in the chemical quality and this diverse use has seriously impaired the whole system. The present work intends to bring about clearly the changes occurring in the quality of the river water and highlight the intensity of pollution quantitatively along the stretch under study.

The watershed of the Kaveri is very near the western edge of Sahayadri ranges of hills and being at higher elevations and nearer to the Arabian sea, this part of the basin has maximum rainfall during the months of June-September. The distribution of rainfall over the entire basin is characterized by two maxima, one during the month of June-September and another during October-January.

The present stretch (Fig. 1) under study lies in the mid basin of the River Kaveri covering a distance of 110 kms from Karur to Grand Anicut which falls in the revenue districts of Perumpidugu Muthirayar. This region serves as the only source of water supply for the corporation, industrial and defence needs. The sewage of the city lying on the banks of the river are ultimately released into the river. Industrial effluents are also mixed either directly or indirectly with city sewage
thereby polluting the whole river to a great extent. There is thus an urgent need for monitoring the quality of water in this region.

A perusal of the previous literature does not reveal any work on quantitative monitoring of the water quality. Hence, an attempt has been made to quantify the water quality along the stretch under investigation. The study was carried out for a period of 32 months (from August 1989 - March 1992). This 32 months period has been arbitrarily divided into three main seasons which are abbreviated as Monsoon (m), Post Monsoon (pM) and dry (d) seasons. The period, August to November is designated as the Monsoon season followed by Post Monsoon period from December to March. The third dry season includes April to July. Even though the entire basin has two maxima, the basin taken up for this study experiences only one maxima.

As many as 11 sampling stations (K₁ - K₁₁) the river stretch (Table II) each having its own significance has been fixed for this study. The first sampling point (K₁) was fixed near Pugalur bridge at Karur with 25 km at the downstream, the second one (K₂) at Mayanoor where the river bifurcates into Kaveri and Uyyakkondan canal. The point coded as K₃ of Unniyur is located on the northern bank to that of the second sampling point. The sampling points K₄ (Fig. 2) and K₅
Table II: Sampling stations and their locations

<table>
<thead>
<tr>
<th>Station code</th>
<th>Name of the station</th>
<th>Sample code</th>
<th>Identified spot for sample collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pugalur</td>
<td>K1</td>
<td>Kaveri bridge - downstream</td>
</tr>
<tr>
<td>2</td>
<td>Mayanoor</td>
<td>K2</td>
<td>Near Regulator-Place of bifurcation</td>
</tr>
<tr>
<td>3</td>
<td>Unniyur</td>
<td>K3</td>
<td>Northern Bank</td>
</tr>
<tr>
<td>4</td>
<td>Musiri</td>
<td>K4</td>
<td>Road Bridge upstream-Northern Bank</td>
</tr>
<tr>
<td>5</td>
<td>Kulithalai</td>
<td>K5</td>
<td>Musiri Road Bridge near water Head Souther Bank downstream</td>
</tr>
<tr>
<td>6</td>
<td>Upper aniout</td>
<td>K6</td>
<td>Aganda Kaveri in between Kaveri and Coleroon</td>
</tr>
<tr>
<td>7</td>
<td>Kambarasampettai</td>
<td>K7</td>
<td>Down to the Head water works</td>
</tr>
<tr>
<td>8</td>
<td>Kaveri Road bridge</td>
<td>K8</td>
<td>Kaveri Road Bridge Southern Bank down stream.</td>
</tr>
<tr>
<td>9</td>
<td>Mullaikudi</td>
<td>K9</td>
<td>Down to the BHEL Head water works - Southern Bank</td>
</tr>
<tr>
<td>10</td>
<td>Vengoor</td>
<td>K10</td>
<td>Southern Bank near sand loading area, downstream</td>
</tr>
<tr>
<td>11</td>
<td>Grand anicut (below the dam)</td>
<td>K11</td>
<td>Near P.W.D. Guest House Northern Bank</td>
</tr>
</tbody>
</table>
(Fig. 3) lie on the northern and southern parts of the downstream part of the river situated at a distance of 40 km to 46 km respectively.

The next sampling station was Upper Anicut known as Aganda Kaveri in between Kaveri and Coleroon at a distance of 65 km, from the first sampling station. The sampling point at Kambaresampettai K7 (Fig. 4) which serves as the pumping station for the corporation water supply for the whole population of Tiruchirappalli town assumes significance for the study.

The sampling station K8 (Fig. 5-7) at Kaveri Road Bridge is a point of interest since it is situated in the heart of the city and receives most of the municipal wastes and was a centre for the whole population to bathe, wash and dump their wastes.

The next sampling station at a distance of 102 km was fixed at Mullaikudi (K9) (Fig. 8). The sampling station K10 and K11 are fixed in the down stream part of the stretch under investigation at a distance of 106 km and 110 km respectively. The sampling station K10 (Fig. 9) is the pumping station for a large residential colony and also for an important Boiler Plant. The downstream end of the present investigation was chosen at Grand Anicut (Fig. 10) at a distance of 110 km from the first sampling station.
The samples were collected at regular monthly intervals and were transported to the laboratory for analysis within 10 hours of collection. As many as 19 important physico-chemical parameters i.e. Biochemical Oxygen Demand (BOD), Calcium Hardness (CaH), Chloride (Cl), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Electrical Conductivity (EC), Fluoride (F), Magnesium Hardness (MgH), Sodium (Na), Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrogen (NO3-N), Nitrite-Nitrogen (NO2-N), pH, Silicate (Si), Sulphate (SO4), Total Hardness (TH), Total Solids (TS), Turbidity (TUR) and Volatile Solids (VS) are included for analysis, the importance of which are being discussed in the following pages.

**BOD**

BOD is a measure of biologically decomposable organic pollutants present in a given sample of water. It is generally considered to be a useful way of expressing stream pollution loads and of comparing one set of conditions with another. The amount of biologically degradable organic pollutants present in a riverine system may be due to the mixing of sewage and sullage waters from industrial effluents.

A high BOD load can pose a threat to the aquatic environment by depressing the dissolved Oxygen concentrations to levels that affect the organisms. BOD levels less than 4 mg/l are
deemed reasonably clean waters and those possessing greater than 10 mg/l are considered polluted as they would contain large amounts degradable organic matter. Bolten et al. consider water with BOD less than 2 mg/l as of good quality, meriting high ranking.

**CALCIUM HARDNESS**

Calcium is an important divalent cation contributing to hardness. It is found in great abundance in all natural waters and it originates from the rocks. Its concentration varies greatly in natural waters depending upon the nature of the basin. It is an important micronutrient in the aquatic ecosystem. It is particularly required in large quantities by the molluscs and vertebrates. Generally, calcium is the predominant cation in river water. Rivers in more arid regions especially where some of the more soluble rock types are exposed, tend to have much higher dissolved calcium concentration.

**CHLORIDE**

Chloride is present in all natural waters, but mostly at low concentrations. In most surface streams, concentrations of Chloride are lower than those of sulphate or bicarbonate. The presence of chloride ions not only affect the taste but also accelerate corrosion. Chlorides are present to some extent in natural water but industrial waste effluents may contribute large quantities
and so can tidal sea water intrusions. No adverse effect on human health has been observed through ingestion of water with large amounts of Chlorides, say 1000 mg/l. The Indian Council of Medical Research (ICMR) standards have prescribed a maximum desirable limit of 200 mg/l of Chloride.

CHEMICAL OXYGEN DEMAND

The BOD indicates the quantity of organic pollutants present in a waste water that can be decomposed by bacteria under aerobic conditions. On the other hand the COD measures the total oxygen required for chemical oxidation of the organic matter in the waste water to carbon-di-oxide and water. Hence COD values are usually greater than BOD values especially when the waste water contains significant amounts of biologically resistant organic matter. The BOD or COD have wide application in the planning and operation of water pollution control programmes.

DISSOLVED OXYGEN

Dissolved Oxygen (DO) is another important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. Its presence is essential to maintain the higher forms of biological life in an aquatic system. Adequate amounts of DO must be present for fish and other aquatic organisms to survive. The amount of DO in natural waters depends upon temperature, salinity, turbulence of the water.
and the atmospheric pressure. The decomposition of organic wastes and oxidation of inorganic wastes may reduce the DO content to extremely low level which may prove harmful to the organisms in the aquatic environment. A minimum of 5 mg/l of DO has been suggested by Hart. The solubility of DO at atmospheric pressure at sea level at 25° is around 8 mg/l.

**ELECTRICAL CONDUCTIVITY**

Electrical Conductivity (EC) is a valuable indicator of the amount of material dissolved in water, the larger the conductance more mineralised is the water. A satisfactory set of relationship between the conductance and ion concentration can be developed only from a few years of intensive sampling. A record of conductivity in any sampling station could be used to compute other chemical characteristics of water with a good level of accuracy for major ions. The specific conductance of the purest water that can be made, would approach 0.5 mho/cm. The conductance of surface and ground water has a wide range varying from 50 mho/cm to 50,000 mho/cm.

**FLUORIDE**

The major natural resources which incorporate fluoride in an aquatic environment are sedimentary and igneous rocks. In certain concentrations of fluoride, tooth decay may be reduced and at higher concentrations, they may cause mottling of tooth enamel.
Apart from natural sources, sewage and industrial effluents may contribute to the fluoride content of natural waters. As per USSR, Canada and Australian standards, a limit of 1.5 mg/l of fluoride is recommended while the Environment Protection Agency (EPA) and the World Health Organisation (WHO) link F-levels in potable waters to the average annual atmospheric temperature prevailing in the area. The Indian Council of Medical Research suggest a limit of 1 mg/l of fluoride.

**MAGNESIUM HARDNESS**

Apart from natural sources, considerable cultural inputs of this element to the environment do occur particularly from industries engaged in the manufacture of some chemicals, imitation, leathers, cement, tanning solutions, textiles and explosives. Sea or tidal water intrusion also affects the magnesium content of fresh water bodies. The standard laid down for Magnesium generally link it to the sulphate content of water. A limit of 50 mg/l of Magnesium has been accepted as the upper limit.

**SODIUM**

When sodium has been brought into solution, it tends to remain in that status. There are no important precipitation reactions that can maintain low sodium concentrations in water. Sodium is retained by absorption on mineral surfaces, especially by minerals having a high cation - exchange capacities such as clays.
Cation exchange processes in fresh water systems tend to extract divalent ions from solution and replace them with monovalent ions.

Human activities can have a significant influence on the concentration of sodium in surface water. The reuse of water for irrigation commonly leaves a residue that is much higher in concentration of sodium than was the original water. Presence of sodium in large concentrations may affect persons with cardiac difficulties, hypertension and medical conditions. Depending on the concentration of calcium and magnesium, sodium may be detrimental to irrigated crops.

**TOTAL KJELDAHL NITROGEN**

TKN represents the organic nitrogen in water which covers nitrogen in aminoacids, amines, amides, imides and nitro derivatives. Nitrogen concentrations are detrimental and reported in different ways. The studies on organic pollution report ammonium, amino and organic nitrogen and nitrate either separately or as a combined figure.

The nitrate and organic species are unstable in aerated water and are generally considered to be indicators of pollution
through disposal of sewage or organic waste. Most of the organic nitrogen occurs in domestic water in the form of proteins or their degradation products i.e. polypeptides and aminoacids.

**NITRATE-NITROGEN**

Nitrogen occurs in water as nitrite or nitrate anions, in cationic form as ammonium and at intermediate oxidation states as part of organic solutes. Nitrogen in reduced organic form is converted by soil bacteria into nitrite and nitrate. The process is commonly termed "Nitrification". The nitrogen used by plants is largely in the oxidized form. Nitrate in anaerobic systems can be reduced by other strains of bacteria to nitrous oxide or nitrogen gas by the process of denitrification. Industries and sewage plants may discharge nitrate containing effluents and pollute water.

Excessive concentrations of nitrate in drinking water may cause methemoglobinemia in small children. Concentrations in excess of 10mg/l of nitrogen, equivalent to 44mg/l of nitrate evidently are hazardous. Occurrence of nitrite and nitrate in water has been studied rather extensively because of public health relationship.

**NITRITE - NITROGEN**

Nitrite is the partially oxidized form of nitrogen found in very low concentration in natural waters. It has no mineral
source in water but occurs as an intermediate form during the nitrification and denitrification processes. Presence of even minute quantities of nitrite in water is an indicator of organic pollution and a lower level of oxygen. At high concentrations, it may cause blue baby diseases. Nitrite is much more toxic to man and animals than nitrate and US, Environment Protection Agency (EPA) limits its concentration to 1 mg/l.

**pH**

pH is a measure of intensity of acidity or alkalinity. It is a measure of the activity of hydrogen ion. Most natural waters are generally alkaline due to the presence of sufficient quantity of carbonates. Most chemical and biological reactions occur at a narrow range of pH. In anaerobic treatments, if the pH goes below 5 due to excess accumulation of acids, the process gets adversely affected. Shifting of pH range from 5 to 10 upsets the anaerobic treatment of the wastes. pH has no direct adverse effects on health, although a lower value below 4 will produce sour taste and higher value above 8.5 an alkaline taste. Higher values of pH hasten the scale formation in boilers, reduces the germicidal potential of chlorine.

The river water in areas influenced by pollution generally has a pH range 6.5 - 8.5 where photosynthesis by aquatic organism takes up oxygen during day light and releases carbon-di-oxide during night by respiration. The pH of natural water ranges from 6.0
to 8.5 but acidmine drainage and industrial waste effluents may
significantly lower the pH of water. The range of pH recom-
mended for potable waters varies to some extent with various
authorities viz. Canada 6.5 - 8.3. Australia 6.5 to 9.0, US, EPA
5.0 - 9.0 and ICMR 7.0 - 8.5. The acceptable limits set by ICMR
has been accepted and the ideal value has been arbitrarily set at
7.5.

SILICATE

Silicon appears as oxides in many rocks and in the com-
bined form as silicate minerals. The range of concentration of sili-
cate most commonly observed in natural water is from 1 to about
30 mg/l. Davis has quoted a median value of silica for surface
water of 14 mg/l and for ground water of 17 mg/l. Inspection
of analysis of surface waters by Livingston indicates that most
streams in the Northern United States carry water containing less
than 10 mg/l.

SULPHATE

Sulphate ions affect the taste and also have a laxative
effect on humans. Apart from natural sources, industrial effluents
from tanneries, paper mills, textile plants, sulphuric acid manufac-
turing units and some metal working industries may discharge sul-
phate into the aquatic environment. The ICMR recommends a level
of 200 mg/l of Sulphate as the highest desirable limit. It gives
water bitter taste and at higher concentrations, has a laxative effect. In combination with calcium it forms a hard calcium carbonate scale in steam boilers.

**TOTAL HARDNESS**

The concept of hardness as an evaluation of certain chemical properties of water has become deeply imbedded in the literature of water analysis. The term total hardness is referred to as "calcium and magnesium hardness and can be defined as the effect of alkaline earth cation". The terms "hard" and "soft" as applied to water are inexact. Durfor and Becker\(^8\) have adopted the following classification.

<table>
<thead>
<tr>
<th>Range of Hardness (mg/l)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 60</td>
<td>Soft</td>
</tr>
<tr>
<td>61 - 120</td>
<td>Moderately hard</td>
</tr>
<tr>
<td>121 - 180</td>
<td>Hard</td>
</tr>
<tr>
<td>&gt; 180</td>
<td>Very Hard</td>
</tr>
</tbody>
</table>

The U.S. Public Health Service and later U.S. Drinking water standards do not specify any value for hardness. The World
Health Organization (WHO) have suggested an upper limit of 500 mg/l. However, according to American Water Works Association, "ideal water should not contain more than 80 mg/l of hardness."

Hardness in water used for ordinary domestic purposes does not become particularly objectionable until it reaches a level of 100 mg/l. It can exceed this level where waters have been in contact with limestone or gypsum. Water from gypsyferrous formation, may contain a level of 1000 mg/l.

A statistical correlation between hardness and cardiovascular diseases has been reported by Lacey\textsuperscript{81}. Reports in the literature show a lower death rate from heart and circulatory diseases occurred in States where the public water supply contained highest levels of hardness. Neri\textsuperscript{82} and others have presented data from Canada supporting the hypothesis that hard water provided some protection from heart disease because of magnesium content.

**TOTAL SOLIDS (TS)**

The presence of inorganic as well as organic pollutants in the water sample contributes to Total Solids. The presence of organic and inorganic substances in the dissolved form affect the physical and chemical properties of water. Apart from natural sources, significant contribution to TDS to fresh water system occurs from Municipal and Industrial effluents and agricultural run
off. Dissolved solid values are often used to compute rates at which rivers transport weathering products to the ocean. This parameter is widely used in evaluating the quality of water and serves as a convenient measure of comparing water from different sources.

In the region of high rainfall and relatively insoluble rocks, concentration of dissolved solids in the run-off stretch may be as low as 25 mg/l. Robinove\textsuperscript{83} and others have proposed the following classification on the basis of dissolved solid content.

<table>
<thead>
<tr>
<th>Classification</th>
<th>TS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly saline</td>
<td>1000 - 3000</td>
</tr>
<tr>
<td>Moderately saline</td>
<td>3000 - 10000</td>
</tr>
<tr>
<td>Very saline</td>
<td>10000 - 35000</td>
</tr>
<tr>
<td>Brine</td>
<td>&gt; 35000</td>
</tr>
</tbody>
</table>

**TURBIDITY**

Turbidity in water is caused by the presence of suspended organic and inorganic matter, plankton and other microscopic organism. This parameter has a bearing on the effectiveness of water treatment processes such as filtration and disinfection. Inadequate coagulation and flocculation followed by sedimentation result in more turbid water which renders filtration
more difficult and costly. Turbidity can inhibit the penetration of light, limiting photosynthetic activity, minimise the biological producers thereby resulting in lower bio-magnification.

The solid materials in suspension in water may result from natural erosion particularly during the rainy season, algal blooms introduction of untreated waste effluents and sewage may contribute to increased turbidity. The ICMR standard suggest a maximum permissible limit of 5 NTU.

**VOLATILE SOLIDS**

One of the major objectives of determining the volatile solids in the domestic and industrial wastes is to get an idea of organic matter that is present. Its determination could be interpreted in terms of organic matter (both biologically decomposable and inert organic matter).

The parameters described in the previous pages have been experimentally determined using standard methods of analysis prescribed in APHA. The results are tabulated and subjected to the following statistical analysis techniques.

1. Measure of variance
2. Seasonal variation
3. Multiple correlation
1. **Measure of variance:**

- The observations made for 32 months were scrutinized for the highest and lowest value exhibited for each of the parameter in the respective sampling points. *(Tables A1 - R5)*

- Average values for all the parameters in each of the sampling stations were computed which is another way of measuring the variance between the sampling stations.

- To quantify further the extent of deviation of a particular parameter in all the sampling points, variance analysis was carried out through the computation of the values with the help of a Microsoft Excel computer. Normally the analysis of variance is used to check the validity of data by verifying that there is no significant variations among the sample. But here the same technique is used to show that there are significant variations between sample points. The values are presented in the graphical form *(V1 - V18).*

**ANOVA**

Analysis of variance is a mathematical technique for partitioning the total variation of a set of data in such a manner so as to identify the component sources of variation. The objective
of the analysis of variance is to locate important independent variable in a study and to determine how they interact and affect response. The basis of this test is the ratio of the two variance:

1. Between samples
2. Within sample

The sum of the two variances is however the total variance. The different steps involved in the analysis are explained and the summary of these steps are shown in a table called analysis of variance. (Table III).

The "F" value is the ratio of the unexplained variance (MSC) over explained and calculated as

\[ F = \frac{\text{Variance between the samples}}{\text{Variance within the samples}} = \frac{\text{MSC}}{\text{MSR}} \]

A comparison of the calculated value of F with the table value of F for the degree of freedom (K-1) and (N-K) at a certain critical level of significance. If the computed value of 'F' is greater than the table value the difference is significant and the difference would not have arisen due to fluctuations of simple
sampling. If the calculated value is lesser than the table value, the difference is not significant i.e the difference has arisen due to simple sampling fluctuations.

ANOVA TABLE III

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>Variance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between samples</td>
<td>SSC</td>
<td>K-1</td>
<td>MSC</td>
<td></td>
</tr>
<tr>
<td>Within samples</td>
<td>SSE</td>
<td>N-K</td>
<td>MSE</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>SSI</td>
<td>N-1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. SEASONAL VARIATION

Streams in regions having alternating wet and dry seasons may fluctuate greatly in volume flow and the water may have a wide range of chemical composition. The influence of season on water quality not only affects the amounts and kinds of solutes but also the annual regime of water quality. To study
the effect of seasonal changes, the variations between the average values of all the parameters were computed and given in tables (A1 - R5).

4. CORRELATION ANALYSIS

Correlation analysis is the statistical tool generally used to describe the degree to which one variable is related to another. On the basis of this theory the comparative changes occurring in two related phenomena and their cause-effect relation can be examined. Correlation can be either positive or negative and would depend upon the direction in which the variables are moving. If both variables are changing in the same direction, the correlation is said to be positive but when the variations in the two variables has taken place in opposite direction, the correlation is said to be negative. When more than two variables are involved in a study relating to correlation then it can be of either be a multiple correlation or partial correlation.

The degree of correlation is expressed in terms of coefficient of correlation symbolically denoted by 'r' the value of this co-efficient can never be more than +1 or -1. A correlation co-efficient of r = +1 indicates that there is a perfect correlation between the two variables. If r = -1, it indicates that the change
Table IV: Summary of River Quality Classification

<table>
<thead>
<tr>
<th>River Quality class</th>
<th>Percentage of DO saturation</th>
<th>Quality criteria BOD mg/1</th>
<th>Ammonia NH₄ as on mg/1</th>
<th>Current and Potential Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>&gt; 80</td>
<td>&lt; 3</td>
<td>&gt; 0.4</td>
<td>All users supported high class Fisheries. High amenity values.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also non toxic to trout and coarse fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>&gt; 60</td>
<td>&lt; 5</td>
<td>&gt; 0.9</td>
<td>Lower quality than class IA but usable for substantially the same purposes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also non toxic to trout and coarse fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&gt; 40</td>
<td>&lt; 9</td>
<td>--</td>
<td>Suitable for potable supply after advanced treatment, reasonable coarse fisheries moderate amenity value.</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 10</td>
<td>&lt; 17</td>
<td>--</td>
<td>Low grade industrial use fish absent or rarely present</td>
</tr>
<tr>
<td>4</td>
<td>Inferior to class 3</td>
<td>--</td>
<td></td>
<td>Grossly polluted completely fishless and likely to cause visual and odour nuisance</td>
</tr>
</tbody>
</table>
of one variable is in opposite direction to that of the other. The value of $r^2$ is used in the present thesis to measure as to how well one variable describes another.

In this study, multiple correlation among various physicochemical parameters are established. The multiple correlation studies have been carried out in a relatively similar way using the Microsoft Excel statistical function and are presented in Tables (T19 - T29).

**RIVER CLASSIFICATION**

The voluminous data has been translated into a language which can give a clear picture on the quality of the river along its stretches under investigation. (Table IV).

**WATER QUALITY INDEX (WQI)**

The above study has been further supplemented by the water quality Index for each one of the sampling points for various months during the period of study. The widely used term to describe the quality of water till recently was with an adjective such as 'clear', 'muddy', foul etc. Such a procedure is simple but lacks reproducibility. Sayer and Ott calculated the water quality index is based on specific water quality parameters like coliform bacteria, turbidity, colour, taste and odour, trace metals, dissolved solids, trace organics, chloride, fluoride, sulphate, nitrate, cyanide
and radioactivity. This index is calculated in order to communicate information to the policy makers and the general public in terms of indices. It also allows a comparison of quality status or pollution of two or more samples of water from different localities and also helps to evaluate the pollution control programme.

A survey of the literature show that the pollution data on Indian rivers are scarce for most rivers and many of the parameters mentioned above have not been determined even for major rivers and hence only ten important water quality parameters indicated by the author and that if all the ten parameters are not available, the computation can be carried out with the available water quality parameters with a minimum number of parameters as 6.

The calculation of WQI depends upon the intended use. The present study is focused on the calculation of WQI with reference to the suitability of river water for human consumption. The standards (permissible values of various pollutants) for drinking water, recommended by the Indian Council of Medical Research are given in the Table V.
The ICMR Standards and Unit Weights of Water Quality Parameters

TABLE V

<table>
<thead>
<tr>
<th>WATER QUALITY PARAMETER $P_i$</th>
<th>ICMR STANDARD $S_i$</th>
<th>UNIT WEIGHT $W_i = \frac{K}{S_i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>5.0$^1$</td>
<td>0.2</td>
</tr>
<tr>
<td>BOD</td>
<td>5.0$^2$</td>
<td>0.2</td>
</tr>
<tr>
<td>pH</td>
<td>7.0 - 8.5</td>
<td>0.004</td>
</tr>
<tr>
<td>Chloride</td>
<td>250.0</td>
<td>0.004</td>
</tr>
<tr>
<td>Nitrate</td>
<td>20.0</td>
<td>0.050</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>120.0$^3$</td>
<td>0.0083</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>300.0</td>
<td>0.0033</td>
</tr>
<tr>
<td>Turbidity</td>
<td>5.0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

All the values except pH and turbidity are in mg/l.

1. European Economic Community (EEC) standard
2. United States Public Health Services (USPHS) Standard
3. World Health Organisation

$$Wt(DO) = \frac{K}{S_i} = \frac{1}{5} = 0.2$$
Each parameter has been given due weightage which depends upon the permissible value or standard values recommended for drinking water. The $W_i$, unit weight for each parameter is equal to $W_i = K/S_i$

Where $W_i = \text{unit weight for the } i\text{th parameter } P_i$, and $K = \text{constant of proportionality and is assumed to be equal to } 1$ and $S_i$ is standard unit.

The values given in the third column of the above table indicate unit weight for the respective parameters indicated in the column. The overall water quality index may be calculated by aggregating the quality rating $q_i$ where $q_i$ is known as sub indices for each of the parameters. According to Tiwari et al. the WQI arrived at can be formulated as

$$\text{WQI} = \left( \sum_{i=1}^{n} q_i \cdot W_i \right) / \sum_{i=1}^{n} W_i$$

The numerical value of the water quality index for each of the 19 parameters monitored are computed with the above equation and the values are given in table (30), and are also represented in the form of graphs ($W1 - W11$).
SINGLE INDEX QUALITY OF WATER

Another modified version of this water quality index has been developed by Prati et.al. This index is a numerical expression of the degree of pollution and takes into account the various pollutants present at the same time. This index increases with the degree of pollution and is used for the numerical evaluation of a purely qualitative characteristic, expressed by the term pollution.

Each parameter contributing to pollution is assigned with a mathematical expression to transform concentration into levels of pollution expressed in new units known as 'units of measurement of pollution'. The final term of the mathematical expression to transform each of the values of the other parameters are included along with the surface water quality table VI as established by the author.

This method has been followed in the present thesis and the SIQW values calculated are given in tables (T31 - T32) as well as graphic representations (S1 - S11).
CLASSIFICATION OF SURFACE WATER QUALITY

TABLE VI

<table>
<thead>
<tr>
<th>Condition Index of</th>
<th>Excellent</th>
<th>Acceptable</th>
<th>Highly polluted</th>
<th>Polluted</th>
<th>Heavily Polluted</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5-8.0</td>
<td>6.0-8.4</td>
<td>5.0-9.0</td>
<td>3.9-10.1</td>
<td>&lt; 3.9 - &gt; 10.1</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>88-112</td>
<td>75-125</td>
<td>50-150</td>
<td>20-200</td>
<td>&lt; 20 - &gt; 200</td>
</tr>
<tr>
<td>BOD</td>
<td>1.5</td>
<td>3.0</td>
<td>6</td>
<td>12.0</td>
<td>&gt; 12.0</td>
</tr>
<tr>
<td>Nitrate</td>
<td>4</td>
<td>12</td>
<td>36</td>
<td>108</td>
<td>&gt; 108</td>
</tr>
<tr>
<td>Chloride</td>
<td>50</td>
<td>150</td>
<td>300</td>
<td>620</td>
<td>&gt; 620</td>
</tr>
<tr>
<td>COD</td>
<td>10</td>
<td>20</td>
<td>40</td>
<td>80</td>
<td>&gt; 80</td>
</tr>
</tbody>
</table>
Equations of Transformation of Concentrations of Pollutants, Expressed in Standard Metric Units (Y) into Levels of Pollution expressed in New Units (X)

\[ X_{7-9} = (Y - 7)^2 \]

Dissolved Oxygen \[ X_{50-100} = 0.08 (100 - Y) \]

BODs (mg/l) \[ X = Y / 1.5 \]

COD (mg/l) \[ X = 0.1 Y \]

Nitrate (mg/l) \[ X = 2^{2.1 \log Y / 4} \]

\[ X_{<50} = 1.57 \left( \frac{Y}{50} \right) + 0.57 \left( \frac{Y}{50} \right)^2 \]

Chloride \[ X_{50-300} = 0.6 + 0.37 \left( \frac{Y}{50} \right) + 0.033 \left( \frac{Y}{50} \right)^2 \]

\[ X_{>300} = 3.75 \sqrt{\frac{Y}{50} - 5.2} \]
The WQI and SIQW values are computed using Microsoft Excel. This software has been used for the data processing in Microsoft Excel for Windows. The system requirement is

- Any IBM compatible machine with an 80286 processor or higher

- A 3.5 or 2.5 inch floppy disk drive

- A hard disk

- A graphic display compatible with Microsoft Windows version 3.1 or a later modification such as EGA or VGA.

- Atleast 4 megabytes of memory

- MS-DOS version 3.1 or any subsequent version in standard or enhanced mode. Microsoft has been chosen because of its versatility in data processing and graphic presentation. The built in formula paste functions makes the data processing easy and error free.