REVIEW OF LITERATURE

Physico-chemical properties of water bodies were assessed to determine the quality of water in them. Various authors have analysed the physico-chemical characteristics of freshwater bodies and evolved methods to estimate water quality. Wilcox (1955) proposed specific electrical conductance as one of the most important criterion to evaluate the rating of irrigation water quality. On the basis of alkalinity, Philipose (1959) classified water as low (40-50 ppm), moderately high (50-100 ppm), and high (100-200 ppm) in productivity, and above 200 is lethal.

Gibbs (1970) proposed a diagram to understand the relationship of the chemical components of waters from their respective aquifer lithologies. Dinius (1972) stated that pollution evaluation in rivers and streams must consider the differences between the actual temperature and temperature standardized for the season.

Jones and Lee (1982) have conveyed that an emphasis on phosphorus control will have to be given while evaluating eutrophication control options because of its ability to stimulate algal growth as well as the growth of other aquatic plants. Bhatt et al. (1984) observed low turbidity during November – February and an increase after May and becomes peak in August in the river Kosi. According to the survey conducted by NEERI (1988) 70% of India’s freshwaters are polluted because these water resources have been freely used for the industrial and public waste water disposal (Basu, 1986).
Khant and Vohra (1990) have rightly suggested that the management of any aquatic ecosystem is conservation of freshwater habitat with an aim to maintain the water quality or to rehabilitate the physico-chemical and biological quality of water. According to Baruah et al. (1993) the hardness of water is not a pollution parameter, but indices of water quality mainly in terms of Ca\(^{2+}\) and Mg\(^{2+}\).

The observed low pH does not cause any harmful effect but may lead to increase desorption of metals cations due to competition of H\(^+\) ions as suggested by Boominathan and Khan (1994). Haniffa et al. (1994) noted that Indian urban local bodies generate 3650 cubic waste water and the major industrial units generate 750 million m\(^3\) of wastewater every year.

Ramesh et al. (1995) said that the anthropogenic activities and improper management of natural resources also led to unequal distribution of major and minor elements in nature. Hosetti (1996) noticed that the increased nutrient levels triggered the growth of aquatic weeds, algae, mosquito and midges in the area as the flow was slow in the river.

Kazmi and Hansen (1997) applied the Mike 11 numerical water quality model for the evaluation of existing water quality conditions and a prediction of effects of different wastewater and other pollution control schemes under the Yamuna Action Plan. Jayakumar and Siraz (1997) examined the results of R-mode factor analysis performed on major ion data from a hydro geochemical survey, during post- and pre-monsoon season, over the coastal quaternary deltaic aquifer of the Cauvery basin, Tamil Nadu, India. Sharma and Pande (1999) developed a
quality map and used map to evaluate the quality of the river water for various uses.

Offong and Edet (1998) classified waters into four chemical facies, CaCl, NaCl, CaSO₄, and CaHCO₃. Harris and Silveira (1999) studied the biogeochemistry of carbon, nitrogen and phosphorus and their associated minor elements like iron and sulphur in rivers, lakes and estuaries. Singh and Ghosh (1999) applied the statistical approaches to water quality evaluation to the river Yamuna based on the published data of Central Pollution Control Board, New Delhi.

Koshy and Nayer (1999) reported that the poor sanitation facilities for the pilgrims, agricultural runoff, sewage effluent and domestic wastes were the cause of pollution of Pamba River. Arienzo et al. (2001) studied the impact of land use and urban runoff on the contamination of the Sarno river basin in Southern Italy and their results indicated degradation in river water quality, especially near the river mouth.

Ramamurthy et al. (2002) estimated the impact of water and soil pollution of Paravanaru river by determining the concentration of elements such as Cu, Zn, Mn, Cr, Cd, Pb, Ni, Al, Mg, Ca and Na. Rao and Mamatha (2004) pointed out that in India inadequate treatment of human and animal wastes contributes to the high incidence of water-related diseases. Chattopadhyay et al. (2005) reported that river water experiences variations in pH over the seasons and under different land use categories albeit, limited.


Various methods of data manipulation have been used to condense these records into a more suitable form to ease data utilization and promote effective communication to all concerned. The water quality index (WQI) system is a well-known method of expressing water quality that offers a simple, stable and reproducible unit of measure which responds to changes in the principal characteristics of water.

One of the earliest attempts in formulating the WQI (Water Quality Index) was made by Horton (1965), with no restriction for the inclusion or exclusion of any variable and the selection depending on the area and the availability of the
data. Brown et al. (1970) used Delphi method to develop a WQI for National Sanitation Foundation of USA.

Ross (1977) used different water quality variable for his WQI calculation. Bhargava (1983) exploited the use of WQI for the classification and zoning of Ganga River. Dojlido et al. (1994) elaborated the method of WQI in accordance with Polish law concerning surface water quality criteria and in accordance with the state management of water quality actually existing in Poland.

Sharma et al. (1996) reported that the water quality index can be a useful tool for quick assessment. Five independent water quality indices for typical beneficial uses such as i) Bathing and swimming ii) Public water supply iii) Agriculture iv) Industry and v) Fish culture was formulated by Pande and Sharma (1999).

Pesce and Wunderlin (2000) verified the usefulness of water quality indices to assess the water quality from multiple measured parameters. Othman et al. (2002) studied the effect of WQI on the distribution of fishes in Labu river system in sub-Langate basin, Malaysia. According to Sinha et al. (2004), if water quality index (WQI) is less than 50 such water is slightly polluted and fit for human consumption, WQI between 51-80 is moderately polluted, WQI between 81-100 is excessively polluted and WQI> 100 is severely polluted.

Magudeswaran et al. (2006) stated that there is no stipulation for the minimum or maximum numbers of parameters required for calculating WQI. Ashok et al. (2006) assessed water quality aspect for the ecosystem initiatives and employs newly developed Canadian Council of Ministers of the Environment
Water Quality Index (CCME WQI), which provides a convenient mean of summarizing complex water quality data that can be easily understood by the public, water distributors, planners, managers and policy makers.

Yu and Fogel (2007) incorporated use-oriented benefits and treatment costs analysis into a water quality index to show an economically optimized concentration for the treatment of the pollutants and the resulting water quality. The results of Simões et al. (2008) showed that the degradation in Médio Paranapanema watershed in São Paulo state, Brazil from aquaculture activity can be easily inferred with WQI, which is more restricted than the others routinely used to infer water quality. Samantray et al. (2009) assessed the water quality index of Mahanadi and its distributary rivers and streams, Atharabanki river and Taldanda Canal adjoining Paradip during three different seasons namely summer, pre-monsoon and winter. Parmar and Parmar (2010) found that the water quality of Subernarekha river varied from excellent to marginal range by Bhargava WQI method. Susilo and Febrina (2011) used graphical method for calculating water quality index without computer or any complex equations.

The distribution and abundance of aquatic organisms are influenced by various physical and biological factors. The potential value of aquatic insects for monitoring water quality has been appreciated for many years. Hynes (1959, 1960) studied the river pollution using benthic invertebrates as indicators. According to Hynes (1970), the time of emergence of Trichoptera is under the dual control of temperature and length of the day and presumably the relative importance of these factors varies from place to place. Hynes (1975) proposed that ‘every stream is
likely to be individual’, moreover, each substrate type exhibits a very distinct community, and faunal similarity.

Williams and Morgan (1977) studied the Trichoptera and other non-Chironomid macro invertebrates pertain to changes in climate, terrestrial and aquatic vegetation, stream size, current velocity or depositional environment. Connell (1978) formulated the Intermediate Disturbance Hypothesis (IDH) to show that only highly tolerant and rapidly colonizing species occurred in habitats exposed to high levels of disturbance and pollution. Ward and Stanford (1979) suggested that temperature pattern influences the life cycle phenomenon of insects such as emergence, which leads to increase in density.

Bronmark et al. (1984) studied the influence of stream size such as stream order, width, depth, and distance from source on species richness and community structure. Gray (1989) summarized the responses of species diversity to water quality into three distinct categories: reduced diversity, increased domination by a single or group of opportunistic species, and reduced individual size.

Morse et al. (1993) have pointed out that many small spring brooks and spring seeps in the Appalachian region harbor a diverse and unique array of invertebrates. Stream insect community of the Silent Valley National Park in South India was observed by Burton and Sivaramakrishnan (1993). Feminella (1996) observed little difference between the number of invertebrate taxa found in permanent streams versus those found in intermittent stream reaches of northern Alabama.
Resh et al. (1996) outlined the advantages and disadvantages of the utilization of macro invertebrates in biological monitoring. Williams (1996) have pointed out that invertebrates inhabiting temporary streams can have high diversity and faunal similarity with permanent streams, therefore they should be considered in conservation plans designed to protect species and their habitats.

Ward et al. (1999) suggested that low genus richness should be associated with the loss of connectivity during the warmest months since exchanges of matter, energy and organisms are confined to isolated pools. Martin et al. (2000) noticed the abundance and diversity of macro invertebrates and fish in the Tamiraparani river, South India. Relyea et al. (2002) used stream insects as bioindicators of fine sediments.

Bustos-Baez and Frid (2003) used the concept of indicator species using presence and / or absence of dominance of characteristic taxa to determine the degree of community change due to the effects of pollution. Fialkowski et al. (2003) suggested the use of mayfly nymphs as biomonitors of heavy metal pollution in streams since they can provide information on the different sources of bioavailable trace metals present in aquatic ecosystems.

The acceptance of a species as an indicator depends not only on its occurrence in one type of habitat (in this case lowland or highland), but on the species being very common in the given habitat as well, was pointed by Schmera (2003). The influence of increasing altitude in decreasing the diversity of stream insects was well established by Vinson and Hawkins (2003).
Anbalagan et al. (2004) studied the aquatic insects of Courtallam hills of Western Ghats. Acuna et al. (2005) suggested that flow reduction increase the detritus coverage, their by enhancing spatial habitat heterogeneity, which may increase taxon richness. Variation in the diversity and distribution of aquatic insects across habitats and microhabitats was reported by Subramanian and Sivaramakrishnan (2005).

Anbalagan and Dinakaran (2006) studied the aquatic insects of Gadana river basin, South-West Ghats. The impacts of anthropogenic activities on the distribution and biodiversity of benthic macro invertebrates and water quality of the Langat river was studied by Azrina et al. (2006). Aquatic insects in small stream of Sirumalai hills of Southern Western Ghats were studied by Dinakaran and Anbalagan (2006).

Dinakaran and Anbalagan (2007) studied the diversity patterns of aquatic insects among sampling sites lying within the unprotected and protected areas of Western Ghats, he also concluded that in Southern Western Ghats, there are rare specimens of habitat-sensitive organisms such as Ephemeroptera, Plecoptera and Trichoptera still occurred in unprotected areas and total resurgence of pollution sensitive taxa in unprotected or polluted or sites would be possible if the riparian corridor is protected.

Gupta et al. (2008) pointed out that a significant difference in the diversity of aquatic insects may be attributed to the fluctuations in water temperature, high values of dissolved oxygen, pH, and alkalinity in addition to the natural and anthropogenic disturbances. Luoto (2009) used aquatic insects and mites as
indicators of past environmental change. A macroinvertebrate based biotic index to evaluate water quality in freshwater river streams of Sikkim in Eastern Himalaya has been proposed by Bhatt and Pandit (2010). Muralidharan et al. (2010) summarized the aspects of biomonitoring, utility of macroinvertebrates in predicting condition of aquatic systems and the need for research with emphasis on recent advances. Nesemann et al. (2011) studied the macro invertebrates and dolphins of Ganga river.

High species diversity and density of caddisflies in unpolluted surface waters, communities of Trichoptera and other macroinvertebrates are often used to detect the presence of pollution. Nehring (1976) tested the biomonitoring ability nature of Macrostenum sp. (Insecta: Trichoptera) by using lead as the major Symons and Metcalfe (1978) studied the mortality of Brachycentrus numerosus (Say) after exposure to fenitrothion. Simpson (1980) noticed the atrophied gills in Cheumatopsyche sp. collected from streams receiving chlorinated crude oil wastes. Development and man’s activities have considerably reduced Trichoptera species diversity and the need for remedial measures to prevent further damage to ecosystems and loss of Trichoptera species have been discussed by Botosaneanu (1981). Otto and Sevensson (1981) suggested that some caddisfly larvae aggregate at pupation to reduce the risk of chironomid predation. Colburn (1982) measured the level of molybdenum in the aquatic ecosystem from the mine effluent by using Hydropsyche sp.

Havas and Hutchinson (1983) studied the effect of low pH on the Na⁺, Cl⁻ and Ca⁺ ion regulation in Limnephilus pallens. Malicky (1983) proposes a dinodal
biome for explaining the restricted distribution of specialised mountain-stream Trichoptera. Petersen and Petersen (1984) observed the abnormalities in the net-spinning behaviour of caddis larvae after exposure to paper-pulp effluent. Correa et al. (1986) examined the oxygen consumption of Limnephilus sp. at different pH.

Frankenhuyzen and Green (1987) noticed the effect of pH and Ni on the survival and growth of Clistoronia magnifica (Banks). Day and Scott (1990) studied the change in acetyl cholinesterase enzyme levels after exposure of Hydropsyche slossonae (Ross) and H. betteni Ross to low concentrations of organophosphate insecticides. Camargo (1991) found out that the residual chlorine damaged the gills of Hydropsyche pellucidula (Curtis). Moore et al. (1991) studied the effects of various metals of the mine effluent on Arctopsyche grandis, Brachycentrus sp., Hydropsyche sp. and Limnephilus sp.

Resh (1992) concluded that Trichoptera have been used in a variety of different ways in water quality monitoring programs, that they are essential components of benthic macro invertebrate analyses for this purpose, and that their value could be greatly expanded through future research, especially at the organismal and sub-organismal level and according to him, approximately 2.1% of literature citations for Trichoptera are related to water pollution which is comparable to that been found for other aquatic insect groups.

Nolen and Pearson (1993) found that a shredder species of Calamoceratidae, processed leaves more quickly when temperatures were higher during summer. Jarzembsowski (1995) pointed out that the modern and fossil caddisfly larvae are known to use a wide variety of building materials for their
portable cases including sand grains, gastropods, ostracodes, leaves, twigs, bark, fish bones and valves.

Malicky (1998a and 1998b) reported species from the genus *Macrostemum* (Hydropsychidae: Macronematinae) from Darjeeling, Kerala, Rajasthan, Sikkim and Tamil Nadu and *Amphipsycyhe* and *Aethaloptera* (Hydropsychidae) from Delhi. Wiggins (1998) found that trichopterans of the genus *Psilotreta* fasten their cases for pupation in dense layers on the underside of rocks. Drysdale (1999) suggested that the micro relief of the caddisfly larvae retreats can increase in carbon dioxide outgassing and an increase in the rate of carbonate precipitation. Wiberg-Larsen et al. (2000) suggested that the identification of trichopteran larvae to species level is relatively easy because they exhibit a large diversity in morphology, feeding and behaviour. Tessier et al. (2000) noticed that the use of capture net anomalies of hydropsychid larvae could represent a valuable indicator of sublethal toxicity induced by malathion and other organophosphorus insecticides in running waters. Berenzen et al. (2001) found that the trichopteran larvae *Limnephilus lunatus* Curtis has the ability to withstand certain level of ammonium pollution.

Vuori and Kukkonen (2002) noticed the gill abnormalities in the Trichopterans, *Cheumatopsyche lepida* (Pictet) and *Hydropsyche pellucidula* (Curtis) larvae collected from a polluted river. Leggitt and Loewen (2002) revealed that the caddisfly larvae played direct and indirect roles in the deposition and erosion of tufa in Lake Gosiute during the deposition of the Laney member of the Green river formation.
Becker (2005) observed seven distinct larval instars in *Agapetus fuscipes* Curtis based on their pronotal length, larval biomass and case length. Ponel *et al.* (2007) noticed that the sudden increase in number of *Hydropsyche* larvae indicates an increase of flowing water and appears to be indicative of an increased river gradient and thus a lowering of sea level.

The subordinal names Annulipalpia and Integripalpia were first established by Martynov (1924). Betten (1934) included detailed information on the diversity of morphological structures found in Trichoptera, including special features of the head and mouthparts, the thorax and its appendages, especially the wings, abdomen and its structures.

Ross (1956, 1967) was the first to identify explicitly any derived characters for caddisfly taxa and he recognized 2 monophyletic suborders, Annulipalpia (equivalent to the superfamily Hydropsychoidea) and Integripalpia. Fischer (1960 - 1973) produced a world catalogue that recorded 5,546 species. Ross (1964 and 1967) provided the first modern phylogenetic hypotheses of subordinal and superfamily relationships of Trichoptera, but earlier workers also constructed general classifications for the order, including Martynov (1924), and Milne and Milne (1939).

Weaver (1983, 1984, 1992a, b; Weaver and Morse, 1986) was the first to apply strict cladistic principles to caddisfly higher-level classification and examined about twice as many morphological characters as Ross (1964 and 1967). Wiggins (1984) noted the uneven distribution pattern of Trichoptera families in the world, with distinct northern and southern hemisphere differences being
particularly discernible in the Integripalpia. Weaver (1984) concluded that Spicipalpia was monophyletic and had a sister-taxon relationship to the infraorder Curvipalpia (= Annulipalpia of Ross).

Weaver and Morse (1986) proposed that the ancestral trichopteran habitat was in subterranean silk-lined tubes in saturated soil. The closed, semipermeable cocoons of parchment like silk found in the spicipalpian families (limiting them to cold, well-oxygenated streams) represent the ground plan condition of the order and that the cocoons of permeable silk with ventilation openings found in the Annulipalpia and Integripalpia are uniquely derived and an evolutionary relationship between Annulipalpia and Integripalpia was advocated based on the interpretation of pupal cocoon evolution in Trichoptera. (Wiggins and Wichard 1989; Wichard, 1991; Wiggins, 1992; Wichard et al., 1993; Wichard et al. 1997).

Schmid (1989) discussed the major features of Trichoptera adult morphology. According to Wiggins (1992), the pupation hypothesis was not intended as a statement of higher-level trichopteran relationships. Wallace (1996) studied the genera of North American caddisfly larvae.

Francia and Wiggins (1997) hypothesized that the ancestral habitat for the order Trichoptera was in cool, flowing, well-oxygenated water. Morse (1997b) provided a thorough summary of the hypotheses of relationships proposed for the major groups of Trichoptera and also of the status of phylogenetic work at the family and genus level undertaken up to about 1996.

Ivanov (1997) specifically challenged Weaver’s hypothesis of spicipalpian monophyly, providing evidence that each of Weaver’s 4 spicipalpian apomorphies
are plesiomorphic. Li and Morse (1997a, 1997b) provided cladistic analyses of the genera in the family Psychomyiidae and of the species in *Paduniella*.

Kjer *et al.* (2001) found that Annulipalpia to be the most basal of the three suborders, with Spicipalpia and Integripalpia forming a clade. Kriska (2001) stated that the characteristic substratum of the habitat determines the case building material of trichopteran larvae. The first combined molecular and morphological analysis of subordinal relationships in Trichoptera was done by Ivanov (2002).

Wiggins (2004) suggested that taxonomy progresses were best when based on rigorous analysis of phylogenetic relationships. The monophyly and phylogenetic relationships among the subfamilies of Hydropsychidae has been studied by Scheffer (1996 and 2005) and Geraci *et al.* (2005). Temporal and spatial distribution patterns of lotic larval trichopteran assemblages in relation to environmental variables were investigated by Hughes (2006).

Molecular techniques, and more detailed morphological and cladistic techniques have revealed that many of the presently classified large genera are paraphyletic or even polyphyletic (deMoor and Ivanov, 2008). Wiggins and Currie (2008) provided a well illustrated overview of adult, pupal, and larval morphology of Trichoptera. Mendez *et al.* (2011) established the Trichoptera Literature Database, to improve access to bibliographic information, which contains over 8,500 citations of literature on Trichoptera. Saini *et al.* (2011) described two new species of Genus *Chimarra* from Sikkim, India.