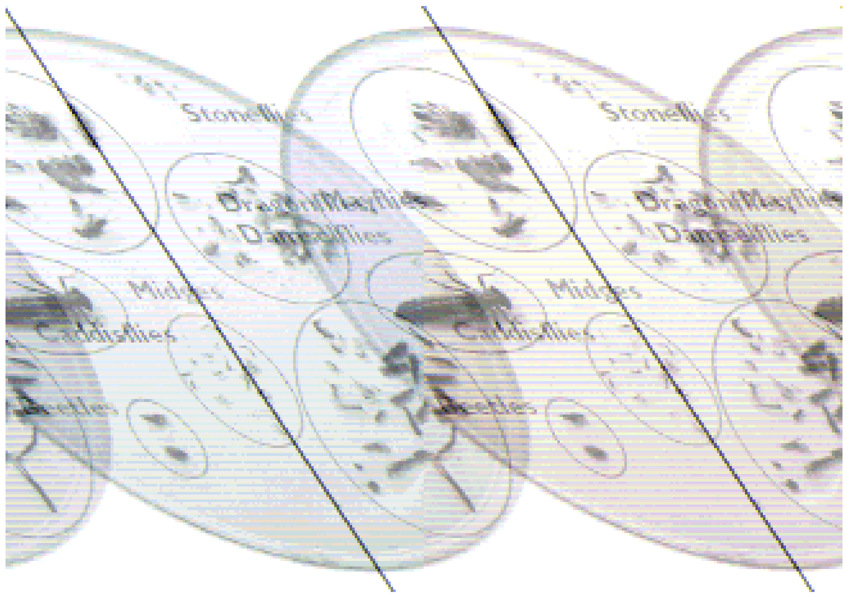
2.1. INTRODUCTION:

Biomonitoring involves the use of indicators, indicator species or indicator communities. Generally benthic macro invertebrates, fish, and/or algae are used. Certain aquatic plants have also been used as indicator species for pollutants including nutrient enrichment (Phillips and Rainbow, 1993; Batiuk *et al*., 1992). Macro invertebrates are most frequently used component of water quality (Rosenberg and Resh, 1993). Biochemical, genetic, morphological, and physiological changes in certain organisms have been noted as being related to particular environmental stressors and can be used as indicators.

Biomonitoring is used to measure the response of aquatic communities to anthropogenic stressors like energy source, water quality, habitat quality, flow regimes and biotic interactions. Toxic substances, urban influences, sedimentation and flow regulation are some of the stressors that impact the water quality considerably. Benthic macro invertebrates have been found as the most common faunal assemblages for bio assessment and provide more reliable assessment for long term ecological changes in the quality of aquatic system compared to its rapidly changing physico-chemical characteristics.

Structure of macroinvertebrate has long been used as bio-indicators to assess the water quality of a water body (Hynes, 1972 and Reynoldson *et al* 1989). The presence/absence, numbers (% abundance), morphology, physiology or behaviour of these indicator organisms can significantly predict the physico-chemical conditions defining the status of given water body at a given location e.g. the presence of some families of highly tolerant organisms is usually an indication of poor water quality (Tyagi, 2006).

Advantage of macroinvertebrates as bio-indicators inhabiting the lakes, reservoirs, rivers, streams and other water bodies are that they are visible to unaided eyes and can be retained by a sieve having a mesh size of 500 µm pore diameter, have sedentary and long life span and are significantly sensitive to organic pollution, thermal pollution, substrate alteration and toxic substances. Qualitative and quantitative changes in the benthic communities have also been used as tool for checking pollution through use of indices [Dhillon *et al*, 1995]. Sharma *et al* (2006) have conducted the bio assessment of Behta River with benthic macroinvertebrates using Nepalese Biotic Score (NEPBIOS) and National Sanitation Foundation Water Quality Index (NSFWQI) system to see impact of slaughter house located on the bank of river.



Stream order (stream size) affects a stream’s natural characteristics, including the biological communities that live in stream, such as fish and invertebrates. Very small 1st-order and 2nd-order streams are often quite clear and narrow and are frequently shaded by grasses, shrubs, and trees that grow along the stream bank. The food base of these streams is found along the stream bank and tends to consist of leaves and terrestrial insects, which dominate the streams’ ecology, along with algae that attach to rocks and wood, aquatic insects adapted to shedding leaves and scraping algae, and small fish that feed on these organisms. In contrast, larger 6th and 7th order rivers typically appear muddy because their flow carries accumulated sediments downstream. These rivers are wide enough that the canopy cover along their banks shades only a narrow margin of water along the river’s edge. The food base for these water bodies shifts towards in-stream sources, such as algae; downstream drift of small organisms; and deposition of fine detritus. Although the aquatic communities of larger rivers include the algae and terrestrial insects found in streams, these rivers are dominated by insects adapted to filtering and gathering fine organic particles, and larger fish that are omnivorous (feeding on plants and animals) and/or piscivorous (feeding on smaller fish).

The BWQC uses benthic macroinvertebrates (e.g., aquatic larval stages of insects, crustaceans, worms, mollusks) as the biological indicator of a stream's ecological condition. Benthic macroinvertebrates live throughout the stream bed, attaching to rocks and woody debris and burrowing in sandy stream bottoms and among the debris, roots, and grasses that collect and grow along the water's edge. The BWQC focuses on these macroinvertebrates because of their inherent capacity to integrate the effects of the stressors to which they are exposed, in combination and over time. Stream macroinvertebrates generally cannot move very quickly or very far; therefore, they are affected by, and may recover from, a number of changes in physical conditions (e.g., habitat loss), chemical conditions (e.g., excess nutrients), and biological conditions (e.g., presence of invasive or non-native species). Some types of macroinvertebrates are affected by these conditions more than others.

Macro-invertebrates provide a measurement of biological condition or health relative to the biological integrity of a stream. Biological integrity represents the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

Physical stressors are physical habitat of a stream or its watershed, such as through extensive urban or agricultural development, excessive upland or bank erosion, or loss of streamside trees and vegetation. Chemical stressors include toxic compounds (e.g., heavy metals, pesticides), excess nutrients (e.g., nitrogen and phosphorus), or acidity from acidic deposition or mine drainage. Biological stressors are characteristics of the biota that can influence biological integrity, such as the proliferation of non-native or invasive species (either in the streams and rivers, or in the riparian areas adjacent to these water bodies). The BWQC water chemistry data allow an evaluation of the distribution of nutrients, salinity, and acidification in the riverine system. The physical habitat data provide information on the prevalence of excess sediments, the quality of in-stream fish habitat, and quality of riparian habitat alongside rivers.

Data on biological condition are invaluable for managing the nation's aquatic resources and ecosystems. Water quality managers can use these data to set protection and restoration goals, decide which indicators to monitor and how to interpret monitoring results, identify stresses to the water body and decide how they should be controlled, and assess and report on the effectiveness of management actions.

The metrics used to develop the Macro-invertebrate index for the WSA covered six different characteristics of macroinvertebrate assemblages that are commonly used to evaluate biological condition:

• **Taxonomic richness –** This characteristic represents the number of distinct taxa, or groups of organisms, identified within a sample. Many different kinds of distinct taxa, particularly those that belong to pollution-sensitive insect groups, indicate a variety of physical habitats and food sources and an environment exposed to generally lower levels of stress.

• **Taxonomic composition –** Ecologists calculate composition metrics by identifying the different taxa groups, determining which taxa in the sample are ecologically important, and comparing the relative abundance of organisms in those taxa to the whole sample. Healthy stream systems have organisms from across many different taxa groups, whereas unhealthy stream systems are often dominated by a high abundance of organisms in a small number of taxa that are tolerant of pollution.

• **Taxonomic diversity –** Diversity metrics look at all the taxa groups and the distribution of organisms among those groups. Healthy streams should have a high level of diversity throughout the assemblage.

• **Feeding groups –** Many macroinvertebrates have specialized strategies to capture and process food from their aquatic environment. As a stream degrades from its natural condition, the distribution of animals among the different feeding groups will change. For example, as a stream loses its canopy (a source of leaves and shading), the aquatic community will shift from a more diverse food chain to one of predominantly algal-feeding animals that are tolerant of warm water.

• **Habits –** Just like other organisms, benthic macroinvertebrates are characterized by certain habits, including how they move and where they live. These habits are captured in the habit metrics. For example, some taxa burrow under the streambed sediment, whereas others clinge to rocks and debris within the stream channel. A stream that naturally includes a diversity of habitat types will support animals with diverse habits; however, if a stream becomes laden with silt, the macroinvertebrates that cling, crawl, and swim will be replaced by those that burrow.

• **Pollution tolerance –** Each macroinvertebrate taxa can tolerate a specific range of stream contamination, which is referred to as their pollution tolerance. Once this level is exceeded, the taxa are no longer present in that area of the stream. Highly sensitive taxa, or those with a low pollution tolerance, are found only in streams with good water quality.

Invertebrate families exhibit different sensitivities to organic pollution, specifically the resultant low oxygen levels, and a characteristic that makes them effective water quality indicators. Each family is assigned a biotic score between 1 and 10 according to this tolerance with no weighting given to the relative abundance of individual organisms. Pollutant intolerant species like mayflies are assigned a high score, tolerant organisms like worms a low score and shrimps, an intermediate organism a mid range score.

Benthic macroinvertebrates are widely used to determine biological condition. These organisms can be found in all streams, even in the smallest streams that cannot support fish. Because they are relatively stationary and cannot escape pollution, macroinvertebrate communities integrate the effects of stressors over time (i.e., pollution-tolerant species will survive in degraded conditions, and pollution-intolerant species will die). These communities are also critically important to fish because most game and non-game species require a good supply of benthic macroinvertebrates as food. Biologists have been studying the health and composition of benthic macroinvertebrate communities in streams for decades. Biological condition is the most comprehensive indicator of water body health; when the biology of a stream is healthy, the chemical and physical components of the stream are also typically in good condition. In fact, several states have found that biological data frequently detect stream impairment where chemistry data do not. (Plafkin *et al*, 1989)

2.2 ADVANTAGES OF BIOMONITORING:

- Benthic macroinvertebrates are found in most of the aquatic habitats.

- Large number of species and different environmental stresses produce different macroinvertebrate communities.
- Small order streams often do not support fish but do support extensive macroinvertebrate communities.
- Macroinvertebrates generally have limited mobility [except high current streams]. Thus they are indicators of localized environmental conditions.
- Benthic macroinvertebrates may retain (bioaccumulation) toxic substances, where levels of toxins are undetectable in the water resource.
- Water quality of a stream can be assessed by identifying the benthic community structure whether the stream is environmental degraded or not?
- Benthic macroinvertebrates are small enough to be easily collected and identified.
- Sampling of macroinvertebrates under a rapid assessment protocol is easy, requires few people and minimal equipment, and does not adversely affect other organisms.

Macroinvertebrates are the primary food source for recreationally and commercially important fish. An impact on macroinvertebrates impacts the food web and designated uses of the water resource.