Chapter 2

Literature Review

2.1 Definition

Benthic macroinvertebrates are animals inhabiting the substratum of lakes, streams, estuaries and marine waters. They may construct attached cases, tubes, and nets that live on or in, or roam freely over rocks, organic debris and other substrates during all or part of their life cycle (APHA, AWWA, and WPCF, 1989). They have been explained as benthic or bottom dwelling, communities, intimately associated with sediment particles and pore water, relying on the association for habitat, food, exchange of gases, and nutrient uptake. Moreover, they have specific attributes to maximize the association, especially for the exchange of material and behavioral characteristics (Maughan, 1993).

2.2 Benthic communities as bioindicator organisms

The theoretical basis of the ecological approach for the biomonitoring purposes is the fact that the primary effects of either toxic inhibitory or enriching nature will cause the ecosystem to respond to the stress by adjusting the dynamic equilibrium among its components (Petersen, 1992). Therefore, in principle, an ecological assessment of pollution can be carried out by analyzing biocoenological approach for the investigation of the communities (Strin, 1981).

Abel (1989), summarized the advantages of considering the macrozoobenthos for biological monitoring for well known and various reasons:

1. They are diverse groups in which some hundreds of common species from several phyla are represented.

2. They have relatively limited mobility and relatively long life cycles.

3. Their high level of abundance under favorable conditions facilitates quantitative analysis.

4. Sampling techniques are fairy simple and well developed.

5. The assemblage integrates the effects of pollutants over long periods of time.

6. It can also show the synergetic effects of several pollutants acting simultaneously.

The bioindicator approach involves measuring selected stress which range from bimolecular / biochemical to the population and community levels (Adams et al., 1989). The use of structural parameters of aquatic ecosystems for water quality assessment and monitoring has been reported by Kolwitz and Marsson as early as 1908, 1909, using community composition to assess the effects of organic pollution on aquatic system called a "saprobian " spectrum (Persoone et al., 1978). Patrick (1949) published a paper showed how various aspects of community structure could be used to monitor the conditions of stream affected by sewage and industrial waste. She concluded that the assessment of water quality could best be made using biological rather than physico-chemical monitoring techniques because of the fact that it is difficult to reduce the complex physico-chemical environment to a few simple parameters for monitoring purpose and it is impossible to test all possible toxic or hazardous agents in every waterway. There are many examples of such assemblages in marine pollution, showing effects of pollutants, e.g. oil pollution (Davis et al. 1984., 1989; Reierson et al. 1989; Gray et al. 1990), organic enrichment (Pearson and Rosenberg, 1978; Mirza and Gray 1981; Bellan and Bourcier 1988, 1990); tannery effluents (Zentos and Papthanassio, 1989) as explained by Gray et al.(1992).

2.3 Impact of sand and silt on benthic communities

Macoinvertebrate community responses to the environmental changes are also useful in assessing the impact of municipal, industrial, oils, and agricultural wastes. In summary, the situations for which the macroinvertebrate community patterns change have been documented are organic loading, substrate alterations and toxic chemical pollution (Mureihead-Thompson,1989). Impact of agricultural land areas has been reported mainly resulting in an increase in intensity of water run off (Hynes,1970). Significant increase in the volume of stream water in the wet season in the Ping River at Chiang Mai and at ChomThong (P1 gage station) have been reported to be 42 % and 54 % respectively during 1970s as compared to 1952-69. This was attributed to be effects of deforestation for agricultural land use in upper watershed because of increased evapotranspiration (keen, 1970). Changes in community structure of lotic macrozoobenthos due to input of nutrient, sewage, silt, pesticides and its interaction with current velocity as well as downstream changes in substrate composition have been reported by Dudgeon (1984) and as undesirable habitat for many of the invertebrate organisms characteristic of stony faunas (Newbold, 1986). Siltation is now explained as extremely high even on the hard rocks like granite and affecting the survival of fish eggs and benthic invertebrates (Gorden, 1992). Effect of sand deposition on macroinvertebrates have been reported by Chutter (1969). This can increase in the abundance and diversity of certain groups of invertebrates due to increases in sand and silt in stony biotops (riffle), but not necessarily change in overall fauna diversity (1986). Hynes (1970), explains about the reduction of fauna on stony substrate due to presence of silt. With the filling in of the interstices within bottom substrata with fine sediment, the intergravel water velocities are reduced. At the same time the D.O. of intergravel water supply decrease because of increased retention time of intergravel water. Clear cutting watersheds of small stream has reported to result in decrease in DO about 40 % in the . water with the effect persisting for at least three years after logging (Hall and Lanz, 1969 cited by Welch, 1992). In partially clear cut watershed , where buffer strips were left along the stream in affected areas and trees were not felled in the stream, D.O was reported to decrease only ~ 10 % and no damage to fishes were reported (Welch, 1992).

2.4 Impact of pesticides on benthic communities

Assessing the effects of pesticides in the field should serve as an alternative way for monitoring biotic changes resulting from pollution. Very few systematic surveys of water bodies have been reported prior to intensive pesticide use. Threshold International Center for Environmental Renewal, commencing on the US Agency for International Developments of environmental impact statement on its pesticide programme, concluded that " the consequences to Asian farmers due to the use of chlorinated hydrocarbons in the control of rice stem borer is the cause for elimination of fish from rice paddies" (Bull, 1982).

Field methods for the investigation of pesticide impact studies on aquatic communities have been explained to improve prediction of potential problems arising from the use of new pesticides (Mathlessen, 1988). Synergetic effect are explained as a consequence of routine application where more than one pesticide for various organisms in specific ecosystem levels is in agricultural practice (Ware, 1979).Various forms of synergism with different classes of pesticides have been observed in fish . Most combinations showing synergism contained one or two organophosohates Ware (1979) explains DDT and 2-4 D to be synergetic to fish.

Examples of orchard drainage ditches receiving large amounts of insecticides and acaricides sprays resulted in the loss of mite populations and greatly reduced species diversity of other insects. Many Diptera families are reported to adjust to wide spectrum of pesticides, but Tricoptera and Neuroptera are reported to be easily eliminated (Casper and Heckman, 1982).

DDT, as a representative of organochlorine (OC) group, have been reported widely to cause many environmental problems worldwide. OC insecticides are known to induce the production of hepatic detoxifying enzymes in mammals, birds, and fish at extremely low levels of intake. This phenomenon has been have adverse effects in the general environment (Ware, 1979). Detrimental effects that can be caused by DDT on stream-dwelling invertebrates was reported as early as 1949 by Adam (Heckmen,1982). Springer and Wester (1951) reported to have observed considerable mortality among non-target salt marsh species in New Jersy after DDT was applied to the habitat (Heckman,1983). Long term effects of intensive pesticide application on aquatic communities in orchard drainage ditches near Hamburg, Germany revealed that many species had become resistant to agricultural chemicals to which they were exposed, while others had become completely eliminated.

The comparative study of Hoffman and his co-worker's work on effect of pesticide spray with DDT in oil at one pound per acre to control the gypsy moth in Pennsylvania (USA) showed that 70 to 90 % of bottom dwellers were eliminated within 3 days after the spraying (Gaufin et al., 1961). Hartfield (1969), also reported a nearly complete elimination of common stream insects by DDT. These lipophilic pesticides have been reported to have stronger affinity for particles than free water (Prapamontol, 1994). Therefore, organisms living in contact with sediment may be exposed to more contamination to pesticide residues than those living in the ambient water. This fact has been proven by laboratory experiments on midges which, in contact with sediment, absorbed more Polychlorinated biphenyl (PCBs), Dichlorodiphenyl ethylene (DDE), and Pentachlorophenol (PCP) than those separated from sediment (Heckmen, 1993). Build up of higher concentrations at various tropic levels was reported from Lake Michigan in sediment by 0.01 ppm small invertebrates 0.42 ppm, fishes 3 to 8 ppm , due to agricultural run off (Ware, 1994). Effects of pesticide on non target organisms e.g. aquatic invertebrates, including insects, near Hamburg were found to contain residues of DDT and its breakdown product, as well as lindane, more than ten years after the production and use of these substance were locally discontinued (Heckman,1981). Additional OC insecticides such as hexachlorobenzene (HCB), heptachlor, lindane and chlordane have been reported to be in common use in developing countries. These have also been reported to effect insects by interfering with their nervous activity .

Direct introduction of a variety a of pesticides near cultivated land was reported to contaminate the surface waters, streams, and river systems downstream from the points of contamination (Kerswill and Elson,1955). Bekken et al. (1991) has also attributed pesticides as one of the major factor affecting the brook, rivers and, ponds, and lakes. This has been supported by various results like repeated insecticidal treatment in an Appalachian river where the community structure shifted from diverse insect dominance towards one dominated by Copepods, Oligocheates, Collombella, and Chironomids (Wallece et al., 1989). Similarly, a forest stream treated with permethrin, a pyrethroid insecticide, to determine the response of brook trout found that the treatment resulted in massive invertebrate drift and significant reduction of benthos fauna, but did not produce any trout mortality or evidence of unusual behavior

(Kreytzweiser, 1990). A study conducted by Brodtmann (1976) on the level of OC pesticide in raw water samples on a weekly basis detected residues of eight pesticides (including heptachlor epoxide and DDD) throughout the season near an agricultural field with massive pesticide use. Heptachlor epoxide were detected highest during the late spring and summer, reflecting seasonal use (Hills, 1978).

In connection with pesticide impact on aquatic insects under laboratory conditions, lower concentrations of pesticides like 2-Methyl-4-Chloro phenoxyacetic acid (MCPA), dichloroprop, and atrazine in water were reported not to produce any acute effects on the macroinvertebrate fauna. In similar experiment increase in drift response, were expected to cause long term effects in the field (Baekken et al, 1991). Well developed detoxification enzyme systems in aquatic insects have been reported to contribute to higher sensitivity of aquatic insects with regard to insecticide susceptibility (Siegfried et al., 1993) . Moreover, simple pesticides containing metals and metalloids have also been reported to leave permanent residues with toxicological properties. Like other pollutants, generally streams, rivers, ditches, canals, ponds and lakes serve as sinks for their residues (Heckmen,1990). These sediments are likely to become highly contaminated after the metal and metalloid based pesticide have been used for several years. The spray of a mercurial fungicide, emission 6, was found to cause changes in the brain monoamine levels and the monoamine oxidase activity in the catfish *Claris batrachus*. This has been explained to be similar to that observed in mammals displaying neurotoxicological effects of mercury (Chang, 1977) .

To minimize the accumulation of persistent pesticide, second generation pesticides i.e. organophosphorous pesticides were recommended. These substances are said to decompose very shortly after application. The rate of decomposition was found to vary according to temperature in surface and ground water, suggesting hydrolysis is the main mode of degradation (Frank et al., 1991). The initial breakdown products of organophosphorous pesticides are reportedly almost completely unknown (Heckman, 1993). These group of insecticides act by blocking the nervous system of animals (Heckman, 1993). Among the organophosphorous, parathion has proven to be the most dangerous to humans (Mellanby, 1977). Still this pesticide is reported to be in use in Thailand (Putprichapong,1992). Of the insect fauna, water bugs were reported to be acutely affected, floating to the water surface almost immediately when exposed to 0.005 ppm parathion in a fish pond (Gasth, 1978).). In another experiment, the effect of an organophosphorous insecticide, abate CE200, demonstrated to have serious effect on non target benthic fauna like Odonata, Gomphidae, and Libullidae (Samman et al, 1978). The impact arising from use of pyrethroid have been explained as behavioral and physiological manifestation of poisoning leading to hyperexitation leading to loss of coordination, convulsions, and death (Hassall, 1982).

The group of pesticides, such as carbaryl, are suspected of having carcinogenic, mutagenic, and teratogenic effects to at least to some mammals (I.O.C.U. 1984). These are thought to kill animals by inhibiting acetylcholinesterase, especially in the thoracic ganglion (Heckman,1993). Therefore, measures of stress to the benthic community due to chemicals have been recommended to measure directly using drift index as demonstrated in various experiments. The group of bottom dwelling macroinvertebrate using drift as their characteristic feature has been used as a measure to test residues in portable water. No detection of organophosphate and carbamates have been made on the sediment (Spear, 1991).

Fungicides, especially with copper or mercury as active ingredients is widely used in agricultural practice. In situ, experimental study of the evolution and recolonization of polluted sediment, showed that the different metal content in the module sediment were one of the factors delaying recolonization of benthic communities (Arnoux et al. 1985). Some freshwater organisms are described to be tolerant of pollution as they accumulate significant quantities of metals in their body as demonstrated in some larvae of Tricopteran like P. Conpersa (Hopkin,1993) . According to Hopkin (1993) most recent research have been directed towards developing in situ bioassays for the recognition for detecting sublethal effects at organisms level. Maughan (1993) describes the analysis of benthic communities to be the biological equivalent of bulk chemical testing of sediment as the community characteristics are comparable in relation to the factors that could account in variation and the influence of sediment quality, particularly the concentration of contaminants. In connection with contaminants in sediment benthic invertebrates from different taxonomic groups including insect have been used for testing freshwater sediment on comparative work basis (Reynoldson et al., 1992).

2. 5 Trends of pesticide consumption in Thailand

The types of agricultural chemicals used in the highlands of northern Thailand can be divided into 3 groups.

1. Insecticides: There are 42 types of insecticides used by hilltribes. The five important were Ambush, Tamaron, Lannate, Furadan and Folidon.
2. Fungicides: There are 24 types of fungicides used by them. The five important were Cupravit, Benlate, Antracol and Dithane M-45.
3. Herbicides: There are 3 types of herbicides used viz. Grammoxone, Round-up and Spark.

The department of toxic substances division of Thailand has reported about traces of many pesticides including Dieldrin, DDT, carbofuran, and 2,4-dichlorophenoxy acetic acid (2,4-D) contamination in almost all samples of dead fish collected during the massive fish kill in the waterways of the 71 provinces of the country (Titayavan, 1993). The use of organochlorine pesticide in Thailand can be reflected from the figures that it imported 2.9 % active ingredients of OC pesticide, of the total pesticides imported in the country in 1990 (Sinhaseni et al. 1992). Heckmen, (1993) reports about massive fish killing that occurred in the rice field of northeastern Thailand due to introduction of modern agricultural chemicals .