CHAPTER 3

EROSION AND FILTRATION

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3.1 FILTRATION BY THE TRANSITION ZONE

The transition zones (mainly the supralittoral and littoral zones) have been shown to remove organic and inorganic material from water that flows through them. They have several attributes which influence the chemicals (natural or artificial) that flows through them (Sather and Smith, 1984). This effect is most pronounced for particulate matter, which is removed almost completely in the transition zone, provided that the zone is sufficiently large and kept under natural conditions. The importance of the transition zone, reducing the amount of suspended matter carrying nutrients or toxic substances reaching the open water (the limnetic zone), is obvious.

Erosion is the transport and disintegration of soil. An area with high erosion will imply a high load of particulate matter to adjacent aquatic ecosystems.

The amount of particulate matter entering the transition zone by erosion is dependent on a number of factors:

- slope of the surrounding land (**land morphology**);
- **soil characteristics** particularly its composition and particle size distribution;
- amount and distribution of precipitation (**climatic conditions**);
- **land vegetation;**
- **land use** including agricultural and industrial activities. Road building is likely to have major effect on lakes, especially if care is not taken to reduce erosion;
- **water utilization and management.**

The chemical composition of particulate matter entering the transition zone by erosion is also dependent on a number of factors. The most important of these factors are:

- **climatic conditions;**
- **soil characteristic** particularly its composition and particle size distribution;
- **land vegetation,**
- **population density** of the area;
- land use including **agricultural and industrial activities;**
- **traffic intensity;**
- **local environmental legislation.**

The filtration of the suspended matter imply that the nutrients, biodegradable and toxic matter are adsorbed on its surface and thus remain in the transition zone. The fate of this material is discussed in section 3.3. and in the next chapter on the water quality aspects of shore management. The next section 3.2. will present the possibilities for quantifying the input of particulate matter to the shore zone.

3.2. QUANTIFICATION OF EMISSIONS TO THE TRANSITION ZONE

Table 3.1 gives an estimation of the nutrient input to lakes from non-point sources. It has been estimated by Lewis et al (1984) that 20-50% of the nitrogen input and 30-90% of the phosphorus input is carried by particulate matter. Is has been suggested that almost all the particulate matter accumulates in the shore zone, provided that the lake posesses a proper supralittoral and littoral zone with vegetation of macrophytes. Exceptions may be found where major tributaries enter the lake at high flow rates.

TABLE 3.1.
Sources of nutrients

Export scheme of phosphorus E_P and nitrogen E_N (mg m^{-2} y^{-1}) 1)

Land use	E_P Geological classification Igneous	Sedimentary	E_N Geological classification Igneous	Sedimantary
Forest runoff				
Range	0.7 - 9	7 - 18	130 - 300	150 - 500
Mean	4.7	11.7	200	340
Forest + pasture				
Range	6 - 16	11 - 37	200 - 600	300 - 800
Mean	10.2	23.3	400	600
Agricultural areas				
Citrus	18		2240	
Pasture	15-75		100 - 850	
Cropland	22 - 100		500 - 1200	

The figures are based on an interpretation of the following references: Dillon and Kirchner (1975), Lønholt (1973) and (1976), Vollenweider (1968) and Loehr (1974).

These figures are representative and should only be applied if other, more accurate, estimations are not available. In the case of pronounced erosion in the area, it is not possible to use the figures in Table 3.1, rather the modelling approaches mentioned and refered to in chapter 8 should be used as better estimation methods.

Another approach to the estimation of the transport to the littoral zone is proposed and applied by Lewis and Grant (1979). It relates the annual precipitation to the annual transport of particulate matter from the watershed to the transition zone:

$$L = a^* P^b \qquad (3.1)$$

where L is the load calculated for instance as mg per m^2 and year, and P is the precipitation in mm or in liter per same unit of area as L (m^2), while a and b are constants. A regression analysis between L and P shows generally an excellent fit for data from the same watershed, but the problem is to find a and b for a watershed when there is limited data available. The same relationship is valid for particulate matter, nitrogen, phosphorus, heavy metals and toxic organics, but of course varying for a and b. Table 3.2 gives some a and b values found in various case studies. (Lewis et al., 1984)

TABLE 3.2.
Values of a and b in equation (3.1)

L in mg/m^2*y and P in mm/y

Case	Component	a	b
Background Undisturbed area	P	0.000782	1.37
	N	0.0841	1.15
Residential on sewer	P	0.00400	1.22
	N	0.308	1.10
Urban on sewer	P	0.00842	1.29
	N	0.783	1.10
Residential areas on septic tanks	P	3.44	0.759
	N	0.705	1.00
Interstate highways	P	0.00209	1.799
	N	1.71	1.13
Agricultural land	P	0.000716	1.725
	N	0.0954	1.29
Medium intensity	Pesticides (totally)	0.0000073	1.824
Industrial area	P	0.000553	1.54
	N	0.0843	1.26
	Heavy metals	0.0000089	1.76
Agricultural land High intensity	P	0.00125	1.682
	N	0.181	1.28
	Pesticides	0.0000523	1.795

If a few or no data are available it may be possible to use the values for a and b shown in this table, taking the nearest example to the case study under consideration. The factors mentioned in section 3.1. are in this context of great importance and the following list should be considered in addition to the values in Table 3.2 when estimating a and b:

- Increased application of intensive agriculture will result in an increase in the values of a and b for particulate matter, nitrogen, phosphorus and pesticides. A loss 0.2 - 5% of the pesticides applied or 1- 500 g/ha*year is generally recorded from agricultural areas (Jørgensen et al 1990).
- Increased industrial activity means an increased a-value for heavy metals and toxic organics.

- Both a and b will increase rapidly with high slopes in the surrounding area.
- Tropical climate will imply an increased value of b due to the occurrence of heavy rainfalls.
- Heavy metals and pesticides have a very high adsorption affinity to soil, particularly when it is rich in humus and/or clay. If sand comprises less than 50% of the soil then more than 98% and in many cases as much as 99.9% of heavy metals and pesticides will be adsorped in the soil particles (Jørgensen et al 1990).

TABLE 3.3.
Acculumation of heavy metals in plants in macrophytes. Simpson et al., 1983.

		June	July	September	November (as litter)
Biomass	g/m^2	200	725	500	725
N	g/m^2	6.0	15.1	11.5	9.4
P	g/m^2	0.45	0.95	0.60	0.90
Cd	mg/m^2	0.52	0.81	0.72	1.72
Zn	mg/m^2	55	53	53	270
Pb	mg/m^2	4	10	16	118

3.3 FATE OF THE PARTICULATE MATTER IN THE TRANSITION ZONE

Most of the particulate matter entering the littoral zone will settle there, except during very heavy rainfall events. Fig. 3.1 gives an overview of the possibilities for further transformation of this material.

Organic biodegradable matter, in general, is easily decomposed as the bacterial biomass in the littoral zone. In a 5 cm layer as much as 0.4 - 65 g of bacterial biomass per m^2 may be found (Ulehlova 1978). The high content of organic matter in the littoral zone implies that it is often anaerobic and denitrification occurs. A denitrification rate as high as 2727 kg /ha*y has been measured in a reed swamp adjacent to a lake (Jørgensen et al 1988). The nutrients carried by the particulate matter will fertilize the littoral zone and it is often rich in macrophytes and algae. It is possible to remove the nutrients from the zone by harvesting the macrophytes. Kurata and

Satouchi (1989) and Kurata and Vira (1986) have estimated the harvest of *Phragmites communis* from a lagoon adjacent to Lake Biwa will imply a removal of 36.6 g nitrogen and 4.3 g phosphorus per m^2.

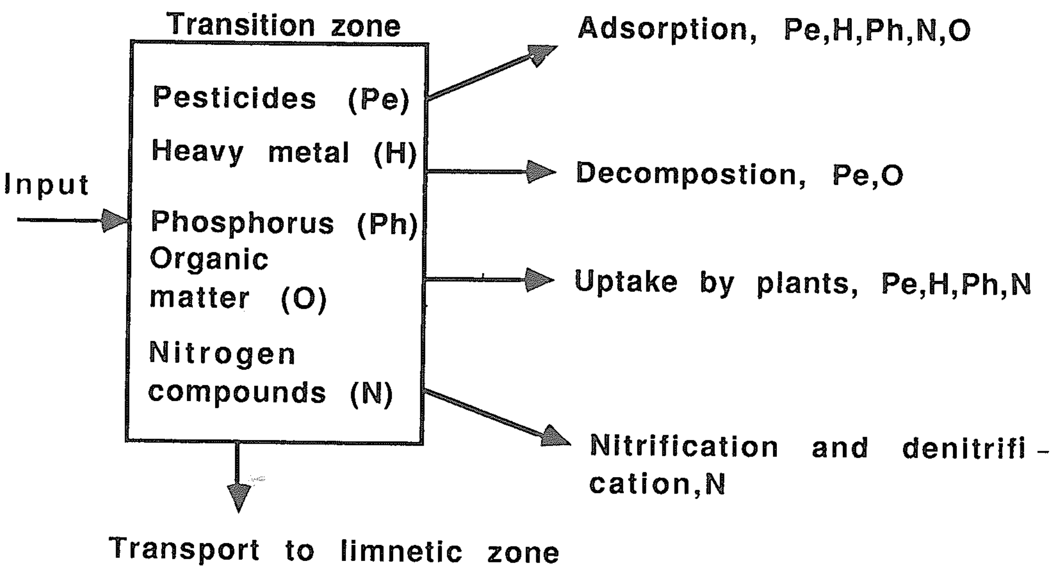

Fig. 3.1. Processes in the transformation zone.

Pesticides carried by the particulate matter to the littoral zone will accumulate in the sediment and slowly decompose through bacterial activity in accordance with the biodegradability of the pesticides. The biological half life of pesticides is significantly lower in the mud of the littoral zone than in soil. Pesticides may accumulate in the macrophytes - especially the more water soluble types.

Heavy metals are adsorbed in the mud in the littoral zone. However, the minor amount of heavy metal solutions in the interstitial water could accumulate in the plant biomass, as demonstrated in Table 3.3.

The role of the shore area for lake water quality is discussed in the next chapter in detail.

3.4 CONCLUSIONS

The transition zone between a lake and its surroundings serves as a filter for particulate matter. The amount of particulate matter entering the lake is highly dependent on the management of the lake environment. Every decision which results in an alteration in the land uses of the watershed may change the emissions from the land to the lake and thereby influence the water quality of the lake. Fortunately, the transition zone will accumulate most of the particulate matter coming from non-point sources and the nutrients, biodegradable organic matter, heavy metals and toxic organics carried by the particualte matter will therefore not reach the limnetic zone and thereby not effect to the same extent the water quality of the lake. This emphasizes the importance of conserving the transition zone and the need for proper shore management. It is however equally important to reduce erosion and other sources of particulate matter inputs to the lake. Although the particulate matter is better handled in the transition zone, the protective ability of this zone is limited. These problems will be discussed further in Chapters 8 and 9.

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