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Nitrogen content of suspended matter in the Kam Tin River, Hong Kong

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Abstract There is little information about the physical and chemical properties of suspended matter in the streams and rivers of Hong Kong. Observations have been made in the Kam Tin drainage basin of the nitrogen content of suspended matter near the settlement of Kam Tin in the developed lowland area of the basin. The median %N of the suspended matter was 4.27 (n = 53) and 1.7 (n = 58) for stable flow and storm flow samples, respectively. Two small upland streams have been sampled and they afford an interesting contrast to the lowland site. At the KARC stream, where secondary woodland dominates, stable flow and storm flow sediment samples have median %N values of 1.01 (n = 49) and 0.97 (n = 154), respectively. A second small undisturbed upland stream (RDH) has a storm period median %N value of 0.61 for suspended matter where n = 38. The data show evidence of spatial variation in the nitrogen content of suspended matter in the Kam Tin basin and enrichment compared to soil and regolith materials. Comparison of N in suspended matter to fresh leaves reveals depletion of N in suspended sediment with the exception of samples collected under stable flow conditions at Kam Tin.

Key words enrichment; Kam Tin basin, Hong Kong; nitrogen; suspended matter

INTRODUCTION

Traditionally suspended sediment has been regarded as a physical pollutant in the riverine environment (e.g. Guy & Ferguson, 1970) and it has been recognized that it may be an important control upon geomorphological and biological processes. For example, Ongley (1996) highlights the impact of sediment on turbidity that affects the penetration of sunlight into the water. This may reduce food chain production and limit, or prohibit the growth of algae and aquatic plants. Other researchers who note the impact upon aquatic ecology include Shiel & Walker (1984) and Walling & Webb (1992).

It is now well established that, in addition to its physical effects, suspended sediment plays an important role in the transport and biogeochemical cycling of nutrients and other contaminants in the aquatic system (e.g. Ongley *et al.*, 1981; Kronvang, 1992; Gao *et al.*, 2003). The importance of particulate elemental transfer is well evidence by Meybeck (1982) who reported that particulate phosphorus represents 95% of P transported by rivers whilst 55% of river-borne nitrogen is associated with particulates.

Whilst observations on suspended sediment transport and loads in the streams and rivers of Hong Kong have been undertaken (e.g. Lam, 1978) with expansion to include sedimentation (e.g. Port Works Division, 1988), relatively few observations have been made on the physical and chemical properties of suspended matter. However, Dudgeon (1984) and Peart (1993, 2003) provide some information on the physical and chemical properties of suspended sediment. This lack of observation in Hong Kong is paralleled in the rivers of South China with the work of Gao *et al.* (2002, 2003) being a notable exception.

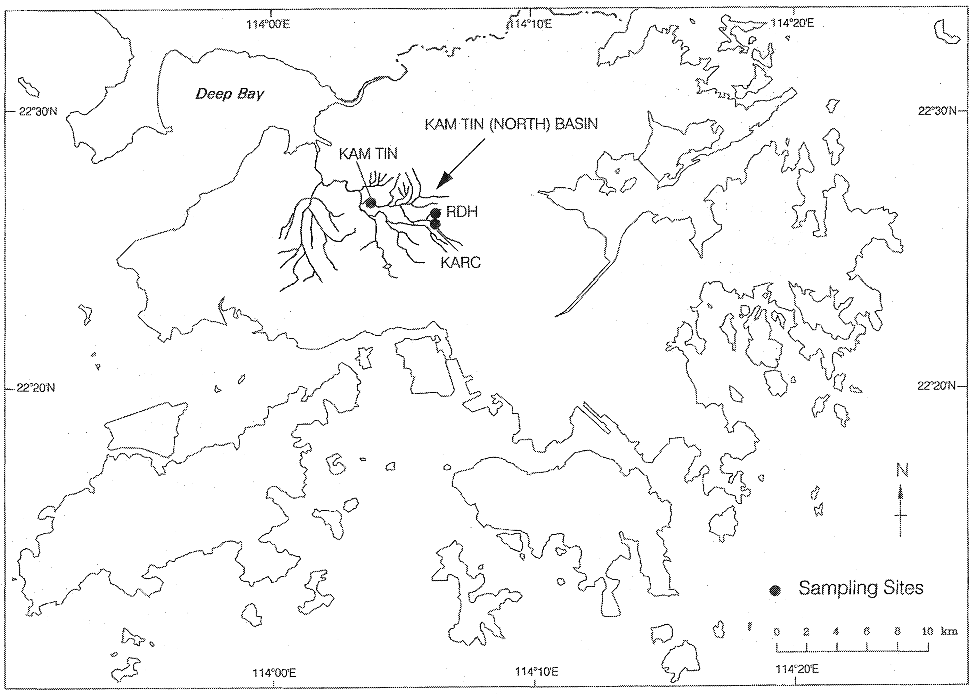

Fig. 1 Location of the sampling sites.

STUDY BASIN AND METHODS

The Kam Tin basin is located in the North West New Territories and it drains the slopes of Kai Keung Leng, Tai To Yan and the western slopes of Tai Mo Shan. The solid geology of the basin is dominated by granodiorite along with volcanic rocks of Mesozoic age. Topographically the basin consists of steep uplands and a contrasting lowland alluvial plain. The steep upland slopes are well vegetated with grass, fern, scrublands and woodland. Agriculture has dominated the lowland plain and remains important. However, an increasing area is occupied by housing (high and low density), open storage and some light industrial uses. Most of the houses and other buildings are not connected to a public sewer system. Near Kam Tin, at the now defunct Water Supplies Department gauging station, the basin has an area of 11.75 km^2. A flood improvement scheme involving the training of some lowland sections of the river has been undertaken.

The drainage system consists of two main branches, the Kam Tin (north) and Kam Tin (south) systems which meet near Yuen Long and ultimately discharge westwards into Deep Bay. A sampling programme was undertaken to monitor the nitrogen (N) content of suspended matter at three points in the drainage basin (Fig. 1), one of which is in the developed lowlands on the Kam Tin (North) River near the settlement of Kam Tin. Two sampling sites were established in the undisturbed uplands. The first site is a small (around 0.1 km^2), steep basin with a predominantly woodland and tall scrub vegetation cover at the Kadoorie Agricultural Research Centre (KARC). The second is a small and steep catchment, but with a grass/fern/low shrub vegetative cover, called RDH. This small stream may become dry in the winter whilst that at KARC always has water present.

Only the Kam Tin and KARC sites were been sampled under steady flow conditions; large volume water samples were collected due to the generally low suspended sediment concentrations that occur under such flow conditions. At all three sites storm-period sampling was undertaken using sample volumes of 400 ml or more with volume dependent upon prevailing sediment concentration. At Kam Tin, most samples were collected during the period 1998 to 2000. Sampling of sediment quality began at KARC and RDH in 1998. For the RDH basin most samples have been collected since 2001. The suspended sediment was separated by filtration using GF/C filter papers that were not pre-ignited because they are composed of 100% borosilicate and are binder free. The filter papers were air dried and the sediment disaggregated before analysis. Suspended matter was not pre-treated to remove carbonates prior to analysis.

Soil samples were collected to allow comparisons with the suspended matter. Samples were obtained from four landslide scars, one of which was just below the outlet of the KARC basin, and the other three being in the headwaters and adjacent slopes of the RDH basin. Landslide scars were sampled because they afford a convenient means to sample the full range of soil and regolith materials. Samples were collected so as to represent the organic A horizon, with sampling typically being of the top 0–20 cm. Material from deeper down the profile was collected to represent sub-soil/regolith materials. The landslides were typical of those in the uplands of Hong Kong being quite shallow. Fresh leaf material from a number of shrub and tree species was also collected during both summer and winter seasons from the KARC drainage basin. A total of 10 alluvial channel bank material samples were collected from two active meander bends on the Kam Tin River just above the settlement of Kam Tin. The soil, regolith, channel bank material and leaves were returned to the laboratory where they were air dried prior to analysis. All samples were passed through a 250 micron sieve before analysis. Total N, along with total carbon (C) was determined on the suspended sediment, soil, regolith, channel bank and leaf material using a Perkin Elmer 2400 elemental analyser. All values are the means of at least two samples.

During the period 1961–1990 Hong Kong had an average annual rainfall of 2214.3 mm of which over 80% fell in the period from April to September inclusive. A rain gauge located in the Kam Tin basin at the KARC recorded an average annual rainfall of 2747.5 mm for 1998–2001 inclusive, of which 87% fell in the summer wet season. Runoff is similarly concentrated in the wet season. For the period 1961–1990 mean monthly air temperature peaked in July at 28.8°C with the minimum occurring in January at 15.8°C.

RESULTS

Table 1 presents mean and median values for total N, along with mean values for total C and their weight ratio for the three study sites in the Kam Tin drainage basin. The presence of N in the suspended matter, and therefore, its transport in particulate form is shown in Table 1. Median %N values range from 1.01 to 4.27 under stable runoff and 0.61 to 1.70 during storm flow conditions. At the two stations for which both storm and stable flow samples are available (Kam Tin and KARC) the N content of suspended matter is lowest under storm flow runoff although this contrast is most pronounced at Kam Tin. Some evidence of a relationship between sample location and N content in the suspended matter can be detected. For example, under stable flow conditions the suspended matter N content is highest at the lowland site with the mean %N value being ~4 times that of the upland KARC site. Under storm flow conditions, the highest mean nitrogen content is again exhibited at the downstream lowland site, with %N content at Kam Tin being 2.0 and 3.2 times that for the KARC and RDH basins respectively. Table 1 also shows considerable variability of N content in suspended matter under storm flow runoff conditions at all sites, with coefficients of variation ranging from 50 to 101%. In contrast, under stable flow conditions the downstream site at Kam Tin exhibits a comparatively low coefficient of variation for N content of 18.5%. However, in the upland stream at KARC much more variability is apparent under stable runoff conditions.

The mean C content of suspended matter ranges from 12.6 to 31.8% under stable runoff, and from 6.95 to 13.9% during storm flow. A pronounced spatial contrast exists under stable runoff but is less apparent under storm flow conditions, with the lowland site at Kam Tin always exhibiting the highest amount of C in the suspended solids.

Tables 2 and 3 present data on N, C, and their ratio, for the potential source materials of the suspended sediment in the study basin. Soil and regolith materials are characterized by Table 2 whilst a range of plant leaf materials are presented in Table 3. Comparison of the data in Tables 1 and 2 reveals considerable enrichment of the suspended matter at both lowland and upland sites in comparison to soil and subsoil/regolith samples. For example, a comparison of suspended matter collected during storm flow conditions to topsoil material

Table 1 N, C and C/N ratio of suspended matter at the sampling sites.

Site	Hydrological sample	Size	Median N (%)	Mean N (%)	Coeff. variation N (%)	Mean C (%)	Mean C/N ratio
Kam Tin	Stable flow	4.27	4.22	18.5	31.83	7.62	53
	Storm flow	1.70	1.94	65.5	13.90	7.32	58
KARC	Stable flow	1.01	1.05	96.2	12.60	12.36	49
	Storm flow	0.97	0.96	101.0	12.65	13.21	154
RDH	Storm flow	0.61	0.60	50.0	6.95	11.5	38

Table 2 Soil/regolith sample N, C and C/N ratio.

	Median N(%)	Mean N (%)	Mean C (%)	Mean C/N ratio	Sample size *n*
Topsoil	0.2	0.24	2.86	13.05	9
Subsoil regolith	0.02	0.05	0.34	15.95	11

Table 3 Mean N, C and C/N ratios for fresh leaves.

Vegetation type	Species	N (%)	C (%)	C/N	Sample size *n*
Tree	*Bridelia monoica*	3.03	44.76	14.81	6
	Helicia cochinchinensis	1.73	41.33	23.87	5
	Stereulia nobilis	2.33	43.63	19.58	4
	Hibiscus tiliaceus	2.31	42.97	18.74	5
	Psychotria rubra	2.40	43.99	18.81	4
Average for all samples		2.39			
Shrub	*Rhodymyrtus tomentosa*	1.66	47.64	30.72	4
	Litsea rotundifolia	2.43	47.07	20.41	4
Average for all samples		2.05			

using mean values reveals enrichment ratios for N of 8.1, 4.0 and 2.5 for Kam Tin, KARC and RDH respectively. The equivalent storm flow enrichment ratios for N using subsoil/regolith samples as source materials are 38.8, 19.2 and 12 respectively for Kam Tin, KARC and RDH. Table 3 reveals that the leaf material has N contents that are rather higher than those observed in the suspended matter collected under storm flow conditions, especially for the two upland sites. Using a mean N content of fresh leaf matter from trees gives N enrichment ratios at the Kam Tin, KARC and RDH sites of 0.81, 0.40 and 0.25, respectively, for storm-period samples, whilst shrubs give enrichment ratios of 0.95, 0.47 and 0.29. These values of less than 1 indicate a loss of N in suspended matter compared to the source materials. Comparison of tree and shrub leaf materials under stable runoff conditions to the suspended matter reveals a contrast between the upland site (KARC) and the lowland sampling station, with the former evidence of depletion of N whilst the latter exhibits considerable enrichment (enrichment ratios = 1.77 and 2.05 for tree and shrub leaf materials, respectively). In terms of channel bank material, analysis identified two types of sample, those containing no N and those with only a small amount, ranging from 0.06 to 0.08% N. Considerable enrichment occurs in the suspended matter of the Kam Tin River as documented in Table 1, in comparison to channel margin sediments.

DISCUSSION

The data presented in Table 1 confirms the presence of N in the suspended matter of the Kam Tin drainage basin. This recognition may be timely given the recent occurrence of red tides in Hong Kong coastal waters (e.g. Hodgkiss & Ho, 1997) and the release of nutrients from sediment documented by Hu *et al.* (2001). The mean particulate organic nitrogen (PON) content of suspended matter was reported by Meybeck (1982) as typically between 0.1 and 1.3%. The values for the two upland sites are within this range but the downstream site, Kam Tin, exceeds these values, especially under stable runoff conditions. Meybeck (1982) cites the Sopchoppy River in the USA as having a PON value of 4.04% and suggests that in that river organic material constitutes much of the suspended matter. Interestingly, Table 1 indicates that the Kam Tin River has a much higher C level in comparison to the upland KARC site under stable runoff conditions and this might help account for the high N levels downstream at Kam Tin. As noted in the previous section, spatial variation of N occurs in the Kam Tin River basin. Few other researchers have observed the spatial variation of N in suspended matter in a single drainage system.

Comparison of the fresh leaf material to the suspended matter is also instructive in that it reveals that, at the upland sites (KARC and RDH), and at Kam Tin under storm flow conditions, the suspended matter contains less N than the potential source material, be it trees or shrubs. This suggests that if the ultimate source of the N is allochthonous organic matter, which Dudgeon (1983) revealed to be important in some streams in Hong Kong, it must have undergone some decomposition. The lower C/N ratios of the suspended matter, and the much decreased C content, relative to the fresh leaf material, are also suggestive of this. Decomposition of leaf material in streams and rivers is widely reported in the literature (e.g. Lopez *et al.*, 2001). The enrichment of N in the suspended matter at the Kam Tin sampling station under stable flow conditions, coupled with its mean C/N ratio of around 7.6 is suggestive of very different influences at this site under these flow conditions. Olley (2002) suggests that a C/N ratio of 5–6 may be indicative of algae or phyto plankton and this may be relevant to the Kam Tin site, especially under stable runoff. The lowering of the percentage C and N in the suspended matter at the Kam Tin site during storm events may reflect an input from channel bank materials and such a process has been observed in the field.

The enrichment of suspended sediment in comparison to potential source material, such as soil and regolith, has not been reported previously for Hong Kong. The enrichment reported for the study basin shows evidence of spatial variation with the greatest enrichment being associated with the lowland Kam Tin site. A number of investigators have, however, reported that eroded sediments are enriched in N as compared to the soils from which they are derived (e.g. Johansen *et al.*, 2001; Avnimelech & McHenry, 1984). It should be noted, however, that erosion processes are very scale dependent (e.g. Walling, 1983; Johansen *et al.*, 2001) and, therefore, comparison between studies is difficult and the contrast between the small upstream basins and the larger downstream station may reflect the size of the drainage basins. There may also be a need to consider the lowland agricultural soils, for the data in Table 2 refers to undisturbed upland soils. Nevertheless, it is important to recognize that suspended matter may be enriched in N in comparison to soil/regolith source materials for this indicates selective erosion and transportation which may give rise to degraded soils. Peart (1993) mentions the possibility of selective erosion in Hong Kong.

CONCLUSION

N has been shown to be present in the suspended matter at three sampling stations in the Kam Tin drainage basin. Evidence of spatial variation has been presented. The presence of N in suspended matter indicates that water quality monitoring in Hong Kong may need to consider this aspect, and that N export in particulate matter may need to be considered in studies of soil degradation.

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