

Development and water quality in the Kam Tin basin, Hong Kong

MERVYN PEART

Department of Geography, University of Hong Kong, Pokfulam Road, Hong Kong

Abstract The economic development of Hong Kong has meant that some once rural areas have been transformed. They have become characterized by low-density housing, open storage and makeshift factories, in addition to agriculture. This change in land use may have consequences for water quality especially as many areas are not connected to mains sewerage. In the Kam Tin basin, under baseflow conditions, water samples from the river in the developing lowland are characterized by much higher concentrations of calcium, magnesium, potassium, nitrate-nitrogen and dissolved phosphorus, than an undisturbed upland tributary. The Kam Tin River also has much greater suspended solids concentrations than the upland stream and a significant amount of floating debris and rubbish which is never seen in the upland tributary. More attention needs to be given to sewerage and waste disposal in the basin. Runoff pH appears little influenced by the acid rain input.

INTRODUCTION

Hong Kong has undergone dramatic expansion in terms of population and economic development and is now regarded as a world city. A number of factors have contributed to this growth. For example, the influx of refugees fleeing from China between 1948 and 1951 brought Hong Kong labour, capital and entrepreneurial skills. Similarly, from the 1980s the open door policy of China provided a further impetus.

This population growth and economic expansion has not, however, been achieved without cost. Industry, port facilities and people all need space. Consequently, once rural areas have become transformed. As the Planning Department (1995, p.50) state "there are already extensive urban fringe areas characterized by proliferations of mixed farming activities, village houses, Spanish style villas, open storage and make-shift factories/go-downs. The result is a highly degraded and disorderly landscape with considerable problems of pollution, traffic congestion and flooding". They add that such areas are now committed to urban use and plans should be made for upgrading.

One such area is the Kam Tin plain in the North West New Territories. As Jim (1997) reports much of the lowlands were given over to agriculture before the 1970s but from this date, the need for housing and urban orientated uses have intruded into the farmlands. This paper examines the spatial variation of water quality in the urbanizing Kam Tin basin, North West New Territories, Hong Kong.

STUDY BASIN AND METHODS

The Kam Tin basin is located in the North West New Territories of Hong Kong and the drainage system has its origin on the western slopes of Tai Mo Shan and flows into

Deep Bay. In terms of physiography the basin has two distinct parts: steep uplands and an alluvial plain. Upland areas are currently well vegetated with grass, shrubs and woodland while the alluvial plains until recently were dominated by agriculture. Kam Tin existed as a community from the Hau Chau period (AD 951–959) and therefore the area has a long history of settlement.

With the development of Hong Kong, agricultural land use has come under pressure (Jim, 1997). An increasing amount of agricultural land has been given over to open storage. There has also been expansion of low density suburban style dwellings. Livestock farming has also declined in the basin due to the introduction of the Water Pollution Control Ordinance of 1980. It led to the creation of Water Quality Objectives, which were applied to this basin from December 1st, 1990. The Waste Disposal (Livestock Waste) Regulations of 1988 are also having an increasing impact, especially with more rigorous enforcement.

Sampling for water quality has taken place in an upland stream and downstream on the alluvial plain; the sites are shown in Fig. 1. The upland basin at the Kadoorie Agricultural Research Centre (KARC) is developed on steep slopes underlain by igneous rocks with a well developed woodland/shrubland vegetation cover. The basin outlet is around 200 m P.D. and there is no settlement in the catchment. Downstream from this site, samples have been collected near Kam Tin at which point the basin has an area of 11.72 km². At this point an alluvial floodplain has formed and there is significant human development of the plain which accounts for around 50% of the

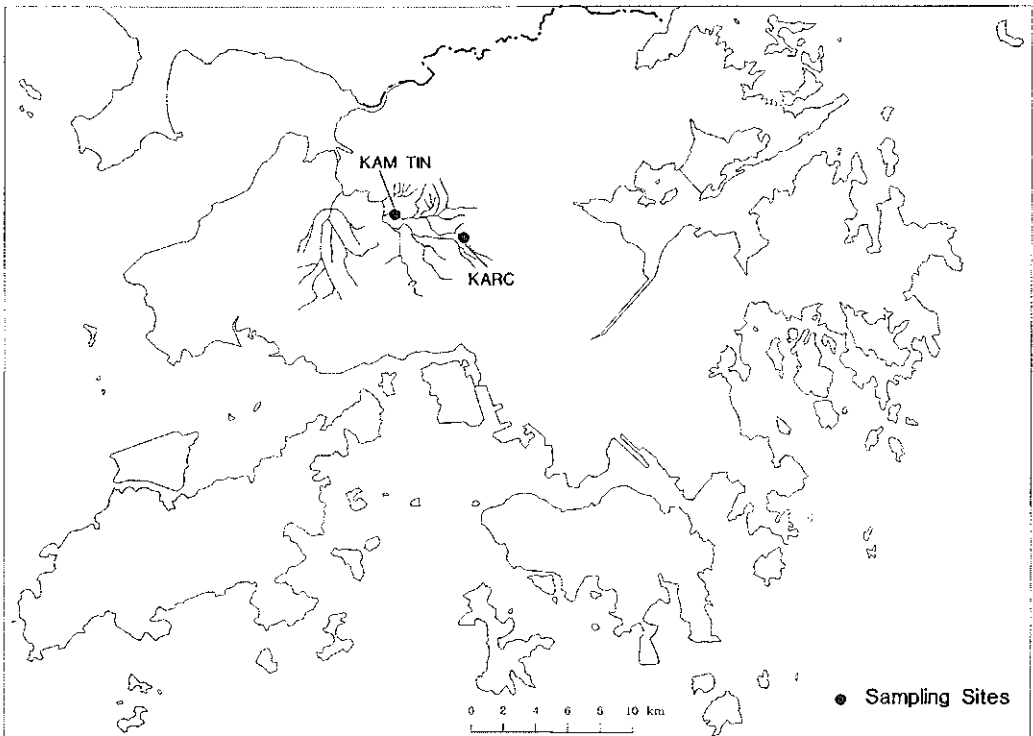


Fig. 1 Location of sampling sites.

basin. There is a population of over 15 000 and settlement of low and high density accounts for around 47% of the land area. A large number of open storage sites have appeared since the 1980s. For example, in the NW New Territories open storage sites increased from 158 in 1984, to 1024 by 1990. Most of the houses and other buildings are not connected to a public sewer system. Wells dug to around 10 m for irrigation near Kam Tin remained in soft alluvial sediments.

A sampling programme has been undertaken to monitor suspended solids, pH, specific electrical conductance, aluminium, magnesium, calcium, potassium and phosphorus at both sites. All samples were collected under baseflow conditions to avoid the complications introduced by rainfall generated storm events. Suspended solids were measured by means of filtration using pre-weighed GFC filter papers. Calcium, magnesium, aluminium, potassium and phosphorus were determined by means of ICP, after filtration through 0.45 μm filter papers. Nitrate-N was determined using an ion selective electrode. Specific electrical conductance was determined using a Schott Gerate meter, while pH was measured using a glass electrode calibrated at pH 7 and 4. Two further observations were made. Rainfall at the upland basin at KARC, was collected daily after rainfall and its pH determined by glass electrode calibrated at pH 7 and 4. Floating debris and rubbish was counted and classified at the Kam Tin site.

RESULTS

The water quality data for the baseflow sampling programme are presented in Table 1. Downstream changes are evident in all determinands except pH which is close to neutral at both sampling sites. Electrical conductance shows the upland stream to be dilute in terms of dissolved material, the mean value at Kam Tin being over 18 times higher than that measured in the headwaters. The individual cations of potassium, calcium, aluminium and magnesium are all present at higher levels downstream. Suspended solids are also greatly enhanced downstream with, for example, a mean concentration of 88.85 mg l^{-1} at Kam Tin compared to only 11.01 mg l^{-1} at KARC. Median values of 54.38 and 8.30 mg l^{-1} upstream and downstream respectively tell a similar story.

It is also of interest to consider rainfall pH monitored at the upland site. The volume weighted average is 4.53 while the median value is pH 4.45. Of the 98 rainfall days in the data set only 8 experienced rainfall pH of 5.6 or greater, amounting to 7.8%

Table 1 Water quality from 1997–1998 in the Kam Tin basin.

Sampling site	pH	Elect. cond. ($\mu\text{S cm}^{-1}$)	K (mg l^{-1})	Ca (mg l^{-1})	Mg (mg l^{-1})	Al (mg l^{-1})	P (mg l^{-1})	NO ₃ (mg l^{-1})	S.S.** (mg l^{-1})
KARC									
Mean	6.74	41.7	0.53	1.85	0.40	0.05	0.21	3.34	11.01
Std. dev.	0.24	5.6	0.25	0.62	0.10	0.02	0.14	2.40	7.56
No. of samples	67	67	63	67	67	67	41	49	57
Kam Tin									
Mean	7.32	757.4	17.92	29.95	1.63	0.10	6.16	10.56	88.85
Std. dev.	0.23	309.3	6.43	6.51	1.00	0.02	3.30	10.55	106.17
No. of samples	91	91	91	91	91	91	80	44	77

S.S.** = suspended solids.

of the sample. Acid rain occurs in the basin but buffering occurs in the hydrological cycle because the stream and river are close to neutral, as evidenced by the mean and median pH at KARC of 6.74 and 6.78. Downstream at Kam Tin, baseflow pH average and median values are 7.32 and 7.37 respectively.

During May 1998, in excess of 8 m³ of floating rubbish and debris accumulated under and against the bridge at Kam Hing Wai, part of the settlement of Kam Tin. This material was washed down during storms in the previous week. Some 897 pieces of debris/rubbish were counted and classified with plastic distilled water bottles of less than 2 l forming the largest category (163 pieces or 18.2%). If other categories of drinks and miscellaneous contents are included this volume of plastic bottle accounted for 31.7% of the samples (284 pieces). The next most common type of debris were polystyrene food containers (107 pieces or 11.9%) followed by drink boxes (84 pieces or 9.4%). Detergent, shampoo and other such containers accounted for 68 pieces or 7.6% of the sample. A wide range of other rubbish was recorded and included tin cans, motor oil containers, glass bottles and jars, plastic pots and jars, plastic bags, flip-flops, light bulbs, wood, aerosol cans and basket-balls. Large debris not included in the count were car tyres and wheels, a 100 gallon oil drum, several 20 litre drums, wood pallets, 14 cupboard draws, and a small polystyrene surf board. Surveys of counts of debris moving down the river during subsequent storm events revealed the above findings to be not unusual. For example, in the storm of 9 June 1998 during a 15 minute counting period, 42 pieces of rubbish/debris were counted. Polystyrene accounted for 21.4%, plastic bottles of less than 2 l, 16.7% of the sample. Plastic materials accounted for a further 14.3% while tin cans were 4.8% of the sample.

For comparison purposes results of a survey from the 1993–1994 water year carried out under baseflow conditions are presented (Peart & Jayawardena, 1996). The data in Table 2 support the upstream–downstream contrast in water quality with suspended solids, nitrate nitrogen, sodium, potassium, calcium and magnesium all being present in higher levels at Kam Tin.

DISCUSSION

Calcium and magnesium are present in much higher levels downstream at Kam Tin than in the upland basin both in the 1993–1994 survey and the current study while

Table 2 Water quality from 1993 to 1994.

Sampling site	pH	Elect. cond. (µS cm ⁻¹)	K (mg l ⁻¹)	Na (mg l ⁻¹)	Ca (mg l ⁻¹)	Mg (mg l ⁻¹)	NO ₃ (mg l ⁻¹)	S.S.* (mg l ⁻¹)
KARC								
Mean	6.61	34.5	0.43	3.47	0.31	0.19	1.30	4.3
Std. dev.	0.15	6.0	0.23	0.63	0.17	0.08	0.92	3.6
No. of samples	100	100	98	99	99	99	83	67
Kam Tin								
Mean	6.82	463.1	15.7	17.0	9.7	4.0	13.8	80.6
Std. dev.	0.15	245.6	9.9	7.4	5.6	3.0	16.3	98
No. of samples	101	101	9.5	95	95	95	66	77

* S.S. = suspended solids.

sodium included in the 1993–1994 survey only is higher at Kam Tin. Lam (1983) indicates that agricultural waste and domestic sewage typically have large amounts of sodium, magnesium and calcium. He also states that when carbon dioxide charged waters low in dissolved solids encounter silicate minerals, cations and silica may be leached. Where alluvium is derived from granites or acid volcanics, he suggests the cations released to the water are predominantly sodium and calcium with smaller amounts of magnesium and potassium. Soil water or groundwater seepage from the alluvium to the river may also explain the higher cation levels at Kam Tin. Aluminium levels are also enhanced downstream. This might reflect greater weathering input or point source pollution such as open storage sites.

Suspended solids concentrations are much higher at Kam Tin. Under baseflow conditions these are unlikely to result from erosion of the alluvial banks of the river. It most likely reflects pollution input from domestic, agricultural and industrial sources. The contribution from this source was evidenced in a survey of the drainage system to identify channel bank erosion in late 1995; it also revealed numerous point source inputs from domestic, industrial and commercial sources. The work of Keung (1984) and Pak (1992) also attest to the importance of these sources, while Jim (1996) points out the potential problem from non-conforming land uses such as open storage. In this basin the water quality objectives include an annual median of $\leq 20 \text{ mg l}^{-1}$ for suspended solids. This study indicates that compliance is still some way off and that the much higher concentrations observed downstream in the 1993–1994 water year continue to exist.

Phosphorus concentrations are much higher downstream. This is at least partly attributable to disposal of domestic wastewater to the river system. It is all too easy to find village houses discharging kitchen sullage water and other waste into the water courses (e.g. Keung, 1984; Pak, 1992; and a survey conducted in autumn/winter of 1995). This state of affairs reflects the lack of a sewerage system for many areas in the basin. Plans are being prepared to upgrade the sewerage system. A further nutrient, nitrate nitrogen is also present in enhanced levels at Kam Tin. This reflects the disposal of pig, poultry and to a lesser extent human waste into the nullahs, streams and rivers. The disposal of livestock waste has been greatly reduced due to legislation and tougher enforcement. A number of farms have ceased operation and many more have installed wastewater treatment facilities. The recent data suggests that problems may still exist, however the Environmental Protection Department (1996) do present some evidence of improvement since they began monitoring in 1984.

Perhaps the clearest evidence of the impact of development upon water quality is provided by the floating rubbish or debris that accumulates against the bridge at the eastern end of Kam Tin and has been observed during storm events. There is a wide variety of debris and the supply seems to be inexhaustible in that storms monitored late in the year were still transporting considerable amounts of rubbish. The river seems to be regarded as a waste disposal system. In a survey of open-storage land use in Kam Tin, Lai using photographs (1996) provided good evidence of the volume of floating rubbish/debris in the water courses in this area. These photographs also provided visual evidence that livestock waste disposal remained a problem. Pak (1992) also provides pictorial evidence of rubbish accumulation in the Kam Tin drainage system and good illustrations of point source inputs.

The variety and amount of rubbish in the river at Kam Tin is disappointing given the availability of refuse disposal points provided by the Regional Council. Clearly if further development is to occur much more thought needs to be given to waste disposal.

The upland stream at KARC contains no floating rubbish/debris; it does transport natural organic debris such as leaves and so forth. It provides a great contrast to the downstream channel.

Table 2 reveals that baseflow water pH in the 1993–1994 survey averaged 6.61 at KARC and 6.82 downstream at Kam Tin. In this current survey the upstream and downstream sites averaged pH 6.74 and 7.32 respectively. Runoff is therefore close to neutral despite the existence of acid rain in the basin as evidence by this study and the fact that in 1993 the volume weighted average pH was 4.3. Furthermore, of the daily rainfall events monitored in 1993, 93% of the 107 samples had a pH equal to or less than 5.6, a result not dissimilar to the current data set. Development in Hong Kong and the region has clearly impacted rainfall which forms an input to an undisturbed area in the upland basin at KARC. It appears that both upland and lowland sections of the basin are able to ameliorate the acid rain input. However this may release aluminium to the surface waters.

CONCLUSION

There are large differences in water quality between an upland undisturbed drainage basin and a downstream monitoring station where development has taken place. Given the inevitability of further development in the area, attention needs to be given to waste disposal. While control measures have reduced input from livestock the disposal of domestic waste needs more attention. Implementation of the Yuen Long and Kam Tin sewerage masterplan proposals may solve some of the problems. However, the significant volumes of rubbish observed in the river do not come under this scheme. Attention needs to be given to improving the collection and disposal of domestic waste.

REFERENCES

- Environmental Protection Department (1996) *River Water Quality in Hong Kong for 1995*. Water Policy and Planning Group, Environmental Protection Department, Hong Kong Government.
- Jim, C. Y. (1996) Proliferation of non-conforming land uses in agricultural envelope of Hong Kong. *Environ. Manage.* 20(4), 461–474.
- Jim, C. Y. (1997) Rural blight and land use planning in Hong Kong. *The Environmentalist* 17, 269–281.
- Keung, M. K. (1984) A study of the quality of groundwater in wells of Yuen Long. BA Dissertation, Department of Geography and Geology, University of Hong Kong, Hong Kong.
- Lai, S. K. (1996) Open storage land-use and environmental impacts in Kam Tin. BA Dissertation, Department of Geography and Geology, University of Hong Kong, Hong Kong.
- Lam, K. C. (1983) *The Chemical Quality and Use of Well Water in the New Territories*. Department of Geography & Geographical Research Centre, The Chinese University of Hong Kong, Occasional Paper no. 44.
- Pak, S. M. (1992) Water pollution resulting from open storages in Pat Heung, Kam Tin. BA Dissertation, Department of Geography and Geology, University of Hong Kong, Hong Kong.
- Planning Department (1995) *A New Development Framework for Hong Kong – A Response to Changes and Challenges. Part Two. The study process and inputs for strategy formulation*. (The Final Technical Report on Territorial Development Strategy Review–1995). Planning Department, Hong Kong Government.
- Peart, M. R. & Jayawardena, A. W. (1996) Water supply and catchment management in Hong Kong. In: *Water Resources and Environmental Research: Towards the 21st Century* (Proc. Int. Conf.), vol. 2, 517–524. Water Research Centre, Kyoto University, Japan.