Estimation of Pollution Load from Houay Mak Hiao Watershed, Vientiane-Laos from GIS and Observed Water Quality Data

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Abstract

Houay Mak Hiao catchment, which has land area 436.91 Km^2, is one of the sub-basins of Mekong River in Vientiane, the capital of Laos. The catchment contributes significant pollution load to Mekong River from point and non-point. The aim of study is to estimate pollution load from the catchment area based on existing GIS data, observed water quality data and various publicly available data. Pollutant load were estimated in terms of T-P, COD and NH_4-N during year 2001-2004.

Keywords: GIS, non-point source pollution, catchment area, runoff, water quality, Mekong River

1. Introduction

Mekong River is an important water resource for the Greater Mekong Sub-region countries. Water quality deterioration of the Mekong River from point and non-point sources of pollution is one of the issues of major concern. Vientiane has no wastewater treatment facilities except for wastewater from toilets that is treated by individual household septic tanks. Therefore wastewater and stormwater runoff are discharged to surface waters and rely mainly on natural purification within surface water systems. The aim of this paper was to estimate pollution load from the Houay Mak Hiao catchment area through checking points A-C (Figure1).

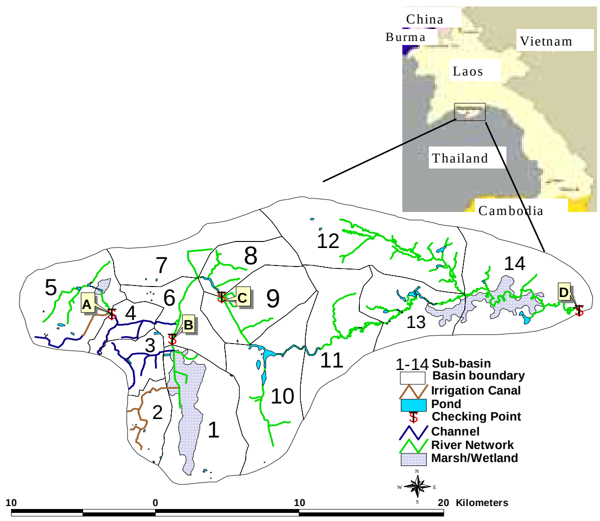

Figure 1. Houay Mak Hiao Watershed

Table 1. Land use Category

	Land use area (ha)				
	Agriculture	Urban	Bush/ Forest	Marsh/ Wetland	Total
Point A	3175	353	166	79	3773
Point B	2126	2338	1697	1237	7398
Point C	12068	3049	2468	1316	18900
Point D	26561	3049	11885	2196	43691
Runoff coefficient	0.23	0.37	0.15	0.70	—

2. Method

The catchment boundary was delineated from existing GIS data using ArcView3.2 software. The basin was divided into 14 sub-basins (1- 14 in Figure1). Table1 shows the land use area draining into each of the four checking points (A-D) calculated using X-tool extension of ArcView3.2 for calculation. Water quality data measured once every month at checking points A, B and C. Daily rainfall data for Vientiane were obtained from the Mekong River Commission (MRC) for 2001-2004. Pollution load was estimated during runoff and base flow through checking point A - C. Runoff volume and pollution load were estimated by following equations:

Runoff = land use area*runoff coefficient*rainfall ……………………..…..…(1)

Pollution load = (Runoff + Base flow)*pollutant concentration ……..…......(2)

Flow data at the checking points are not available. Therefore a filed survey was implemented in the dry season in March 2007 to measure base flow at checking points B and C. The base flow in the dry season is mainly due to domestic wastewater discharge (point source). Base flows at point B and C, respectively, were calculated by Weir Equation (3) and from mean velocity (Equation (4) and (5)) as follow:

Base Flow $= C_w * B * (H)^{3/2}$………………………………………………… ..(3)

Base Flow $= A * V_{mean}$ ………………………………………………..………..(4)

$V_{mean} = K * V_{surface}$ …………………………………………..…………...………...(5)

Equation (3) - (5), Base Flow in (m^3/s), C_w is discharge coefficient of weir (1.84), B is width of weir (m), H is over flow height (m), A is cross section flow area (m^2); V_{mean} is mean velocity (m/s), K is correction coefficient (0.8~0.9 for smooth artificial channel, and 0.67 for stream) and $V_{surface}$ is mean surface velocity (m/s). Flow at checking point A was not measured because of ongoing construction at the time of the field survey. Therefore, a base flow value of 0.07 m^3/s obtained in the previous study (JICA, 1990) was assumed.

3. Result and Discussion

Outline of monthly rainfall were presented in Table 2. The base flow for 2001-2004 were estimated from those calculated from flow data measured in 2007, taking into consideration annual population growth rate of 2.1% as reported by data from The National Statistic Centre (1995-2005). Table 3 shows the results of base flow and runoff calculation from checking point A - D.

Table 2. Monthly Rainfall Data

	Monthly Rainfall (mm)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2001	2	0	77	32	355	178	314	341	277	81	4	0
2002	0	22	25	54	322	288	277	411	279	134	16	17
2003	8	28	74	112	170	385	130	236	297	42	0	0
2004	2	81	2	152	221	287	350	288	238	0	8	0

Table 3. Average Monthly Runoff and Base Flow (2001-2004)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Check point A	Runoff (10^3m3)	30	309	417	825	2510	2675	2520	3000	2566	602	64	39
	Base Flow(10^3m3)	170	154	170	165	170	165	170	165	170	165	170	165
Check point B	Runoff (10^3m3)	78	813	1096	2171	6603	7037	6627	7891	6749	1584	170	103
	Base Flow(10^3m3)	268	242	268	259	268	259	268	259	268	259	268	259
Check point C	Runoff (10^3m3)	164	1707	2301	4557	13862	14773	13914	16567	14169	3326	356	217
	Base Flow(10^3m3)	2119	1914	2119	2050	2119	2050	2119	2050	2119	2050	2119	2050
Check point D	Runoff (10^3m3)	333	3468	4677	9261	28169	30022	28275	33667	28795	6759	723	441
	Base Flow(10^3m3)	1218	1100	1218	1178	1218	1178	1218	1178	1218	1178	1218	1178

Total pollution load from point and non-point were calculated by Equation (2) from checking point A-C during 2001-2004. Pollution load at point D was not calculated because water quality data is not available. The results of calculation presented in Table 4.

Table 4. Average Monthly Pollution Load at Checking Point A-C (2001-2004)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Check point A	T-P (Kg/month)	8	27	19	71	427	485	468	377	129	61	31	25
	COD (Kg/month)	1812	3226	2728	4836	11609	13206	17013	10847	13102	4779	1867	1145
	NH4-N (Kg/month)	46	97	35	2075	778	831	2546	2359	449	398	262	353
Check point B	T-P (Kg/month)	84	367	180	865	3694	1099	756	705	469	108	39	37
	COD (Kg/month)	3667	10054	11869	17365	47682	50000	49808	52556	46203	11747	3800	2851
	NH4-N (Kg/month)	726	2065	1243	7013	6703	2890	14914	4465	2420	1353	754	717
Check point C	T-P (Kg/month)	208	233	335	1812	5430	2541	2598	1382	1180	401	341	145
	COD (Kg/month)	19580	32775	34571	39520	100523	80896	117008	89530	91221	36655	20656	15576
	NH4-N (Kg/month)	1605	1673	688	11333	19801	6754	12227	6696	2354	2946	5217	3180

The climate of study area consists of a dry season (November-April), and a wet season (May-October). Pollution load during dry and wet season were greatly different. The pollution loads for the wet season (L_{wet}) and dry season (L_{dry}) were calculated separately, and pollution load from non-point source in the wet season ($L_{non\text{-}point}$) estimated as $L_{non\text{-}point} = L_{wet} - L_{dry}$. The results are presented in Table 5.

4. Conclusion

This study examined pollution load at checking points A, B and C from 2001-2004. The relative contribution of non-point T-P load in the wet season was relatively higher at point A (91%) than at points B (77%) and C (77%). This was not the case for COD and NH_4-N. This may be explained by the fact that most of the T-P load in non-point source load exists in particulate form. Upstream of point B, there is a marsh in which most of the particulate phosphorus is possibly removed through sedimentation. Therefore, the relative contributions of non-point source load to T-P load at point B and point C that is downstream of point B are lower than at point A. Study on other factors that influence water quality such as natural purification, and estimation of point source load from household domestic wastewater discharge are recommended for further study.

Table 5. Average Pollution Load in Wet and Dry Season (2001-2004)

Point	Season	Pollution Load	T-P (Kg/month)	COD (Kg/month)	NH4-N (Kg/month)
A	Dry	Point Source	30	2602	478
	Wet	Non-point	294	9157	749
		Point and Non-point	325	11759	1227
B	Dry	Point Source	262	8267	2086
	Wet	Non-point	877	34732	3371
		Point and Non-point	1139	42999	5457
C	Dry	Point Source	512	27113	3949
	Wet	Non-point	1743	58859	4514
		Point and Non-point	2255	85972	8463

References

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