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Article

Influence of Land Use on the Pollution Load in the Saemangeum Basin

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The SMG project has been driven to secure food and water resources by closing of the SMG dyke for the preparation of the unification of Korean peninsular. It was investigated for pollution loads, land use distribution and water consumption for environmental assessments in two watersheds, the Mankyeong River (MK) and the Dongjin River (DJ) to assess the role of agricultural land on the alleviation of pollution loads to the SMG basin. It is needed to give the priority in managing pollution sources to conserve freshwater in the Saemangeum (SMG) basin after the completion of the SMG reclamation from tideland. The MK has 700 million m^3 water of which 14.1% were used for living, 73.6% for agriculture and 12.3% for industry. The DJ has 505 million m^3 water of which 3.0% for living, 94.5% for agriculture and 2.5% for industry. As compared to proportion of each land of total area, agricultural land was 1.4 times larger, livestock farming 7 times larger, forest 0.74 times smaller, and built-up area 0.67 times smaller in DJ watershed than in MK watershed.

Pollution sources in MK and DJ watersheds were originated at a higher proportion from population including the sewage disposal and a livestock farming area rather than from the land. Water consumption and land use distribution influenced the water quality of the rivers; DJ watershed had far lower value of electric conductivity, BOD_5, TN and TP than MK watershed. A large proportion of paddy field also influenced to reduce pollute loadings after rainfall; DJ watershed, which has a relatively large area of paddy fields, had a far lower delivery load after rainfall than MK watershed even though DJ watershed had large livestock farming area.

As paddy fields was irrigated by Iksancheon water, 37% of nitrogen, 50% of phosphates and 14.0% of BOD_5 was removed by the paddy field just after flowing 150 meter, and rice plants could remove TN 100.0 kg, P_2O_5 24.0 kg, and K_2O 119.2 kg per hectare at harvest by irrigation of Iksancheon water. Conclusively, rice paddy fields played a positive role to conserve the water quality in the Iksancheon watershed.

Key words : Dongjin River, Land use, Mankyeong River, Paddy fields, Pollution load

Introduction

Surface waters in rivers, streams, lakes, and estuaries are among the first environmental media inducing a widespread attention due to their chemical pollution. This attention was in part due to an extensive public usage of surface waters, as well as to their historical use as waste receptors. Pollution of waters by industrial wastes, livestock wastes, sewage, floating refuse and run off from the land has encouraged scientific and regulatory communities to study and regulate sources and sinks of pollutants. A major goal of such works was to determine acceptable levels of waste loadings to surface waters. Flood control, water utilization, and environments along the river are all related to human life. Therefore, it will be desirable to manage them at a balanced manner. When a river construction project is planned with regards to flood control and water utilization, it should not be an issue of choice between utilization and environment, but be balanced among all the three with the agreement of local residents.

The SMG tidal reclamation project has been developed to reclaim 40,100 ha of tideland since 1991 constructing 28,300 ha of farmland and 11,800 ha of water reservoir. The purpose of the SMG project is to secure food and water resources for the preparation of a drastic deficiency of food and water of the after-unification of Korean peninsular.

Two of nutrients causing the greatest concerns are

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nitrogen and phosphorous, which in high concentrations can lead to large algae blooms in still waters. As the algae die and putrefaction by bacteria causes a severe depletion of dissolved oxygen, and subsequently fish will die. At the moment, water of the MK and the DJ can pass the estuary by tidal flow, and the mixing with seawater can prevent the quality of the water from deteriorating.

DJ flows through a large plain with a relatively little urban area and much agricultural land, therefore the water has little possibility of eutrophication after completion of the dyke. On the while, MK flows through both a plain land with big urban areas such as Jeonju City, Iksan City and Wanju County. Even though water quality of MK has been improved gradually due to Korean governmental policy for the management of point pollution, the concentration of total nitrogen (TN) and total phosphate (TP) is still high in terms of the industrial use.

Therefore, there could be severe contrary opinions on the conservation and the reclamation of tideland based on the water quality of the SMG Lake. After a long debate, Korean government has prepared 'the environment friendly sequential development plan'. It contains a scheme to construct sea dyke by 2006 and then to develop the DJ area first, which has better water resources at this moment. After that, the MK area will be developed with the view of enhancing water quality in the area to the standard level.

This study was focused on relationships among water use, land distribution and pollution loads in two river watershed, MK and DJ watersheds. And a purification role of paddy fields in these areas was also assessed with irrigation of nutrient-rich Iksancheon stream water.

Materials and methods

Classification of drainage district The SMG reclamation district is located at western Jeonbuk province, ROK as shown in Figure 1. There are two rivers, the Mankyeong (MK) and the Dongjin (DJ) in the district. Drainage zone was classified into 10 watershed districts in MK from 28 watersheds and 6 watershed districts in the DJ from 17 watersheds considering basin map by Korean Ministry of Environment.

Water sampling and calculation of pollution load Surface waters were sampled and water flux was measured monthly at each tributary stream from Jan. 2002 to Dec. 2004, respectively. Water flux was calculated by velocity area method. Average data was used to compare seasonal variation of water quality; spring, summer, autumn and winter.

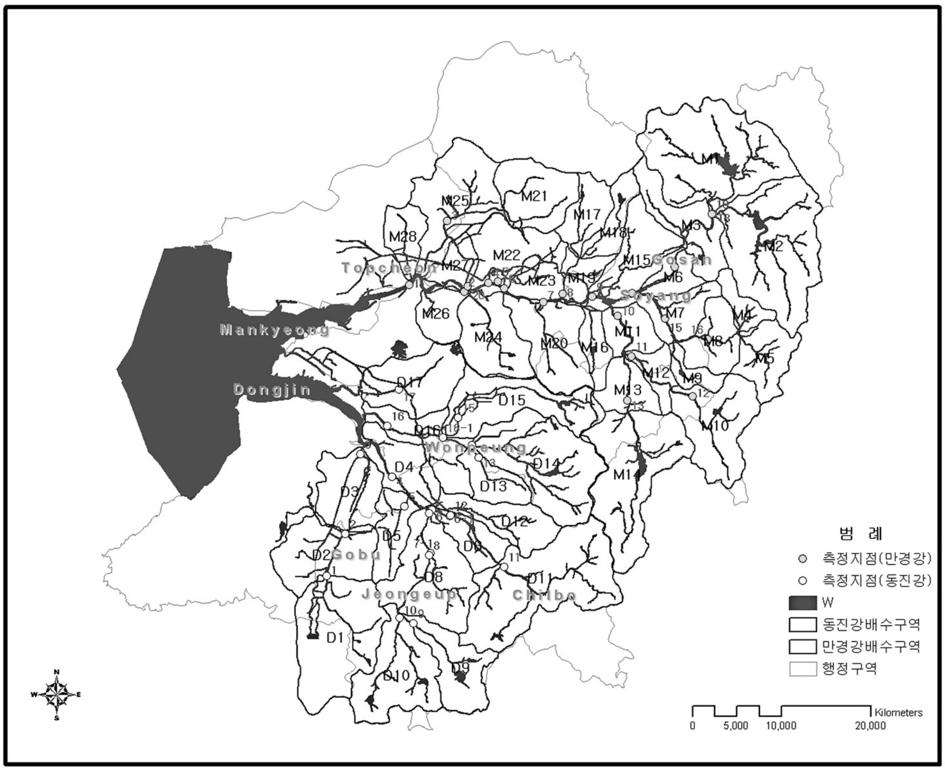

Figure1. Classification of drainage districts and monitoring sites of the Saemangeum basin

Basic data on population, livestock and land use distribution were collected based on Korean basic administrative district unit, Myeon, Li and Dong of each county (2003, Jeonbuk Statistics, ROK). The pollution load was calculated with basic environmental data and the pollution load rate proposed by Korean Ministry of Environment (1999). The raw load was estimated from the origin and the effluent load was calculated by the difference of the raw load and the reduction load. Delivery load was calculated using the flux and water quality. To estimate daily delivery load between flood and dry season, it was classified for the rainy season from June to September and dry season from October to May of next year. It was assessed the pollution load between the Mankyeong and the Dongjin River using two papers (Lee et al 2005a, 2005b).

Rice cultivation and sampling This study was carried out in paddy fields at the riverbed with a nutrient-rich water of Iksancheon stream. The paddy fields was 150 m in length with the width of 15 m. Nitrogen was applied 110 kg ha^{-1}, phosphate 58 kg ha^{-1} and potassium 58kg ha^{-1}. 70% of Nitrogen was applied before transplanting and 30% at tillering stage and all of phosphate and potassium were applied before transplanting. The water was pumped into the paddy fields via flux meter and sampled by the submerging for 0, 1, 2, 3 and 4 day at flow distance of 0 m and 150 m. The sampled water was stored at refrigerator to be analyzed.

Chemical analysis of water The chemical analysis of water was carried out using instruments as follows. Biochemical Oxygen Demand (BOD_5) was analyzed by Orion 940 Ion Analyzer; Electrical Conductivity, Orion ion meter Model 162A; T N and T P, Shimazu UV Vis Spectrophotometer. Analytical methods were based on Standard Methods for the Examination of Water and Wastewater (US EPA, 1974).

Results and Discussion

Water consumption of MK and DJ watershed Rivers carry a significant load of elements, e.g. carbon, nitrogen, and phosphorous, in dissolved and particulate phases from both natural and anthropogenic sources. So geological condition and anthropogenic activity could influence on the river water quality.

MK watershed transferred about 700 million cubic meter of potential utilizable water, including 73.6% of which, 515 million cubic meter was used for agriculture, 14.1% was used for living and 12.3% for industry (Table 1). DJ watershed transferred about 505 million cubic meter water, 2.9% of which were used for living, 94.5% for agriculture and 2.5% for industry. DJ watershed showed higher proportion of water consumption in agriculture and lower in living and industry as compared to MK watershed. This type of water consumption in the watershed could influence the amount of water flow into the rivers and water quality, namely pollution load to the SMG basin.

Land use distribution in the Mankyeong and the Dongjin River watershed The total area was 138,180 ha in the MK watershed (Table 2). Among the streams, the Gosan watershed had the largest area, 35,143ha with the lowest ratio of paddy fields to total area, 8.8%.

The Jeonju watershed had the second lowest ratio of paddy fields to total area, 9.9%. On the while, the ratio of paddy fields to total area of the Gocheog·Tab watershed was 46.9%, the Mokcheonpo watershed 42.7%, and the Seogtab watershed 41.3%. Collectively, MK watershed has 24.0% of paddy field, 9.2% of upland 0.2% livestock farming, 49.2% of forest, 14.6% of built-up area, and 2.8% of the others, respectively.

The total area was 109,159 ha in DJ watershed (Table 3). Among the streams, the Wonpyeong watershed had the largest area, 25,603 ha with the second lowest ratio of paddy field to total area, 36.4%. The ratio of paddy field to total area of the Chilbo watershed was 15.3%, the Jeongup watershed 22.9%, the Gobu watershed 35.4%, the Yongho·Deogcheon watershed 48.5%, and the Sinpyeong watershed 49.1%. Totally, DJ watershed had 33.7% of paddy field, 12.9% upland, 1.4% livestock farming, 36.7% forest, 9.9% built up area, and 5.4% the others. Compared proportion of each land use distribution in Table 2 and Table 3, DJ watershed had 1.4 times in the

Table 1. Comparison of water consumption between the Mankyeong and the Dongjin River watershed (1,000 m^3 $year^{-1}$)

River	Living	Agriculture	Industry	Total
Mankyeong	98,470 (14.1)	515,424 (73.6)	86,145 (12.3)	700,039 (100)
Dongjin	15,072 (2.9)	478,265 (94.5)	12,545 (2.5)	505,882 (100)

Table 2. The land use distribution of the Mankyeong River watershed (ha)

Watershed	Paddy	Upland	Livestock Farming	Fish farm	Forest	Built-up Area	The others	Total
Gosan	3,094	1,634	53	0.9	28,273	980	1,108	35,143
Soyang	1,817	943	22	0.3	9,683	939	315	13,720
Jeonju	1,443	976	6	0	8,832	3,127	233	14,617
Samcheon	2,020	967	7	0	9,789	1,985	408	15,176
Seogtab	2,394	673	6	0	1,001	1,266	450	5,790
Iksan	2,784	1,094	31	3.7	2,027	1,186	142	7,268
Masan·Jocheon	2,943	1,467	20	3.2	2,005	1,337	262	8,037
Mokcheonpo	4,826	852	4	6.0	386	4,416	816	11,306
Gocheok·Tab	8,231	2,245	49	6.9	3,941	3,012	82	17,567
Cheongha	3,572	1,805	127	0	2,066	1,883	5	9,458
Total	33,124	12,657	324	21.0	68,003	20,131	3,821	138,180
Proportion (%)	24.0	9.2	0.2	>0.1	49.2	14.6	2.8	100

Table 3. The land use distribution of the Dongjin River watershed (ha)

Watershed	Paddy	Upland	Livestock Farming	Fish farm	Forest	Built-up Area	The others	Total
Gobu	7,909	4,376	213	15	6,117	2,105	1,571	22,308
Yongho·Deogcheon	8,748	1,963	105	10	3,591	2,418	1,189	18,023
Jeongup	4,961	2,270	1,095	15	10,601	1,818	900	21,659
Chilbo	2,164	921	32	8	9,686	870	436	14,116
Wonpyeong	9,320	3,519	58	>0.1	8,823	2,696	1,188	25,603
Sinpyeong	3,662	1,025	12	0.3	1,219	930	601	7,449
Total	36,765	14,074	1,514	48	40,037	10,837	5,885	109,159
Proportion (%)	33.7	12.9	1.4	>0.1	36.7	9.9	5.4	100.0

paddy field, 1.4 times in upland, 7 times in livestock farming, 0.74 times in forest, and 0.67 times in built up area than MK watershed.

Water quality in the Mankyeong and the Dongjin River Seasonal variation of water quality showed that the concentration of pollutants was lowest in summer and intermediate in spring and autumn and the highest in winter.

The low concentration in the summer was resulted from increased rainwater retaining capacity and active nutrients absorption in the agricultural land.

Irrigation requirement by rice plants could influence movement of pollutants. In addition to this, DJ watershed had far lower value of electric conductivity, BOD_5, TN and TP as compared to MK watershed. This difference was closely related to proportion of paddy field to total area in both watersheds. Considering above two factors,

Table 4. Seasonal variations of water quality in the Mankyeong and the Dongjin River

River	Season	EC (μs cm^{-1})	BOD_5 (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})
Mankyeong	Spring	889.0	4.8	11.1	1.3
	Summer	643.7	5.7	5.5	0.6
	Autumn	860.7	7.2	7.0	1.0
	Winter	1129.0	5.6	16.5	1.7
	Mean	902.8	5.0	10.0	1.2
Dongjin	Spring	146.3	2.2	3.9	0.1
	Summer	105.0	1.7	3.3	0.2
	Autumn	130.3	2.6	2.8	0.2
	Winter	283.6	1.7	4.3	0.3
	Mean	166.3	4.4	3.6	0.2

paddy rice cultivation plays a positive role in the conservation of river water quality in the SMG district.

Effluent load of pollutants In MK watershed, pollution sources of BOD were driven mainly from no sewerage, sewage disposal, and livestock farming, that of TN were sewage disposal and livestock farming, and that of TP was livestock farming and sewage disposal. Generally, agricultural land was pointed as the major non point pollution source because of application of fertilizer and agrochemical. But the agricultural land was less major pollution source than livestock farming, sewage disposal in the MK watershed.

This result suggests that it should give priority to countermeasure the livestock farming and management of the sewage to conserve the water quality in the MK watershed.

In DJ watershed, pollution source of BOD_5 were driven mainly from the livestock farming, fish farm and no sewerage, that of TN and TP was the livestock farming. The proportion of land was similar to fish farm and no sewerage as a effluent load of TN, and 6% in the effluent load of TP. This result suggests that it should give priority to countermeasure the livestock farming and manage the sewage rather than the land to conserve the water quality in the DJ watershed.

Delivery load between dry and flood season The main hydrologic component transporting non point pollutants to surface water bodies is runoff, which is driven by precipitation or snowmelt. The effect of this transport mechanism is evident during and after heavy rainfall. Precipitation also is a factor in the transportation of pollutants into an aquifer.

The delivery ratio is the amount of a pollutant generated at its source compared to the amount of the pollutant actually reaching a water resource. There was much increment in delivery load in the MK watershed than DJ watershed in the flood season. In MK watershed, delivery ratio of BOD was increased 6.7 times, that of TN 6.3 times, and that of TP 3.7 times in the flood season. On the while in DJ watershed, that of BOD increased 3.0 times, that of TN 2.4 times and that of TP 3.3 times. This difference between two watersheds was related to the lower proportion of paddy field and upland, the higher proportion of built up area in MK watershed than in DJ watershed. The paddy fields could hold rainwater like little dam and mitigate soil erosion at rainy events.

Role of the rice cultivation in the watershed Among the 11 tributaries in MK watershed, the Iksancheon had high concentration of nitrogen and phosphate than the other watersheds because of the inflow from the Wanggoong livestock district (Lee et al, 2004). On the while, nitrogen and phosphate in the water could play in both nutrient source for the plant and eutrophic source in the hydrosphere. There are 2,784 ha of paddy fields in the Iksancheon watershed. It is known that rice plant required 1,025 mm of irrigation water annually in Korea (Cho et

Table 5. Composition of effluent load between the Mankyeong and the Dongjin River watershed (%)

River	Pollutant	No sewerage	Industry	Livestock Farming	Sewage disposal	Fish farm	Land
Man kyeong	BOD	23	3	24	20	12	18
	TN	10	2	32	41	4	11
	TP	9	2	52	22	7	8
Dongjin	BOD	20	3	34	2	29	12
	TN	11	5	51	8	12	13
	TP	1	3	69	4	17	6

Table 6. Change of daily delivery load of pollutants by the rain condition in the Mankyeong and the Dongjin River (kg d^{-1})

Season	BOD5		TN		TP	
	Mankyeong	Dongjin	Mankyeong	Dongjin	Mankyeong	Dongjin
Dry (D)	10,257	2,956	9,637	4,254	1,705	212
Flood (F)	68,752	8,832	61,194	10,023	6,365	701
F/D	6.7	3.0	6.3	2.4	3.7	3.3

Flood : June to September, Dry : October to May al, 1999) and 71% of the water irrigated into paddy fields is returned eventually to rivers and 23% of that recharged to groundwater (OECD, 2004). In this aspect, it is thought paddy fields could foster lots of water, and rice plants could purify the river water by absorbing nutrients.

Table 7 shows the change of total nitrogen content after flowing 150m into the paddy field with time fully irrigated nutrient rich stream water. Total nitrogen concentration was 14.6 mg L^{-1} at the inlet and 9.2 mg L^{-1} at the outlet just after full irrigation of Iksancheon water; 37.0% of nitrogen was removed and/or diluted with the already remained water after flow to 150m. And the total nitrogen concentration was decreased by 51.4% at the inlet (0m) and by 69.8% at the outlet (150m) in one day, and by 93.1% at the inlet and by 90.4% at the outlet (150m) in 96 hours submergence. Total phosphate concentration was 1.6 mg L^{-1} at the inlet and 0.8 mg L^{-1} at the outlet just after full irrigation of Iksancheon water; 50.0% of phosphate was decreased and/or diluted with the already remained water during flowing 150m. The total phosphate concentration was decreased by 56.2% in one day and by 75% in 4 days submergence. Biochemical Oxygen Demand was decreased and/or diluted by 8% with the already-remained water during flowing to 150m within 2-3hours. And BOD_5 was decreased by 37.2% in one day and by 43.0% in 4 days submergence. Conclusively, rice paddy fields has been played role in environmental conservation of river water.

Table 8 represents the amount of nutrients absorbed by rice plants at different fertilization levels as Iksancheon water was irrigated. Rice plant absorbed TN 168 kg ha^{-1}, P_2O_5 46.0 kg ha^{-1}, and K_2O 197.3 kg ha^{-1} at conventional fertilization, TN 141.3 kg ha^{-1}, P_2O_5 42.4 kg ha^{-1}, and K_2O 164.2 kg ha^{-1} at 50% level of conventional fertilization. Thus, the amount of nutrient absorbed by rice plants was increased because of increment of biomass production by increased fertilization. Considering absorbed amount of nutrients from irrigation water without chemical fertilization, rice plants could remove TN 100.0 kg, P_2O_5 24.0 kg, and K_2O 119.2 kg per hectare from the irrigated water and paddy field. This result represents another evidence of paddy fields has plays a role to alleviate the pollution load to the SMG basin.

Conclusion

The SMG tidal reclamation project has been developed to reclaim 40,100 ha of tideland including 28,300 ha of farmland and 11,800 ha of water resources with two rivers, the Mankyeong River (MK) and the Dongjin River (DJ) in the western coast of Korea since 1991.

At the moment, pollutants from the water watershed of MK and DJ can pass the estuary by tidal flow, and the mixing of fresh water with seawater prevents water quality from deteriorating. After the completion of the SMG dyke, the flow velocity will be decreased in general and the mixing will be decreased. Therefore, there have been severe contrary opinions between the conservation and the reclamation of tideland based on the water quality of the SMG Lake that is to be constructed. As the results of debate, Korean government has planned an environment friendly sequential development plan that includes for the construction of the sea dyke by 2006.

The MK has 700 million m^3 and DJ has 505 million m^3 water resources, 73.6% of which was used for agriculture

Table 7. Change of concentration of total nitrogen, total phosphate and BOD_5 after irrigation of Iksancheon water (mg L^{-1})

Submerged hour	TN		TP		BOD_5	
	Inlet (0m)	Outlet (150m)	Inlet	Outlet	Inlet	Outlet
1	14.6	9.2	1.6	0.8	8.6	7.9
24	7.1	4.4	0.7	0.7	8.4	5.4
48	2.6	1.3	0.6	0.4	7.4	5.3
72	2.6	1.3	0.6	0.3	7.7	5.0
96	1.0	1.4	0.4	0.4	6.2	4.9

Table 8. Amount of nitrogen, phosphate and potassium absorbed by rice plants at different fertilization levels

Fertilization	TN (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Biomass (kg ha^{-1})
Conventional (CF)	168.0	46.0	197.3	15,381
50% of CF	141.3	42.4	164.2	14,373
No fertilization	100.0	24.0	119.2	9,850

in MK watershed and 94.5% for agriculture in DJ watershed. Paddy field was distributed 24.0% in MK watershed, and 33.7% in DJ watershed. On the while, pollution source in MK and DJ watershed was derived mainly from population, livestock farming rather than the land. These results suggest that a priority should be given in the management of pollution from livestock farming and sewage rather than the land to conserve the water quality in the SMG basin.

In addition to this, DJ watershed had far lower concentration of pollutants and far lower delivery load after rainfall than MK watershed. It was closely related to the higher proportion of paddy field to the total area in DJ watershed having flood mitigation by retaining rainwater, nitrogen cycle, prevention of landslides and soil erosion with respect to water conservation.

Rice plants also could play a role to alleviate the pollution load to the SMG basin by absorbing TN 100.0 kg and P_2O_5 24.0 kg per hectare from the Iksancheon water. Conclusively, rice paddy fields had contributed in alleviating pollution load in the SMG basin. These results suggest that agricultural land will be one of the positive functions for the water conservation even in the SMG new reclaimed land.

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새만금 유역에서 토지 이용이 오염부하에 미치는 영향 평가

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한반도 통일 후 식량 안보와 수자원 확보를 위해 추진되어 오고 있는 새만금 간척 사업 완공 후 담수호 수질 보전을 위해서는 오염 물질 관리의 우선순위 설정에 의한 토지 이용 계획 수립이 필요하다.
새만금 유역에서 오염 물질 부하를 경감시키기 위한 농경지의 역할을 평가하기 위하여 만경강과 동진강 유역에서 오염 부하, 토지 이용 및 분포, 용수 사용을 조사하였다.
만경강 년간 하천수는 700만㎥이며 이중 14.1%는 생활 용수, 73.6%는 농업용수, 12.3%는 산업 용수에서 유래하고 있다. 동진강 하천수는 505백만㎥이며 이중 3.0%는 생활 용수, 94.5%는 농업용수, 2.5%는 산업 용수에서 유래한다.
동진강 유역은 만경강 유역에 비해서 농경지 면적 비율은 1.4배, 축산 농지 면적 비율은 7배가 많았고, 임지는 0.74배, 주택지는 0.67배 적었다.
만경강 유역과 동진강 유역의 주요한 오염원은 토지 유래보다도 오히려 생활 하수와 축산 오수로 나타났다.
이같은 용수 사용과 토지 이용은 하천 수질에도 영향을 주어, 동진강 유역은 만경강 유역보다 전기전도도, BOD_5, TN 그리고 TP값이 훨씬 낮았다. 동진강 유역은 하천 유역의 논 면적 비율이 높아 축산업 면적이 넓었음에도 불구하고 강우 후 유달 부하량이 훨씬 낮았다.
만경강 지류인 익산천 하천수를 논에 관개 후 150 m 유거 중 침전 및 흡착에 의해 질소는 37%, 인산은 50%, BOD_5는 15%가 저감되었으며, 수확기 벼는 ha당 TN 100.0 kg, P_2O_5 24.0 kg, K_2O 119.2 kg을 흡수한 결과로 보아, 새만금 유역에서 벼 재배는 하천 수질 보전에 긍정적 기여를 하고 있다는 것을 알 수 있다.