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**Biological evaluation of water quality, using
macrobenthos**

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macrobenthos**

2000 8

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.....	
.....	1
.....	4
.....	5
1.	5
1-1.	5
1-2.	7
2.	7
2-1.	7
2-2.	10
2-2-1. National Sanitation Foundation's Water Quality Index	10
2-3.	11
2-3-1. (Dominance Index, DI)	11
2-3-2. (Species Diversity, H')	12
2-4.	13
2-4-1. Trent Biotic Index	13
2-4-2. Family-level Biotic Index	16
2-4-3. Modified Biological Monitoring Working Party Score System	18
2-4-4. Biotic Index	20
2-5.	28
.....	29
1.	29
2.	34
2-1. (Temperature)	34
2-2. (pH)	34

2-3.	(Conductivity)	35
2-4.	(DO)	35
2-5.	(Turbidity)	35
2-6.	(BOD ₅)	36
3.	.....	38
3-1.	(Dominance Index, DI)	38
3-2.	(Species Diversity, H')	40
4.	.....	43
4-1.	Trent Biotic Index	43
4-2.	Family-level Biotic Index	46
4-3.	Modified Biological Monitoring Working Party Score System	49
4-4.	Biotic Index	52
4-5.	National Sanitation Foundation's Water Quality Index	55
5.	.....	57
6.	.....	58
.	.....	61
.	.....	66
.	.....	69
=Abstract=	.....	78
.	.....	81

List of Tables

Table 1. Trent Biotic Index	14
Table 2. Tolerance values assigned to family levels for the purpose of calculating a Family-level Biotic Index (FBI)/Korea	16
Table 3. The Modified BMWP Score System	18
Table 4. Tolerance values assigned to species levels for the purpose of calculating a Biotic Index (BI)	21
Table 5. Number of taxa collected in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea during one-year survey period (1998-1999)	32
Table 6. Numbers of species and individuals collected in each station during one-year survey period (1998-1999)	33
Table 7. Physical and chemical measurements of water samples at stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea (1998-1999)	37
Table 8. Dominant species and dominance indices (DI) in the stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998-1999)	39
Table 9. Species diversity index (H') values in the stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998-1999)	42
Table 10. Trent biotic index (TBI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998-1999)	44

Table 11. Family-level biotic index (FBI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)	47
Table 12. Modified biological monitoring working party score system (BMWP-ASPT) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)	50
Table 13. Biotic index (BI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)	53
Table 14. National sanitation foundation's water quality index (NSFWQI) values in the water specimens sampled from the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999).	56
Table 15. Spearman's correlation coefficients (r) among five chemical parameters on six biological indices	59
Table 16. Spearman's correlation coefficients (r) among the biological indices applied in the stations of Namdae-chon, Muju, Korea	60

List of Figures

Fig. 1. A map showing the field stations where the benthic macrorinvertebrates were collected at the tributaries of Namdae-chon, Muju, Chunlabuk-do	6
Fig. 2. The devices for collecting benthos	9
Fig. 3 The percentage of number of taxa collected in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	31
Fig. 4. Species diversity index (H') values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	41
Fig. 5. Trent biotic index (TBI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	45
Fig. 6. Family-level biotic index (FBI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	48
Fig. 7. Modified biological monitoring working party score system (BMWP-ASPT) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	51
Fig. 8. Biotic index (BI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea	54
Fig. 9. The photographs of indicator species	80

가

1998 6

1999 5 1

가

Trent Biotic Index (TBI), Modified Biological Working Partly Score System-Average Score Per Taxon (BMWP-ASPT), Hilsenhoff's Biotic Index (BI) Family-level Biotic Index (FBI), (H') (DI) , National Sanitation Foundation's Water Quality Index (NSFWQI)가

가 4

가 1

3 가

4 가

Duncan's multiple range test

H'가 1, 4 group

가

가

•

가

가

가

(Hynes, 1960).

가

,

가

bacteria,

,

,

.

90%

(benthic macroinvertebrates)

(spacial)

가 1

1

가

.

,

가

.

,

가

(Hilsenhoff,

1977; Wilhm, 1972; Woodiwiss, 1978; Whitton, 1984).

(Boesch and Rosenberg, 1981; Gray, 1981; Hartley, 1982; Pearson and Rosenberg, 1978).

가 .
, 5
가 , ,
, , , ,
(Yoon, 1978; Kim *et. al.*, 1979, 1980; Yoon *et. al.*, 1984, 1986, 1987, 1992a, b; Yoon and Byon, 1981, 1982; Oh *et. al.*, 1983; Wui *et. al.*, 1983, 1991; Ra and Cho, 1986; Oh and Chon, 1991a, b; Chung *et. al.*, 1992). (biotic indices) 가
, Kolkwitz Marsson (1967) (arthropods)
가 가 , Hilsenhoff (1977)
가 .
가 가
(Trent Biotic Index, Sladeczek, 1973; Chandler's Score System, Sladeczek, 1973; Modified Biological Monitoring Working Party Score System, Armitage *et. al.*, 1983; Hilsenhoff's Biotic Index, Hilsenhoff, 1977; Family-level Biotic Index, Hilsenhoff, 1988).

Chung *et. al.*

(1998)

가 ,

BI

가

가 ,

FBI/ROK

BMWP-ASPT

4 ,

2 ,

1

1 (1998 8 - 1999 7)

(benthic macroinvertebrates)

가

가

•

(BOD),

(COD),

(DO)

가

가

가

(Armitage *et. al.*, 1983; Merritt

and Cummins, 1984; Metcalfe, 1989).

(chemical monitoring)

(biomonitoring)

가

.

1.

1-1.

3 (Station 1, 2, 3), 1 (Station 4)

,

가

1 (C3) 3 가 2 (C1, C2), (Fig. 1).

Station C1 ,

Station C2 ,

Station C3 ,

Station 1 ,

Station 2 ,

Station 3 ,

Station 4 ,

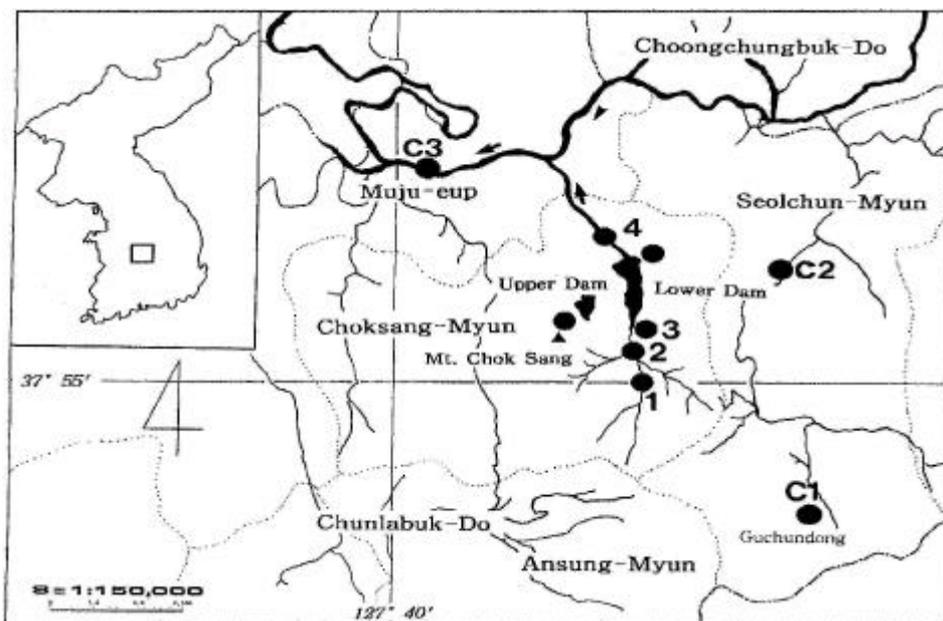


Fig. 1. A map showing the field stations where the benthic macrorinvertebrates were collected at the tributaries of Namdae-chon, Muju, Chunlabuk-do

1-2.

1998 6 1999 5 1 4
 . 1 1998 8 , 2
 10 가 . 3 1999 1
 , 4 5 .

2.

2-1.

(macrobenthos)

. Hand net (90 x 60cm), scoop (25cm/ diameter) D-frame net substrate (cobble, pebble, gravel/sand)

Surber sampler (Wildco Instruments Co., MI, USA; 30cm x 30cm)

2 . Ponar grab (Wild Co., Saginaw, MI, U.S.A) (Fig. 2).

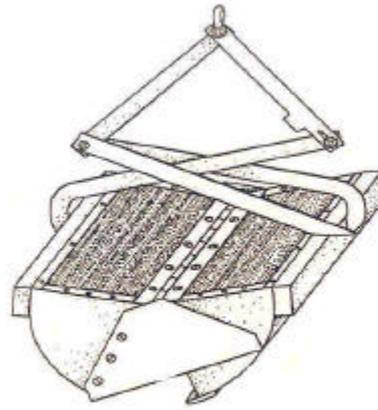
Kahle's fluid (Edmunds *et. al.*, 1976) , forcep white pan

70% ethanol 80 X

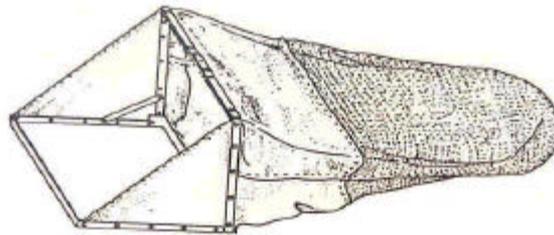
, (Yoon, 1988)
(Tsuda, 1962; Kawata, 1962;
Kawai, 1985; Kwon, 1990; Yoon and Kim, 1992). , oligochaete
worms, midge larvae scuds Simpson (1980)



D-frame aquatic net.



Ponar grab.



Surber sampler.

Fig 2. The devices for collecting benthos

2-2

가
dissolved oxygen (DO), temperature, pH,
conductivity turbidity ,
biochemical oxygen demand (BOD₅) BOD

**2-2-1. National Sanitation Foundation's Water Quality Index
(NSFWQI; Ott, 1978)**

Ott (1978)

0-100

$$\text{NSFWQI} = \sum_{i=1}^n W_i I_i$$

I_i = subindex value from the appropriate rating curve
for pollutant variable i ,
 W_i = subindex weight.

(Appendix 2)

NSFWQI DO, BOD, pH, temperature,
 turbidity subindex value (I_i) Ott (1978) graphs
 , subindex weight (W_i) Ott (1978)
 . 0- 100 100

2-3.

2-3-1. (Dominance Index, DI)

, 가 가
 2 , (DI)
 (McNaughton, 1967).

$$DI = \frac{n_1 + n_2}{N}$$

n_1, n_2 = number of individuals in the 1st and 2nd dominant species

N = total number of individuals in all the species

2-3-2.

(Species Diversity, H')

(species diversity)

가

(Wilhm and Dorris, 1968; Wilhm, 1972).

Shannon-Weaver function (H') Llyod *et. al.*, (1964)

. ,

$$H' = - \sum_{i=1} (n_i/N) \log_2 (n_i/N)$$

n_i = number of individuals in the given species (i th species)

N = total number of individuals in the station.

Staub *et. al.*, (1970)

가 .

0 - 1.0 :

1.0 - 2.0 : -

2.0 - 3.0 : -

3.0 - 4.5 :

2-4.

2-4-1. Trent Biotic Index (TBI; Sladeczek, 1973)

Trent biotic index (TBI) Trent River
가 , ,
가 가
(Persoone and De Pauw, 1979). TBI

(Woodiwiss, 1978; Hawkes, 1979)

key group

10 (Table 1).

Table 1. Trent Biotic Index (from Sladeczek, 1973)

Table 1-1. Key groups for the Trent River Board Biotic Index (TBI) (Woodiwiss, 1964, quoted according to Chandler, 1970)

A "group" consists of :	Common name
Each family of Trichoptera larvae	Caddis flies
Each family of Coleoptera larvae and adults	Beetles
Each family of Diptera (except blood worms)	True flies
Each family of Annelida Oligochaeta	Worms
Each genus of Plecoptera nymphs	Stoneflies
Each genus of Ephemeroptera nymphs	Mayflies
Each species of Annelida Hirudinea	Leeches
Each species of Mollusca	Snails, limpets, etc
Each species of Crustacea	Shrimps, water hoglice
Each species of Megaloptera larvae	Alder flies
<i>Chironomus thummi</i>	Blood worms

Table 1-2. Trent River Board Biotic Index (TBI) (Woodiwiss, 1964, cited according to Chandler, 1970)

		Total number of groups present				
		0-1	2-5	6-10	11-15	16+
Clean	Plecoptera nymphs present	-	VII	VIII	IX	X
	More than 1 species	-	VI	VII	VIII	IX
Organisms in order of tendency to disappear as degree of pollution increases	Ephemeroptera nymphs present (excl. <i>Baetis</i>)	-	VI	VII	VIII	IX
	More than 1 species	-	V	VI	VII	VIII
	One species only	-	V	VI	VII	VIII
	Trichoptera larvae or <i>Baetis</i> present	-	V	VI	VII	VIII
	More than 1 species	-	IV	V	VI	VII
	One species only	IV	IV	V	VI	VII
	<i>Gammarus</i> present	III	IV	V	VI	VII
	All above species absent	III	IV	V	VI	VII
	<i>Aseillus</i> present	III	IV	V	VI	VII
	All above species absent	III	IV	V	VI	VII
	Tubificid worms and/or red Chironomid larvae present	I	II	III	IV	-
Polluted	All above species absent	-	I	II	-	-
	Some organisms such as <i>Eristalis tenax</i> not requiring dissolved oxygen may be present	-	I	II	-	-

2-4-2. Family-level biotic index (FBI/ROK)

Chung (1994) 가
 FBI/ROK (Table 2).
 FBI/ROK BI 가

Table 2-1. Tolerance values assigned to family levels for the purpose of calculating a Family-level Biotic Index (FBI)/Korea

Higher taxa	Family	Tolerance value
Plecoptera	Nemouridae	1
	Capniidae	1
	Perlodidae	1
	Perlidae	1
Ephemeroptera	Siphonuridae	1
	Baetidae (excl. Baetis nla, Cloeon dipterum)	1
	Oligoneuridae	1
	Heptageniidae	1
	Leptophlebiidae	1
	Potamanthidae	1
	Ephemeridae	1
	Ephemerellidae	1
	Neophemeridae	1
	Caenidae, Baetis nla, Cloeon dipterum	3
Odonata	Calopterygidae	3
	Gomphidae(excl. Nihonogomphus, Davidius lunatus)	3
	Nihonogomphus, Davidius lunatus	1
	Cordulidae	3

Table 2-2

Tricoptera	Stenopsychidae	1
	Psychomyiidae	1
	Hydropsychidae	1
	Rhyacophilidae	1
	Glossosomatidae	1
	Hydroptilidae	1
	Limnephilidae	1
	Lepidostomatidae	1
	Odontoceridae	1
	Leptoceridae	1
	Megaloptera	Corydalidae	1
Coleoptera	Dytiscidae	3
	Hydrophilidae	3
	Elmidae	1
	Psephenidae	1
Diptera	Tipulidae	1
	Simuliidae	1
	Psychodidae	4
	Chironomidae	4
	Tabaniidae	1
Decapoda	Atyidae	3
Amphipoda	Gammaridae	1
Isopoda	Asellidae	3
Oligochaeta	Tubificidae	4
Hirudina	Erpobdellidae	3
	Glossiphoniidae	3
Gastropoda	Pleuroceridae	3
	Lymnaeidae	3
	Physidae	3
	Planorbidae	3
	Bithyniidae	3
Tubellaria	Planariidae	1

2-4-3. Modified Biological Monitoring Working Party Score System (BMWP; Armitage *et. al.*, 1983)

BMWP/ASPT family 가 , 1-10
 BMWP score system , 1-10
 10 (Table 3).

Table 3-1. The Modified BMWP Score System (from Armitage *et. al.*, 1983).

Families	Score
Siphonuridae Heptageniidae Leptophlebiidae Ephemerellidae Potamanthidae Ephemeridae	10
Taeniopterygidae Leuctridae Capniidae Perlodidae Perlidae Chloroperlidae	
Aphelocheiridae	
Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	
Astacidae	8
Lestidae Agriidae Gomphidae Cordulegasteridae Aeshnidae Corduliidae Libellulidae	
Psychomyiidae Philopotamidae	
Caenidae	7
Nemouridae	
Rhyacophilidae Polycentropodidae Limnephilidae	

Table 3-2.

Neritidae Viviparidae Ancylidae	
Hydroptilidae	
Unionidae	6
Corophiidae Gammaridae	
Platycnemididae Coenagriidae	
Mesoveliidae Hydrometridae Gerridae Nepidae Naucoridae	
Notonectidae Pleidae Corixidae	
Haliplidae Hygrobiidae Dytiscidae Gyrinidae	
Hydrophilidae Clambidae Helodidae Dryopidae Elminthidae	5
Chrysomelidae Curculionidae	
Hydropsychidae	
Tipulidae Simuliidae	
Planariidae Dendrocoelidae	
Baetidae	
Sialidae	4
Piscicolidae	
Valvatidae Hydrobiidae Lymnaeidae Physidae Planorbidae	
Sphaeriidae	
Glossiphoniidae Hirudidae Erpobdellidae	3
Asellidae	
Chironomidae	2
Oligochaeta (whole class)	1

2-4-4. Biotic Index (BI; Hilsenhoff, 1977)

Hilsenhoff (1977)

$$BI = \frac{\sum n_i a_i}{N}$$

n_i = number of individuals in each species or genus,

a_i = index value (tolerance value) for that species or genus

N = total number of individuals in the sample.

tolerance values (a_i) Pantle and
Buck's saprobic indices (1955) Chung (1994)
(Table 4)

4 가 .
0 - 1.5 : Clean unpolluted waters
1.6 - 2.5 : Slightly polluted waters
2.6 - 3.5 : Polluted waters
3.6 < : Heavily polluted waters

Table 4- 1. Tolerance values assigned to species levels for the purpose of calculating a Biotic Index (BI)*.

Order	Family	Species	Tolerance values*	
Plecoptera	Nemouridae	<i>Nemoura tau</i>	1	
		<i>Nemoura</i> KUa	1	
		<i>Amphinemura</i> KUa	1	
	Capniidae	<i>Capnia</i> KUa	1	
		<i>Eucapnopsis</i> KUa	1	
	Perlodidae	<i>Perlodes</i> KUa	1	
		<i>Archynopteryx</i> KUa	1	
		<i>Megaracys ochracea</i>	1	
		<i>Starvsolus</i> spp.	1	
		<i>Isoperla</i> spp.	1	
		Perlidae	<i>Paragnetina flavotincta</i>	1
			<i>Neoperla quadrata</i>	1
	<i>Oyamia coreana</i>		1	
	<i>Kamimuria</i> spp.		1	
	<i>Kiotina decorata</i>		1	
	Scopuridae	<i>Scopura longa</i>	1	
	Taeniopterygidae	<i>Taenionema</i>	1	
	Leuctridae	<i>Rhopalopsale mahunkai</i>	1	
	Peltoperlidae	<i>Yoraperla</i> KUa	1	
	Pteronarcidae	<i>Pteronarcys sachalina</i>	1	
	Chloroperlidae	<i>Swelsta</i> spp.	1	
	Ephemeroptera	Siphonuridae	<i>Siphonurus chanke</i>	1
<i>Ameletus montanus</i>			1	
Baetidae		<i>Baetis thermicus</i>	1	
		<i>Baetis</i> nla	3	
		<i>Baetis</i> KUa	2	
		<i>Cloeon dipterum</i>	3	
		<i>Pseudocloeon japonica</i>	2	
		<i>Pseudocloeon japonica</i> na	1	
		<i>Ameletos costalis</i>	1	
		<i>Baetis</i> (others)	2	

Table 4-2.

Oligoneuridae	<i>Isonychica japonica</i>	1
Heptageniidae	<i>Bleptus fasciatus</i>	1
	<i>Epeorus (Epeorus) latifolium</i>	1
	<i>Epeorus (Epeorus) curvatulus</i>	1
	<i>Epeorus (Iron) aesculus</i>	1
	<i>Epeorus (others)</i>	1
	<i>Cinygmula KUa</i>	1
	<i>Cinygmula KUb</i>	1
	<i>Ecdyonurus yoshidae</i>	2
	<i>Ecdyonurus kibunensis</i>	1
	<i>Ecdyonurus dracon</i>	1
	<i>Ecdyonurus KUa</i>	1
	<i>Ecdyonurus KUb</i>	1
	<i>Heptagenia kihada</i>	1
	<i>Heptagenia kyotoensis</i>	1
	<i>Rithrogena na</i>	1
Leptophlebiidae	<i>Paraleptophlebia chocorata</i>	1
	<i>Characteries trifurcata</i>	2
Potamanthidae	<i>Potamanthus yooni</i>	2
	<i>Rhoenanthus coreanus</i>	2
	<i>Ephemerella strigata</i>	1
	<i>Ephemerella orientalis</i>	2
	<i>Ephoron shigae</i>	1
Ephemerellidae	<i>Drunella aculea</i>	1
	<i>Drunella triacantha</i>	1
	<i>Drunella cryptomeria</i>	1
	<i>Drunella longipes</i>	1
	<i>Cincticostella tshernovae</i>	1
	<i>Cincticostella tshernovae</i>	1
	<i>Acerella longicaudata</i>	1
	<i>Serratella setigera</i>	1
	<i>Serratella rifa</i>	2
	<i>Ephemerella keijoensis</i>	1
	<i>Ecdyonurus spp.</i>	1
	<i>Ephemerella imanishi</i>	1
	<i>Ephemerella nba</i>	1
	<i>Ephemerella (others)</i>	1

Table 4-3

	Neophemeridae	<i>Neophemera</i> KUa	2	
	Caenidae	<i>Caenies</i> KUa	3	
Odonata	Calopterygidae	<i>Calopteryx atrata</i>	1	
		<i>Calopteryx japonica</i>	1	
	Gomphidae	<i>Gomphus postocularis</i>	3	
		<i>Stylurus annulatus</i>	3	
		<i>Davidius lunatus</i>	1	
		<i>Onychogomphus ringens</i>	1	
		<i>Nihonogomphus</i> KUa	1	
		<i>Sieboldius albardae</i>	2	
		<i>Anisogomphus maacki</i>	2	
		<i>Trigomphus</i> spp.	3	
		Corduliidae	<i>Macromia manchuria</i>	2
			<i>Macromia amphigena fraenata</i>	2
	<i>Eitheca marginata</i>		2	
	Coenagrionidae	<i>Ischnura</i> spp.	3	
		<i>Cercion</i> spp.	3	
	Platycnemididae	<i>Platycnemis</i> spp.	2	
<i>Copera amulata</i>		2		
Tricoptera	Stenopsychidae	<i>Stenopsyche griseipennis</i>	1	
		<i>Stenopsyche bergeri</i>	1	
	Psychomyiidae	<i>Psychomyia</i> KUa	1	
	Hydropsychidae	<i>Archtopsyche ladogensis</i>	1	
		<i>Hydropsyche</i> KUa	1	
		<i>Hydropsyche</i> KUb	2	
		<i>Hydropsyche</i> KUc	1	
		<i>Hydropsyche</i> KUD	1	
		<i>Hydropsyche</i> KUE	2	
		<i>Cheumatopsyche brevilineata</i>	2	
		<i>Cheumatopsyche</i> KUa	1	
		<i>Cheumatopsyche</i> (others)	1	
		<i>Macronema radiatum</i>	2	
<i>Hydropsyche</i> KD	1			

Table 4-4

		<i>Rhyacophila impar</i>	1
	Rhyacophilidae	<i>Rhyacophila bilobata</i>	1
		<i>Rhyacophila shikotsuensis</i>	1
		<i>Rhyacophila nigrocephala</i>	1
		<i>Rhyacophila</i> KUa	1
		<i>Rhyacophila articulata</i>	1
		<i>Rhyacophila</i> (others)	1
		<i>Apsilochorema</i> KUa	1
	Glossosomatidae	<i>Glossosoma</i> KUa	1
	Hydroptilidae	<i>Hydroptila</i> KUa	1
	Limnephilidae	<i>Notopsyche</i> KUa	1
		<i>Neophylax ussuriensis</i>	1
		<i>Goera japonica</i>	1
		<i>Hydatophylax nigrovittatus</i>	1
	Lepidostomatidae	<i>Goerodes</i> KUa	1
		<i>Goerodes</i> KUb	1
	Odontoceridae	<i>Psilotreta kisoensis</i>	1
	Leptoceridae	<i>Ceraclea</i> KUb	1
		<i>Mystacides</i> KUa	1
	Philopotamidae	<i>Dolophilodes</i> spp.	1
		<i>Wormaladia</i> spp.	1
	Polycentropodidae	<i>Plectrocnemia</i>	2
	Ecnomidae	<i>Ecnomus tenellus</i>	3
	Sericostomatidae	<i>Gumaga</i> spp.	1
	Molannidae	<i>Molana</i> spp.	2
Megaloptera	Corydalidae	<i>Protohermis grandis</i>	1
		<i>Parachauliodes continentalis</i>	1
	Sialidae	<i>Sialis</i> spp.	2
Hemiptera	Belostomatidae	<i>Diploonychus japonicus</i>	3
	Nepidae	<i>Laccotrephes japonensis</i>	3
	Aphelocheiridae	<i>Aphelocheirus nawae</i>	1
	Hebridae	<i>Hebrus nipponicus</i>	2
	Gerridae	<i>Gerris (Aguaris) paludum insularis</i>	2
		<i>Gerris (Gerris) lacustris latiabdominis</i>	2
	Corixidae	<i>Hesperocorixa kolthoffi</i>	3
	Notonectidae	<i>Notonecta triguttata</i>	3

Table 4-5

Collembola		<i>Collembola</i> spp.	1
Coleoptera	Dytiscidae	<i>Laccophilus difficilis</i>	3
		<i>Hyphyolurus japonicus</i>	3
		<i>Neonectes natrix</i>	2
		<i>Rhantus pulverosus</i>	2
		<i>Hydaticus grammicus</i>	2
		<i>Hydaticus</i> sp.	2
		<i>Agabus</i> spp.	2
		Helodidae	<i>Helodes</i> spp.	1
	Hydrophilidae	<i>Helochares striatus</i>	3
	Elmidae	<i>Stenelmis vulgaris</i>	1
		<i>Zaitzevia nitida</i>	2
	Psephenidae	<i>Psephenoides</i> KUa	1
		<i>Mataeopsephus</i> KUa	2
		<i>Eubrianax</i> KUa	1
Diptera	Tipulidae	<i>Tipula</i> KUa	1
		<i>Tipula</i> KUb	1
		<i>Tipula</i> KUe	1
		<i>Tipula</i> KUf	1
		<i>Tipula</i> KUG	1
		<i>Tipula</i> KUh	1
		<i>Pedicia</i> KUa	1
	Limnoniidae	<i>Eriocera</i> KUa	1
		<i>Antocha</i> sp.	1
		<i>Dicranota</i> Kua	1
		Dixidae	<i>Dixa</i> sp.	1
	Simuliidae	<i>Simulium</i> sp.	1
	Psychodidae	<i>Psychoda</i> sp.	4
	Ceratopogonidae	<i>Ceratopogonidae</i> sp.	2
	Chironomidae	<i>Chironomus</i> sp. 1	2
		<i>Chironomus</i> sp. 2	3
		<i>Chironomus</i> sp. 3	2
<i>Chironomus</i> sp. 4		2	
<i>Chironomus plumosus</i>		4	

Table 4-6

	Chironomidae	<i>Chironomus halophilus</i>	4
		<i>Chironomus dorsalis</i>	3
		<i>Chironomus salinarius</i>	4
		<i>Chironominae</i> (red type)	3
		<i>Chironominae</i> (white type)	2
		<i>Chironominae</i> (others)	4
		<i>Cryptochironomus</i>	3
		<i>Procladius</i> sp.	3
		<i>Pentaneura</i> sp.	2
		<i>Phaenopsectra</i>	4
		<i>Calopsectra</i>	2
		<i>Tanypodinae</i>	2
	Athericidae	<i>Atherix</i> KUa	1
		<i>Suragina</i> KUa	1
	Dolichopodidae	<i>Dolichopodidae</i> sp.	1
	Tabaniidae	<i>Tabanus amaenus</i>	2
		<i>Tabanus kinoshitai</i>	2
		<i>Chrysops suavis</i>	3
	Muscidae	<i>Muscidae</i> sp.	4
	Blepharoceridae	<i>Blepharoceridae</i> spp.	1
	Syrphidae	<i>Eristalis</i>	3
Decapoda	Potamobiidae	<i>Cambaroides similis</i>	1
	Atyidae	<i>Neocaridina denticulata koreana</i>	3
Amphipoda	Gammaridae	<i>Gammarus</i> sp.	1
		<i>A sellus hilgendorfi</i>	3
Oligochaetae	Tubificidae	<i>Limnodrilus socialis</i>	4
	Glossoscolicidae	<i>Branchinura sowerbyi</i>	4
		<i>Chaetogaster limnaei</i>	2

Table 4-7

Hirudina		<i>Helobdella</i>	2	
	Erpobdelliidae	<i>Barbronia weberi</i>	3	
		<i>Erpobdella lineata</i>	3	
		<i>Erpobdelliidae</i> (others)	3	
Nematoda	Glossiphoniidae	<i>Glossiphonia complanata</i>	3	
		<i>Alboglossiphonia heterolia</i>	3	
		<i>Nematoda</i> spp.	2	
Mollusc	Pleuroceridae	<i>Cipangopaludina</i>	2	
		<i>Semisulcospira gottschei</i>	3	
			<i>Semisulcospira coreana</i>	3
	Bithyniidae	<i>Parafossarulus manchouricus</i>	3	
	Lymnaeidae	<i>Radix auricularia coreana</i>	3	
	Physidae	<i>Physa acuta</i>	4	
	Planorbidae	<i>Hipppeutis(S.) cantori</i>	2	
	Mytilidae	<i>Limnoperla fortunei</i>	4	
	Corbiculidae	<i>Corbicula fulminea</i>	2	
	Unionidae	<i>Unio douglasiae</i>	2	
		<i>A donata acroformis</i>	3	
		<i>A donata woodana</i>	3	
	Planariidae	<i>Phagocata kawakatsui</i>	1	

Remark : * = modified from Yoon *et. al.* (1992a) and originated from Pantle and Buck's saprobic indices (1955)

2-5.

,

Spearman's rank correlation coefficient analysis

, 4

one-way ANOVA test , ,

Duncan's

multiple range test .

.

1.

1998 8 1999 7 1
4 2
, 1
. 11 (order), 54 (family), 125 taxa가
, (Tricoptera)가 9 30 가
, (Ephemeroptera)가 8 30 ,
(Odonata)가 4 12 (Plecoptera)가 7 13 ,
(Hemiptera)가 2 3 , (Megaloptera)가 2 3 ,
(Coleoptera)가 5 10 , (Diptera)가 8 15 , 가 2 ,
Hirudinea (Annelida)가 1 , Planaridae가 1 , Tubificidae가 1 ,
가 4 4 (Table 5). Station 1 48
437 (38.4%), Station 2 46 705 (36.8%), Station 3 34 454
(30.0%), Station 4 74 1,439 (59.2%) .
(Station C1) 21
143 (16.8%), (Station C2) 52 1,136 (41.6%)
(Station C3) 23 183
(23.2%)가 (Fig. 3). station 4
74 taxa(59.2%)가 가

(C2) 52 taxa (41.6%)가
(C1)
(C3) 21(16.8%), 22(23.2%) taxa가
(C1) ,
(St. 4) (C3) (,
plecopterans) 가 (1).
50 596 , 37 564 ,
가 52 532 , 58 1,343 .
station
4 가 , 39, 38
1,439 , (C2) 52 ,
1,136 (Table 6).

Fig. 3 The percentage of number of taxa collected in the station of Namdae-chon, Muju, Chunlabuk-do, Korea

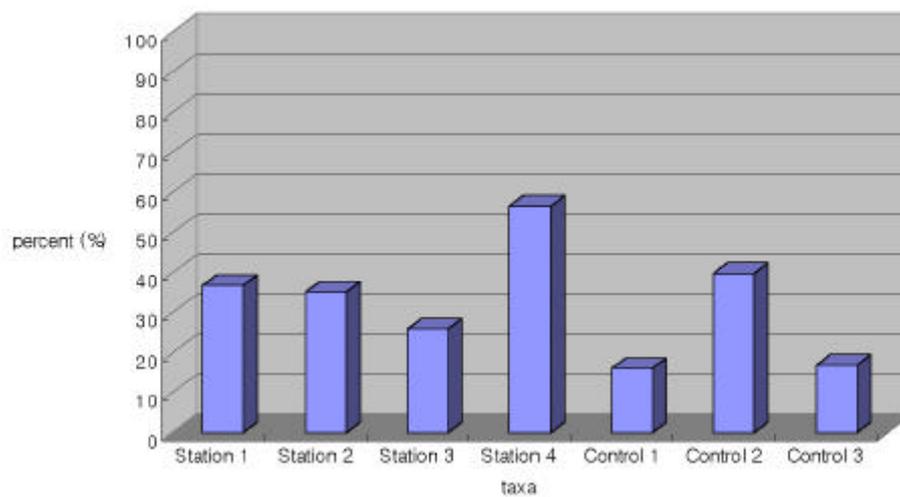


Table 5. Number of taxa collected in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea during one-year survey period (1998- 1999)*.

Phylum	Class	Order	No. of taxa (species)						
			St.1	St.2	St.3	St.4	C1	C2	C3
Arthropoda	Insecta	Ephemeroptera	14	10	15	22	9	15	11
		Odonata	1	3	3	7	-	3	4
		Plecoptera	1	4	0	6	5	7	-
		Hemiptera	3	2	0	2	-	-	-
		Megaloptera	1	1	0	3	-	1	1
		Trichoptera	11	8	9	17	4	17	2
		Coleoptera	1	2	1	7	-	-	-
		Diptera	13	10	6	9	2	6	2
Annelida	Oligochaeta	Haplotaxida	1	1	-	-	-	-	1
	Hirudina		-	1	-	-	-	-	-
Mollusca	Gastropoda	Mesogastropoda	1	3	-	1	-	3	1
Platyhelminthes	Turbellaria	Tricladida	1	1	-	-	1	-	-
	Tubificidae		-	-	-	-	-	-	1
Total taxa (%)			48(38.4)	46(36.8)	34(30.0)	74(59.2)	21(16.8)	52(41.6)	23(23.2)

* A total of 125 macroinvertebrate taxa in 54 families were collected during survey period (1998- 1999).

Table 6. Numbers of species and individuals collected in each station during one-year survey period (1998- 1999).

		Spring	Summer	Fall	Winter	Total (Ind. No.)
Station 1	Sp. No.	16	18	19	23	437
	Ind. No.	75	59	113	190	
Station 2	Sp. No.	20	10	18	27	705
	Ind. No.	84	117	52	452	
Station 3	Sp. No.	19	10	16	16	454
	Ind. No.	140	44	98	172	
Station 4	Sp. No.	29	26	39	38	1,439
	Ind. No.	297	344	269	529	
Control 1	Sp. No.	-	-	21	-	143
	Ind. No.	-	-	143	-	
Control 2	Sp. No.	-	-	-	52	1,136
	Ind. No.	-	-	-	1,136	
Control 3	Sp. No.	23	-	-	-	183
	Ind. No.	183	-	-	-	
Total (Ind. No.)		779	564	675	2,479	

Remarks : Sp. No. = Number of species collected

Ind. No. = Number of individuals collected

2.

(conductivity), (DO) (turbidity) , pH, BOD₅
(Table 7).

2- 1. (Temperature)

가 4
, 1 14.62 가 2, 3
가 4

2- 2. (pH)

pH pH 1 7.72
가 2, 3 8.17, 8.55
4 1 pH 7.63 . 3 8.55
6.5-8.5

2-3. (Conductivity)

1	4	71.5	2, 3
121.8, 141.8	.	4	85.33

2-4. (DO)

1	4	9.62	2, 3, 4
9.80, 9.90, 9.52	2, 3	, 가	.

1

1

2-5. (Turbidity)

, 1	4	가 가	50.0
2, 3	84.6, 84.62	가 4	61.33

2-6.

(BOD₅)

BOD₅ 1 1.05 3
가 4 1.03 1
. 4 1 가
1 C1, C2
C3 ()
3.96 3 . 3
(), 2 ()
, 1 ()
(2).

Table 7. Physical and chemical measurements of water samples at stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea (1998-1999).

	St. 1			Ave.	St. 2			Ave.	St. 3			Ave.	St. 4			Ave.	C1	C2	C3				
	Spr.	Sum	Fall		Win.	Spr.	Sum		Fall	Win.	Spr.		Sum	Fall	Win.					Spr.	Sum	Fall	Win.
Temperature (°C)	10.4	20.4	17.8	9.9	14.62	23.1	26.5	20.2	11.8	20.40	24.3	24.3	19.4	16.4	21.10	24.5	25.7	20.4	12.1	19.16	20.0	16.7	20.79
pH	7.7	7.7	7.9	7.6	7.72	8.3	8.7	8.1	7.6	8.17	9.2	7.8	8.4	8.8	8.55	8.3	7.9	8.0	7.6	7.63	7.6	7.6	7.7
Conductivity (μ mhos/cm)	11	106	123	46	71.5	135	141	150	61	121.8	141	147	150	129	141.8	111	110	90.5	70	85.33	62	58	136
D.O. (mg/l)	10.4	8.9	7.5	11.7	9.62	10.9	9.1	7.9	11.3	9.80	10.3	9.5	9.4	10.4	9.90	10.7	10.1	7.7	10.4	9.52	8.6	9.5	10.46
BOD ₅ (mg/l)	1.05				1.05	0.91				0.91	1.25				1.25	1.03				1.03	0.50	0.68	3.96
Turbidity (mg/l)	9	69	80	42	50.0	91	89	105.5	53	84.6	93	96	97.5	52	84.62	73	71	64	61	61.33	44	44	96

3.

3-1. (Dominance Index, DI)

1 2

(Table 8). (station 1)

, (station 2), (station 3)

가 *Chironomus* sp.가 1

, (station 4)

Hydropsyche KUa *Ecdyonurus* KUa *Ecdyonurus*
*yoshidae*가 1, *Serratella setigera*, *Pseudocloeon japonica*,
Hydropsyche KUa가 2 .

(C2) Tricoptera *Taenionema* KUb가 1

, *Nemoura* KUa가 2 ,

(C3) *Chironomus* sp.

*Serratella rufa*가 1

, *Choroterpes trifurcata*가 2 .

Table 8. Dominant species and dominance indices (DI) in the stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998-1999)

Station	Season	1st dominant species	2nd dominant species	DI
1	Spring	<i>Hydropsyche</i> KUe	<i>Glossosoma</i> KUa	0.439
	Summer	<i>Chironomus</i> sp.	<i>Davidius lunatus</i>	0.433
	Fall	<i>Baetis thermicus</i>	<i>Glossosoma</i> KUa	0.416
	Winter	<i>Cincticostella castanea</i>	<i>Glossosoma</i> KUa	0.516
2	Spring	<i>Hydropsyche</i> KUa	<i>Antocha</i> KUa	0.333
	Summer	<i>Chironomus</i> sp.	<i>Hydropsyche</i> KUe	0.547
	Fall	<i>Epeorus curvatulus</i>	<i>Chironomus</i> sp.	0.423
	Winter	<i>Antocha</i> KUa	<i>Hydropsyche</i> KUa	0.723
3	Spring	<i>Serratella rufa</i>	<i>Chironomus</i> sp.	0.579
	Summer	<i>Hydropsyche</i> KUa	<i>Chironomus</i> sp.	0.568
	Fall	<i>Chironomus</i> sp.	<i>Pertanoura</i> sp.	0.449
	Winter	<i>Antocha</i> KUa	<i>Hydropsyche</i> KUe	0.616
4	Spring	<i>Hydropsyche</i> KUa	<i>Serratella setigera</i>	0.411
	Summer	<i>Hydropsyche</i> KUa	<i>Pseudocloeon japonica</i>	0.558
	Fall	<i>Ecdyonurus</i> KUa	<i>Hydropsyche</i> KUa	0.346
	Winter	<i>Ecdyonurus yoshidae</i>	<i>Hydropsyche</i> KUa	0.388
C1	Fall	<i>Tricladida</i> sp.	<i>Hydropsyche</i> KUa	0.413
C2	Winter	<i>Taenionema</i> KUb	<i>Nemoura</i> KUa	0.301
C3	Spring	<i>Serratella rufa</i>	<i>Choroiterpes trifurcata</i>	0.554

Remarks: Station 1 = , C1 = (unpolluted site)
 Station 2 = , C2 = (unpolluted site)
 Station 3 = , C3 = (polluted site)
 Station 4 = ,

3-2. (Species Diversity, H')

(species diversity index)

, (C2) 4.391 가
, (C3) 가 3.45
(clean water body) C3
가 3.210 .
(station 4) 4 3.15-4.28

(Fig. 4).

1, 2 3 (, ,) 2.55-3.7

(Table 9).

Staub category station 2 station 3
가 -

Fig. 4. Species diversity index (H') values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea

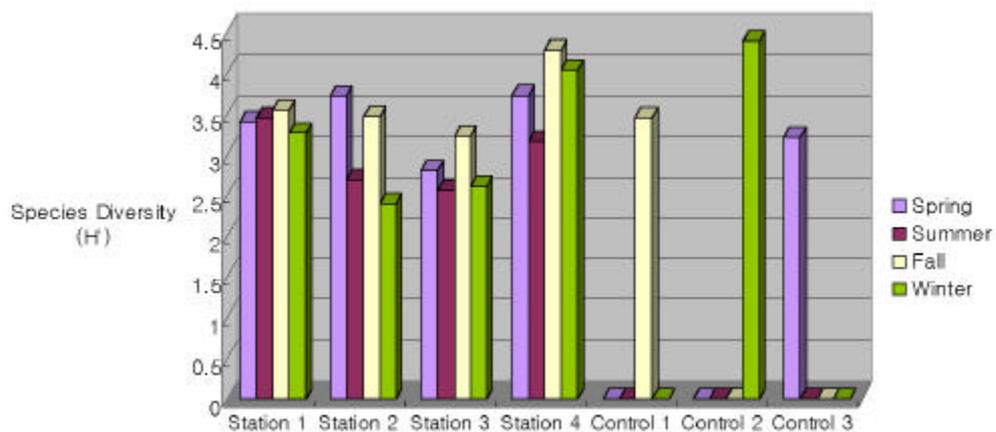


Table 9. Species diversity index values (H') in the stations of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)

Season	Station No.				Control stations		
	1	2	3	4	C1	C2	C3
Spring	3.406	3.717	2.806	3.728	-	-	3.210
Summer	3.451	2.681	2.556	3.152	-	-	-
Fall	3.545	3.471	3.227	4.281	3.452	-	-
Winter	3.262	2.394	2.605	4.039	-	4.391	-

4.

4-1. Trent Biotic Index (TBI)

TBI Table 10 .
(C1) 가 TBI 10 , (C2)
TBI , 4
가
4 TBI 9
(station 2)
(station 4) , 가 , 8
,
5 C3 9 (Fig.
5).

Table 10. Trent biotic index (TBI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)

Station	Spring	Summer	Fall	Winter
1	7	6	9	6
2	5	8	9	8
3	9	7	9	7
4	7	9	9	9
C1	-	-	10	-
C2	-	-	-	10
C3	9	-	-	-

Fig. 5. Trent biotic index (TBI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea

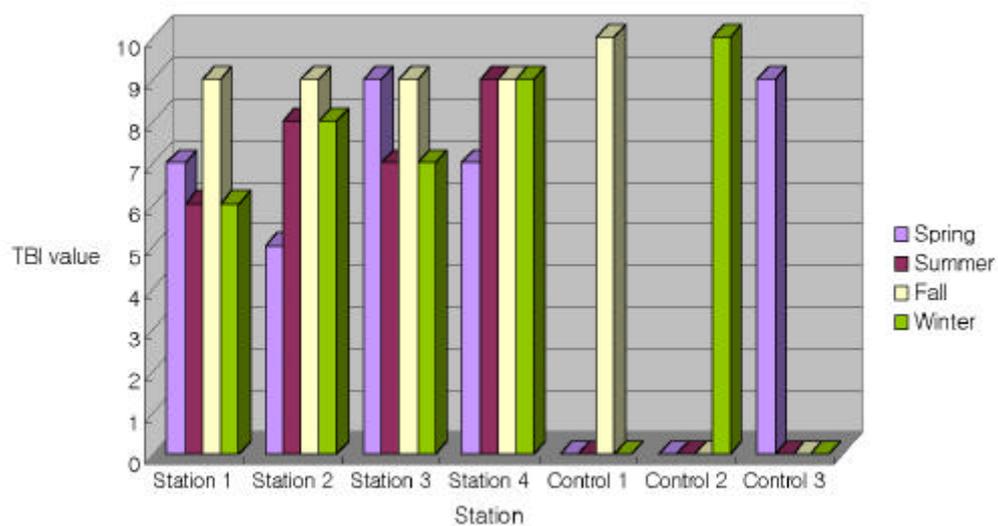
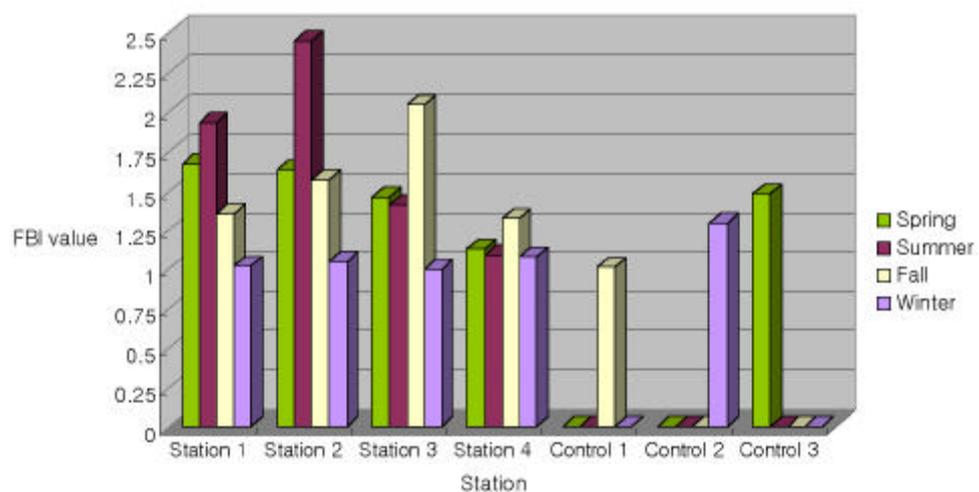


Table 11. Family-level biotic index (FBI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)*

Station	Spring	Summer	Fall	Winter
1	1.67	1.93	1.35	1.02
2	1.63	2.45	1.57	1.05
3	1.46	1.41	2.04	1.00
4	1.13	1.09	1.32	1.08
C1	-	-	1.01	-
C2	-	-	-	1.29
C3	1.48	-	-	-

* Calculated with tolerance values assigned for Korean macrobenthic fauna.

Fig. 6. Family-level Biotic Index (FBI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea



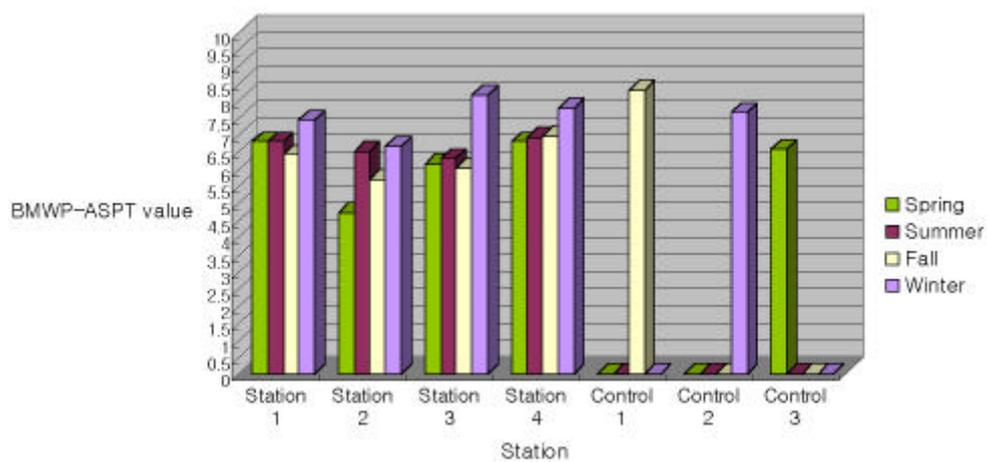
4-3. Modified Biological Monitoring Working Party Score System (BMW P- A S P T)

1- 10
 . (C1) 가 가 8.29 ,
 (C2) 7.63 ,
 4 3 , 1
 5.67- 6.94 (Fig. 7). (station 2)
 4.70 (C3) 6.55
 (Table 12).

Table 12. Modified biological monitoring working party score system (BMWP-ASPT) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)

Station	Spring	Summer	Fall	Winter
1	6.78	6.78	6.40	7.40
2	4.70	6.50	5.67	6.64
3	6.13	6.29	6.00	8.14
4	6.78	6.91	6.94	7.77
C1	-	-	8.29	-
C2	-	-	-	7.63
C3	6.55	-	-	-

Fig. 7. Modified biological monitoring working party score system (BMWP-ASPT) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea



4-4. Biotic Index (BI)

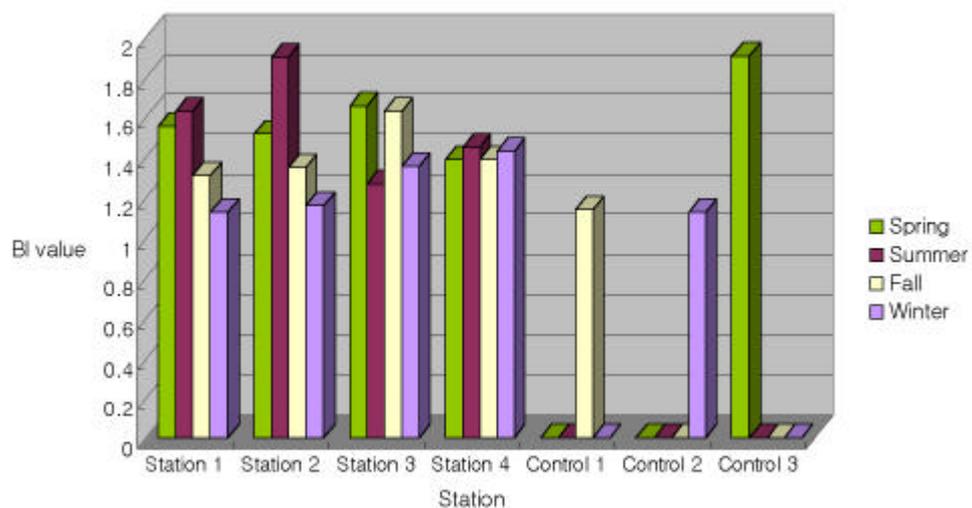
		가 (tolerance value)가		BI	
Table 13 .					
(C1)	(C2)	BI	가	1.14	1.13
(clean unpolluted water)					
(C3)	BI	가	1.91	가	가
"slightly polluted water"					
			. 4	, ,	, 가
			1.5		1.5
			1.5		
		BI	가		가

(Fig. 8).

Table 13. Biotic Index (BI) values of the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999)

Station	Spring	Summer	Fall	Winter
1	1.56	1.63	1.31	1.13
2	1.52	1.90	1.35	1.16
3	1.66	1.27	1.63	1.36
4	1.39	1.45	1.39	1.43
C1	-	-	1.14	-
C2	-	-	-	1.13
C3	1.91	-	-	-

Fig. 8. Biotic Index (BI) values in the stations of Namdae-chon, Muju, Chunlabuk-do, Korea



**4-5. National Sanitation Foundation's Water Quality Index
(NSFWQI)**

		0- 100	
가		. Table 14	
		(2)	
	.	(C1, C2)	90
	(90.8-94.0)	(C3)	81.5
. 4		,	90

Table 14. National Sanitation Foundation's Water Quality Index (NSFWQI) values in the water specimens sampled from the tributaries of Namdae-chon, Muju, Chunlabuk-do, Korea, during one-year survey period (1998- 1999).

	Stations				Control stations		
	1	2	3	4	C1	C2	C3
Average NSFWQI	89.91	85.449	80.233	85.816	90.768	93.989	81.508

Remarks : 1 = , C1 = (unpolluted site)
 2 = , C2 = (unpolluted site)
 3 = , C3 = (polluted site)
 4 = ,

5.

, (BOD₅),
, pH, (conductivity), (DO) (turbidity),
BOD₅ 가 1 2, 3 4
pH,
4
, 가 가 가
가

6.

TBI DO
 (-0.532, $p < 0.05$) . FBI turbidity
 (0.550, $p < 0.05$) . BMWP-ASPT
 $p < 0.01$ conductivity, turbidity
 (-0.694, -0.829) DI H', BI $p < 0.05$
 (Table 15).
 Spearman's rank correlation test
 , DI가 H' (-0.959, $p < 0.01$) 가 . FBI BI (0.710, $p < 0.01$),
 BMWP-ASPT (-0.658, $p < 0.01$)
 (Table 16).
 $p < 0.05$ (H') ($p < 0.033$)
 1, 2, 3 group 1, 4 group
 , $p < 0.05$ BMWP-ASPT ($p < 0.048$) . BMWP-ASPT
 , , 가 group
 group .

Table 15. Spearman's correlation coefficients (r) among five chemical parameters and six biological indices

	Temperature	pH	conductivity	DO	Turbidity
DI	-0.024	0.090	0.097	0.215	-0.097
H'	-0.046	-0.115	-0.216	-0.195	-0.026
TBI	0.102	0.175	0.245	-0.532*	0.321
FBI	0.374	0.322	0.459	-0.475	0.550*
BMWP-ASPT	-0.328	-0.363	-0.694**	0.240	-0.829**
BI	0.460	0.490	0.241	-0.226	0.246

* 0.05 ()

* 0.01 ()

Table 16. Spearman's correlation coefficients (r) among the biological indices applied in the stations of Namdae-chon, Muju, Korea.

	DI	H'	TBI	FBI	BMWP-ASPT	BI
DI	1.000					
H'	-0.959**	1.000				
TBI	0.000	0.107	1.000			
FBI	-0.221	0.056	-0.009	1.000		
BMWP-ASPT	0.074	0.097	-0.084	-0.658**	1.000	
BI	-0.100	0.060	0.102	0.710**	-0.222	1.000

** 0.01 ()

•

1998 6 1999 5 . ,
, 4 , 2
, 1 7

(benthic macroinvertebrates)

가 .

11 (目), 54 (科), 125 (種)

가 가

. 10 (1984. 5 - 1984. 8)

7 18 21 30

가 가

. 1

가 가 , 가

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,

.

1 2, 3

4

.

59.2%가

가

(Oh and Chon, 1991a).

1, 2

(Station 4)

(trichopterans)

(ephemeropterans)가

(Station 1, 2, 3)

(:

Chironomus spp.)

(C3)

Chironomus sp.

*Serratella rufa*가

S. rufa

Yoon *et. al.*, (1992a)

(St. 2, St. 4, C1, C2)

(Simulidae)가 Yoon *et. al.*,
(1992a) Simulidae가
가 (Wilhm and Dorris,
1968) 가 , 1
4 4
2 , 3 ,
C3() 가
(Diptera) 가 (Annelida)
가
가 (Bae *et. al.*, 1993).
TBI (5-8)
BMWP- ASPT FBI/ROK
TBI 3 가
TBI 가 FBI/ROK
가 가
가

BMWP-ASPT

가

•

1998 6 1999 5 1

7

가

.

가

,

, TBI, FBI,

BMWP-ASPT, BI

6가

,

NSFWQI

.

,

.

.

11 54 125 taxa가

(trichopterans)

(ephemeropterans)가 가

.

가 0.5

.

가

1

3 가

4 .

BMWP-ASPT가 conductivity turbidity -0.694, -0.829 ($p < 0.01$) TBI DO가 -0.532 ($p < 0.05$), FBI turbidity가 0.550 ($p < 0.05$) .

, DI H'가 가

($r = -0.959, p < 0.01$) FBI BI ($r = 0.710, p < 0.01$),

FBI BMWP-ASPT ($r = -0.658, p < 0.01$) .

BMWP-ASPT가 가 가

FBI BI .

4 .

1 4 group

가

•

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=Abstract=

Biological evaluation of water quality, using macrobenthos

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This study was carried out 1) to examine the validity of biological indices for assessing water quality at tributaries of Namdae-chon (chon means stream), Muju, Chunlabuk-do in June 1998 through May 1999. We investigated the water quality at 7 sites including 3 control sites, using several biotic indices, and 2) to compare biotic indices for their mutual validities, and with chemical parameters.

The following biotic and chemical indices were employed in order to assess the water quality of each site : Trent Biotic Index (TBI), Modified Biological Working Partly Score System-Average Score Per Taxon (BMWP-ASPT), Hilsenhoff's Biotic Index (BI), Family-level Biotic Index (FBI), species diversity (H'), dominant index (DI), and

National Sanitation Foundation's Water Quality Index (NSFWQI).

For the statistical analyses, Spearman's rank correlation test was employed to compare biotic indices and chemical parameters, and the oneway-ANOVA test for statistical variances of biotic indices among the collection sites. Also, Duncan's multiple range test was applied to get similarity of every site and season visited.

Benthic macroinvertebrates collected in all the field sites composed of 125 taxa, 54 families, 11 orders, and all the sites investigated showed relatively clean water quality.

The value of species diversity (H') in the uppermost site (No. 1) was closer to that of lowest site (No. 4) in this study. It is suggested that the reservoir of Muju pumping hydroelectric power plant was rather self-purifying the pollutants from upper sites, and then the water body ran down to the lower site (No. 4).

The index values of BMWP-ASPT was significantly correlated ($p < 0.01$) with conductivity and turbidity, whereas the values of DI were highly correlated with those of H' ($r = -0.959$, $p < 0.01$). On the other hand, the values of FBI were also highly correlated with those of BI ($r = 0.710$, $p < 0.01$), and with those of BMWP-ASPT ($r = -0.658$, $p < 0.01$).

We concluded that the BMWP-ASPT model is best suited for the bioassessment of lotic system in Namdae-chon, and FBI and BI models are also recommended.



(A)



(B)

Fig. 9 The photographs of indicator species

(A). *Kamimuria* KUa (KUa), commonly occurring in clean streams; (B). *Chironomus* sp., commonly occurring in polluted streams

VIII. 부록

부록 1-1. The individual numbers of macroinvertebrates collected from the tributaries of Nam-Dae Chon, Muju, Chonlabuk-do, Korea, during one-year survey period (1998-1999).

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3	
	spr.	sum.	fall				win.									
		win.	win.		win.	win.										
EPHEMEROPTERA																
Beetidae																
<i>Baetis thermicus</i> (포마하루살이)		4	31		2	3		3	6		32	12		4	1	
<i>Baetis nla</i> (포마하루살이 nla)				2						2	1					
<i>Cloea dipterum</i> (외날개포마하루살이)			3	2				4	12		78	8				
<i>Pseudocloeon japonica</i> (흰날개포마하루살이)		1					4			2						
<i>Pseudocloeon japonica</i> na (흰날개포마하루살이 na)															2	
Oligoneuridae																
<i>Isonychia japonica</i> (민날개하루살이)																
Hepatageniidae																
<i>Epeorus latifolium</i> (흰꼬리하루살이)			3		1	3		8	6	4	41	8		2	9	
<i>Epeorus curvatus</i> (큰흰꼬리하루살이)		1	1		14	1					11		1	7	1	
<i>Epeorus aescallus</i> (포마흰꼬리하루살이)									9		11		5	6	2	
<i>Cinygmula</i> KUa (센꼬리하루살이 KUa)			7											27		
<i>Cinygmula</i> KUb (센꼬리하루살이 KUb)														1	7	
<i>Ecdyonurus yoshidae</i> (꼬리하루살이)		1	1			1				1	7			1	2	
<i>Ecdyonurus kiburensis</i> (개꼬리하루살이)		1	1							1	12			11	1	

부록 1-2

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3
	spr.	sum.	fall	win.	spr.	sum.	fall	win.	spr.	sum.	fall	win.			
<i>Echyronurus</i> KUa (꼬리하루살이 KUa)								2	1		58	19		17	
<i>Echyronurus</i> KUb (꼬리하루살이 KUb)									1			5			
<i>Hepatogenia kulrada</i> (취꼬리하루살이) Leptophlebiidae					1									5	
<i>Paraleptophlebia chocorata</i> (밤색하루살이)	1	1						1		1				18	1
<i>Choroterpes trifurcata</i> (세줄밤색하루살이)							2	3		11		3			27
Potamanthidae															
<i>Potamanthodes kamonis</i> (강하루살이붙이)											3				1
<i>Potamanthus coreanus</i> (강하루살이)										3					
Ephemeridae															
<i>Ephemera strigata</i> (무늬하루살이)	3		2	16			1	1		2	3	6		2	13
<i>Ephemera orientalis</i> (동양하루살이)	1		3	2						1	5	2		12	3
Ephemerellidae															
<i>Drunella aculea</i> (뿔알하루살이)	1			1										2	13
<i>Drunella triacantha</i> (세뿔알하루살이)															9
<i>Drunella cryptomeria</i> (알통알하루살이)		1								1					
<i>Cincticostella castanea</i> (민알하루살이)				63										33	
<i>Serratella rufa</i> (등줄뱃살알하루살이)					1									22	76
<i>Ephemerella keijoensis</i> (알하루살이)				3					63	1				6	
<i>Ephemerella nba</i> (알하루살이 nba)														37	
Caenidae															
<i>Caenis</i> KUb (등뿔하루살이 KUb)															5

부록 1-3

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3				
	spr.	sum.	fall	win.	spr.	sum.	fall	win.	spr.	sum.	fall	win.				spr.	sum.	fall	win.
ODONATA																			
Calopterygidae																			
<i>Calopteryx atrata</i> (검은물잠자리)														1					
<i>Calopteryx japonica</i> (물잠자리)					1									4					
Gomphidae																			
<i>Gomphus postacularis</i> (여리측범잠자리)															1				
<i>Burmagomphus</i> KUa (차루측범잠자리 KUa)															1				
<i>Davidius lunatus</i> (쇠측범잠자리)	1	13	4				1							2					
<i>Onychogomphus ringens</i> (노란측범잠자리)																			
<i>Ophiogomphus obscura</i> (측범잠자리)									2				1						
<i>Nihonogomphus</i> KUa (고려측범잠자리 KUa)																			
<i>Nihonogomphus bifurcatus</i> (고려측범잠자리)													1						
<i>Sieboldius albardae</i> (여리장수잠자리)																			
Corduliidae																			
<i>Macromia manchuria</i> (만주잔산잠자리)																			
Libellulidae																			
<i>Orthetrum albitylum speciosum</i> (밀잠자리)								1											

부록 1-4

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3
	spr.	sum.	fall	win.	spr.	sum.	fall	win.	spr.	sum.	fall	win.			
PLECOPTERA															
Taeniopterygidae															
<i>Taenionema</i> KUa (메추리강도래 KUa)														11	
<i>Nemoura tau</i> (토우민강도래)														205	
<i>Nemoura</i> KUa (민강도래 KUa)							5							1	
<i>Nemoura</i> KUa (민강도래 KUa)							1							5	
<i>Nemoura</i> KUa (민강도래 KUa)														1	
<i>Nemoura</i> KUa (민강도래 KUa)														1	
Capniidae															
<i>Eucapnopsis</i> KUa (짧은꼬리민강도래 KUa)															
Leuctridae															
<i>Rhopalopssole mahunkai</i> (포마강도래)															
Pteronarcidae															
<i>Pteronarcys sachalina</i> (큰그물강도래)				1											
Perlodidae															
<i>Megarctys ochracea</i> (그물강도래)															
<i>Isoperla</i> KUa (줄강도래 KUa)														3	
Perlidae														10	8
<i>Ovaria coreana</i> (진강도래)														7	2
<i>Paragnetina flavotincta</i> (강도래불이)										2				2	1
<i>Kamimuria</i> KUa (강도래 KUa)										2				1	
Chloroperlidae															
<i>Sveltsa nitkoensis</i> (녹색강도래)														1	

부록 1-5

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3
	spr.	sum.	win.												
HEMIPTERA															
Nepidae															
<i>Laccotrephes japonensis</i> (장구애비)		5	1	1	3										
<i>Ranatra chinensis</i> (게아제비)		1													
Belostomatidae															
<i>Diplonychus japonicus</i> (물자라)			5	1		1									
MEGALOPTERA															
Corydalidae															
<i>Protohermes grandis</i> (뱀잠자리)														2	
<i>Parachailiodes continentalis</i> (대륙뱀잠자리)	1														1
Sialidae															
<i>Sialis</i> KUa						1									
TRICOPTERA															
Philopotamidae															
<i>Wormaldia</i> KUa (인술날도래 KUa)															
Hydropsychidae															
<i>Arctopsyche ladogensis</i> (곰줄날도래)			9												
<i>Hydropsyche</i> KUa (줄날도래 KUa)	7	2	13	14	5	63	12	21	34	63	114	35	22	33	10
<i>Hydropsyche</i> KUb (줄날도래 KUb)			1	1	1	22	2	2	4	20	20	15		9	2
<i>Hydropsyche</i> KUc (줄날도래 KUc)							1	2	2	4	4	8		3	
<i>Hydropsyche</i> KUd (줄날도래 KUd)				2		5	2	1	1	8	8	1		23	
<i>Hydropsyche</i> KUe (줄날도래 KUe)			18		18	24	1	5	48	8	38	9		6	
<i>Cheumatopsyche brevitarsata</i> (꼬마줄날도래)		2	3	2	4	14	1	4	4	8	8	14		5	
<i>Cheumatopsyche</i> KUa (꼬마줄날도래 KUa)						4				3	3	4			
<i>Macronema radiatum</i> (큰줄날도래)												4			

부록 1-6

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3
	spr.	sum.	fall	win.	spr.	sum.	fall	win.	spr.	sum.	fall	win.			
Rhyacophilidae															
<i>Rhyacophila yamanakensis</i> (곤봉물날도래)															
<i>Rhyacophila impar</i> (거친물날도래)				2											3
<i>Rhyacophila retracta</i> (옹수물날도래)															1
<i>Rhyacophila articulata</i> (주름물날도래)															2
<i>Rhyacophila brevicephala</i> (넓은머리물날도래)															
<i>Rhyacophila clemens</i> (크레멘스물날도래)															
<i>Rhyacophila nigrocephala</i> (검은머리물날도래)				1											
<i>Rhyacophila</i> KUa (물날도래 KUa)								1							12
<i>Rhyacophila</i> KUb (물날도래 KUb)															7
Glossosomatidae															
<i>Glossosoma</i> KUa (광택날도래 KUa)															
Brachycentridae															
<i>Micrasema</i> KUa (등근얼물날도래 KUa)	13	2	16	35	7	2	6	15	10	5					33
Linnephilidae															
<i>Linnephilus</i> KUa (모시우물날도래 KUa)															
<i>Hydatophylax nigrovittatus</i> (따뚜늬우물날도래)															
<i>Notopsyche</i> KUb (갈색우물날도래 KUb)															
<i>Apatania</i> KUa (애우물날도래 KUa)															
<i>Goera japonica</i> (가시날도래)															
Lepidostomatidae															
<i>Goerodes</i> KUa (베모질날도래 KUa)															
Sericostomatidae															
<i>Psilotreta kisoensis</i> (바수염날도래)	1		2												1

부록 1-8

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3
	spr.	sum.	fall	win.	spr.	sum.	fall	win.	spr.	sum.	fall	win.			
	Limoniidae														
<i>Antocha</i> KUa (명주각다귀 KUa)		1		5	14	1	264	15	1	58			2		48
<i>Dicranota</i> KUa (애기각다귀 KUa)				3			9								
Psychodidae		1													
<i>Tetratocopus</i> KUa (털나방파리 KUa)							1								98
Simuliidae															
<i>Simulium</i> sp.					1									2	
<i>Simulium decorum</i>														1	
Ceratopogonidae		4					17								
<i>Palpomyia</i> sp.															
Chironomidae															
<i>Chironominae</i> sp.	2	13	8		11		1	18	4	29			6	7	68
<i>Chironomus</i> sp.															
<i>Tanypodinae</i> sp.	6												5		11
Chiromidae		5	3		5		10	3		15				15	
<i>Pertanoura</i> sp.															
Tabanidae															
<i>Tabanus</i> sp.	2			2	7			1		1					
Others															
Annelida															
Oligochaeta : earthworm	8														
Oligochaeta unknown															
Hirudinea															
<i>Helobdella transversa</i>															3

부록 1-9

Name of Taxa (sp.)	St. 1			St. 2			St. 3			St. 4			C1	C2	C3	
	spr.	sum.	fall win.	spr.	sum.	fall win.	spr.	sum.	fall win.	spr.	sum.	fall win.				
	Planariidae															
Tricladida																
Tubificidae	3			3									37			
<i>Liriodrilus socialis</i>															6	
Gastropoda																
<i>Semisulcospira libertina</i> (다슬기)	1		2				2							24		
<i>Semisulcospira tegulata</i> (좁주름다슬기)														21	1	
<i>Radix auricularia coreana</i> (물달팽이)				1												
<i>Physa acuta</i> (원뿔이물달팽이)				3										2		
Total individual No.	75	59	113	84	117	52	452	140	44	98	172	297	344	269	529	186
Total No. of species (Taxa)	16	18	19	20	10	18	27	19	10	16	16	29	26	39	38	24

Remark : St. 1 = 전북 무주군 적상면 피복리, 세재 (St. = Station)

St. 2 = 전북 무주군 적상면 피복리, 피목

St. 3 = 전북 무주군 적상면 포내리, 하부읍입구

St. 4 = 전북 무주군 적상면 북창리, 하부저수지 하류

C1 = 구천동 (C = Control station)

C2 = 설천

C3 = 남대천

C1-2 : unpolluted station

C3 : polluted station

부록 2. 환경부의 하천수질환경기준

구분	등급	이용 목적별 적용대상	기준				
			수소이온농도 (pH)	생물화학적 산소요구량 (BOD, mg/ℓ)	부유물질량 (SS, mg/ℓ)	용존산소량 (DO, mg/ℓ)	대장균군수 (MPN, 100mℓ)
생 활 환 경	I	상수원수 1급	6.5 - 8.5	1 이하	25 이하	7.5 이상	50 이하
		자연환경보존					
	II	상수원수 2급	6.5 - 8.5	3 이하	25 이하	5 이상	1,000 이하
		수산용수 1급					
		수영용수					
III	상수원수 3급	6.5 - 8.5	6 이하	25 이하	5 이상	5,000 이하	
	수산용수 2급						
IV	공업용수 1급	6.5 - 8.5	8 이하	100 이하	2 이상	-	
	공업용수 2급						
V	공업용수 3급	6.5 - 8.5	10 이하	쓰레기등이 떠있지 아니할 것	2 이상	-	
	생활환경보전						
사람의 건강보호	전수역	카드뮴 (Cd) : 0.01mg/ℓ 이하					
		납 (Pb) : 0.1mg/ℓ 이하					
		시안 (CN), 수은 (Hg), 유기인, 폴리클로리네이티드비페닐 (PCB) : 불검출					

- Remark : 1. 수산용수 1급 : 빈부수성 수역의 수산생물용
 2. 수산용수 2급 : 중부수성 수역의 수산생물용
 3. 자연환경보전 : 자연경관 등의 환경보전
 4. 상수원수 1급 : 여과 등에 의한 간이정수처리후 사용
 5. 상수원수 2급 : 침전여과 등에 의한 일반적 정수처리후 사용
 6. 상수원수 3급 : 진처리 등을 거친 고도의 정수처리후 사용
 7. 공업용수 1급 : 침전 등에 의한 통상의 정수처리후 사용
 8. 공업용수 2급 : 약품처리 등 고도의 정수처리후 사용
 9. 공업용수 3급 : 특수한 정수처리후 사용
 10. 생활환경보전 : 국민의 일상생활에 불쾌감을 주지 아니할 정도