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Water Quality of the Melamchi Khola.

Impacts of Diversion of Water to Kathmandu Valley, Nepal

Norwegian Institute for Water Research

REPORT

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Abstract

This is a part report on water quality of an extensive EIA report on Melamchi Diversion Scheme.
The Melamchi Khola between the Intake site and Indrawati Nadi, and the tributaries Ribal, Gohare, Gyalthun and Shindhu Khola are the river stretches that will be largely affected by the diversion of water from the Melamchi Khola. The main changes of Melamchi Khola will be: Reduced water flow, increased temperature, and increased concentration of major ions. All river sections will have increased eutrophication and increased turbidity especially during the construction period. According to the different alternatives for minimum water releases of 0.15, 0.5, and 1.5 m^3/sec, the temperature of Melamchi Khola might increase with 4 °C, 3 °C, or 2 °C respectively. At the minimum release of 0.15 m^3/sec the salt concentration may increase 30-35 % at a distance of 10 km downstream the Intake site, and the rate of flow will be reduced by 90-95 % compared to the natural flow in the dry season (November – May). The rest flow of 0.5 m^3/sec will increase the salt content by about 25 %, and reduce the water discharge by 80 % of dry season flow before diversion.

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1. Vassdragsregulering	1. Regulation of river system
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Melamchi Diversion Scheme.

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Preface

This report presents the result of the water quality study performed in the River Melamchi Khola, Nepal, in 1999. The study was a part of the environmental impact assessment (EIA) of the Melamchi Diversion Scheme (MDS). The World Conservation Union (IUCN), Nepal co-ordinated the EIA, and the whole project, Melamchi Diversion Scheme was managed by NORPLAN, Norway.

Leif Lien, NIVA, was engaged as freshwater biology and chemistry expert, and gave inputs to the final EIA report compiled by IUCN, Nepal. Most of the fieldwork and writing took place in April and May 1999. The fieldwork was done in co-operation with NORDPLAN and IUCN, and especially Finn B. Christensen and Drona Rai Ghimire took part in the fieldwork and the latter also in writing the water quality report.

NORDPLAN and IUCN offered transportation and practical services during the study and the fieldwork. Nepal Environmental & Scientific Services (NESS) performed most of the chemical analyses.

Oslo, 25 October 2000

Leif Lien

Contents

Acronyms:

ANC: Acid neutralisation capacity
BPC: Butwal Power Company
EIA: Environmental Impact Assessment
IUCN: The World Conservation Union
LOI: Loss of ignition
Mc: Construction Monitoring
MDS: Melamchi Diversion Scheme
Mp: Permanent Monitoring
NESS: Nepal Environmental and Scientific Services
NIVA: Norwegian Institute for Water Research
NWSC: Nepal Water Supply Corporation
SMEC: Snowy Mountain Engineering Corporation
UTM: Universal Transverse Mercator
WHO: World Health Organisation

Summary

The Melamchi Diversion Scheme (MDS) proposes to transfer water from the Melamchi Khola to the Kathmandu Valley for drinking purpose. The diverted water will also be used for generating hydropower.

There were three main purposes for the assessment of water quality of the Melamchi Khola:
1. Description of the general water quality in the affected sections of the river.
2. Evaluate water quality differences between Melamchi Khola and its tributaries in the affected area.
3. Prepare baseline information of water quality for later monitoring during the construction period and for subsequent permanent monitoring.

The Melamchi Khola between the MDS Intake site and the confluence with the Indrawati Nadi is the river stretch that will be mainly affected by the diversion of water. Also the water qualities of the tributaries Ribal, Gohare and Gyalthun Khola will be influenced. A fourth river, Shindhu Khola will be disturbed as well.

Monthly average water discharge for Melamchi Khola is presented together with measures of water discharge at several locations in the dry season. The reduced flow of water after diversion in different parts of the Melamchi Khola is estimated for the minimum release of 0.15, 0.5, and 1 m^3/sec water from the Intake site. At the minimum release of 0.15 m^3/sec in the dry season (November – May), the Melamchi Khola will only have between 5 and 10 % of its normal water flow downstream the Intake site. Within the 10-km distance downstream from the intake site, only a small amount of water is fed by the side tributaries into the Melamchi River, and the stony riverbed with big boulders will partly appear almost dried out. At the release of 0.5 m^3/sec, 20 % of the normal water flow will remain downstream the Intake site in the dry season.

Only very few and incomplete data sets on water quality were available for Melamchi Khola.
New samples were collected in the Melamchi Khola and tributaries in April 1999. The river was sampled from upstream Intake site and down to the conjunction with Indrawati Nadi. Additional samples from the Intake area were collected in April, May, June and July 1999.

Data from above and at the Intake site indicated good quality for drinking water with a few exceptions: Iron and coliform bacteria. Most of these coliform bacteria came from nearby upstream settlements. Nutrients are also fed into the Melamchi Khola from these settlements.

Several differences were recorded between the Melamchi Khola and its tributaries. Preliminary measures indicated a lower mean temperature by 4.4 °C in the Melamchi Khola compared to five main tributaries. Compared to the Melamchi Khola, the five examined tributaries also showed varying water chemistry. The Ribal Khola had a generally harder water quality compared to the Melamchi Khola. The Timbu Khola also showed somewhat higher salt concentration than the Melamchi Khola did, but less than the Ribal Khola. The Gohare Khola had a much softer water quality compared to both the Melamchi Khola and also compared to all the other tributaries. The Gyalthun Khola indicated a water quality quite similar to The Gohare Khola except for a high concentration of sodium. The Talamaran Khola also had a very high concentration of sodium in addition to most other major ions.

All the tributaries showed increased concentrations of nutrients compared to the Melamchi Khola. Increased eutrophication is therefore expected when a substantial amount of water is diverted. The bio-production in the Melamchi Khola is probably limited by nitrogen content in the water. From the rock deposits and from the workers camps at the tunnel adits, especially nitrogen, but also phosphorus, and organic matter are expected to enter the tributaries and thereafter the Melamchi Khola. Locally,

and in dry seasons, this will increase the eutrophication possibility. However, serious eutrophication problems like oxygen deficiency or overgrowth of attached vegetation is unlikely considering the rapids and small waterfalls along the Melamchi Khola.

Scenarios based on changes of water quality in Melamchi Khola have been estimated according to the minimum discharge release from the Intake site: 0,15 m^3/sec 0,5 m^3/sec and 1 m^3/sec.

- The water temperature in Melamchi Khola might increase on an average by 4 °C, 3 °C, and 2 °C at water releases of 0.15, 0,5 and 1.0 m^3/sec respectively.

- At the release of 0,15 m^3/sec, the upper 10 km of the river will have 30 -35 % higher salt concentration compared with the present values. At the minimum water release of 0,5 m^3/sec the salt concentration will increase by ca 25 %. At the minimum release of 1 m^3/sec the increase in the salt concentration will be less than 20 %. Downstream the conjunction with Gohare Khola the corresponding increase in the salt concentrations would be approximately 5-10 %, 5 %, and less than 5 % for minimum release of 0,15, 0,5 and 1 m^3/sec respectively.

- Eutrophication scenarios should also be prepared. However, in addition to uncertain discharge figures of the tributaries, no data were available on nitrogen and phosphorus effluents from the future workers camps.

Changes caused by the diversion of water from the Melamchi Khola will influence the living conditions for fish and other aquatic life. The main parameters identified are:

1.Reduced water flow

2.Change of water quality:

A) Temperature increase
B) Higher concentration of major ions
C) Increased eutrophication
a) caused by removal of clean water for dilution.
b) caused by new source of nitrogen and phosphorous from tunnel (tips) stone debris and workers camps (mainly during construction period).
D) Increased turbidity from tunnel debris (mainly during construction period)

The decision of the minimum release of water from the Intake site will be vital to the aquatic life and all other use for water, particularly in the first 10 - 15 km downstream the intake. A substantial reduction of water discharge will decrease the fish production of the Melamchi Khola.

Mitigation measures for water quality are given. The greatest impacts on water quality and aquatic life are caused by (1) reduction of water discharge and (2) effluents from tunnel deposits and camps during the construction. Mitigation measures should therefore focus on reducing the effects from these.

Any increase in the minimum water discharge from the Intake site will have great mitigation effects. This has reference to virtually all use of water in the Melamchi Khola today.

The effluents from tunnel deposits and workers camps, especially at Intake site would cause negative impacts on the Melamchi Khola. Special treatments like oil skimmers, pit latrines, septic tanks, and sedimentation lagoons downstream tunnel deposits should be installed and properly maintained especially in dry seasons.

In order to avoid stranding of fish and other aquatic organisms, gradual variation of discharges should be included in the instruction control of water manoeuvring at the Intake site in the Melamchi Khola.

Three localities in the Melamchi Khola were selected for permanent monitoring of water quality. Four additional sites were chosen for temporary monitoring during construction period. General parameters for water quality descriptions were listed together with parameters describing eutrophication, salt concentrations, particulate matters, oil, and faecal contamination. Guidelines for the practical performance of the water quality monitoring were prepared.

1. Introduction

The Melamchi Diversion Scheme (MDS) Project intends to supply drinking water for the greater Kathmandu City, the capital of Nepal. Besides, the project would also produce hydropower electricity. The water will be diverted from Melamchi Khola into the Bagmati Khola in the Kathmandu Valley. The water will be transported through a tunnel, and a total of four adits will be established in order to construct the tunnel (Figure 1). During the construction period, effluents from the adits will have impacts on the qualities of the nearby rivers water. The effluents are expected to include drainage from the tunnel construction in addition to wastewater from the workers camps.

The hydropower station will be located near Sundarijal in the catchment of Bagmati Khola, and the treatment plant of the drinking water will be constructed in the same area.

The water of the Bagmati Khola is currently used as the main source of a drinking water for the Kathmandu City. Downstream Sundarijal, the Bagmati Khola flows for just a few km before virtually all the water is used for irrigation and other purposes. During periods of the dry season in 1999 the Bagmati Khola had no water in a certain section. Due to entries of sewage and heavily polluted tributaries, the riverbed is recharged to some extent further downstream. Compared to former reports (SMEC 1992a, BPC 1996, Balloffet and Associates 1998) the conditions in the Bagmati Khola have obviously been deteriorated during the last few years. Limited amount of excess water from the Melamchi Khola, which is not needed for drinking water to Kathmandu, will hardly show any positive effect on the water quality of the Bagmati Khola. On the other hand, more drinking water to Kathmandu Valley means increased sewage flow into the Bagmati Khola.

In the rainy season, there is abundance of water, and most of the sewage and the particulate waste in Bagmati Khola are annually flushed downstream. The electricity production based on additional 7 - 10 m^3/sec diverted from Melamchi Khola will contribute to the flushing effect on Bagmati. Other improvements can hardly be expected before the main bulk of sewage along Bagmati Khola is properly treated.

The main impacts of the Melamchi Diversion Project are anticipated to take place in Melamchi Khola and its tributaries (Figure 2). Only minor impacts, like slight reduction of water temperature and some increase of particulate matter are expected in Bagmati Khola in addition to possible improvements of the increased amount of clean diluting water. This study of water quality will therefore be focused on the Melamchi Khola. The water quality of the Bagmati Khola, including the quality of the drinking water, will be evaluated in the final EIA study.

The river stretch that mainly will be affected by this diversion of water is Melamchi Khola between the Intake site and the confluence with Indrawati Nadi. Also the tributaries of Melamchi the Gohare Khola and the Gyalthun Khola will be influenced by deposits from tunnel adits and workers camps. A third adit, location of which was not finalised during this field study period, will affect the river Shindhu Khola. Due to this uncertainty this tributary was not sampled for water quality data. After May 1999, a fourth adit has been added to the main tunnel. This adit is located in the catchment of the tributary Ribal Khola (Figure 1). The Ribal Khola was sampled for water quality data in April 1999, but the sample was taken some distance downstream of the expected adit site.

Only one incomplete data set on water quality has been quoted in the former EIA studies for the Melamchi Khola (SMEC 1992a, BPC 1996, Balloffet and Associates 1998), and there is no information of when or where this sample was collected. However, within an appendix in a former report concerning engineering and economics some water quality data are given (SMEC 1992b). These data have never been used in any former EIA studies.

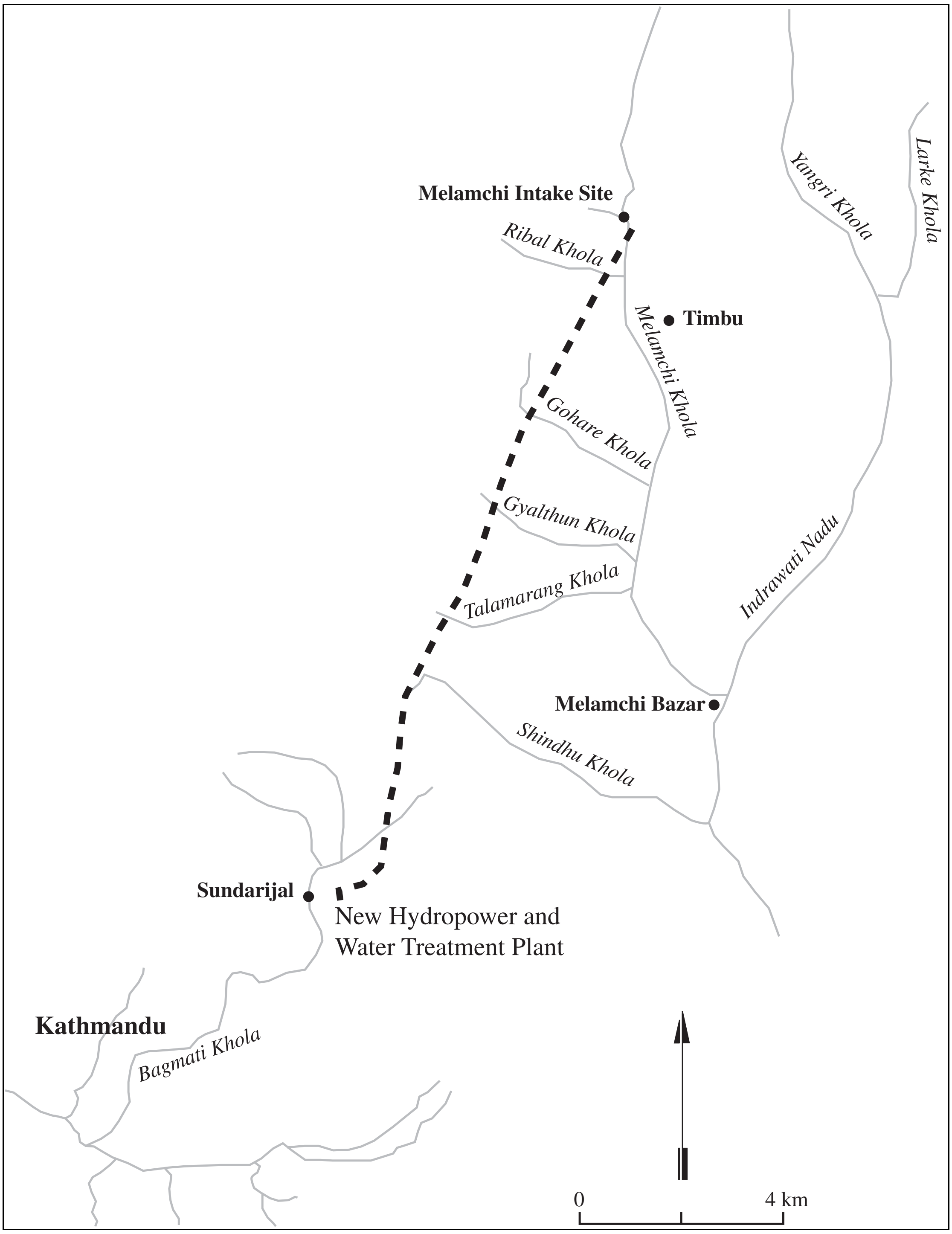

Figure 1. Location of the Melamchi Diversion Scheme including proposed tunnel and new hydropower and water treatment plant.

The latest EIA study report on the Melamchi project was performed by the World Bank (draft 1999). Environmental impacts were only mentioned briefly. Among several objectives of this World Bank mission's was to: "Identify any major water conservation or environmental issues associated with the proposed alternatives and mitigation steps that need to be taken." The World Bank concluded: "That the scheme (Melamchi) would have no significant negative environmental impacts." This conclusion is based on "Further work supported by the World Bank and other donors evaluated the technical feasibility of the Melamchi options." Only a complete lack of information and knowledge of other essential reports on Melamchi (SMEC 1992a, BPC 1996, Balloffet and Associates 1998) can lead to this erroneous conclusion. Another statement in the World Bank (1999) report says: "Melamchi water quality at site of the planned diversion is of good quality." As mentioned above, no satisfactory water quality data do exist for the Melamchi Khola. It must therefore be concluded that the environmental statements in the World Bank report (1999) are incorrect and misleading.

1.1 Water discharge of Melamchi Khola.

A monthly average water discharge for Melamchi Khola is presented in BPC report (1996). In addition, a proposed abstraction of water from the Melamchi Khola is shown. In Table 1 these data are presented together with calculations for the remaining flow downstream the Intake site in the Melamchi Khola given as m^3/sec and as percentage of the average monthly flow.

Table 1. Average flow in Melamchi Khola, proposed abstraction at Intake site (BPC 1996), and rest flow, all given as m^3/sec. The rest flow is also given in percentage.

Month	Average flow	Proposed Abstraction	Rest flow m^3/sec.	Rest flow %
Jan.	3.2	3.05	0.15	5
Feb.	2.7	2.45	0.25	10
March	2.5	2.35	0.15	6
April	2.8	2.50	0.3	11
May	3.7	3.2	0.5	13
June	10.2	7.0	3.2	31
July	27.4	7.0	20.4	75
Aug.	34.4	7.0	27.4	80
Sept.	24.4	7.0	17.4	70
Oct.	8.2	7.0	1.2	15
Nov.	4.9	4.55	0.35	7
Dec.	3.7	3.55	0.15	4

Table 2 shows a recent measure of water discharge at several locations in Melamchi Khola from the water gauge upstream Intake site and down to Melamchi Bazar, close to confluence with Indrawati Nadi. The water flow at Intake site was 2.3 - 2,4 m^3/sec. That is close to minimum average flow given in Table 1. Due to low influx from tributaries and abstraction of water from Melamchi Khola, the discharge in Melamchi Khola does not increase very much in the first 10 km downstream the Intake site. At 14 km from Intake site, and downstream the Gohare Khola, the Melamchi Khola has doubled its discharge. Further downstream it is somewhat reduced again due to abstractions for irrigation.

Table 2. Discharge measures in Melamchi Khola 22 - 26 March 1999, mean values of several samples. Given by NORPLAN 1999.

Distance in km from Gauge 627.5	Date	Site	Discharge m^3/sec
0	22-23/3	Gauge 627.5	1.9
1.4	22-23/3	Just above intake	2.3
1.51	22/3	Just below intake	2.4
3.58	24/3	Sarkathali village	2.3
6.20	24/3	Ambathang below Tartong Khola	2.6
9.62	24/3	Chiurikhara near bridge	2.6
12.1	24/3	Kjulbesi near bridge	2.9
15.3	25/3	Chanaute below Bangare Khola	4.0
18.13	25/3	Upstream Talamaran	4.0
21.75	26/3	Kharkadanda below Nuhar Khola	3.7
23.91	26/3	Melamchipul Bazar	3.9

The minimum releases of water from the Intake to the Melamchi Khola have been suggested to be 0.15 m^3/sec (BPC 1996). In addition, this EIA will evaluate the effects of proposals to two other minimum releases: 0.5 and 1 m^3/sec. The minimum release of 1 m^3/sec has also been mentioned in other reports (SMEC 1992, BPC 1996). The remaining water flows in the various sections of the river have been calculated on the basis of the recent discharge measured in March 1999 (Table 2). March generally has the lowest mean monthly discharge in a year. Therefore, the remaining flows given in Table 3 probably also represent the lowest mean flow in a year for the Melamchi Khola.

Table 3. Rest flow of water in different parts of the Melamchi Khola for the three scenarios of the minimum release of water from the Intake: 0.15, 0.5, and 1 m^3/sec. Values are presented as m^3/sec and percent according to measured discharge at each site.

Distance from Gauge 627.5	Site	Discharge m3/sec	Rest flow m3/sec	%	Rest flow m3/sec	%	Rest flow m3/sec	%
			0,15 m3/sec		0,50 m3/sec		1,00 m3/sec	
0,0	Gauge	1,9	1,9	100	1,9	100	1,9	100
1,4	Just above intake	2,3	2,3	100	2,3	100	2,3	100
1,51	Just below intake	2,4	0,15	6	0,5	21	1	42
3,58	Sarkathali village	2,3	0,05	2	0,4	17	0,9	39
6,2	Ambathang below Tartong	2,6	0,35	13	0,7	27	1,2	46
9,62	Chiurikhara near bridge	2,6	0,35	13	0,7	27	1,2	46
12,1	Kjulbesi near bridge	2,9	0,65	22	1	34	1,5	52
15,3	Chanaute below Bangare	4	1,75	44	2,1	53	2,6	65
18,13	Upstream Talamarang	4	1,75	44	2,1	53	2,6	65
21,75	Kharkadanda below Nuhar	3,7	1,45	39	1,8	49	2,3	62
23,91	Melamchipul Bazar	3,9	1,65	42	2	51	2,5	64

Due to abstraction of water for irrigation the discharges decrease at several sections in the downstream reaches of the Melamchi Khola. A minimum release of 0.15 m^3/sec implies a rest flow of only 50 litres/second, 2 % of the normal dry season flow for ca 2 km downstream the Intake site. Stones and boulders of varying size cover the bottom of this fast flowing river. A water flow of 50 litres/second is therefore equivalent to dry riverbed, and damages to aquatic life could be considerable. The remaining flow between 10 - 20 % will also have considerable effects on the river. This will be discussed in more detail below.

1.2 Water quality of Melamchi Khola and its tributaries.

Until 1999, only one very incomplete data set on water quality has been quoted in the EIA studies for the Melamchi Khola, and there is no information of when or where this sample was collected. However, within an appendix in a former report concerning engineering and economics some water quality data are given (SMEC 1992b). These data were unknown to IUCN, and they have never been quoted in any former EIA studies. These data was collected during three periods: 21/12-1990 to 25/3-1991 (six samples), 26/7-1991 to 1/9-1991 (three samples), and one sample (48.5.17 Nepal time). However there is no information of sampling locality. Selected parameters are given in Table 4 together with the former quoted water analyses (shaded). There is considerable discrepancy between some of the parameters presented in the two sets of analyses: E.g. calcium, total phosphorous, and dissolved oxygen.

Table 4. Former water quality data available from Melamchi Khola (SMEC 1992b, BPC 1996, Balloffet and Associates 1998). All data except last column were analysed by NWSC Scientific Services Central Laboratory, Kirtipur.

Date	21.12.90	09.01.91	31.01.91	23.02.91	05.03.91	25.03.91	26.07.91	17.08.91	01.09.91	?	?
	Winter - dry season						Summer - rainy season			48.5.17	
Appearace	Clear	Clear	Clear			Clear	Hazy	Hazy	Hazy	Clear	Clear
Temperature 0C	5,5				6,2	9	14				13
pH	6,5	6,1	5,8	7,65	7,65	6,2	5,9	5,5	5,8	5,6	7,5
Color Hazen	<5	<5	<5			<5	5	<5	70	5	
Turbidity NTU	<5	<5	<5	10	4	<5	20	5	1000	5	
Conductivity uS/cm	38,1	35,5	47	56	52	45,3	31	38	35	34	
Sup.Solids mg/l	2	5		50	8	6	18	6			
Disol.Solids mg/l	25	35		60	30	55	34	44			
Alk(CaCO3) mg/l	20	16	20	33	26	22	12	12	14	12	
Hardness Ca mg/l	15	24	26	15	15	18	6,1	12	16	12	
Hardness Mg mg/l	41	33	15	11	6,8	8,1	4,1	8,2	14	12	
Ca mg/l	6,5	10	8			7,4	2,5	4,9	6,6	4,9	28
Mg mg/l	7	5	1,4			1,5	1	2	3,5	3	3
Fe mg/l	0,01	0,01	0,01			0,01	0,51	0,09	1,4	0,61	0,11
Mn mg/l	0,005	0,005	0,005		0,05	0,005	0,02	0,03	0,12	0,013	
SiO2 mg/l	2	8		40	7	20	10	16	32	10	
Cl mg/l	3,9	6	3,9			8,8	5,8	5,8	7,7	2,7	
Tot-P mg/l	0,01	0,01	0,01	0,05	0,05	0,01		0,06	0,4	0,01	0,5
NH3-N mg/l	0,02	0,02	0,02			0,02	0,02	0,02	11,2	0,02	
DO mg/l		8,7		8,7	8,4						14
BOD mg/l		1,8		1,8	1,9						0,15
COD mg/l	3,1	5,5		5,5	4,4	5,8	4,8	13	31		
E.Coli no/100 ml	180										

There were three main purposes for collecting new data for a water quality assessment:

1. Description of the general water quality in the affected sections of the Melamchi Khola.
2. Evaluate water quality differences between the Melamchi Khola and its tributaries in the affected area.
3. Prepare baseline information for later monitoring during the construction period and for the more permanent monitoring after commissioning of the water diversion project.

When parts of the water flow of Melamchi Khola at Nakategoan are transferred to Kathmandu, the quality of the Melamchi Khola water downstream the Intake site will be more influenced by the water quality of the tributaries than before the diversion. Before the present study, there was no knowledge of water quality of the tributaries of the Melamchi Khola. The water quality data of the Melamchi Khola was also very limited. There are reasons to believe that differences exist between the main river and the tributaries, and also between the different tributaries. The differences of water quality might influence the suitability for the use of water in the Melamchi Valley (Irrigation, bathing, and also aquatic life).

The parameter certainly to be affected after the transfer of water is the water temperature. The water flow of the Melamchi Khola at the Intake site consists of a certain part of melt water from snow and ice from high altitude regions. Temperature of this water is lower than the tributaries that joins near the Intake site and further downstream. The difference might be several degrees centigrade, particularly during the dry season. If so, its effects on the aquatic life could be significant. For example, a biological community adapted to higher temperature further downstream the river could displace, or partly change the present community between the intake at Nakategoan and Melamchipul Bazar. Preliminary measurements made during daytime on 20 and 21 April 1999 indicated a mean temperature difference of more than four centigrade between the Melamchi Khola and five main tributaries downstream the Intake site.

2. Methods

Samples for water quality analyses were collected by the authors in Melamchi Khola on 20 and 21 of April 1999. The river was sampled from upstream Intake site and down to the confluence with Indrawati Nadi. The samples were delivered to laboratory (Nepal Environmental and Scientific Services, NESS) for analyses the same day that they were collected. Table 5 shows the parameters analysed at NESS, their analytic methods, and the detection limits for each parameter. The main purpose for analyses of the various parameters are also presented in the same table.

In addition to collection of water samples, temperatures, conductivity, and dissolved oxygen were measured in-situ by kits in the main tributaries and at several sites in the Melamchi Khola.

Table 5. Water quality parameters analysed at NESS, analytic method used, detection limits given by NESS, and main purpose for selecting the various parameter: General description of water quality (G), eutrophication (E), drinking- and bathing (DB), monitoring (M), irrigation (I), and fish production and aquatic life (F).

Parameter	Analytical Method	Detection Limit	Purpose for using the parameter
pH			G, DB, M, F.
Alkalinity	Titration $CaCO_3$	1 mg/l	G, DB, M, I, F.
Suspended solids	Gravimetric	0.1 mg/l	G, DB, M, I, F.
Loss of ignition	Gravimetric	0.1 mg/l	G, DB, M, I, F.
Chloride	Titration	0.5 mg/l	G, DB, M, I, F.
Sulphate	Titration	0.5 mg/l	G, DB, M, I, F.
Ca	Titration	0.5 mg/l	G, DB, M, I, F.
Mg	Titration	0.25 mg7l	G, DB, M, I, F.
Pb	At.ab.spect.	5 μg/l	G, D, M, I, F.
Cu	At.ab.spect.	5 μg/l	G, D, M, I, F.
Zn	At.ab.spect.	2 μg/l	G, D, M, I, F.
Ni	At.ab.spect.	10 μg/l	G, D, M, I, F.
Cd	Furnace proce.	0.5 μg/l	G, D, M, I, F.
Cr	At.ab.spect.	10 μg/l	G, D, M, I, F.
Na	At.ab.spect.	10 μg/l	G, D, M, I, F.
K	At.ab.spect.	10 μg/l	G, D, M, I, F.
Fe	At.ab.spect.	5 μg/l	G, D, M, I, F.
Mn	At.ab.spect.	2 μg/l	G, D, M, I, F.
Al	Colorimetric	10 μg/l	G, D, M, I, F.
Ammonia –N	Colorimetric	0.05 mg/l	G, DB, M, I, F, E.
Nitrate –N	Colorimetric	0.05 mg/l	G, DB, M, I, F, E.
Nitrite – N	Colorimetric	0.05 mg/l	G, DB, M, I, F, E.
Total- P	Colorimetric	0.05 mg/l	G, DB, M, I, F, E.

On 20 April 1999 a helicopter was used to reach the upper and most remote localities. On 21 April the lower parts of the Melamchi Khola and the nearby tributaries were visited by car and walking. Water samples from the Intake site and upstream this site was later taken by Finn B. Christensen. These

samplings took place 16 May, 18 June, and 28 July 1999. All the data on physical/chemical parameters of water analysed at NESS or tested in-situ by kits in the field are given below.

The sampling localities are shown on map (Figure 2), and their map references and UTM co-ordinates are given in Table 6. An additional monitoring locality for the construction period will be located to Shindhu Khola. The final position is not yet decided.

Table 6. Sampling sites in Melamchi Khola and tributaries collected for water quality data.

Sampling site	Map sheet no.	UTM co-ordinates	Monitoring site no
Melamchi Khola, above Nakote Gaon	2885 15	35622E 309993N	
Narkote Khola, (at trail)	2885 15	35623E 309950N	
Chiuri Khola, (at trail)	2885 15	35620E 309910N	
Tarkeghyang Khola, (at trail)	2885 15	35630E 309833N	
Melamchi Khola, at Intake site	2785 03A	35605E 309870N	Mp1
Melamchi Khola, above Ribal Khola	2785 03A	35619E 309620N	Mp1
Ribal Khola, at Melamchi Khola	2785 03A	35617E 309669N	Mc7
Timbu Khola, at Melamchi Khola	2785 03A	35702E 309352N	
Gohare Khola, at Dhuseni	2785 03A	35400E 309095N	Mc4
Gohare Khola, at Melamchi Khola	2785 03A	35703E 308858N	
Bolde Khola, at Bharati	2785 02B	64685E 308720N	Mc5
Gyalthun Khola, at Melamchi Khola	2785 03A	35611E 308596N	
Melamchi Khola, Patichaur	2785 03A	35672E 308576N	Mp2
Talamaran Khola, at Melamchi Khola	2785 03C	35643E 308406N	
Melamchi Khola,above Melamchi Bazar	2785 03C	35975E 308013N	Mp3
Shindhu Khola, downstream adit	2785 02D		Mc6

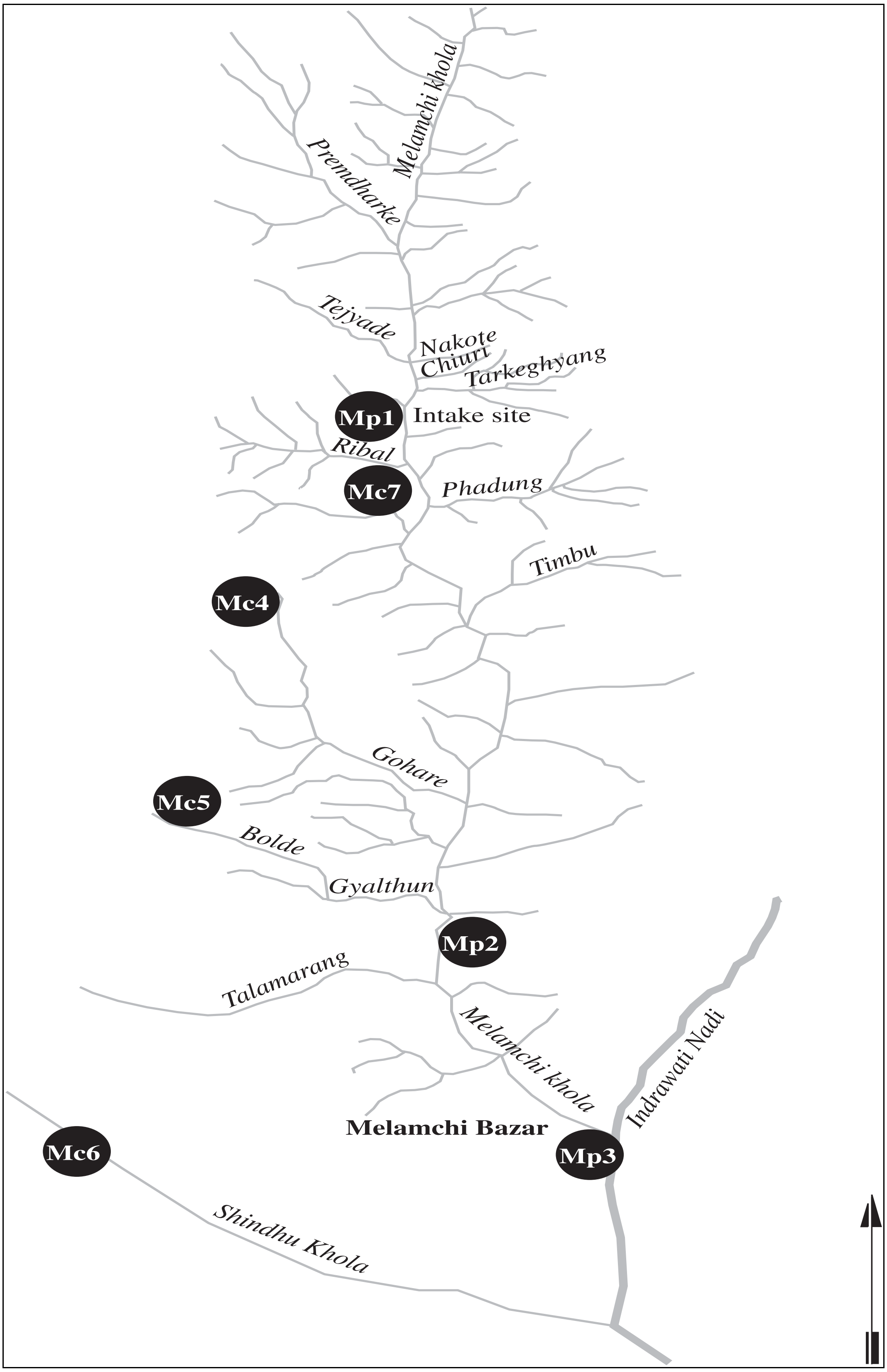

Figure 2. The Melamchi Khola from above Intake site and Shindhu Khola down to confluence with Indrawati Nadi, including locations of permanent monitoring stations (Mp1, Mp2, Mp3) and temporary monitoring sites for construction period (Mc4, Mc5, Mc6, Mc7).

3. Results and Discussions

3.1 Comparisons between former water quality data and the present data.

Data collected in the Melamchi Khola in 1991 (Table 7) does not have any identification of sampling locality. The reported values of the two data sets suggest that the 1991 water sample were probably taken from the Intake site. The sampling dates of the two data sets differ by more than eight years and one month. Comparisons between these two samples presented in Table 7 are therefore quite dubious.

Table 7. Common water quality parameters collected in Melamchi March 1991 and April 1999, presumably at the same locality.µ

Locality	Melamchi Intake	Melamchi ?
Data	20.04.1999	25.03.1991
Time	1200	?
Temp	10,7	9
pH	7,3	6,2
Cond.umhos/cm	34,1/33	45,3
Alkalinity ueqv/l	466	440
Ca mg/l	6,81	7,4
Mg mg/l	0,49	1,5
Cl mg/l	0,5	8,8
NH3 µg / l	40	20
Tot-P µg/l	<50	10
SS mg/l	7,4	6
Fe µg/l	500	10
Mn µ g/l	5	5

Looking at the two data sets with all reservations given above, most of the parameters are within the same order of magnitude. However, some of the data differ quite considerably, especially the pH, chloride and iron values. Due to the lack of information on date and/or sampling locality, the former water quality analyses will not be further used in the present water quality assessment.

3.2 Comparisons between water quality data analysed at NESS and at Norwegian Institute for Water Research (NIVA).

One sample of water taken 9 April 1999 at the Intake site and analysed at Norwegian Institute for Water Research (NIVA) can with some limitations be compared with another sample from the same locality taken 20 April and analysed at NESS. The values of these two samples are shown in the two last columns in Table 8. Most of the figures are of similar extent as expected even if sampled at different times. However, some parameters were quite different. Turbidity was somewhat high at NESS compared to both NIVA measure and to visual observation of the river during sampling. The value of iron was also higher at the NESS laboratory. Most of the heavy metals were below the detection limits at NESS compared to NIVA. This is related to the different methods of analyses.

Different methods of analyses also reflect the values of total phosphorus (Table 8). The detection limits used at NESS laboratory is not useful when dealing with clean water quality like the upper part of Melamchi Khola.

Table 8. Water quality data sampled at the Intake site and in the nearby upstream area in the Melamchi Khola 9 and 20 April 1999. The last column is analysed at NIVA; the rest are done at NESS.

Locality	Melamchi Nakote Gaon	Narkote Khola	Chiuri Khola	Tarkeghyang Khola	Melamchi Intake	Melamchi Intake
Date	20.04.99	20.04.99	20.04.99	20.04.99	20.04.99	09.04.99
Time	1320	1300	1230	1210	1200	1000
Temp	10,7	16	14,1	13,7	10,7	
pH					7,3	7,19
Cond.umhos/cm	32,4	39,5	38,3	35,3	34,1	45,3
Turbidity NTU	4,5				9	0,76
Alkalinity ueqv/l					466	429
Ca mg/l					6,81	7,72
Mg mg/l					0,49	0,38
Na mg/l					0,84	1,1
K mg/l					0,4	0,71
Cl mg/l					0,5	0,2
SO4 mg/l					3,7	3,1
NO3 ug/l	100	115	40	15	95	155
NH3 ug/l	28	20	24	28	40	13
Tot-P ug/l	<50	73	64	90	<50	4
O2 mg/l	10,2	8,5	8,6	9	9,5	
SS mg/l	2				7,4	
LOI mg/l					2,6	
TOC mg/l						0,41
E.Coli no/100 ml	4	23	>1100	43	43	
Tot Coli no/100 ml	23	93	>1100	93	43	
COD mg/l	2,5				3,5	
Tot DS mg/l	63				33,3	
Pb ug/l					<5	0,03
Cu ug/l					<5	0,58
Zn ug/l					16	1,9
Ni ug/l					<10	1,62
Cd ug/l					<0,5	<0,01
Cr ug/l					<10	<0,5
Fe ug/l					500	136
Mn ug/l					5	<1
Al ug/l					32	

3.3 Water quality at Intake site.

Four sets of samples for water quality assessment were taken at the Intake site and in the area just upstream. The results of these analyses are presented in Table 8 above and Table 9 below. Most of the settlements of the Nakote Gaon are located in the Melamchi Khola vicinity at uphill slopes in the intake area. The tributaries Nakote, Chiuri, and Tarkeghyang flow through these settlements and confluence with the Melamchi Khola upstream the Intake site (Figure 2).

As can be seen from the data at the Intake site, the quality for drinking water is good with a few exceptions. Compared with the WHO (1993) recommended values, the concentration of iron (unfiltered) found in the Melamchi Khola water was too high in the sample collected on 20 April (500 μg/l) and 28 July (>1000 μg/l) in the Melamchi Khola. The WHO recommended maximum value is 300 μg/l. Apart from discoloration of textiles, this is not a very essential matter for human consumption. However, more samples from this time period should be analysed at Intake site for possible verification of these high iron values. Further downstream in the Melamchi Khola the concentration of iron was lower: 15 μg/l. Both previous and present tests found the concentration of iron to be136 and between 150 and 180 μg/l respectively at the Intake site (Table 8 and 9).

Similarly, the concentration of coliform bacteria was found too high for drinking water quality (WHO 1993). Most of these coliform bacteria were at times originated from the nearby upstream settlements. The water therefore needs further processing before it can be used for drinking. Arrangement for faecal treatment in these settlements should also be assessed. The evaluation of drinking water will be discussed in detail in the final EIA report. Table 8 also indicates that nutrients like nitrogen and phosphorus are fed into the Melamchi Khola from the surrounding settlements. Some of these spills might be reduced together with any possible faecal treatments. There is an obvious advantage of promoting better sanitation practices such as the use of pit latrines in these communities. This will not only reduce nutrients leaching into the river water but also minimise the treatment requirements for removal of faecal matter.

In addition to values given in Table 8, some other elements were also analysed in Norway. The values for these were: Molybdenum = 2.4, vanadium = 0.52, cobalt < 0.1, arsenic < 0.1, beryllium < 0.1, and silver < 0.01, all values given in μg/l.

Table 9A. Water quality data sampled in the upstream area of Intake site in Melamchi Khola 16 May 1999.

Locality	Melamchi	Narkote	Chiuri	Tarkeghyang	Melamchi
	Nakote Gaon	Khola	Khola	Khola	Intake
Date	16.05.99	16.05.99	16.05.99	16.05.99	16.05.99
Time	1350	1410	1420	1440	1450
Temp	12	16	15	16	12
pH	7,43	7,15	7,2	7,8	7,23
Cond.umhos/cm	40	29	29	33	40
Turbidity NTU	4,5				3
Alkalinity ueqv/l					522
Ca mg/l					6,81
Mg mg/l					0,49
Tot-P ug/l	<50				<50
O2 mg/l	6,94				6,97
SS mg/l	2				2,6
E.Coli no/100 ml	43	120	150	1100	460
Tot Coli no/100 n	75	240	460	>1100	>1100
COD mg/l	2				5
Tot DS mg/l					28,5
Fe ug/l					51
Mn ug/l					7
Al ug/l					8
F ug/l					60

Table 9B. Water quality data sampled in the upstream area of Intake site in Melamchi Khola 18 June 1999.

Locality	Melamchi Nakote Gaon	Narkote Khola	Chiuri Khola	Tarkeghyang Khola	Melamchi Intake
Date	18.06.99	18.06.99	18.06.99	18.06.99	18.06.99
Temp	13	17	17,2	18,6	14
pH	6,8	6,86	6,9	6,95	6,95
Cond.umhos/cm	24	52	27	21	27
Turbidity NTU					11
Alkalinity µeqv/l					304
Ca mg/l					3,6
Mg mg/l					0,5
Tot-P µg/l	60				50
O2 mg/l	6,45				6,53
E.Coli no/100 ml	93	9	75	9	7
Tot Coli no/100 ml	150	39	120	93	23
COD mg/l	2				1,5
SS mg/l					20,8
Tot DS mg/l					30
Fe µg/l					180
Mn µg/l					<0,05
Al µg/l					11
F µg/l					60

Table 9C. Water quality data sampled in the upstream area of Intake site in Melamchi Khola 28 July 1999.

Locality	Melamchi Nakote Gaon	Nakote Khola	Chiuri Khola	Tarkeghyang Khola	Melamchi Intake
Date	28.07.99	28.07.99	28.07.99	28.07.99	28.07.99
Temp	13,7	16,6	15,2	16	13,4
pH	7,3	7,35	7,2	7,3	7,1
Cond. µmhos/cm	30	42	30	20	25
Turbidity NTU					15
Alkalinity µeqv/l					303
Ca mg/l					2,8
Mg mg/l					0,5
Tot-P µg/l	105				123
O2 mg/l	7,04				7,37
E.Coli no/100 ml	23	23	43	460	43
Tot Coli no/100 ml	1100	43	43	460	93
COD mg/l	<50				<50
SS mg/l					27,2
Tot DS mg/l					28
Fe µg/l					1030
Mn µg/l					150
Al µg/l					6
F µg/l					100

3.4 Temperature differences between Melamchi Khola and some of the main tributaries.

During collection of water samples, temperatures were measured in the water of some of the main tributaries and the Melamchi Khola. In both the tributaries and the Melamchi Khola the measures were taken just upstream their confluences. The data is presented in Table 10.

Above the Intake site the mean difference in temperature between the tributaries and the Melamchi Khola was measured to be 3,9 °C in April 1999. Below the intake the mean difference in temperature was 4.4 °C. Theoretically, both greater and lesser differences could be expected at various times of the day and at different seasons. As can bee seen in Table 9 differences of 3-4 °C were also observed between Melamchi Khola and the tributaries upstream the Intake site in May, June and July the same year. Additional data are obviously required for the more exact figure of a possible rise of water temperature in Melamchi Khola by diversion of water. These data could simply be achieved be measuring the temperature differences between the Melamchi Khola and a few main tributaries during some 24 hours periods at the different major annual seasons (e.g. dry season, dry season with influx of snow melting water to Melamchi, pre monsoon, and monsoon period).

Table 10. Water temperatures (°C) in Melamchi Khola and some of the main tributaries.

Locality	Melamchi Nakote Gaon	Narkote Khola	Chiuri Khola	Tarkeghyang Khola	Melamchi Intake
Data	20.04.99	20.04.99	20.04.99	20.04.99	20.04.99
Time	1320	1300	1230	1210	1200
Temp	10,7	16	14,1	13,7	10,7

Locality	Ribal Khola	Melamchi Ribal	Timbu Khola	Melamchi Timbu	Gohare Khola	Melamchi Gohare
Data	20.04.99	20.04.99	20.04.99	20.04.99	20.04.99	20.04.99
Time	1200	1200	1400	1400	1300	1300
Temp	16,8	12	20	15,5	21,1	17,2

Locality	Gyalthun Khola	Melamchi Gyalthum	Talamaran Khola	Melamchi Talamarang	Talamaran Khola	Melamchi Talamarang	Melamchi Melamch Bazar
Data	21.04.99	21.04.99	21.04.99	21.04.99	21.04.99	21.04.99	21.04.99
Time	1300	1300	1200	1200	1515	1515	1615
Temp	25	20	24,5	20	25,3	21,8	23

As stated above, if a considerably amount of water in Melamchi Khola is diverted to Kathmandu Valley the water temperature in Melamchi Khola will rise. This might imply that also the air temperature would slightly increase in the valley, and thereby alter the general climate. Local climatic changes have been reported around many hydropower plants, and some with considerable impacts. The present data of water temperature should therefore be submitted to a climatological expert for evaluation of possible climatic changes on the terrestrial community in the Melamchi Valley.

Scenarios are evaluated for minimum water releases of 0.15, 0,5 and 1.0 m^3/sec at the Intake site. As described below, accurate estimates of discharges from various tributaries downstream Intake site is not available. However, based on the above temperature measurements and water flow given in Table

2 and 3, the water temperature in Melamchi Khola will increase on an average by 4 °C, 3 °C, and 2 °C at the minimum water releases of 0.15, 0,5 and 1.0 m^3/sec respectively.

3.5 Water quality differences between Melamchi Khola and some of the main tributaries.

In addition to the temperature differences discussed above, other parameters varies between the Melamchi Khola and its tributaries, and also among the different tributaries. Table 10 gives the main water quality parameters for the Melamchi Khola and its tributaries. Table 10 also includes the sum of cations and anions, and their differences in percent. This gives an indication of the accuracy of the water analyses, and differences below 10 % should be acceptable. As can be seen from the table, there is a predominance of anions compared to cations for all sets of analyses, and the differences varies between 6 and 22 %. The main reason for the divergences is probably variations in the accuracy of alkalinity measures.

The three first columns in Table 11 present samples from upper, central, and lower part of Melamchi Khola respectively. The rest of the samples are from lower sections of the tributaries Ribal, Timbu, upper (at Dhuseni) and lower part of Gohare, and upper (Bolde) and lower part of Gyalthun, and lower part of Talamaran.

Table 11. Water quality data for Melamchi Khola and some main tributaries. Dubious values in brackets. (ANC = acid neutralisation capacity = Ca+Mg+Na+K-Cl-SO_4-NO_3 unit μeqv/l). Sum (Σ) of cations and anions are included together with percent differences.

Locality	Melamchi Intake	Melamchi Patichaur	Melamchi Melamch Bazar	Ribal Khola	Timbu Khola	Gohare Dhuseni	Gohare Melamchi	Bolde Khola	Gyalthun Khola	Talamaran Khola
Data	20.04.1999	21.04.1999	21.04.1999	20.04.1999	20.04.1999	20.04.1999	20.04.1999	20.04.1999	21.04.1999	21.04.1999
Time	1200	1300	1615	1200	1400	1230	1300	1330	1300	1200
pH	7,3	8	8,1	8	7,8	7,6	7,94	7,8	8,1	8,2
Cond. μmhos/cm	33	44,8	55,2	68	36	29	38	52	51	82,3
Turbidity NTU	(9.)	2	2	1,5	4,25	1,5	3	1	2	2
Alkalinity μeqv/l	466	518	622	777	520	259	363	570	518	829
Ca mg/l	6,81	6,41	6,41	10,42	7,21	2,81	2	6,41	4,4	8,82
Mg mg/l	0,49	0,24	0,73	1,22	0,48	0,24	0,73	0,73	0,49	0,97
Na mg/l	0,84	2,41	2,8	1,6	1,14	2,14	3,4	3,32	5,25	5,92
K mg/l	0,4	1,15	1,18	0,75	0,64	0,6	0,79	0,83	1,07	2,68
Cl mg/l	0,5	1	0,5	1	0,5	1	0,5	1	1	1
SO_4 mg/l	3,7	(<0,5)	3,23	3,7	2,88	2,67	3,08	1,44	2,35	3,23
NO_3 μg/l	95	80	95	50	110	190	140	170	95	115
NH_3 μg/l	40	20	28	30	20	20	40	32	20	32
Tot-P μg/l	<50	50	110	95	60	153	142	85	98	86
SS mg/l	7,4	5,6	8,8	3,2	3,4	5,6	6,8	3	4	16
LOI mg/l	2,6	2,8	5,2	2,4	1,2	1,2	1,2	1,2	1,2	2
E.coli no/100ml	43	240	460							
ANC μeqv/l	329		442	600	383	170	238	474	429	739
Σ cations μeqv/l	430	474	532	711	466	269	329	546	514	845
Σ anions μeqv/l	534	527	680	856	572	326	421	610	572	902
% difference	19	10	22	17	18	18	22	10	10	6

As can be seen from the three first columns in Table 11, representing upper, central lower, and lower part of Melamchi Khola respectively, the majority of the parameters show (with some irregularity) increasing values, e.g. pH, conductivity, major ions, phosphorous, and organic matter measured as loss of ignition (LOI). The increases in the downstream sections of the river were mainly caused by influxes from the tributaries. For comparisons between the main river Melamchi Khola and its tributaries, the water quality parameters at the Intake site should be used as references in the case of diversion of water to the Kathmandu Valley.

The tributary Ribal Khola has a generally harder water quality compared to the Melamchi Khola as can be seen from the values of conductivity, alkalinity, calcium, magnesium, and sum cations. Timbu Khola also has a somewhat higher salt concentration than Melamchi Khola, but less than Ribal Khola. On the other hand, Gohare Khola has much softer water compared to both Melamchi Khola and also all the other tributaries. Gyalthun shows a water quality quite similar to Gohare Khola except for a high concentration of sodium. Talamaran Khola also has a very high concentration of sodium, and the contents of most other cations are also high.

Most of the tributaries showed increased concentrations of the nutrients, phosphorus and nitrate, compared to the Melamchi Khola at the Intake site. It implies that diversion of diluting water of low nutrient from the Melamchi Khola to Kathmandu Valley will increase the concentration nutrients in the remaining parts of the Melamchi Khola and thereby cause increased bio-production, in other words increased eutrophication. However, considering the many rapids and small water falls along the whole length of Melamchi Khola, the eutrophication problem is not expected to be significant and is unlikely to result in serious oxygen deficiency or overgrowth of attached vegetation.

The ratio between phosphorus and nitrogen in the water of the Melamchi suggest that the bio-production in the Melamchi Khola be limited by nitrogen content. The increase of phosphorus and the non-increase of nitrogen in the downstream parts of the Melamchi Khola support the above statement. The nitrate that influx from most of the tributaries at higher concentrations are used for bio-production in the Melamchi Khola, and therefore not observed in the analyses of the Melamchi river samples (Table 11). Nitrogen, phosphorus, and organic matter are expected to enter the tributaries from the tunnel deposits and from the workers camps at the tunnel adits, and thereafter the Melamchi Khola. Locally, particularly during the dry seasons, some overgrowth of attached vegetation could be expected in the affected tributaries Ribal, Gohare and Gyalthun Khola, and probably also in the Melamchi Khola downstream of the confluence of these three tributaries. However, a community of grazing animals (invertebrates and fish) may be able to utilise the increased production of the attached vegetation. This could be a theme of biological monitoring if it would be included.

The different concentrations of major ions and nutrients in the Melamchi Khola after diversion of various amounts of water to Kathmandu Valley can theoretically be estimated. However, reliable figures for discharges from the different tributaries are not available at present. In addition, there are numerous extractions of water, mainly for irrigation, along the Melamchi Khola and also from the tributaries. Until more date on discharges are available, only indicative predictions on the effects on the Melamchi Khola can be made. Data on discharges can also be estimated according to specific monthly runoff and the catchment areas of the various tributaries. If data for runoff is not available, figures of monthly precipitation and evaporation can also be used for theoretical determination of discharges from the different tributaries.

However, a preliminary evaluation of major cation concentration in the Melamchi Khola can be made based on the given water discharges in Tables 2 and 3. At the released flow of 0,15 m^3/sec from the Intake, the upper 10 km of the river will have a 30-35 % higher salt concentration compared with the present value. At the minimum water release of 0,5 m^3/sec, the salt concentration will increase by ca 25 %. The minimum release of 1 m^3/sec will increase the salt concentration by less than 20 %. Downstream at the confluence with the Gohare Khola, the corresponding increase in salt concentrations would be approximately 5-10 %, 5 %, and less than 5 % for the minimum release of 0,15, 0,5 and 1 m^3/sec respectively.

A similar estimate could also be made for eutrophication factors mainly nitrogen and phosphorus. However, in addition to the uncertain discharge values from the tributaries, there is no data available at present on the effluents from the future workers camps. Nitrogen runoff from the tunnel deposits containing nitrogen remnants from explosives is given below.

3.6 Nitrogen runoff from tunnel waste rock deposits.

A total of about 300 000 m^3 of rocks will be removed from the Melamchi tunnel. (The length of the tunnel will be 29 km, the cross section will be 10 m^2, and some additional masses will be removed i.a at the adits and the sedimentation chambers.) The blasting agents used consist mainly of ammonium nitrate (NH_4NO_3), and certain amount of the blasting agents is still left in the tunnel masses after the explosions. This leftover of ammonium nitrate will later on be washed out from the tunnel deposits when exposed to rain water.

The amount of runoff of nitrogen has been estimated at 15 % of the total use of blasting agents (Bækken 1998). The runoff of nitrogen could thereby be estimated according to the entire use of blasting agents. The total runoff of nitrogen was also calculated according to tons of tunnel masses removed. Bækken (1998) gave runoff values of 24,2 g nitrogen per ton of tunnel masses. This included 11,5 g N/ton of ammonium and 12,7 g N/ton of nitrate. The 300 000 m^3 of rocks with a specific gravity of about 3 will consequently be 100 000 ton of tunnel masses, and the runoff will be in the order of magnitude of 1,15 ton ammonium and 1,27 ton nitrate, all together 2,4 ton of nitrogen. This will be differently distributed at the various adits, Intake site, and at the outflow site.

The study of Bækken (1998) included a method of repeated washings of the tunnel masses by filling tanks containing the masses with surface water. The first washing was found to remove about 50 % of the nitrogen and less than 5 % was left after the fifth washing. This means that the washing out of nitrogen from the Melamchi tunnel masses deposited during the monsoon period will be quite fast. However, tunnel masses deposited during the dry season will probable reach considerably thickness, and the nitrogen washing out are expected to take place over a longer time period. We can expect especially high amounts of ammonia and nitrate in the runoff water from the deposits after longer dry periods followed by heavy rainstorms. However, if the amount of rainwater is high, the concentration of nitrogen does not necessary have to be high.

Some further information are needed on runoff from the tributaries and the number of workers and additional personnel at the adits and Intake site, in order to estimate the contribution of increased nutrients flow into the Melamchi Khola.

3.7 Monitoring

The main purposes of the monitoring are to confirm the described and expected changes of water quality in The Melamchi Khola, to reveal any unforeseen effects of the diversion of the water, and to detect pollution of the tributaries by the effluents during the construction.

3.7.1 Permanent monitoring sites.

Three localities in Melamchi Khola were selected for permanent monitoring of water quality (Figure 2).

Melamchi Khola at Intake site. Samples were collected near the planned intake site. The 1: 25,000 scale topographical map reference is Sheet No. 2785 03A, and the UTM co-ordinates are 35605E 309870N. After diversion of water to Bagmati the monitoring station will be moved downstream to UTM co-ordinates 35615E 309690N. The downstream transfer of the monitoring site is done in order to observe the effects of the deposits of the tunnel rock material and workers camp, in addition to measuring the general water quality. The values of the overall water quality parameters are not expected to change significantly due to this short transfer of the monitoring location.

Melamchi Khola at Patichaur. The next, permanent monitoring site is located at the Patichaur in the downstream when the Ribal Khola, Gohare Khola and Gyalthun Khola join the Melamchi. Tunnel deposits and workers camps in their upper parts will affect these tributaries, and impact can also be expected in the Melamchi Khola. Besides, impacts on the water quality of the river can also be expected by human activities between the upper and this monitoring site. The map references and UTM co-ordinates to the site are given in Table 6.

Melamchi Khola upstream Melamchipul Bazar. This monitoring station will describe the water quality of the Melamchi Khola just before the water flow into the Indrawati Nadi. All changes, including effects from the diversion of water to Bagmati will be recorded here. The map references and UTM co-ordinates are given in Table 6.

3.7.2 Monitoring of water quality during construction period.

It is expected that the permanent monitoring stations will demonstrate effects of the constructions of the diversion tunnel on the Melamchi Khola. Four adits to the tunnel are planned. Three additional monitoring sites are therefore proposed in order to identify the more pronounced effects of the construction on the tributaries. These tributaries will receive effluents from the tunnel deposits and from workers camps. The tributaries are Ribal Khola, Bolde Khola that enters Gyalthun Khola, and Gohare Khola. Samples from these three tributaries were collected on 20 April 1999. The sampling sites are shown on the map (Figure 2), and their UTM co-ordinates are given in Table 6. The fourth adit will be located in the catchment of Shindhu Khola, which is a tributary to the Indrawati Nadi. Water sample will be collected from this site when the final location of the tunnel is decided.

A tunnel deposit and a workers camp will also be located near the Intake site in the Melamchi Khola. Effluents from this site will enter the Melamchi Khola and be monitored by the permanent monitoring station situated in Melamchi Khola upstream of the Ribal Khola.

3.7.3 Recommendation for water quality monitoring

Locations

Water samples should be collected at three sites along the Melamchi Khola for permanent water quality monitoring. See Figure 2 and Table 6 for accurate locations.

1. Intake site. During construction period and later the site will be relocated to upstream the confluence with Ribal Khola. (Mp1)
2. Melamchi Khola downstream Gyalthun Khola, at Patichaur. (Mp2)
3. Melamchi Khola above Melamchi Bazar. (Mp3)

During construction period four additional sites should be monitored. These sites are the tunnel adits with tunnel deposits and workers camps.

4. Ribal Khola near Melamchi Khola. (Mc7)
5. Gohare Khola, at Dhuseni. (Mc4)
6. Bolde Khola, at Bharati. (Mc5)
7. Shindhu Khola, downstream the tunnel adit. (Mc6)

The construction period monitoring sites together with the permanent monitoring site in the Melamchi Khola will record the effluents from the tunnel deposits and workers camp at the Intake site.

Monitoring parameters.

The following parameters should be analysed at all samplings:
Temperature, pH, conductivity, turbidity, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrite, nitrate, ammonia, total phosphorous, suspended solids, loss of ignition, and coliform bacteria. Before construction period, one sample for oil should be analysed at all stations during dry season, preferably in March. (No oil pollution is expected at present situation at these sites, but this must be confirmed before construction begins.)

Monitoring frequency.

Before the construction period, all monitoring sites should be sampled four times throughout one year.
1. Dry season preferably in March.
2. Pre-monsoon period in May (June) at increasing water flow.
3. Monsoon period in August.
4. After monsoon (November)

During the construction period and at least one year after the commissioning, samples should be collected each month. When more stable water quality condition is restored, the sampling frequency could be reduced to four times a year as suggested for the pre-construction period. When stable water quality are achieved at these four temporary monitoring sites, these sites could be closed. However, the three permanent monitoring sites should be sampled for decade(s) after the commissioning of the MDS.

The parameter list could also be reduced after the completion of the construction. However before doing so, stable water quality and pre-construction conditions should have been achieved. Parameters that can be removed from the monitoring program are major ions (Ca, Mg, Na, K, Cl, and SO_4), and hopefully also oil.

The laboratory responsible for the analyses should identify the volume of water required for analyses of the different parameters. The laboratory should also recommend the collecting procedure, the handling of samples, and time requirement between sampling and analyses. This is of great importance for accurate results.

The following sampling procedure should be used. At the site, the bottles should be labelled with site identification name, site identification number, date and time. This should be noted together with temperature and other possible parameters analysed in-situ using field-kits. Bottles for collecting water for testing of main parameters should be rinsed at least two times with the water to be sampled without touching the inner part or top of the bottle. The bottles should be filled by lowering them below the water surface with the bottleneck against the water current to avoid sample water coming into contact with the tester's hand. The sampling site should be properly located from the riverbank and water sample should preferably be collected from the deep, fast running part of the river.

4. Epilogue

The plans for the Melamchi Diversion Scheme (MDS) project have been considerably changed during 2000. The production of hydropower has been left out, and drinking water is now the only use of the diverted water. The Intake site in Melamchi Khola is moved a few km downstream the river to below the Ribal Khola. The tunnel alignment is located to lower altitude and towards the east and the number of adits is reduced from six to four. Plans also exist to extend the tunnel further to the east in order to include Yangri- and Larke Khola for additional water supply to Kathmandu. A supplementary EIA is under preparation for "Melamchi Diversion Scheme Based on Stand Alone Water Supply Only". An initial environmental examination on the extension of the tunnel towards Yangri- and Larke Khola will also be prepared this year.

During the supplementary EIA of MDS additional samples of water were analysed for the Melamchi Khola and its tributaries during the monsoon season. The description of water quality given in the present report was confirmed by the supplementary study. However, it was revealed that the high concentration of iron shown at the Intake site was based on unfiltered samples. When filtering the water samples, the concentration was found to be well below recommended limits for drinking purposes.

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