Geophysical Research Abstracts, Vol. 7, 07161, 2005
SRef-ID: 1607-7962/gra/EGU05-A-07161

Modelling of inorganic N load from anthropogenic sources in a boreal river basin

K. Rankinen and K. Kenttämies
Finnish Environment Institute (katri.rankinen @ymparisto.fi)

Introduction

Eutrophication of surface waters due to increased nutrient loading during the last decades is one of the main environmental concerns in Finland. Long term analysis of nutrient concentration trends showed that municipal and industrial waste water purification has effectively decreased nutrient load from point sources leading to improved water quality, but no clear effects of decreasing non-point loading are found. On the contrary, nitrate concentrations were found to increase in some rivers located in northern Finland (Räike et al. 2003).

Agriculture currently comprises the largest single source of nutrients to surface waters by changing hydrology and nutrient status of soils. The effects of forestry differs from those of agriculture, as some effects are strong but of brief duration whereas some are long lasting. In their natural state peat lands act as sinks but when drained they become sources of inorganic nutrients. The increase in runoff ceases about in 15-20 years (Kenttämies 1998, Laine et al. 1995, Seuna 1990). Forest felling, especially clear cuts, increases annual runoff and sharpens peak runoffs in spring and summer because decreased evaporation and interseption. This increase is not long-lasting as new vegetation starts to recover soon after felling (Kenttämies 1998).

Peat mining causes elevated nutrient and suspended solids leaching and concentrations in downstream waters (Heikkinen, 1990, Klöve, 2001). Futhermore, about 19% of Finnish citizens are not connected to municipal sewer networks but have on-site sewage systems which is defective especially in old one-family houses. Loading of organic matter and phosphorus per person is approximately 6-8 times higher from these systems than from sewer networks.

In this study the aim was to find out the origin and timing of inorganic nitrogen (N) load by using INCA-N model. The study area is located in boreal vegetation zone in northern Finland. Main anthropogenic sources of nutrients are agriculture,forestry and peat mining.

Material and methods

Simojoki The river Simojoki discharges to the Bothnian Bay in the Baltic Sea. The Simojoki river basin (3160 km2) is located partly in middle boreal and partly in northern boreal vegetation zone. Over the period 1961-1975, mean annual precipitation was 700 mm and mean annual runoff 400 mm. Mean daily flow at the outlet was 37.2 m3 s-1 during 1965-1990. The maximum discharge was 730 m3 s-1 and the minimum discharge 3 m3 s-1, and discharge peaks in spring when snow melts in early May (Perkkiö et al. 1995). Growing season (daily mean temperature =5 oC) started on the average on 10th May in the period 1961-1990. The length of the growing season was on average 140 days.

The river Simojoki is not regulated and it is a Atlantic salmon river without any major point pollution sources. The dominant human impacts are forestry, agriculture and atmospheric deposition. Atmospheric deposition was left out from this study as it was noticed to have no influence (Rankinen et al. 2004a). Peatlands and peatland forests are common in the region and an average of 0.5% of the total catchment area is felled annually. Forest drainage was most extensive during 1960s and 1970s, and by 1991 over 30% of the total river basin area had been drained. In 1995 peat mining areas covered 0.4% of the catchment area. Urban areas cover only 0.1% of the catchment area (Perkkiö et al. 1995). Grass cultivation for animal husbandry is the most common form of agricultural production (Rankinen et al. 2004b).

INCA-N The dynamic, semi-distributed INCA-N model integrates hydrology, catchment and river N processes (Whitehead et al. 1998, Wade et al. 2002). The term semi-distributed is used, as it is not intended to model catchment land surface in a detailed manner, but to use land-use class in a sub-basin as a basic modelling unit. River, soil water and groundwater NO3-N and NH4-N concentrations and fluxes are produced as daily time series by using process-based equations. Sources of N include direct discharges, the terrestrial environment and atmospheric deposition.

The INCA-N model can be calibrated to observed discharge and NO3-N and NH4-N concentrations along the river. In addition, observed NO3-N and NH4-N concentration in soil and groundwater in different land use classes and sub-catchments can be used in calibration. The INCA-N model calculates also annual N process loads from every land use class which can be compared to experimental data or literature values of these processes when checking that the N process loads are on the correct level.

Calibration of the INCA-N model INCA model was calibrated using input data for the years 1995-1999 which corresponded to the land use classification and forest drainage data. Calibration followed the procedure described by Rankinen et al. (2004a). In calibration strategy each land use class was assumed to be a small catchment which represented typical forestry or cultivation practices. This approach allowed effective use of experimental data from small catchment studies.

Forest on mineral soil covers 35%, new (1-10 years old) forest felling on mineral soil 4%, forest on organic soil 52%, new forest felling on organic soil 1%, agriculture 2% and open surface water 6% of the whole river basin area. The forest areas on organic soil were assumed to be drained during 1960s or 1970s. Ground vegetation was assumed to start to recover on forest felling areas. Net loading of inorganic N from new forest ditching areas, peat mining areas and from scattered settlement were added as effluent time series.

All the fields were under perennial grass ley which was assumed to be harvested on 23rd June and on 15th August. Two growth periods were simulated by using the Multiple Growth Period option in the INCA model. Agricultural fields were fertilized at 30th May (100 kg N ha-1) and second time at 28th June (54 kg N ha-1). Inorganic N leaching from agricultural catchments is typically 8.8-14 kg ha-1 a-1 (Vuorenmaa et al. 2002).

Simulated annual inorganic N leaching from forest areas was compared to observed long term leaching (0.5 kg ha-1 a-1 from organic soil and 0.38 kg ha-1 a-1 from mineral soil) from forested experimental catchments in Finland (Kortelainen, Saukkonen et al. 1997). Inorganic N leaching from forest felling sites were compared to average measured inorganic N leaching (0.92 kg ha-1 a-1) from Nordic catchments (Lepistö et al. 1995). Experimental data of the small experimental catchment located in north eastern Finland were used to derive specific inorganic N loading from forest drainage areas by comparing loading to untreated catchments. The area of the catchment was 118 ha from which 57% was mire. In 1983 27% of the area was ditched. During the next ten years after treatment increase in specific loading from treated areas was 0.97 kg N ha-1 (Ahtiainen and Huttunen 1999).

There are about 1400 ha of peatmining areas in the Simojoki river basin. Inorganic N loads from these areas were taken from official annual monitoring reports of pollution load on water bodies (Kaikkonen and Salo 2003). Reported net loading of NH4-N was 27.9 kg d-1 from peat mining areas in the Simojoki river basin during harvesting season in 1999. N loading from the areas of scattered settlement in catchment scale was based on previous research results and the statistics of the year 2000. The most common methods for sewage treatment in the area were septic tanks (14.5 g N day-1 person-1) and subsurface disposal systems (5.3 g N day-1 person-1).

Results

At the upper parts of the river Simojoki inorganic N was mainly originated from unmanaged forest areas, but the influence of anthropogenic sources increased at the lower parts of the river. At the outlet roughly half of the inorganic N load was from anthropogenic sources, so that inorganic N load from agricultural areas covered one third, load from forestry one third and load from scattered settlement one third of the anthropogenic part. Loading from the river basin was concentrated on peaks during high flow periods, especially snow melting period in spring. Both peat mining and forest drainage tended to increase inorganic N leaching in spring.

References

Ahtiainen, M. and P. Huttunen 1999. Long-term effects of forestry managements on water quality and loading in brooks. Boreal Environment Research 4: 101-114. Kaikkonen, K. and O. Salo. 2003. Lapin ympäristökeskuksen alueen turvetuotantosoiden kuormitus- ja vesistötarkkailu vuonna 2002. Lapin vesitutkimus Oy. Kenttämies, K. 1998. The effects of modern boreal forestry practices on waters. XX Nordic Hydrological Conference, Helsinki, Finland 10.-13. August 1998. Nordic Hydrological Programme NHP Report 44:142-162. Kortelainen, P., S. Saukkonen and T. Mattson. 1997. Leaching of nitrogen from forested catchments in Finland. Global Biogeochemical Cycles 11(4): 627-638. Laine, J., H. Vasander and T. Sallantaus 1995. Ecological effects of peatland drainage for forestry. Environmental Reviews 3: 286-303. Lepistö, A., L. Andersson, B. Arheimer and K. Sundblad 1995. Influence of catchment characteristics, forestry activities and deposition on nitrogen export from small forested catchments. Water, Air and Soil Pollution 84: 81-102. Perkkiö, S., E. Huttula and M. Nenonen 1995. Simojoen vesistön vesiensuojelusuunnitelma. Vesi- ja ympäristöhallinnon julkaisuja-sarja A 200. 102 p. Räike, A., O.-P. Pietiläinen, S. Rekolainen, P.Kauppila, H.Pitkänen, J.Niemi, A.Raateland, J. Vuorenmaa 2003. Trends of phosphorus, nitrogen and clorophyll a concentrations in Finnish rivers and lakes in 1975-2000. The Science of the Total Environment 310: 47-59. Rankinen, K., K. Granlund, and A. Lepistö 2004a. Integrated nitrogen and flow modelling (INCA) in a boreal river basin dominated by forestry: scenarios of environmental change. Water, Air and Soil Pollution: Focus 4: 161-174. Rankinen, K., H. Lehtonen, K. Granlund and I. Bärlund 2004b. Assessing the Effects of Agricultural Change on Nitrogen Fluxes Using the Integrated Nitrogen CAtchment (INCA) Model. Complexity and Integrated Resources Management, Transactions of the 2nd Biennial Meeting of the International Environmental Modelling and Software Society, Manno, Switzerland, iEMSs, 2004. Seuna, P. 1990. Metsätalouden toimenpiteet hydrologisina vaikuttajina. Vesitalous 2:

38-41. Vuorenmaa, J., S. Rekolainen, A. Lepistö, K. Kenttämies, P. Kauppila 2002. Losses of nitrogen and phosphorus from agricultural and forest areas in Finland during the 1980s and 1990s. Environmental Monitoring and Assessment 76: 213-248. Wade, A., P. Durand, V.Beaujoan, W. Wessels, K. Raat, P.G. Whitehead, D. Butterfield, K. Rankinen, A. Lepistö 2002. Towards a generic nitrogen model of European ecosystems: New model structure and equations. Hydrology and Earth System Sciences 6(3): 559-582. Whitehead, P. G., E. J. Wilson and D. Butterfield 1998. A semi-distributed Integrated Nitrogen model for multiple source assessment in Catchments (INCA): Part I-model structure and process equations. The Science of the Total Environment 210/211: 547-558.