PERIODICA POLYTECHNICA SER. CIVIL ENG. VOL. 38, NO. 2, PP. 205-217 (1994)

WATER MANAGERIAL AND ENVIRONMENTAL ASPECTS OF TRANSPORTATION

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Received: March 31, 1994

Abstract

The transportation — even those branches of it which are thought to have no immediate impact on the elements on the hydrological cycle — greatly influence the quality of the water resources. Polluting the air and the vicinity of the motorways the water bodies receive large amount of waste washed into them. Altering the runoff pattern is also very considerable and intrusion into the landscape has to be mentioned, too.

Concentrating more on navigation, utilizing the advantages of the water body as a mean for transportation we had to look more into the details and the impacts of navigation on the water management are enumerated, too.

Keywords: water management, transportation, environmental impacts, navigation.

Introduction

Despite of all the recognition that the transportation is responsible to a relatively large share for the degradation of the environment it is a sector of the world economy which is continuously growing every year and all the publications dealing with the problem forecast an equally constant growth for the coming 30–40 years. This brings us to the point: how is it possible to cope with this growth with the minimum harmful effects to the environment. How to improve the performance of the transportation sector and at the same time to reduce and diminish as much as possible the damage caused to the natural and human environment.

Several publications are dealing with the impacts of the transportation on the environment, since the profession recognized the magnitude of the problem long ago. My aim with this paper is to introduce very briefly the phenomena connected to the topic and to make the first step on the area: what are the connections of the transportation in general and also discussing it more in details on the specific elements of the hydrological cycle. On this basis I will very briefly summarize the adverse effects of the transportation on the environment, then some remedial actions, and

finally point out the connections of transportation with the river basin as the most obvious element of the water resources management.

The harmful effects of industry, agriculture and other branches of national and international economy are also considerable, but there are a few emissions, where traffic has the lion's share. The most important note is that the emission originated from transportation in urban areas especially densely populated city centres is overwhelming compared to other emission sources.

When discussing the harmful impacts of transportation sometimes the transportation as a whole, sometimes freight transport is in the middle of the attention. Hereby a brief summary of the environmental impacts is given.

Freight Transportation

For example in the Netherlands according to the present trends the pollution caused by freight transport alone will exceed the emission standards set in force. Already in the present situation the freight transport is responsible for more than 50% of the pollution characteristic of the diesel engines. Especially the noise pollution of the freight transport is disproportionally high (SCHOEMAKER – BOUMAN, 1991).

There are arguments, which branches of the freight transport is less harmful to the environment, and among the arguments not only the emission counts, but the energy consumption of different branches of transportation has to be kept in mind as it is in the table below after RYDING, (1991):

Trucks	0.26 kWh/tonkm
Rail	0.24 kWh/tonkm
Ships	0.13 kWh/tonkm

The harmful effects of transportation are not only the ones based on the fuel consumption and consequently on the emissions, other factors such as land acquisition, visual performance also should be considered. As the largest part of the traffic nuisance is the emission, the table above puts forward preferences among the transportation branches.

Road Haulage

During the last decades the majority of the increase in freight transportation was realized on the roads. There are good reasons for it: it is flexible enough to reach easily every destination, it does not require the terminal

for transfer of goods like rail and navigation, the capital investment to establish a fleet of lorries is smaller than the fleets of the others, and the organization of such an activity is also relatively easy.

Although trucks in relatively small streets of inner cities are frighteningly big and noisy, they are the only means to reach the final destinations of goods so far. However, we have to keep in mind that there is a recognized shift in that, too, as in the inner cities the delivery vans are taking over a relatively high ratio of the freight traffic. As a consequence of the above the emissions and adverse effects caused by these relatively small freight transport facilities are extremely high.

To see the share of the longer distance road haulage and the shorter ones there are some data in the table below after SHOEMAKER – BOUMAN, (1991).

While discussing the environmental effects of the road haulage we kupin mind the lorries, since for example ' ... In Europe the road transport of freight accounts for almost three-fourth of the transportation market.' (RYDING, 1992).

Table 1
Distance distribution of freight traffic in the Netherlands (SHOEMAKER – BOUMAN, 1991)

	Share in %	
distance covered by vehicle	tons	tonkm
0–150 km	81	45
>150 km	19	55

While the improvement of passenger cars has remarkable result such as catalitic converters and others which lessen the emission of these kinds of cars considerably in the area of the vans and lorries there is no technological breakthrough observed so far.

The transportation on the highways is causing a well tangible separate effect on all the elements of the human environment. As it is not easy to define, what part of the environmental pollution is originating from the freight transport and what can be directly attributed to the passenger transport, this will be discussed on page 5 of this material.

Railway

Railway has the advantage that having slightly less energy consumption than the road haulage, the emissions originated from rail traffic are remarkable less than the big competitor, the road transport, which gained field after the second world war and still grows faster, while the rail traffic

seems to remain constant. Although railway transportation has advantages in contrast to the road traffic in terms of emission, it still has remarkable disadvantages. First of all, although the emissions are less than the ones of the road traffic, they are still very high. The other adverse effect is the intrusion to the landscape and the enormously high land acquisition. Similarly to the road transportation the alteration of runoff pattern can also cause serious problems.

Navigation

Exploring the adverse effects of navigation we focus on the environmental problems of inland navigation, and do not concentrate on the transcontinental navigation with substantially different environmental problems.

Inland navigation has twofold adverse impact on the water resources: the direct impacts and the indirect impacts of creating, managing and maintaining navigable waterways.

The direct adverse impacts of navigation on the water resources are as follows:

- leaking material from the cargo,
- waste material from the engine or the fuel for the engine,
- wastewater from the ship,
- wastewater resulted from cleaning ships,
- leftover cargo thrown overboard illegally and
- leaking material as a result of accidents.

These adverse effects should be tackled by shipbuilders and those responsible for the safety of navigation.

Creating, managing and maintaining navigable waterways also has a serious impact on the water resources as follows:

For the sake of navigation there has to be a constant water depth and low stream velocity maintained, which may cause conflict of interests with other users of the available water resources. (Other users need more water for consumption for example, when the navigation still needs the necessary depth, at the same time seriously influencing the groundwater table in the neighbouring area.)

There must be hydraulic constructions to maintain the navigation routes such as dams, shiplocks, which also has impact on the natural regime, and their maintenance also has to be taken into consideration.

The maintenance of the navigation route consists of two activities:

- maintenance of the embankment stability and
- maintenance dredging to provide the constant and sufficient water depth.

Aviation

In aviation the most important environmental impacts affect the water resources via secondary effects since primarily the land acquisition, the effluence of gaseous pollutants in high atmospheric layers and noise control are the most important ones to be mentioned. However, the drainage of airports is a serious problem to be considered together with the waste washed into the recipients from the airfield. In the case of the airport excess water there are all the pollutants whatever is possible to find in highway drainage water, so see the discussion of them on page 2.

Passenger Transport

Passenger car traffic witnesses growth which has never been experienced before. Since the consolidation period after the Second World War not only the freight transport increased rapidly, but in private motoring there is a tremendous increase.

The increase in private motoring slowed down in the most developed countries lately, in publications it is stated that for example in the EEC countries it is not more than 1–2 per cent per year. The big challenge is the developing countries or the changes in the former socialist block, where the expected economic growth will (might) also stimulate the formal signs of the well-being, among them the private motoring. If this happens then it is perceived: the car ownership will increase rapidly (unless other values can override this trend, which is very unlikely) with consecutive increase in transport pollution and nuisance.

It is important to note, that 'even though highways may only occupy 5–8% of the urban catchment area, highway drainage can contribute to as much as 50% of the total suspended solids, 16total hydrocarbons and 75% of the total metal inputs to a receiving stream' (HAMILTON – HARRISON, 1991).

There are two important blocks of personal mobility which can be discussed under separate entries: the public transportation in urban centres and the highway nuisance.

Public Transportation

The public transportation is one possible solution for the problems which individual motoring is causing in big and crowded urban centres. There are data to prove the efficiency of the public transportation in terms of energy consumption per passenger in *Table 2* (after HOLCOMB, 1988).

Table 2
Energy intensity for selected transportation modes (HOLCOMB et. al. 1988)

Mode of transportation	Energy intensity (calories/passenger-km)
Car, one occupant	1153
Transit bus	570
Transit rail	549
Walking	62
Bicycling	22

The Highway Nuisance

When we are discussing the nuisance caused by transportation we have to make clear, what is the magnitude and share of the pollution caused by transportation in comparison with the other sources of the antropogenous air pollution.

Short Summary of the Harmful Effects on the Components of the Environment

The summary of the harmful effects of the different modes of the transportation are comprised into *Table 3.*

Air Pollution

Although the freight and the passenger motoring is responsible for the lion's share of most of the air pollution originating from traffic sources we cannot neglect the other branches of transportation. According to SHOEMALER – BOUMAN, (1991) the distribution of emission of different modes in the Netherlands in 1985 was as it is shown in *Table 4.*

Table 4
Transported freight in tons, in the Netherlands, 1985 (SHOEMAKER – BOUMAN, 1991)

	Emissions in gr per tonkm					
	CO_2	CO	HC	NO_x	Aer	SO_2
Road transport	211	0.90	0.68	2.97	0.39	0.20
Inland waterways	33	0.11	0.05	0.26	0.02	0.04
Railway	102	0.02	0.01	1.01	0.01	0.07

Table 3
The main environmental effects of the various transport modes (OECD, 1998)

Mode	Impact on Air	Water resources	Land resources	Solid waste	Noise	Accident risk	Other impacts
Rail			Land taken for rights of way and terminals; dereliction of obsolete facilities	Abandoned lines, equipment and rolling stock	Noise and vibration around terminals and along lines	Derailment or collision of freight carrying hazardous substances	Partition or destructon of neighbourhoods, farmlands and wildlife habitats
Road	Local (CO, C_xH_y, NO_x, fuel additives such as lead and particulate) Global (CO_2, CFH)	Pollution of surface water and groundwater by surface runoff; modification of water system by road building	Land taken for infrastructure; extraction of road building materials	Abandoned spoil tips and rubble from road works; road vehicles withdrawn from service; waste oil	Noise and vibration from cars, motorcycles and lorries in cities and along main roads	Deaths, injuries and property damage from accidents; risk from transport of hazardous substances; risk of structural failure in old or worn road facilities	Partition or destruction of neighbourhoods, farmland and wildlife habitats; congestion
Air	Air pollution	Modification of water tables, river courses and field drainage in airport construction	Land taken for infrastructure; dereliction of obsolete sites	Scrapped aircraft	Noise around airports		Congestion on access routes to airports
Marine and inland water		Modification of water system during port construction and canal cutting and dredging	Land taken for infrastructure; dereliction of obsolete port facilities and canals	Vessels and craft withdrawn from service		Bulk transport of fuels and hazardous substances	

Primary air pollutants are the particulate, which are emitted strait from the engines. While the primary air pollutants can be measured in the vicinity of the emission sources e. g. along the highways or in city centres, the effect of the secondary pollutants as photochemical oxidants and acid deposition is much more widespread.

Water Resources

Transportation has impact on water resources up to a great extent. The effects of navigation are discussed in an other paragraph, but the other effects are enumerated here briefly.

All means of transportation have an impact via precipitation since all the emissions to the air are deposited on the surface and later washed into the water bodies or are dissolved in the atmosphere by precipitation and get into the surface or subsurface water resources.

While the point-source pollution control proved to be effective to reduce municipal sewage effluent and industrial releases the water quality of natural recipients does not improve accordingly as a consequence of the non-point sources pollution control, to which the runoff from paved surfaces contribute on the top of agricultural and other sources. Pollution to natural recipients originating from paved surfaces related to short and random wet weather periods. Majority of the contamination are strongly related to the following: 'road surface material, fuel combustion products, lubrication system losses, degradation of automobile tyre, transported load losses, road surface cleaning/de-icing, paint and corrosion products.' (HVITVED, – YOUSEF, 1991)

The pollutants themselves belong to the following categories: suspended solids or particulate, oxygen consuming constituents, nutrients, heavy metals, trace organic and microorganisms. The standard pollutants are as follows: 'total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorus (TP), orthophosphate (OP), total Kjeldahl nitrogen (TKN), nitrite plus nitrate nitrogen (NO_2+NO_3−N), copper (Cu), lead (Pb), zinc (Zn), nickel (Ni), chromium (Cr), iron (Fe), and cadmium (Cd), hydrocarbons and coliform bacteria' (HVITVED, – YOUSEF, 1991). The pollution content of urban highway runoff is reported by YOUSEF et al. (1986) in *Table 5.*

Because of the ever increasing paved surface for transportation purposes the runoff patterns of earlier times are changing continuously and the runoff time is getting always shorter, peak discharges even higher.

Table 5
Standard analysis of urban highway runoff at Maitland Interchange near Orlando, Florida (after YOSEF et al. 1986)

Parameter	Unit	No. of obs.	Statistical analysis			
			Mean	Cov.	Median	Range
pH		13	6.6	0.30	7.5	5.9 – 7.8
Turbidity	NTU	11	9.3	0.60	9.1	2.51 – 22.5
Alk.	μmho/cm	13	41	0.26	44	10 – 70
Sp. Conduct.	μg/l	12	107	0.49	80	45 – 175
Organic N	μg/l	6	965	0.64	741	292 – 1891
NH_3-N	μg/l	13	152	0.63	78	9 – 972
NO_2-N	μg/l	13	13	0.35	8	1 – 37
NO_3-N	μg/l	12	306	0.49	246	46 – 665
OP	μg/l	13	76	0.81	65	26 – 178
TP	μg/l	13	170	0.66	147	62 – 346
Total Pb	μg/l	16	163	0.70	119	30 – 379
Diss. Pb	μg/l	16	34	0.81	25	13 – 128
Total Zn	μg/l	16	71	0.68	53	13 – 173
Diss. Zn	μg/l	16	40	0.74	33	13 – 134
Total Cu	μg/l	16	37	0.63	35	10 – 101
Diss. Cu	μg/l	16	26	0.59	22	10 – 64

Land Resources Requirements

With the growing demand for the different kinds of transportation, especially for road and rail transport vast amount of previously agricultural or natural land is paved, used for the transportation or for its infrastructure. While intruding into the landscape it also cuts off migration routes and threatens wildlife and natural life in various ways. It is a matter of taste to decide if highways and railroads are intruding into the landscape or improving, it is a fact that they alter the landscape substantially.

Reducing Adverse Effects of Transportation by Means of Traffic Management Solutions

Discussing the adverse effects of transportation there is little doubt that serious actions should be taken in order to lessen them and to make the transportation sector sustainable on the longer run.

There are several possible strategies to reduce the harmful effects of the too dense road traffic (mostly the air pollution and the noise control) among which the three more important ones are mentioned here first, applied in urban areas after RYDING, (1992):

Traffic volume reductions: Providing constant speed on the roads leads to much lower emission, resulted from better traffic management. Constructing ring and arterial roads also may ease the density of traffic of central areas of cities, especially if coupled with restricted areas kept for pedestrians only. However, it is important to note that improving the road capacities does not necessarily solve the congestion problems, but it encourages the population for more motoring, which leads to jams on the improved road system.

Park and ride systems: Public transportation as discussed in other parts of this material considered more sustainable than private motoring since the space requirement and also the effluent emission per passenger is much lower. It facilitates the parking on the perimeter of urban areas and routes the traffic to mass transportation as trams, underground and buses. As a consequence the inner parts of the city will be eased from the load of the traffic pollution (exhaust gas and noise mostly) and pedestrian districts can be developed.

Dynamic traffic management: 'Dynamic traffic management is the management of traffic streams, of vehicles, and even of demand for traffic, with the help of data on the actual and predicted traffic situation. Dynamic traffic management is based on the dissemination of correct information to drivers to influence traffic flows. Computer models for decision making play crucial role in this process.

The different functions in dynamic traffic management are:

- traffic data collection, traffic data processing and transmission to drivers;
- enforcement of control mechanisms like speed control;
- tolls, tariffs and reservations of use of the roads and parking places; and
- services to customers like tourist information maps and signage.' (RYDING, 1992.)

Noise Control

One of the most immediate and negative impact of transport is the noise pollution of the transportation. It has various aspects which should be discussed, but concentrating on the water managerial and environmental aspects of transportation this can be mentioned briefly. It is a very delicate issue especially in city centres, junctions of urban areas, where the noise pollution is the most direct on the human society. Near highways and airfields the noise level may be even higher, but then it causes distur-

bance not only to the human environment but also it damages the natural environment.

To tackle this problem the Austrian example for the possible drastic reduction of freight transport in the night hours which leads to considerably reduction in the noise level of the highways has to be mentioned.

Emission Control

Freight transport has relatively higher share in the air pollution than the passenger motoring. However, this is not overwhelming, so the emission of both of them should be discussed. It is important to note the difference in emissions since the ways to tackle the problems are really different. It is also very important to see that the reduction in air pollution in case of most of the components will not stop the present trends in environmental degradation. Even if effective steps are taken to reduce the immediate emissions, the recovery of the environment will take very long.

Geographical Location and Match to the River Basin

The river basin by its nature is like an organ: its arterial collecting the excess water from the catchment area toward the outlet of the basin. The different branches of transportation have different patterns on that scheme. Long distance travelling may be as follows:

- road traffic
- railway
- aviation
- navigation.

In relation to the slope of the catchment area road and railway construction can happen in two possible way: to follow the pattern of the natural runoff lines, e. g. the rivers or without taking them into account. The first case happens, if the slope of the basin is steep, and the settlements or focal points mainly located on the valleys and the traffic is not heavy (which means, it is not too difficult to cope with the relatively steep slope on the road or rail itself and also a lot of sometimes sharp bends are not jamming the traffic. In these cases the construction of the traffic system does not influence and alter the natural runoff processes too much. In almost every other case the pattern of the roads does not consider the natural runoff lines, and most of the cases go across the rivers. In hilly areas the highways and the rail lines go relatively straght, with constant and

relatively small slope, in flat areas nothing too much is considered from the natural runoff processes except that bridge construction is relatively expensive, so it is avoided if it is possible. In these cases the runoff is influenced, sometimes altered significantly related to the original situation.

Aviation is nodal activity on the surface of the river basin, airports and runways are constructions which have serious effects on their surrounding, detailed later.

Navigation by its nature follows the course of the natural runoff lines as construction of new waterways is always expensive, and when the route alters too much from the naturally given ones the costs become unreasonably high.

Local transportation by its nature is always point-like or sometimes is concentrated around a focal point. As it will become clear later, this is one of the most serious sources of efluent harmful to the environment.

The Adverse Effects of Transportation on the Main Physical Elements of the River Basin

The two categories have to be combined in this parts such as:

- the adverse effects on the following elements of the natural environment:
  - air,
  - flora and fauna,
  - surface and subsurface water resources,
  - soil and
  - landscape and land use pattern;
- the adverse effects as follows:
  - emission of exhaust gas from engines,
  - space and severance effects,
  - drain water from the paved surfaces and
  - others specified later.

The Society's Administrative Structure on the River Basin

In this chapter it can be discussed only very briefly that the organizations of the society taking care for the river basin as a whole have authority over the water resources only in most of the cases. Water District Authorities seldom have any say on other issues than their immediate concern on water quality and quantity, let alone the traffic pattern of the basin. When planning of big routes is under process until now the basin concept was not

taken into consideration and only the improvement of the latest decades such as Environmental Impact Assessment in the design process force the designers to pay more attention to the natural and social environment. However, good cooperation can be established with the local authorities and then the interest of the basin concept can be enforced.

Acknowledgement

The material for this paper was collected during my scholarship provided by the PHARE TEMPUS programme of the European Communities. From TEMPUS project 0266, Environmentally Sound River Basin Development I got the possibility to collect the material on the topic. I am especially grateful to Prof. I. IJJAS, and to Prof. J. WESSEL, the key people of this project to provide the excellent working conditions for me to collect the material and also for their encouragement to carry on with it. I also have to thank the help of my colleagues, who carried on with the educational activities at the Department of Water Resources, Technical University of Budapest, while I was away.

References

HOLCOMB, M. C. et al. (1988): Transportation Energy Data Book; President's Council on Physical Fitness and Sports

HVITVED, T. – YOUSEF, Y. A. (1991): Highway Runoff Quality, Environmental Impacts and Control (in Highway Pollution, eds: Hamilton, R. S. – Harrison, R. M.) Elsevier, Amsterdam.

KARDOSS, L. (1992): Inland Navigation and Environment, RBA Series on River Basin Administration, Reader No. 1.

KROON, M. – SMIT, R. – HAM, VAN J. (eds.) (1991): Freight Transport and the Environment, Studies in Environmental Science, Vol. 45, Elsevier, Amsterdam.

LINSTER, M. (1990): Background Facts and Figures (in Transport Policy and Environment, European Conference of Ministers of Transport, ECMT Ministerial Session) OECD Publications Service, Paris.

MAY, T. (1993): Transport Policy and Management (in Transport, the Environment and Sustainable Development, eds.: Banister, D. – Button, K.) E & FN Spon, London.

NOORT, VAN R. B. J. C. (1991): The Present Environmental Crisis, Studies in Environmental Studies, Vol. 45 Kroon, M. – Smit, R. – Ham, van J. (eds.), Elsevier, Amsterdam.

RYDING, SVEN-OLOF (1992): Environmental Management Handbook, IOS Press, Amsterdam.

SHOEMAKER, J. H. – BOUMAN, P. A. (1991): Facts and Figures on Environmental Effects of Freight Transport in the Netherlands in Kroon, M. – Smit, R. – Ham, van J. (eds.) (1991): Freight transport and the environment, Studies in Environmental Science, Vol. 45, Elsevier, Amsterdam.

UNITED NATIONS ENVIRONMENT PROGRAMME (1991): Environmental Data Report, UNEP Cambridge Center, Massachusetts, USA.

YOUSEF, Y. A. et. al. (1986): Effectiveness of Retention/Detention Ponds for control of Contaminants in Highway Runoff, Final Report submitted to FDOT, FL, ER-34-86. 111.