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HEALTH DAMAGE OF AIR POLLUTION AND BENEFITS AND COSTS OF AMMONIA CONTROL IN THE NETHERLANDS

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Abstract

The paper gives a benefit-cost analysis of ammonia emission control policy in The Netherlands. Particular care has been given to calculation of the health benefits. A dose-response relationship between air pollution and the number of work loss days has been estimated by applying the one-way fixed-effects method to data on work loss days due to illness and average year concentrations of air pollution in 29 districts. A significant relationship is found between ammonia (NH_3) and the number of work loss days (WLDs) and also for sulphate aerosol(SO_4). The dose-response relationship for ammonia has been used to calculate the health benefits of reducing ammonia deposition in The Netherlands in the periods 1987-1995 and 1995-2000. Together with information on other benefits and costs of ammonia emission control the health benefits are incorporated in a benefit-cost analysis of recent and current ammonia control policy in The Netherlands. The benefit cost ratio turns out to be 1/3 from a national point of view and 2/3 if transfrontier benefits are included.

1 Introduction

Acid rain is a major environmental problem in Europe. The Netherlands are one of the countries where soils and ecosystems are highly vulnerable for acidification. The deposition of SO_2 and NO_x on Dutch territory stems for a large part from emissions abroad but the third acid pollutant, ammonia deposition originates for 80 percent from sources in The Netherlands, mainly intensive cattle farming. This suggests that a relatively intensive abatement of ammonia may be an efficient national policy to cope with acid rain. In this chapter we shall investigate whether the Dutch policy to reduce ammonia has paid off. The costs as well as the social benefits of the ammonia abatement programme will be calculated for the period 1987-1995 and 1995-2000.

The main conclusion of the cost-benefit analysis is that the costs are considerable higher than the benefits. A major factor contributing to this result is that the measures taken have been much less effective in reducing ammonia than policymakers had expected.

This is the first study in which a full social cost-benefit analysis is made of a specific environmental policy in The Netherlands. The benefits from abatement of ammonia include recovery of nature, improvement of cultural goods and drink water supply and other items. The information about these benefits is obtained by using earlier studies on monetary damage caused by acid rain. We supplemented this information with our own estimates of the health impacts of ammonia and calculation of the health benefits of reducing ammonia emissions are part of the research presented in this chapter.

Sections 2 and 3 discuss how the relationship between pollution and health has been estimated. Section 2 reviews the literature and section 3 gives our own estimates of the dose-response relationship for The Netherlands. Health impacts have been measured in terms of work loss days which are translated in money terms in section 4 where also other figures on damage to nature and other items are presented. In section 5 health and other benefits from reducing ammonia emission in The Netherlands are calculated for the period 1987-1995 and compared with the cost of emission control. Next the expected benefits and costs for the period 1995-2000 are assessed. Section 6 discusses further research possibilities and presents uncertainties which arise in this research. Summary and conclusions are presented in section 7.

2 Review of the research literature

In the literature on the health impacts of air pollution, a DRR is usually a function of a large number of variables, such as air pollution: nitrogen oxides, sulphur dioxide, sulphate aerosol, black smoke, particulates, ozone and ammonia. In addition to these variables, the number of WLDs is influenced by other variables as well. The literature on epidemiology mentions, among others: education and occupation, income, job situation (employed or not), race, sex, age, and habits such as drinking and smoking.

For empirical research we have to confine ourselves to an equation with a small number of variables, because only then can the relationship be estimated. The research in this field has mainly been done for the US. Their emphasis is placed on the estimation of the relationship between air pollution and the number of WLDs. Air pollution, however, can also result in an increase in mortality. We shall concentrate on morbidity (=WLDs) and not deal with mortality.

Table I Estimation techniques, place and period in studies about morbidity

Studies	Estimation techniques	Place[1]	Period
Cropper (1981)	Tobit model	US	1970, 1974 & 1976
Krupnick, Harrington and Ostro (1990) & 1979	Logit estimation procedure	Los Angeles	1978
Ostra (1983a)	OLS[1] Tobit model Logit linear combination	US	1976
Ostra (1983b)	OLS Logit linear combination	US	1976
Ostra (1987)	Fixed-effects method by using a Poisson distribution	US	1976-1981
Ostra (1990a)	Logit estimation	US	1979-1981
Portney and Mullahay (1986)	Maximum likelihood method by using a Poisson distribution	US	1979

[1] OLS = ordinary least squares method

Table I classifies the seven major studies of a number of air pollutants for the United States. It shows that the DRRs have been estimated by applying different techniques. Apparently, no standard technique exists for the estimation of a DRR. The studies were published in the eighties and early nineties, but refer to different regions in the US in the seventies.

The types of pollutants that have been distinguished, and the other explanatory variables are shown in table II. The variable measuring WLDs is based on the response to the survey question asking how many days in the past 2 weeks did illness prevent one from working. Other data on background variables have been obtained from the same set of panel data. The variables included in DRRs differ between the studies. Which variables are actually taken into account is to a large extent determined by pragmatic reasons, such as the availability of data.

The pollutant NO_2 is only examined in the study by Krupnick et al. (1990), but it is not statistically significant. SO_4 is significant in only one of the four cases. Statistically significant in all cases are ozone, total suspended particulates and the coefficient of haze. The conclusion can be drawn that the most important variables are ozone and the four types of particulates.

It appears from table II that the variables chronic condition, education, age, and sex are usually statistically significant. Smoking is only significant in one of the three studies.

Up to now it has not been tried for The Netherlands to estimate dose-response relations on the basis of Dutch data that can be used for calculations of benefits of abatement of air pollution. Research has been of the epidemiologic type; like Hoek *et al.* (1990, 1993), who found a significant short term association between concentrations of O_3, SO_2, TSP and the pulmonary function of children.

Of a quite different category is the research of Jansen (1974), the OECD (1981) and Ostro et al. (1990b). They estimated the monetary health damage due to air pollution for the Netherlands, using a DRR estimated for the US by Lave and Seskin (1971; 1977). In another publication, Jansen (1980) used Crocker's so-called Wyoming study. If one takes the American DRR for granted the damage to health in the Netherlands was about half a billion euro per year in the early seventies, in 1967 prices (Jansen 1974). OECD (1981) estimates range from 45 million to 1.1 billion euro health damage per year. These figures are high compared with our findings for ammonia . However, regional concentrations of SO_2 were much higher in the late sixties and early seventies than they are presently.

Table II Dose-response relationship for morbidity

Studies	Pollutants								Health situation
	NO2	SO_2	SO_4	O_3	TSP2)	IP2)	FP2)	COH2)	Existence of chronic condition
Cropper (1981)		*							-
Krupnick, Harrington and Ostro (1990)	-	-		*				*	*
Ostro (1983a)			-		*				*
Ostro (1983b)			-		*			*	-
Ostro (1987)							*		*
Ostro (1990a)4)			*		*3)	*3)	*3)		
Portney and Mullahy (1986)			-	*					-

1) * = significant;
- = in significant;
2) TSP = total suspended particulates;IP = unhealable particles; FP = fine particles; COH = coefficient of haze (= a surrogate for fine particles);
3) Only significant if lagged by one 2-week period
4) Several socio-economic and demographic variables are included in the DRR. It is, however, not known which variables are significant.

Table II Dose-response relationship for morbidity

	Socio-economic variables		Demographic variables				Habits	Other variables
Studies	Income	Education	Age	Marital status	Race	Sex	Smoking	Population density
Cropper (1981)	-	-		-	-			
Krupnick, Harrington and Ostro (1990)		*	*		-	*	*	
Ostro (1983a)	-		*	-	-	*	-	-
Ostro (1983b)		*	-	-		-		-
Ostro (1987)	*	*	*	*	*	*		
Ostro (1990a)[4]								
Portney and Mullahy (1986)	*	-	-		*	-	-	

1) * = significant;
- = in significant;

2) TSP = total suspended particulates;IP = unhealable particles; FP = fine particles; COH = coefficient of haze (= a surrogate for fine particles);

4) Only significant if lagged by one 2-week period

4) Several socio-economic and demographic variables are included in the DRR. It is, however, not known which variables are significant.

3 A dose-response relationship for the Netherlands

3.1 The model

As a starting point for estimating an empirical DRR we have formulated the following health model.

$WLD = f(P_1, \ldots, P_6, X_1, \ldots, X_4)$ (1)
WLD = annual work loss days;
P_1 = sulphur dioxide (SO_2);
P_2 = sulphate aerosol (SO_4);
P_3 = black smoke;
P_4 = particulates;
P_5 = ammonia (NH_3);
P_6 = ozone (O_3);
X_1 = unemployment percentage in a region;
X_2 = percentage of labour force in a region receiving a pension under the Dutch Disablement Insurance Act;
X_3 = population density as an indicator for the urbanization rate of a region;
X_4 = average annual gross income per capita in a region.

Since we are interested in the health impacts of air pollution only WLDs caused by illnesses of the respiratory system, such as chronic bronchitis, asthma and chronic non-specific lung disease (CNSLD) have been used.

The selection of air pollutants has been influenced by availability of information. In further defence of this choice we recall that US studies suggest that the following pollutants may have a significant positive effect on WLDs: SO_2, SO_4, particulates, black smoke and ozone. To this we have added ammonia, which has not been researched in US studies. It, however, is a major air pollutant in the Netherlands (see p. 3).

Human health is also affected by socio-economic variables. The choice of explanatory variables is partly inspired by theoretical considerations and partly influenced by availability of data. In this study aggregated cross-sectional data have been used. We would have preferred to use microdata because these data contain person-specific information. Unfortunately no suitable dataset is available in the Netherlands. When compared with the models used in section 2 (table II), it is striking that in equation (1) the following background variables are lacking: chronic condition, age, race, sex, smoking and drinking. The reason for this is that there is no information available on a regional level for the Netherlands. Next, we discuss the variables in equation (1).

3.2 Data

The data on work loss days, air pollution and socio-economic figures used for the estimation of the DRR are totals or averages per year for 1987, 1988 and 1989.

Work loss days

In the empirical research in the US, data are obtained by asking people how many days in the past 2 weeks did illness prevent them from working. In our research, however, the WLDs are not obtained by using a survey but by registration by the Industrial Insurance Administration Office, the so-called GAK. Workers registrated as being ill are monitored by inspectors who came to visit them at home. Some of the inspectors are physicians, who make a diagnosis of the type of illness.

For the registration The Netherlands is divided in 29 administrative health districts. For each district we have information on WLDs of employed persons due to illnesses of the respiratory system for the years 1987, 1988 and 1989. This means that aggregated data (cross-sectional and time series) had to be used and we lack the person-specific information (smoking habits, age, sex, etc.) that are contained in micro data that have been used in the US studies.

Nevertheless we think that our study has important advantages over American studies. The first advantage is that the WLDs used in this study is registrated by an administration office (GAK) and refers to about 80 percent of the labour population of the whole territory of The Netherlands. In the American research, however, a survey is used which is less reliable than in case of official registration.

The second advantage is that our WLDs are diagnosed by a physician, while in the American studies the WLDs are obtained by only asking people about illness in the past 2 weeks.

For estimation purposes WLDs per district have been expressed as a percentage of the district's employed labour population. Its variation between districts is large with the maximum more than three times the minimum.

The total number of WLDs diagnosed by a physician is 36.2 million in 1989 and 1.5 million of these WLDs are due to illnesses of the respiratory system. The category WLDs which has not been diagnosed contains 18.2 million, which means that the total number of WLDS (36.2 + 18.2) is 50 percent higher than the number of WLDs diagnosed by a physician. In our estimates of dose-response relationships only the diagnosed WLDs have been included. It should be clear that this implies an underestimate of the true number of WLDs. Assuming that the undiagnosed category contains the same percentage illnesses of the respiratory system as the group which has been diagnosed by a physician, the effect of ammonia on the number of WLDs will be 50 percent higher than the effect estimated in this paper (see table VI, p. 15).

Air pollution

The data refer to outdoor air pollution. Although the influence of occupational exposure on the health situation of people is possible, this influence is not included in the DRR. The reason for this is that there is no data set available.

Data about outdoor air pollution come from the annual reports of the National Institute of Public Health and Environmental Protection (RIVM) for 1987, 1988 and 1989. Air pollution is monitored at a number of monitoring sites. The air pollution in a "district" is estimated by taking an average of the air pollution at the monitoring sites in that "district". We use annual averages since WLDs have also been measured on a per year basis.

The pollutants SO_2, SO_4, black smoke (BS), particulates (Part) and O_3 are measured in µgm-3 and NH_3 in mol ha-1. Figures on concentration are presented in table III. They show that differences across the regions are considerable. The maximum concentration is about two to three times higher than the minimum value. In general the northern part of the Netherlands is the least polluted and the southwestern part the most.

Table III Minimum and maximum concentration of air pollution in the Netherlands Measured in µg m-3, except NH_3 (mol ha^{-1})

Air pollution	1987		1988		1989	
	Min.	Max.	Min.	Max.	Min.	Max.
SO_2	10	36	7	24	7	26
SO_4	7	9	4	6	7	19
BS	11	30	7	24	10	28
Part.	42	57	33	55	36	61
NH_3	430	890	320	1060	490	1000
O_3	27	56	26	57	28	58

Part. = particulates
BS = black smoke
NH*3* = ammonia

min. = region with lowest annual pollution
max. = region with highest annual pollution

Socio-economic data

The socio-economic data on unemployment percentages, disablement percentages, population density and average gross nominal income per capita come from the Dutch Central Statistical Office. These figures are available for 40 areas, the so-called "Corop regions", which differ from the health districts. Therefore all socio-economic data about Corop regions had to be assigned to the 29 health districts. In doing this the number of inhabitants per Corop region has been used as weights.

The unemployment and disablement percentages are calculated as percentages of the labour force per district. The population density is calculated by dividing the population of a district by the number of square kilometres. The variance of the population density, however, is very large. Amsterdam has more than 4000 inhabitants per km^2 and Assen has less than 170. The variance in the unemployment and disablement percentages across the regions is considerable. The variance of the incomes across the regions is small. The maximum income is about 10 percent higher than the minimum income.

3.3 Estimation technique: one-way fixed-effects method.

The DRR for the Netherlands is estimated by means of data that refer to 29 regions in the Netherlands. When the relation is estimated by application of the ordinary least squares method it is actually assumed that the same DRR holds for each region. This is, however, very unlikely. Some regions may have a specific population composition which influences the number of WLDs. Urban areas could therefore have health models that differ from those for rural areas. If these differences are not taken into account the effect of air pollution on the number of WLDs cannot be estimated in an unbiased way. A method which can take into account the fact that the DRRs differ across the regions is the *one-way fixed-effects method* (OWFEM), see, among others, Judge et al. (1988, chapter 11.4) and Greene (1990, chapter 16.4). The essential difference between the least squares method and OWFEM is that in the latter method the intercepts are different across the various regions while in the former method they are all equal. On the other hand, it is assumed that the independent variables and their impacts on health are the same for the various regions. Because specific regional differences in the WLDs are reflected in the intercepts it is not necessary to use different DRRs for the various regions. The method is called fixed-effects because the differences across the regions can be considered as shifts of the functions.

The computer program LIMDEP 6.0 has been used for the estimation of the equations; see Greene, (1991). Assuming we have i=1,2,..., N regional observations and t = 1,2,..., T time-series observations, and K explanatory variables, the (i,t) observation can be written as:

$$Y_{it} = \beta_{1i} + \sum_{k=1}^{k} \beta_k \cdot X_{kit} + e_{it} \qquad (2)$$

The fact that each region has a different DRR can be adequately captured by specifying a different intercept coefficient for each region. All the information is used in estimating equation 2. Output consists of X-effects (that is $\beta_2,...,\beta_k$) and the N values for intercepts β_1. Only when the intercepts differ significantly is there a basis for applying the fixed-effects method. This turns out to be the case with 99 percent certainty for all six pollutants.

By means of an analysis of variance total variation in WLDs has been split up in within region variation and between region variation. Within region variation is the variation in the regions and between region variation is defined as the variation between the regions. In both variations information of all the years is used. Systematic differences between the regions that cannot be related to differences in explanatory variables, in particular air pollution, are caught by the differences in the intercepts.

Table IV Variance in WLDs

Number of regions	Pollutant	Variance within regions	Variance between regions	Total variance
29	SO_2	460.23	9436.71	9896.94
9	SO_4	97.82	2440.51	2538.33
14	BS	261.51	5180.98	5442.49
5	Part.	48.38	1738.95	1787.32
11	NH_3	136.73	3588.56	3725.29
20	O_3	349.21	6428.11	6777.32

Table IV shows that total variance of the number of WLDs consists for more than 95 percent, of variance between the regions. This means that the explanatory variables explain only a small part of the total variance in the number of WLDs. This indicates that it is especially useful to apply a technique like the fixed-effects method in which this is taken into account.

3.4 Empirical results

We assume that the DRR is a linear function in the pollutant variables and the socio-economic variables. In addition, it is assumed that the function neither has a threshold nor a kink, below which the relationship may be different.

The DRRs for the Netherlands are estimated, with each equation containing only one pollutant variable. The reason for this is that multicollinearity exists between the various pollutants. A consequence of this estimation procedure, however, is that the effect of a specific air pollutant on the number of WLDs may be overestimated.

The constants (intercepts) - as many as there are regions and for each pollutant - are not shown. They differ considerably, with a minimum of 24 WLDs and a maximum of 62 WLDs per year for SO_2.

Equation (3) is estimated by application of the one-way fixed-effects method.

$$WLD = a.Pi + b.Pd + d.u + c \qquad (3)$$

In equation (3) the variable disablement has been omitted since it turned out to be correlated positively with unemployment. Income per capita has also been left out. It has no significant impact; possibly because of low regional variance between regions.

Table V Relationship between number of work loss days and air pollution (P_i), population density (P_d) and unemployment (u)

N		Pi	Pd	u	R^2	F-value
29	SO_2	0.081 (1.207)	0.017 (0.676)	-0.185 (-1.975)[1]	0.958	42.18
9	SO_4	0.021 (3.456)[2]	0.322 (2.850)[2]	-0.149 (-1.166)	0.982	86.60
14	BS	0.203 (1.206)	0.024 (0.815)	-0.125 (-0.731)	0.959	35.06
5	Part.	-0.186 (-0.903)	-0.202 (-0.977)	-0.551 (-1.705)	0.982	9.63
11	NH_3	0.007 (1.880)[1]	0.267 (1.848)[1]	-0.187 (-1.272)	0.975	58.53
20	O_3	-0.189 (-1.639)	0.015 (0.577)	-0.251 (-1.986)[1]	0.955	29.03

t-statistics is in parentheses;
[1] = coefficient is significant at a 10 per cent level;
[2] = coefficient is significant at a 1 per cent level;
N = number of regions.

The estimation results are presented in table V. The following conclusions can be drawn.

1. R^2 is high, over 0.95 for all six equations.
2. The impact of air pollution on WLD is usually positive. The exceptions are ozone and particulates: both have a negative coefficient (but neither of them differs significantly from zero).
3. Two pollutants, SO_4 and NH_3, have a significant positive effect on WLDs. For SO_4 with 99 percent certainty and for NH_3 with 90 percent certainty.
4. The effect of population density on work loss days is usually positive and significant for SO_4 and NH_3.

The empirical results of this study show important differences with results of research in the US. As table II shows, the significant pollutants in US studies are: TSP and other small particles, O_3 and to a lesser extent SO_4 and SO_2. In our OWFEM approach only pollutants SO_4 and NH_3 significantly influence the number of WLDs in the Netherlands.

The pollutant NH_3 does not occur in the US studies because it is of minor importance. For the Netherlands, however, this is different. Ammonia concentrations in specific regions of the Netherlands are very high, so it need not come as a surprise that they have a negative impact on health.

The injurious influence of particulates has been proved various times in the

United States. The reason that a significant negative correlation cannot be found for the Netherlands with OWFEM may be that the number of observations for this pollutant is rather low (5 regions over 3 years supplies 15 data).

4. Health benefits from reducing ammonia

In section 3 the impact of air pollution on health has been estimated in terms of work loss days. In this section these physical impacts will be valued in money terms. In section 5 we shall see how the health benefits can be incorporated in an analysis of total costs and benefits of air pollution control in The Netherlands. Such empirical studies are very rare since usually the necessary data are lacking. However, for ammonia we have been able to collect sufficient information to make such an assessment of benefits and costs feasible.

Impact of ammonia on WLDs in sample
The estimation results in table V can be used to calculate the work loss days caused by air pollution. We shall do this for ammonia. The estimated value of the regression coefficient for ammonia is 0.007. This implies that an increase of NH_3 deposition per ha by 1 mol raises the number of workloss days due to illness of the respiratory system by 0.007 days per 100 employees. Assuming that the relation holds over the whole range of deposition levels the total number of workloss days caused by deposition of NH_3 can be calculated for the 11 districts for which we have sufficient informtion. Table VI shows the results for the years 1987, 1995 and 2000. Figures for the districts contained in the sample are presented as well as their aggregate. Ammonia deposition in the districts has decreased by 13 percent on average (unweighted) between 1987 and 1995. For the districts together the workloss days that can be attributed to ammonia were 68,618 or 316.2 work years in 1987 and 58,125 days, or 267.9 years in 1995; that is a reduction of 15 percent[1].

The number of WLDs caused by ammonia in the year 2000 is calculated by multiplying the number of WLDs in 1995 (58,125) with the calculated average national deposition level of ammonia in 2000 (appendix 1) divided by the deposition level in 1995, see RIVM (1997, p. 120). This figure is also presented in table VI.

$$WLDs_{2000} = WLDs_{1995} \text{ x } D_{2000}/\ D_{1995} = 58{,}125\text{x}(1{,}250/1{,}320) = 55{,}043.$$

Since ammonia deposition explains only about 5 percent of all workloss days caused by lung diseases in 1987, the impact of the decrease in ammonia deposition in the period 1987-1995 is rather modest. Per district the elasticities - that is the relative change in WLD from lung diseases divided by the relative change in NH_3 deposition - vary from 0.08 to 0.21. Lung diseases together are only responsible for 3 percent of all WLDs due to illness. This implies that the reduction of

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[1] The calculation has been made holding the number of employees equal on the 1989 level. A working year is equal to 217 working days.

ammonia deposition by 13 percent between 1987-1995 reduced WLDs due to all kinds of illness by about 0.05 to 0.1 percent.

Table VI Work loss days in selected districts cause by ammonia deposition

No.	District name	Deposition of NH_3 mol/ha		Number of employees	WLDs caused by ammonia		Decrease in WLDs due to a reduction in NH_3	WLDs caused by NH_3	Decrease in WLDs
		1987	1995	1989	1987	1995	1987-1995	2000	1995-2000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2	Alkmaar	430	510	151,800	4,569	5,419	(-)850		
3	Haarlem	445	380	139,600	4,349	3,713	635		
5	Rotterdam	685	440	239,700	11,494	7,383	4,111		
6	Assen	760	590	92,500	4,921	3,820	1,101		
7	Goes	640	610	106,300	4,762	4,539	223		
8	Breda	670	620	140,200	6,575	6,085	490		
10	Maastricht	660	540	74,800	3,456	2,827	629		
13	Utrecht city	760	580	201,700	10,730	8,189	2,541		
14	Zwolle	700	540	115,300	5,650	4,358	1,292		
23	Venlo	890	870	95,600	5,956	5,822	134		
25	Enschede	825	800	106,600	6,156	5,970	186		
Total				1,464,100	68,618	58,125	10,493	55,043	3,082

In table VII the decrease in WLDs due to a reduction of ammonia is presented for the period 1987-1995 and 1995-2000 (see table VI). The WLDs are expressed in work loss years (WLYs) by dividing by 217 days.

Table VII Decrease in Work loss days (WLDs) and Work loss years[1] (WLYs) due to ammonia reduction in selected districts

Number	District name	Decrease in WLDs due to a reduction of ammonia		Decrease in WLYs due to reduction of ammonia	
		1987-1995	1995-2000	1987-1995	1995-2000
2	Alkmaar	[-] 850		[-] 3.92	
3	Haarlem	636		2.93	
5	Rotterdam	4,111		18.94	
6	Assen	1,101		5.07	
7	Goes	223		1.03	
8	Breda	490		2.26	
10	Maastricht	629		2.90	
13	Utrecht city	2,541		11.71	
14	Zwolle	1,292		5.95	
23	Venlo	134		0.62	
25	Enschede	186		0.86	
Total		10,493	3,082	48.35	14.20

1) 217 working days is 1 working year

Health damage and benefits for The Netherlands in 1987-1995 and 1995-2000

The 11 districts in table VII are a representative sample of The Netherlands. The districts have different degrees of urbanisation and are scattered over the whole territory of The Netherlands. The deposition levels in the 11 districts in 1987 are between 430 and 890 with an average of 670 (weighted with the number of employees). The average deposition in The Netherlands is 710. Because of these similarities the figures of the 11 districts can be used to extrapolate the effect of ammonia deposition and of reducing ammonia deposition on WLDs for the whole labour force in The Netherlands. In table VIII the figures are presented, differentiating between employees only and the whole labour force. To be able to make the calculation for the whole labour force the assumption was made that the impact of ammonia on WLDs of self-employed persons is equal to the effect on WLDs of employees. The number of work loss years in The Netherlands in 1987 due to ammonia deposition is 894.8 for employees and 1026.9 for the total labour force.

A next step in the assessment is the choice of the wage rate. It is clear that only the health impacts of reducing ammonia deposition on paid labour have been estimated and calculated for The Netherlands. This implies that only the damages and benefits in terms of a decrease, respectively increase, of output can be estimated. As a measure for the marginal productivity of working people average gross wage has been chosen (This is the wage sum including the social insurance premiums paid by employers.) The gross annual wage paid in 1987 was 25,460 euro.

Multiplying the above mentioned number of work loss years in The Netherlands with the gross wage rate for 1987 (25,460 euro) the value of health damage in 1987 is obtained and presented in table VIII. Total benefits of reducing ammonia in the period 1987-'95 and 1995-2000 can be calculated forward looking, taking 1987 as reference year and multiplying the relevant category of workers in 1987 with its wage rate for that year. This implies that health damage in 1995 and 2000 is also assessed at prices of 1987. The benefits are presented in table VIII. It reveals that the health benefits of reducing ammonia in the period 1987-1995 are 4 million euro and in the period 1995-2000 1.2 million euro[2].

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[2] An alternative option is to look backward from 1995 to 1987 and ask how much output in 1995 would be lower had ammonia deposition not been reduced since 1987. In the case the number of employees respectively labour force in 1995 has to be used as a base to calculate WLD in 1995 and in 1987 and the appropriate wage rate is the deflated wage rate in 1995. The same reasoning can be given for looking backward from 2000 to 1987. This is not presented in table VIII.

Table VIII Total health damage per year from ammonia in 1987, 1995 and 2000 and health benefits from reducing ammonia deposition for the total employed labour force in The Netherlands (mln euro; low estimate)

Category	Health Damage per year (mln euro)			Health Benefits per year from ammonia reduction (mln euro)	
	1987	1995	2000	1987-1995	1995-2000
employees	22.782	19.298	18.275	3.484	1.023
total employed labour force	26.147	22.162	20.975	3.985	1.187

As was said in section 3.2 (pp. 8-9) only the diagnosed WLDs have been included in our estimate of the dose-response relationship. There are good reasons to expect that the share of illness of the respiratory system in the non diagnosed group does not differ from the diagnosed group. This means that actual impacts of ammonia on WLDs are 50 percent higher than our estimate. Taking this into account the health benefits of reducing ammonia emissions for the total labour force are 5.977 mln euro in 1987-1995 and 1.780 mln euro in 1995-2000. It is important to mention that only the low estimte is presented in table VIII, while both the low and the high estimate are presented in table X.

5. Benefits and costs of reducing ammonia

In this section the damage of ammonia to health and the benefits of reducing emissions and deposition of ammonia will be incorporated in a benefit cost analysis of ammonia reduction policy in The Netherlands in the period 1987-1995 and planned policy for the years 1995-2000.

Damage by acid rain

Together with sulphur dioxide and nitrogen oxide, ammonia is responsible for acid rain. Estimates of monetary damage caused by acid rain, reflecting emissions and depositions up to the mid nineteen eighties, have been published by the Ministry of Housing, Physical Planning and Environment (see VROM, 1985) and Van der Linden & Oosterhuis (1988). The figures are presented in table IX.

Table IX Estimates of damage per year from acid rain in the early eighties (mln euro)

Category	Low	High
Agriculture	257	298
Nature	7	23
Forestry		
reduction of wood output	9	23
capital loss/reparation cost	77	250
Recreation (forest and heath)[1)]	659	659
Cultural goods	25	45
Consumption goods	18	18
Drink water supply	9	23

[1)] Van der Linden & Oosterhuis (1988); other categories VROM (1985).

The largest figure on the list is the loss of recreation value of forests and heath. It has been obtained by applying the contingent valuation method. A sample of Dutch consumer households have stated their willingness to pay (WTP) for the prevention of further decrease of vitality of forests (from 50 percent of trees vital in 1986 to 25 percent in 2010) and reduction of overgrowth of heath by grass. WTP is 10.38 euro per month per household; extrapolated to all households it amounts to 659 mln euro per year.

The item forestry consists mainly of capital loss/reparation cost. In our view the reparation costs refer to restoring the recreational value of forests. The compensation cost method is applied here instead of WTP. To avoid double counting we delete the item of 77-250 mln for capital loss. We shall use the "corrected" table X and our own calculation of health benefits as the basis for calculating the total benefits of ammonia reduction in The Netherlands.

Benefits of reducing ammonia deposition

In calculating the damage in 1987 caused by ammonia deposition to the items recreation (valuation of forests and heath), output reduction of forestry and other damage (cultural and consumption goods, drink water supply) in table X we have assumed that the damage to be attributed to ammonia in 1987 is proportional to its share of 28,9 percent in total potential acid deposition in that year (see RIVM 1990). The figures are presented in table X. Of the three acidifying pollutants only SO_2 reduces the output of agriculture. Therefore the category agriculture has a value of zero in table X. Health damage has been taken from our calculations in table VIII.

Table X Damage per year from ammonia deposition and benefits from reducing ammonia (mln euro)

Category	Damage in						Benefits in			
	1987		1995		2000		1987-1995		1995-2000	
	low	high	low	high	low	high	low	high	low	high
Health	26	39	22	33	21	31	4	6	1	2
Recreation	190		154		142		36		12	
Agriculture	0		0		0		0		0	
Forestry (output)	3	7	3	6	3	6	0	1	0	0
Other damage	15	25	12	20	11	18	3	5	1	2
Total	234	261	191	213	177	197	43	48	14	16

As a next step the reduction of damage (= benefits) because of a decrease in ammonia deposition in the period 1987-1995 has to be assessed (column 5). In analysing the impacts on recreation values of heath and forests it has to be taken into account that soils that are susceptible to acid deposition can sustain a certain load of acid pollutant without negative impacts. For The Netherlands a critical load of 1400 mol/ha has been formulated[3]. The reduction of ammonia deposition by 210 mol/ha between 1987 and 1995 reduces the gap between 1987 and the critical level of acid deposition (where damage can be assumed to be zero) by 5.4 percent (see appendix 1). Assuming a proportional relation between deposition above critical level and damage the reduction of monetary damage between 1987 and 1995 is 5.4 percent of damage of acid rain caused to nature and forests in 1987. The benefits of 0.054 x 659 mln euro = 36 mln euro for recreation are included in table X (column 5). Next the damage to recreation in 1995 has been calculated, by subtracting the decrease of the damage (36) from the damage in 1987 (190).

The same procedure has been used to calculate benefits and damage of forestry output and (for want of adequate information) to 'other damage'.

Health benefits have been taken from table VIII. The 1987 wage and labour force have been used for consistency with other categories used in table X. Health benefits are 9 percent of total benefits of reducing ammonia deposition (column 5). If the higher number of WLDs is taken into account the percentage will be about 14 percent.

The decrease of the damage in the period 1995-2000 is calculated in the same way as the decrease in the damage in the preceding period. The decrease in health damage is taken from table VIII. The reduction of ammonia deposition in the period 1995-2000 is 70 mol/ha (see appendix 1). As a result, the gap between

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[3] This is a safe norm. See: RIVM [1997; p. 124].

1987 level of acid deposition and the critical level is decreased by 1.8 percent and the recreation benefits are then equal to 0.018 x 659 mln euro = 12 mln euro (column 6). The benefits for the other categories are calculated in the same way (column 6).

An estimation of ammonia emissions and of costs of reducing ammonia emissions

More than 90 percent of ammonia emissions in The Netherlands are released by cattle farms, see RIVM (1997, p. 242). In 1995 50 percent of the ammonia emissions from Dutch sources were deposited outside Dutch territory (70 percent of them in Germany) and of total ammonia deposition 20 percent was imported. Measures to reduce ammonia emissions have been taken from about 1987 on.

In the appendix we have calculated that the reduction of ammonia emission in the period 1987-1995 has been 17.5 percent: from 232 kton in 1987 to 191 kton in 1995. These figures and the costs of emission control are presented in table XI.

Table XI Emissions and control costs of ammonia from agriculture per year.

Year	Emission (kton)	Total yearly control costs (mln euro)	Emission reduction (kton)	Additional yearly control costs (mln euro)
1987	232[1)]	10[1)]		
1995	191[3)]	142[2)]	41	132
2000	179[3)]	180[2)]	12	38

[1] CBS (1992);
[2] RIVM (1997); EC scenario: goal unchanged policy;
[3] Calculated in appendix 1

Why the emission targets for ammonia are not met

The emission target for The Netherlands is a decrease of ammonia emissions to 144 kton in 1995; RIVM (1997). The actual emission, however, has decreased much less as table XI reveals. It is now already clear that the target for the year 2000 will not be met, because according to our estimates the emission will be 179 kton in 2000 (table XI), while the target is 121 kton; RIVM (1997).

In order to answer the question why the emission targets have not been met it is important to discuss briefly the abatement policy. This policy includes:

- obligatory injection of manure into the soil during application;
- a ban on the application of manure in winter;
- covering of manure storage basins.

According to Erisman and Monteny (1999) the measures taken have been much less effective than had been expected for two reasons. First, the manure is now stored in the basins during a longer period. In that period more ammonia is produced, which results in a larger ammonia content of the manure. Second, the emphasis in the abatement policy is on the injection of manure into the soil. But it has been overlooked that plants emit a large part of the ammonia in the soil by the leaves. If the amount of nitrogen is greater than the plant needs, re-emission of ammonia takes place (Erisman and Monteny 1999; pp. 6-7).

Benefit cost ratio's

Benefits, costs and benefit-cost ratios of ammonia reduction are presented in table XII. For the period 1987-1995 and 1995-2000 the benefit-cost ratios are about 1/3, which means that the costs are a factor 3 higher than the benefits. Partly this is brought about by the ineffectiveness of the abatement program. But even if the programme would have met the expectations about its effectiveness, which means an emission reduction that is twice higher, then the benefit cost ratio would not have exceeded 2/3. The difference between a low and a high value for the benefit-cost ratio is small and the ratios are almost the same for both periods.

It should be remembered that a significant part of Dutch ammonia emissions are deposited abroad, especially in Germany. Since 50 percent of emissions is "exported", reduction of emission could have major positive spillovers in neighbour countries. It reduces, however, the cost-effectiveness of abatement policies from a national point of view. The national benefits of 43-48 mln euro in the period 1987-1995 might be used as an indicator of benefits abroad; in particular in Germany, that recieves 70 percent of Dutch ammonia "export". This means that if costs and benefits are assessed from an international point of view the B/C ratio might be increased to 2/3. The conclusion can be drawn that present ammonia abatement policy in The Netherlands is inefficient, even if the benefits external to the Dutch economy are included in the cost-benefit analysis.

Table XII Benefits and Costs and benefit/cost ratio of ammonia reduction in The Netherlands 1987-1995 and 1995-2000.

Period	Yearly benefits (B) (mln euro)		Yearly costs (C) (mln euro)	B/C	
	low	high		low	high
1987-1995	43	48	132	0,33	0,36
1995-2000	14	16	38	0,37	0,42

6. Uncertainties and further research options

6.1 Further research

In this paper a cost-benefit analysis has been applied to ammonia reduction. In the benefits are included the health benefits for which a DRR for ammonia has been estimated on the basis of Dutch data. Next to that DRRs have been estimated for five other air pollutants. The paper is a report of research in progress. In this section we will briefly discuss the options we see for further research on the subject.

Multicollinearity

As multicollinearity exists between the different pollutants, the estimated coefficients are biased. In our research, we have solved this problem by estimating six DRRs, each on the basis of one pollutant. The disadvantage of this is that the coefficient can be overestimated. There are, however, other methods that can be used to estimate relationships when collinearity exists. One of these methods is the so-called principal components regression; see Greene (1990, chapter 9) and Judge et al. (1988, chapter 22). According to this method, one should look for combinations of explanatory variables which show a low collinearity. These variables are the principal components. The variables that are strongly correlated are left out. Through a test, it can be decided which variables should be left out. Subsequently, the DRR is estimated by applying the one-way fixed-effects method. The principal components are then taken as explanatory variables.

Additional information

Within the dataset, the data about air pollution are not complete. For every district, information is required for each of the three years. If one or two observations are missing, the district is left out in the estimation procedure. To avoid such a loss of valuable information one can try to fill in the missing data, if possible. These data are particularly useful if principal components regression is applied. In the literature, different possibilities are mentioned to fill in the missing data; see Greene (1990, chpter 9). Greene distinguishes different techniques and also emphasises the differences between cross-section and time-series problems. For time-series the data can be acquired by applying interpolation.

A priori information

For our research, we have not made use of the so-called extraneous information or a priori information. The reason for this is that we prefer to estimate the DRR solely on the basis of Dutch data. It could, however, make sense to do further research, and make use of extraneous information from other research, such as:

- information about coefficient values and inequality restrictions;

- information that certain coefficients are equal to zero.

Subsequently, a priori information and sample information are combined to gain knowledge about population parameters.

Other specifications

Because the average annual concentration of air pollution is not extremely high in The Netherlands, we have assumed that in this area the DRR is linear. It is, however, possible that the relationship changes with low or high concentrations. In that case, the DRR will show kinks and can be described as a spline function. Further research on non-linear relationships of the DRR is desirable. Specifically, research could be done on thresholds and other kinks in the DRR; see Greene (1990, chapter 8).

Time scale

DRRs have been estimated using data on illness and air pollution on a year basis. This makes sense if concentrations are spread rather evenly within the year. However from epidemiological studies it is known that a pollutant like O_3 has short run impacts on days that high concentrations occur. Moreover O_3 is a pollutant with a pattern of peaks and throughs within the year. Therefore it would be useful to have information on concentrations and respiratory illness over shorter time spans than a year.

6.2 Uncertainties

Above it is discussed that various uncertainties arise in the estimation of a DRR for The Netherlands. In addition uncertainties and gaps arise in the calculation of ammonia reduction. Only by further research can these be reduced. The major uncertainties are the following:

Health benefits

It should be kept in mind that the monetary value of WLDs only shows the production value of health impacts on the formally employed labour population. Production value of unpaid labour within households is not included. Neither is included the direct "consumption" benefits of not being ill both of workers and the non working population.

Recreation

The benefits to recreation have been estimated with the Willingness to Pay method. A disadvantage of this method is that the responses to questions are not very stable. Another problem is that the revealed preference for an improved quality of nature needs not to reflect the true preference because of strategic behaviour of the people.

Benefits of neighbour countries

It has been assumed that the impact of lower ammonia deposition is proportional to that in The Netherlands. It should be clear that this a questionable assumption.

Costs of emission control

Only recently it has been discovered that the measures to reduce ammonia emissions have been rather ineffective and results of the calculations seem rather preliminary. The disappointing results may be partly due to the fact that costs which supposedly have been made, have not been made at all since farmers simply did not comply with the measure.

These considerations suggest that costs may be lower than we have calculated and health benefits are probably higher. With benefits 30 percent higher (62.4 mln euro) and costs 30 percent lower (92.4 mln euro) the national benefit cost ratio is 2/3, but if benefits in neighbour countries are included the ratio may raise to a value above 1. This is to show that our calculation is a first answer to the question on the efficiency of Dutch ammonia policy and certainly not the last word.

7. Conclusions

This is the first effort to assess both the costs and the benefits of a specific environmental policy in The Netherlands. From the references in this paper it is clear that calculations of potential benefits and costs have been made in the past, but they have never been integrated as to make them comparable in one study. Neither has it been tried to estimate dose-response relations for The Netherlands on the basis of Dutch data and to use this as a base for calculating of benefits of abatement of air pollution.

First we have estimated the health impacts of reducing air pollution in The Netherlands in terms of reduction of work loss days and in monetary benefits. The decrease in the number of WLDs due to abatement of ammonia in the period 1987-1995 is 34,078 (low estimate) to 51,117 (high estimate) a year. As a result health benefits are obtained of 4 (low) to 6 mln euro (high) a year.

Next we have integrated the health benefits of reduction of ammonia in a cost benefit analysis of ammonia reduction policy in The Netherlands in the period 1987-1995. Total benefits are 43 to 48 mln euro per year, of which 4 to 6 mln euro are health benefits; annual costs of measures to reduce ammonia deposition are 132 mln euro. The main difference between the two periods 1987-1995 and 1995-2000 is that emission reduction in the second period is much smaller than in the first period. As a result health benefits and other benefits also are much lower. Consequently benefit-cost ratios are nearly the same for both periods. This results in a national benefit cost ratio of about 1/3 and an international benefit cost ratio which may be twice as high. We conclude that the ammonia abatement policy has been inefficient.

We are the first to admit that our effort to calculate benefits of cost is full of assumptions the validity of which can be doubted; the margin of possible errors is wide and some readers might even doubt the moral acceptability of evaluating environmental impacts in money terms. Our view on this issue is that cost-benefit analysis is helpful in making the political discussion on environmental choices, which have to be made, more transparent. First efforts, although vulnerable for justified criticism, can be the beginning of further studies to provide decision makers with information on what exactly they are doing.

Appendix 1: CALCULATION OF AMMONIA EMISSIONS IN 1995 AND 2000 AND OF AMMONIA DEPOSITION IN 2000

I. Calculation of emission of ammonia in 1995.

As RIVM has underestimated ammonia emissions in 1995 and 2000, we have estimated the emission by using relationships between emission and deposition of ammonia. It is important to mention that 50 per cent of the ammonia emissions from Dutch sources was deposited outside Dutch territory, while 20 per cent of the total ammonia came from outside Dutch territory.

Emission and deposition figures are:
X_{87} = 232 kton;
D_{87} = 1530 mol/ha;
D_{95} = 1320 mol/ha.
whereby:
X_{87} = emission of ammonia in 1987;
D_{87} = deposition of ammonia in 1987.

From above the following relationship between emission and deposition can be deduced.

$$0.5\ X_{87} + 0.2\ D_{87} = D_{87}$$

For convenience we take D_{87} equal to 100. Substitution of this value in this equation gives:

$$0.5\ X_{87} + 20 = 100.$$

The emission of ammonia can be calculated as follows:
1987: $0.5\ X_{87} + 20 = 100$ -----> $X_{87} = 160$
1995: $0.5\ X_{95} + 20 = 86$ -----> $X_{95} = 132$ -----> $\Delta X = -28 = -17.5$ percent of X_{87}.

So the emission of ammonia decreased with 17.5 percent of X_{87} between 1987 and 1995, resulting in an emission reduction of 41 kton. The emission in 1995 is 191 (= 232 - 41) kton.

II Calculation of the emission of ammonia in 2000.

RIVM has forecasted that the emission of ammonia will be 144 kton in 1995, which is an emission reduction of 78 kton in the period 1987-1995. The actual emission reduction, however, was 41 (232-191) kton. Efficiency of abatement that plays an important role here can be defined as actual reduction divided by forecasted reduction. For the period 1987-1995 efficiency was 41/78 x 100 = 52 %. For the calculation of the emission in the year 2000 we assume that during the period 1987-2000 efficiency will be 52 %. As the official forecast is an emission reduction of 23 kton between 1995 and 2000 (efficiency 100 percent) we expect an emission reduction of 12 kton (0.52 x 23). The emission is then 179 kton (191-12) in 2000; X_{2000} = 179 kton.

III Calculation of the deposition in 2000.

As the actual emission is higher than the forecasted emission, the actual deposition will be higher than the forecasted deposition. Therefore the deposition in 2000 is calculated by using the two equations below, whereby the emissions are known.

$0.5\ X_{1987} + 20 = 100 \quad ----> X_{1987} = 160$

$0.5\ X_{2000} + 20 = D_{2000}$

In section II of this appendix it is calculated that the emission of ammonia will decrease by 23 percent between 1987 and 2000; or $X_{2000} = 0.77X_{1987}$.

Substitution in the second equation gives: $D_{2000} = 81.6$

Because the deposition in 1987 is set equal to 100 in the first equation, the result of $D_{2000} = 81.6$ means that deposition in 2000 will be 81.6 per cent of deposition in 1987. Actual deposition in 1987, however, is 1530 mol/ha. Deposition in 2000 will therefore be:

$D_{2000} = 0.816 \times 1530 = 1250.$

This means that the average deposition in The Netherlands in 2000 will be 1250 mol/ha.

Next emission and deposition figures are presented in the following table.

Table XIII: Emission and deposition of ammonia.

Year	Deposition (mol/ha)	Emission (kton)	Emission reduction (kton)
1987	1530[1]	232[2]	
1995	1320[1]	191[3]	41[3]
2000	1250[3]	179[3]	12[3]

1 RIVM (1997), p. 120;
2. CBS (1992);
3. Calculated values.

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