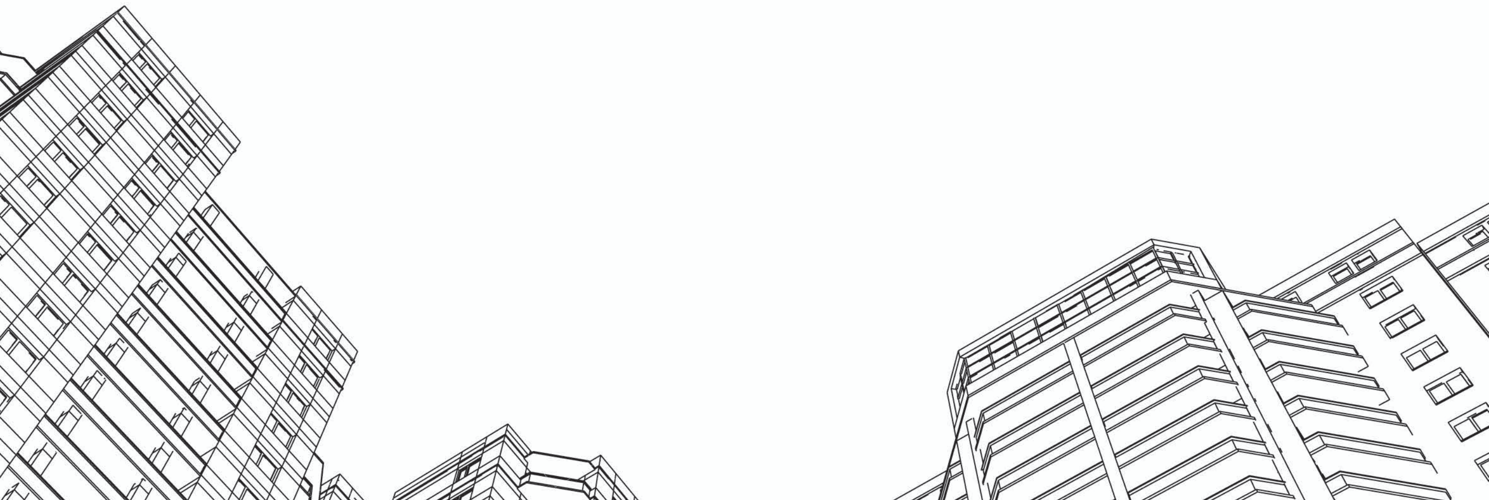
RESEARCHES 2020

UCG
Univerzitet Crne Gore

UNIVERSITY OF MONTENEGRO
FACULTY OF CIVIL ENGINEERING

40 YEARS

1980 - 2020



UNIVERSITY OF MONTENEGRO
FACULTY OF CIVIL ENGINEERING

RESEARCHES 2020

Special Issue of the Journal *Istraživanja/Researches*, on the occasion of the 40th anniversary of the Faculty of Civil Engineering in Podgorica, 1980 – 2020

Podgorica, 2021

RESEARCHES 2020 – Special Issue of the Journal *Istraživanja/Researches*,
on the occasion of the 40th anniversary of the Faculty of Civil Engineering in Podgorica

Publisher
UNIVERSITY OF MONTENEGRO, Cetinjska 2, Podgorica, Montenegro, www.ucg.ac.me

For the Publisher
Prof. Dr Vladimir Božović, Acting Rector

Editors-in-Chief
Prof. Marina Rakočević, Dr-Ing.
Assoc.Prof. Biljana Šćepanović, Dr-Ing.

Editors
Prof. Mladen Ulićević, Dr-Ing.
Prof. Radomir Zejak, Dr-Ing.
Prof. Duško Lučić, Dr-Ing.
Prof. Zvonko Tomanović, Dr-Ing.
Prof. Srđan Janković, Dr-Ing.
Prof. Miloš Knežević, Dr-Ing.
Prof. Goran Sekulić, Dr-Ing.
Assoc.Prof. Milan Radulović, Dr-Ing.
Assist.Prof. Biljana Ivanović, Dr-Ing.

Review
Prof. Todorka Samardžioska, Dr-Ing.

Technical Editing
Goran Pavlović, Dipl.Ing.

Proofreading
Branka Živković, PhD

Printing
ARTGRAFIKA D.O.O.

Number of copies 200

Publishing of this university publication has been approved by the Editorial Committee of the University of Montenegro, decision no. 01/9-1417/4, 19 April 2021.

CIP - Каталогизација у публикацији
Национална библиотека Црне Горе, Цетиње

ISBN 978-86-7664-198-7
COBISS.CG-ID 17407748

EDITORS' FOREWORD

The journal "Researches", published by the Faculty of Civil Engineering, University of Montenegro, is a periodic publication designed to contribute to the improvement of civil engineering science and practice. The special issue entitled "Researches 2020" celebrates 40th anniversary of the Faculty of Civil Engineering in Podgorica.

The previous journal issues were bilingual. On the occasion of the Faculty of Civil Engineering jubilee, the Editorial board has decided to implement certain changes due to the necessity of adjusting the journal form to the contemporary requirements in the scientific publication activity. Starting from this one, further issues will be published exclusively in the English language.

Enormous devotion of previous Editors of the "Researches", within the period of 23 years of its existence, resulted in publishing numerous original scientific papers as well as professional articles. In addition, detailed results of experimental research studies conducted in the Laboratory for Materials and Structures of the Faculty of Civil Engineering in Podgorica, were published in special issues of the "Researches" edition.

The special issue entitled "Researches 2020" offers a variety of the latest findings and achievements in the domain of scientific and professional activity in different fields of civil engineering. We present you a collection of 22 papers comprising various issues of theory of structures, steel, concrete, composite and aluminium structures, contemporary building materials and structural strengthening, earthquake engineering, geotechnical engineering, hydraulic engineering, management in civil engineering and the ecology aspect of the road construction.

A special emphasis should be put on the papers summarising research activities over a span of several decades: the paper comprising experimental analyses of structures conducted at the Faculty of Civil Engineering in Podgorica since its foundation, and the paper presenting an overview of 20-year research of different aspects of "patch loading" in steel structures having been analysed by the research team of the Faculty of Civil Engineering in Podgorica with associates from several countries.

Hoping that the published papers will be interesting and inspiring to wide scientific and professional audience, the Editorial board strongly believes that the "Researches 2020" issue will also encourage other authors to publish their research in future issues of this journal.

Finally, the Editorial board would like to express sincere gratitude to all paper authors for their efforts and contributions to the "Researches 2020", as well as deep appreciation to reviewers who have given rise to a higher quality level of papers and a publication as a whole.

Podgorica, December 2020 Editors-in-Chief

Table of contents

ROAD INFLUENCE ON THE ECOLOGICAL SAFETY OF THE ENVIRONMENT

Zlatko Zafirovski, PhD, Associate Professor
Faculty of Civil Engineering, University "Ss. Cyril and Methodius" in Skopje

Born in 1979. Graduated in 2003 from the Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. MSc: 2009, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. PhD: 2014, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. Research domain: railways; multi-criteria analysis; tunnels and roads.

zafirovski@gf.ukim.edu.mk

Slobodan Ognjenovik, PhD, Associate Professor
Faculty of Civil Engineering, University "Ss. Cyril and Methodius" in Skopje

Born in 1969. Graduated in 2000 from the Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. MSc: 2007, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. PhD: 2014, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. Research domain: roads.

ognjenovic@gf.ukim.edu.mk

Ivona Nedevska, MSc
Faculty of Civil Engineering, University "Ss. Cyril and Methodius" in Skopje

Born in 1991. Graduated in 2014 from the Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. MSc: 2016, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. Research domain: railways; multi-criteria analysis; tunnels and roads.

ivona.nedevska@gmail.com

Vasko Gacevski, MSc
Faculty of Civil Engineering, University "Ss. Cyril and Methodius" in Skopje

Born in 1994. Graduated in 2017 from the Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. MSc: 2019, Faculty of Civil Engineering, University „Ss. Cyril and Methodius" in Skopje. Research domain: railways; tunnels and roads.

vaskogacevski@yahoo.com

Abstract

The analysis and estimation of the influence of roads on the environment complex procedure, including measurements, analysis and quantification of numerous influence types, were carried out.

A unique methodology and regulations in the field of some influence on a wider European level does not exist. The construction and exploitation of each road include large-scale works and changes of the ecological equilibrium of the environment and of the economy in the region where it is supposed to pass through. The specific character of this problem can mostly be seen in a multi-dimensional influence of the road and traffic on the environment. There, the environment appears as a limiting factor, and the space is an absolutely limited resource. As a concept, there are different approaches to and methods for determination of the ecological safety of the roads, but one can freely say that none of them has been totally objective and complex.

The paper presents certain methodological approaches to a quantitative estimation of the environmental safety of roads, from the viewpoint of environment pollution and from that of traffic noise, which are valid in some countries as an integrated index of these influences.

Keywords:

Safety, traffic, environment, ecological safety.

1. INTRODUCTION

The problem of traffic safety can be solved by technical means, while the problem of negative environmental effects can be successfully solved only by spatial isolation from spatial contents.

The level of road safety, apart from the technical and economic aspect, should be treated equally from the ecological aspect, and in the future ecological safety should be a program and inviolable obligation. Significant problems and difficulties arise for the qualitative, and especially for the quantitative assessment of the negative impacts of road traffic, due to very complex problems and the impossibility to express and quantify all impacts in terms of values.

In the phase of evaluation and assessment of environmental safety of roads, there are different categories and sizes that have a completely different nature in terms of measures of expression and the area to which they belong. Therefore, to make it a complex impact assessment, it is expedient to reduce them to a common denominator, i.e. indicator.

Due to insufficient study of the functional dependence of road traffic on the natural environment, there is still no sophisticated mathematical apparatus (with the exception of some simulation models and methods), which would enable an adequate assessment of their interaction. In practice, when designing and evaluating projects, as well as in evaluating the ecological condition of existing roads, often only certain types of impact are treated, which does not provide a complete insight into economic and social damages due to man-made changes in natural environment parameters.

2. METHODS FOR ASSESSMENT OF ECOLOGICAL SAFETY FROM THE ASPECT OF ENVIRONMENTAL POLLUTION

There is still no single methodology for assessing and quantifying the environmental safety of roads in the world, i.e., there are no two countries that quantify environmental problems as a complex of impacts in the same way. At the same time, conceptually, there are different approaches to different models for assessment and evaluation of the degree of ecological safety of roads, i.e. evaluation of roads from the point of view of environmental protection. In addition, such evaluation depends on the levels, i.e. the planning and design phases. Each phase, i.e. step in the design, brings with it a certain level of detail in the analysis. The needs for environmental safety assessment are current in the management and maintenance of roads, which is why it is necessary to constantly monitor certain parameters and indicators that change in the function of changing the intensity and structure of traffic and road conditions.

There is no single methodology and unique analytical basis for the assessment and evaluation of environmental potentials and parameters for the economic-value presentation of all parameters. In our country, for now, the methodology from the instructions for the preparation of feasibility studies for road projects is used [1], where each environmental indicator is expressed separately and gives a very relative assessment of the same through the so-called "Weights", which consists of weights of the significance of the impact and weights of the magnitude of the impact expressed in numerical terms in points and money, depending on the nature of the impact. The cumulative score is expressed by summing the weights, i.e. points. In doing so, there is a so-called preliminary assessment and detailed assessment, and certain impacts are presented through tabular matrices and graphs. This is a rather complex procedure, the assessment is relative and does not provide a common indicator of a complex impact assessment.

Due to the complexity of multidimensional methods, there are already simpler elaborated principles of some authors [2] with a systematic approach, assessment and quantification of environmental impacts in the design, construction, reconstruction and operation of roads. Such methods enable a complex assessment of irreversible ecological changes as a consequence of the exploitation of the road-traffic complex. The practical realization of such a methodology is possible by introducing the so-called "Coefficient of ecological safety", which characterizes the ecological qualities of the designed or existing roads.

The coefficient of ecological safety, in this case, is an integral quantity that is based on certain indicators of the level of impact (pollution) of the environment. Individual indicators are determined by direct measurements, statistical and analytical data. Direct natural measurements are performed with special equipment, and the measured results are processed digitally.

Analytical determination of components - indicators of environmental pollution is done using known or derived patterns. Thus, the concentration (C), i.e. the level of air pollution is determined as follows:

$$C = \frac{2 \cdot q}{\sqrt{2 \cdot \pi \cdot \sigma \cdot v}} + F \quad [gr / m^3] \tag{1}$$

q - intensity of emission of a certain type of pollution from all means of transport [gr / m sec];

σ - standard deviation of the dispersion of the normal Gaussian distribution in the vertical sense [m];

v - wind speed [m / s]

F - pollution-concentration according to the data of the competent authorities [gr / m^3].

The intensity of the emission of harmful substances is determined by the formula:

$$q = 2.06 \cdot 10^{-4} m \cdot \left(\sum_{1}^{m} G_{ik} \cdot N_{ik} \cdot K_k + \sum_{1}^{m} G_{jd} \cdot N_{jd} \cdot K_d \right) \; [gr / m \cdot s] \tag{2}$$

where:

m - coefficient of dependence of the emission volume on the speed of the vehicle;

G_{ik}, G_{jd} - average fuel consumption for petrol and diesel engines [l / km];

N_{ik}, N_{jd} - vehicle intensity for petrol and diesel engines;

K_k, K_d - coefficient according to the type of emission of harmful substances for petrol and diesel engines.

The amount of soil pollution with lead Pb is determined according by the formula:

$$P_b = \frac{P_p}{h \cdot \gamma} \quad [mg / kg] \tag{3}$$

P_b - amount of lead sediment on the soil surface [mg / kg];

h - thickness of the contaminated soil layer [m];

γ - soil density [m^3].

The amount of lead on the soil surface is determined by:

$$P_p = 0.4 \cdot K_i \cdot U_v \cdot T_p \cdot P + F \quad [mg/kg] \tag{4}$$

K_i - coefficient depending on the distance from the edge of the road [l / m];

U_v - coefficient that depends on the strength and direction of the dominant wind;

T_p - road exploitation time [days];

P - amount of lead emission at medium traffic intensity [mg / m day];

F - basic measured quantity on the soil surface [mg / m^2].

The intensity of lead pollution for a certain average traffic intensity is determined as follows:

$$P = 0.74 \cdot m_p \cdot \sum_{1}^{m} G_i \cdot P_i \cdot N_i \ \ [mg / m\ day] \tag{5}$$

m_p - coefficient that depends on the speed of traffic flow;

P_i - lead content in fuel [g / kg].

All these parameters and indicators can be determined by other analytical models and methods known in the literature.

Statistical methods are based on determining the dependence of the required indicators on a group of independent factors: traffic intensity and structure, traffic flow speed, wind speed and direction, distance from the road edge, longitudinal slope of the road, type of road, exploitation time, etc.

Based on statistically processed data, obtained experimentally, formulas for the dependence of individual environmental indicators can be obtained by reducing them to several indicators in the form:

$$y_i = f(x_1, x_2, x_1, \ldots\ldots x_n) \tag{6}$$

x_i - factors affecting the indicator.

The "Coefficient of ecological safety" of the road can be defined as a general indicator, as an integral indicator of the actual individual indicators of the ecological condition of the road corridor.

As a criterion of optimality, the minimum value of the sum of exceeding the maximum allowable concentrations for each indicator can be adopted.

$$E_k = \sum_{1}^{m} \left(\frac{C_{fi} - C_{ni}}{C_{ni}} \right) \rightarrow \min \tag{7}$$

E_k - coefficient of ecological safety;

C_{fi} - actual concentration of harmful emissions;

C_{ni} - normative allowable concentrations.

3. TRAFFIC NOISE PROBLEM

The analytical determination of traffic noise levels can also be carried out according to known and recognized formulas, available in the professional literature and in practical manuals, as well as in statistical bulletins, yearbooks and meteorological and sanitary services.

In the analyses, the so-called standard noise emission level is additionally corrected depending on the type of road construction, characteristics of the traffic flow and the longitudinal slope of the road.

$$L_{m,E} = L_{m,E,o} + \Delta L_k + \Delta L_v + \Delta L_i \qquad (8)$$

$L_{m,E}$ - medium noise level at 25m from the edge of the road;

$L_{m,E,o}$ - standard noise level at 25m from the edge of the road;

ΔL_k - correction due to the type of road construction (e.g. asphalt-concrete -0.5dB (A), cube +4.0 dB (A));

ΔL_v - correction due to flow rate, e.g. allowed max. 50km / h decreased 4.0dB (A), 50-60km / h decreased 3.0dB (A);

ΔL_i - correction due to longitudinal slope, e.g. from 0-5% correction 0d (A), for each further 1% increase of + 0.6dB (A).

The standard noise level at 25m from the edge of the road (Lm, E, o) depends on the traffic load and the structure of the traffic flow.

$$L_{m,E,o} = 36,7 + 10 \cdot \log(Q \cdot (1 + 0.08 \cdot p)) \quad [dB(A)] \qquad (9)$$

$L_{m,E,o}$ - standard noise level at 25m from the edge of the road;

Q - traffic load [vehicles / h / both directions];

p - percentage of trucks in the traffic flow.

Noise, in the first place, depends on the amount of traffic. As a rule, noise endangers all street corridors with a flow rate of Q> 500 [vehicles / h]. Starting from this volume of traffic, it is considered that the sound source is of a linear character, i.e. continuous action. In such conditions, the noise along the edge of the road can reach a level over 80 dB (A), which is a very high degree of sound, which, when exposed to it for a long time, causes permanent consequences for the hearing and neurovegetative system.

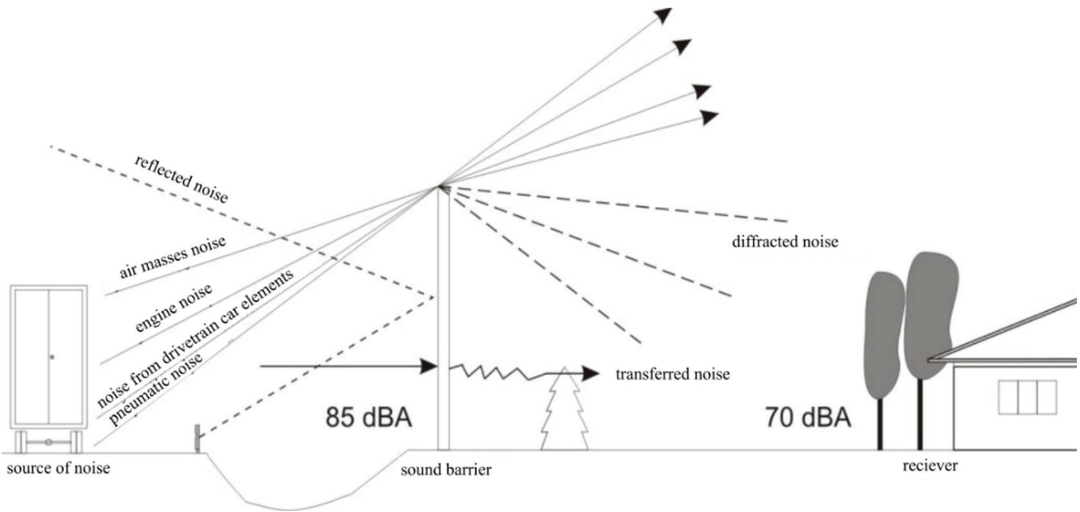


Figure 1. Acoustic concept of sound barrier

Absolutely effective means of protection against traffic noise do not exist and they range from planning and urban measures, through a design approach to route management, to the application of technical measures to sections where urban facilities are endangered.

The noise level can be reduced by limiting the permitted vehicle speed. Its successful implementation would require the introduction of automatic speed monitoring. Not only does this measure reduce noise levels but also increases driving safety. Double reduction of the vehicle speed reduces noise levels by 6 to 8 dB (A).

The road surface with an open and porous texture is not only suitable for reducing noise, but also ensures a better tire grip, and thus greater driving safety. This driving surface has the effect of reducing noise levels from 2 to 4 dB (A).

Good road maintenance reduces the dynamic impacts of vehicles and load on the pavement, but also reduces noise levels.

Reducing the traffic load by redirecting part of the total traffic or vehicles of a certain type to other roads, limiting the time in which traffic can move (e.g. banning heavy vehicles at night), and ensuring the state of free traffic flow (e.g. turning off traffic lights at night), reduce noise to 4 dB (A).

The noise level of an individual vehicle depends not only on the speed of the vehicle, but also on the degree of transmission and the way of deceleration and acceleration. Passive driving can reduce noise levels by about 5 dB (A), and for motorcycles by up to 7 dB (A). Motorcycle traffic is a special problem because it is possible to increase the noise by up to 20 dB (A). Therefore, driving bans can be introduced, e.g. at night or driving ban without built-in special silencers.

4. APPLICATION OF GIS IN URBAN TRAFFIC NOISE POLLUTION

Geospatial Information Systems (GIS) can conveniently be adapted to gather, analyze and present noise information. GIS can also be extended to answer to user specific problems through deterministic and statistics models. The objectives of this research were to measure urban traffic noise levels, analyze temporal and spatial dynamics of urban traffic-induced noise pollution in the first districted of Tehran estimate the noise for pollution concentration, assess the results of Federal Highway Administration Traffic Noise Model (FHWA-TNM) and Iranian Traffic Noise Predictor (ITNP); and represent them in a GIS environment. Measurements were done at the traffic peak time and also when the traffic was at its minimum, during three successive months.

Numerous traffic noise prediction models have been developed, some of which are highly specific and solve a reduced class of problems. The more popular ones include the CRTN model in the UK, the FHWA-TNM model in the US, the RLS90 model in Germany, the OAL model in Austria, the Statens Planverk 48 model in Scandinavia, the EMPA model in Switzerland, and the ASJ model in Japan. FHWA-TNM is arguably the most widely used noise model. The FHWA-TNM (Federal Highway Administration Traffic Noise Model) is a computerized model used for predicting noise impacts in the vicinity of highways. It uses advances in acoustics and computer technology to improve the accuracy and ease of modelling highway traffic noise, including the design of efficient, cost-effective highway noise barriers.

Abo-qudais and Alhiary developed three statistical models for predicting equivalent, maximum and minimum noise levels at signalized intersections [8]. Tang and Wang analyzed the effects of urban forms on the noise magnitude. They showed that urban layouts in historical areas with narrower roads, complex road networks and a higher density of intersections lead to lower traffic volumes and thus lower noise pollution [9].

The most significant factor for increase in traffic induced noise pollution is the privately owned outdated vehicles. Public transportation must be encouraged to replace the personal cars, as each bus can conveniently function instead of 25 personal cars.

5. CONCLUSION

Determining and using the coefficient of ecological safety leads to an objective assessment of the state of the natural environment in the road corridor and the necessary set of protective measures. Given the complex issues from several aspects, including methodological and normative, mathematical research, testing, improvement of methods using appropriate software tools are needed. In the context of complex environmental road safety, we believe that it is necessary to treat both the radioactivity and toxicity of certain building materials that are used in the construction and maintenance of roads.

LITERATURE

[1] Кузовић Љубиша, “*Вредновање у управљању, развоју и експлоатацији путне мреже*”, Београд 1994

[2] Упутство за израду студија о изводљивости пројеката путева, Савез организација за путеве Југославије, Београд 1992

[3] Подолски В. П., “*Екологическаја оценка автомобилни дороги*”, Автомобилние дороги, Москва, 1993

[4] Малетин Михаило, “*Градске саобраћајнице*”, Београд, 1996

[5] McGraw-Hill, “*Highway Engineering Handbook*”, New York, 2003

[6] Стоименов Павле, Авдовић Орхан, Огњеновић Слободан, “*Комплексна оцена на еколошката безбедност на патиштата*”, Скопје, 2005

[7] Lakušić Stjepan, Dragčević Vesna, Rukavina Tatjana, “*Mjere za smanjenje buke od prometa u urbanim sredinama*”, Građevinar 57, Zagreb, 2005

[8] Abo-qudais S, Alhiary A, Statistical model for traffic noise at signalized intersections. Build Environ 2007; 42: 2939-2948.

[9] Tang UW, Wang ZS, Influences of urban forms on traffic – induced noise and air pollution: Results from a modeling system. Environ Model softw 2007; 22(12): 1750-1764.