ARCHIVES OF ACOUSTICS
27, 4, 291–302 (2002)

THE UTILISATION OF THE GIS AND GPS SYSTEMS IN CREATING ACOUSTICAL DATABASES IN THE OUTER ENVIRONMENT

J. KOMPAŁA

Central Mining Institute
40-166 Katowice, Plac Gwarków 1

In the paper, the usefulness of recent computer-based GIS and GPS techniques related to charging the environment with vibroacoustical hazards has been characterised. These techniques, joining the computer maps of the area with extensive databases, provide new research and application possibilities in investigating the propagation of noise and mechanical vibration in the environment and are a valuable tool in the so-called environmental management.

1. Introduction

The necessity of simultaneous interference in the influence of many (all) agents loading the human living environment had created the need to develop effective tools serving in minimising the destruction of the environment. In the literature there have appeared such concepts as eco-development — i.e. economic development with the minimal loss in the environment; sustainable development — being the economic development with an optimum impact on the environment, etc., cleaner production — selection of the technologies with the minimum loading the environment. The primary concept that comprises the above mentioned is the environmental management defined [1] as the organisational structure, planning of actions, responsibilities, practices, procedures and resources for the development, implementation, achievement, review and maintenance of the environmental policy.

In the eighties, the British Standard Institution had developed the BS 7750 package of standards, published 1994, defining the principles in the above mentioned fields. These standards were then accepted, with some editorial changes, by the International Standard Organisation (ISO), denoted as ISO 14000. The above mentioned documents, accepted also by the European Union institutions, provide currently a basis for the assessment of the quality of actions in the field of environmental protection. The package, containing at present about a dozen of standards, becomes, also in this country, a basis for the evaluation of economic undertakings influencing (loading) the environment. The obtainment of a certificate is a confirmation that a given business or local government organisation acts in accordance with the standards of the environmental management

package and confirms the correctness of its pro-ecological working, and leads most often to a considerable reduction of financial loads such as taxes, fines and insurance premiums, etc. The operation of the System relies on the implementing and consequent observance of the actions depicted in Fig. 1. The undertaking of actions shown in the figure is based on a voluntary acceptance declared by all the employees to understand and submit to the objectives leading to obtainement of a positive ecological effect. The actions, as shown in Fig. 1, are repeated many times in the course of the implementation of the management system until a state is reached which by the auditors is considered to be a state meeting the standards being currently in force.

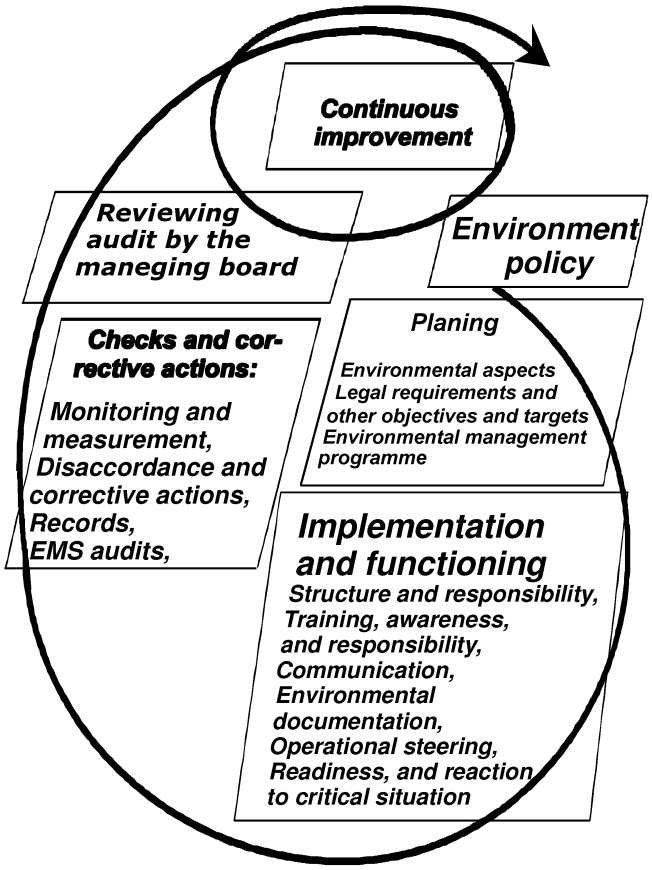

Fig. 1.

For the scope of this paper, of importance are the acoustical questions included in the discussed package of standards. In the sheets of the standards that have appeared hitherto, the noise is not separated as an agent liable to particular evaluation. The authors consider this condition as resulting from the fact that these hazards are local in their

character within the border of a given country or even area, while the remaining influences are transnational in character, and thereby are separately specified in the international document.

Taking into account the ecological situation in Poland where the range of noise impact in the environment includes the 8 million population (according to ITB data), and continually increasing number of complaints directed to local government offices, this justifies the vibroacoustical problems to be included in the most important procedures of the environmental management system. In the authors' team, a number of more extensive works have been undertaken on preparing the management procedures for the area of vibroacoustics [3 – 7].

The following procedures were prepared:

- Procedure for identifying the sources of vibroacoustical hazard.
- Procedure for carrying out vibroacoustical measurements in the outer environment.
- Procedure for determining acoustical power of the sources.
- Procedure for assessment and recording effects of vibroacoustical domain.

The structure of the developed procedures is based on utilising the block schemes of proceeding. An example of the scheme for the procedure "Assessment and recording of consequences for vibroacoustical impacts on the environment" is based in Fig. 2. The procedure comprises the actions as follows:

1) List of all components (in machinery enterprise, in local government organisation, plants in a given area, etc.), description of technological processes broken down into individual departments of an enterprise or organisation.

2) Preliminary verification of the sources with the view of the emitted vibroacoustical energy, based on a specially prepared form sheet.

3) Formation of an input database on the sources of noise and vibration within the premises of the plant which constitute potential hazards for the outer environment.

4) Performing the measurements of acoustical power of individual, selected sources.

5) Performing the measurements of vibration emitted by individual, selected sources.

6) Verification with determining: source name, location, vibroacoustical properties.

The preparation of individual procedures is a laborious process which requires a detailed knowledge both of methods, measurements and vibroacoustical evaluation in the environment, legal-standardisation questions, as well as recognition of the structure and principle of functioning of the organisation for which the environmental management system seems, at a glance, to be a bureaucratic form of the clerk's performance. However, by making a more detailed analysis on a basis of authors' own experience, the arranging character was also noticed, first of all in the organisational area of the enterprise, and in tech responsibility of individual persons and personnel teams, in parallel with the execution of clearly assigned tasks defined in the procedures prepared and accepted by individual employees [8 – 14].

The applied formalism of proceeding when establishing the management system in accordance with the standards under consideration, creates the need to use special tools to assist the prediction of the acoustical climate, supervision of correcting actions aimed at reducing the hazard to effectively control (manage) all the agents influencing the con-

dition of the environment. These tools are of particular importance in large organisations as they help both to collect and select the measurement data and other numerical quantities, and, in connection with the tools for economic and legal assessment, assist the decision processes in the discussed management area.

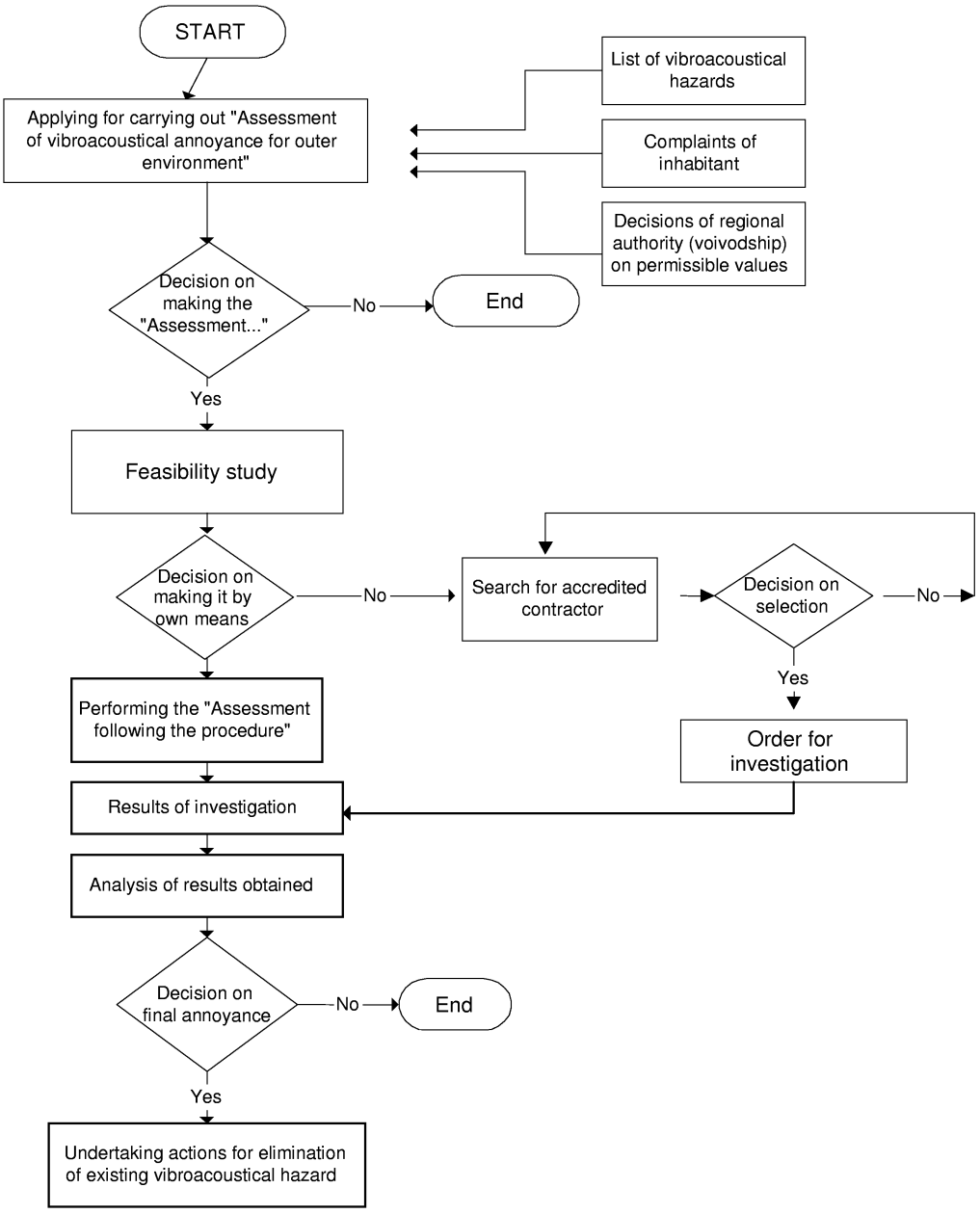

Fig. 2.

A closer analyses of these questions points at a particular usefulness of GIS and GPS techniques.

2. Noise parameters

Sound can be generated by many different sources and can be perceived as noise by humans in many circumstances. Environmental noise is the sound generated by human activity (road traffic, railways, industry, ...) and perceived in the domestic environment [17].

The variety of noise sources appearing in the field requires the application of manifold classification sections [18, 19, 20]. In relation to the shape, they are divided into:

- linear (transportation routes, ...),
- superficial (airports, depots, railway stations, large industrial plants, ...),
- punctual (small industrial plants, individual machines, ...),
- spatial (building type).

Instead, considering the environment in which the noise exists and the type of the source generating it, one can divide the noises into:

- noise coming from the means of transportation, the so-called traffic noise,
- industrial noise, and
- noise in habitable rooms, public utilities and rest and recreation areas, i.e. municipal noise.

Apart from the size, the way in which the noise is emitted into the surroundings is also of importance in assessing the impact of a specified type of noise on the environment. Its prediction in the environment is presently based on calculation methods of the external noise determination.

However, the necessity of mathematical simplification of the assumed models introduced at every stage of the calculations leads to many mistakes; the results obtained from those operations are of lower practical importance than one could expect [16, 18–21]. The choice of the approach results also from the fact that the most accurate transformation of the existing state is ensured by a measuring method relying upon determination of the sound levels A under maintaining strictly defined and neutral methodology conditions [21, 22].

The application of a suitable method depends on the way of determining an initial parameter of the acoustic field. Forecasting works insisting on a prognosis of the acoustical climate of a specific terrain basing on established parameters characterising the source and environment, are an important problem in this range. Practically, the calculations are made basing on popular dependence [16]:

$$r_x = R_z \cdot 10^{\frac{\Delta l}{10k}}$$

where R_x – substitute distance, K – coefficient, depending on the kind of terrain's cover.

Our tests made in the years 1994–1998 [3, 5, 6, 8–11, 14, 15, 23–25], proved important differences in the size of a areas of the noise's influence set on the base of real

measurements in different terrain's conditions. Basing on them, general dependences correcting current dependences were educed. For example, for the most common used traffic noise, they are:

$$\begin{aligned} r &= 4 \cdot 10^{\frac{\Delta l}{13}} \Rightarrow \text{ for } \Delta l \leq 3.9 \\ r &= 8 \cdot 10^{\frac{\Delta l - 3,9}{13,3}} \Rightarrow \text{ for } \Delta l \leq 7.9 \\ r &= 16 \cdot 10^{\frac{\Delta l - 7,9}{13,3}} \Rightarrow \text{ for } \Delta l \leq 11.9 \\ r &= 32 \cdot 10^{\frac{\Delta l - 11,9}{14}} \Rightarrow \text{ for } \Delta l \leq 16.1 \\ r &= 64 \cdot 10^{\frac{\Delta l - 16,1}{14,3}} \Rightarrow \text{ for } \Delta l \leq 16.1 \\ \Delta l &= L_{ZM} - L_{DOP} \end{aligned}$$

where L_{ZM} – measured noise level L_{DOP} – permissible noise's level for the precised terrain.

The dependence mentioned above connects measured noise level with permissible values, specified by suitable norms and laws.

From among many factors, the influence of which on the level of annoyance is the highest one, one can quote [19, 20, 22]:

- sound level A at the source,
- type of noise emitted,
- course of the spectrum of noise emitted by the source,
- type of the casing of the source or lack of thereof,
- occurrence and localization of areas liable to anti-noise protection.

Presently, the following documents [26] concerning the assessment of the hazard for the environment by noise are in force Order of the Ministry of Environmental Protection Natural Resources and Foresty of the 13th of May, 1998 on the protection of the environment against noise. The Order of the Ministry of Environmental Protection Natural Resources and Foresty on the protection of the environment against noise is an administrative act to this one mentioned above. The critical values of the equivalent sound level A determined in it are given separately for the day ($6^{\underline{00}} - 22^{\underline{00}}$) and the night ($22^{\underline{00}} - 6^{\underline{00}}$). It was assumed that during the day there are 16 hours, while during the night only 8 hours.

New law regulations [17] putting the long-term critical values for the state of the acoustical climate's valuation into force, will require dissemination of methods of the outer environment noise monitoring or creation databases about the outer environment. If there are noise monitoring tests carried on, the measured sound level will be formed by many different elements like: changing the traffic's spread, different structure of the measured squirt of vehicles, road parameters or the urbanistical arrangement of the area in the road's neighbourhood. Modern methods of designing the space, valuation of the influence on the environment, and forecasted noise multipoint measurements in the terrain would require an automatic localisation of the points and connection the elements collected in measurements with the maps of measured terrain. In works carried on in this scope, the techniques of GIS and GPS should be used to connect cartographic maps with databases for the visualisation of scores of basic measurements and calculations connected with the terrain tested.

3. Geographical information system (GIS)

The block scheme presented in Fig. 2 points to the usefulness of the application the numerical information connected with the map picture of the area in which the tested object (building, industrial plant, parcel of ground subjected to assessment of environmental noise) is located. For this purpose special computer software named GIS is used. The GIS systems [following 2] are computer programmes that serve to handle digital maps. The functions of such a software resolve themselves into assisting the preparation of maps, storage them in the computer memory and make possible to analyse extensively of the data of the objects located on the map. Therefore, the basic activity in the GIS technique is the formation of a digital map of the area subjected to testing and a related computer database containing the data that characterise the object(s) located on the map. Digital maps of the area are characterised by several important features – vectorisation enabling a continuous changing of the map scale, while the digital version of the map is kept in the computer memory in the 1 : 1 scale. There is a possibility to apply a set of differentiated graphical parameters such as: line thickness, sort of line (solid, broken, dotted, etc.), line colour, various types and colours of filling of surface objects, variable dimensions and shapes of the description characters, an ease choice of various symbols for marking point objects. The properties of computer graphics make possible to divide the digital map into a number of layers comprising defined information being of importance for a selected analytical cross-section. This enables to group the objects in such a way that the information insignificant or useless for this analytical cross-section are excluded. The presentation of the area map in the geographical coordinate system enables to make thorough representation of the objects in the area. As mentioned above, the GIS system containa, a part from a digital map, computer databases which are in general easily configurable to local requirements. Apart from the digital data relating, for example, to results of measurements, text data (e.g. description of the object, addresses, names of persons related to the object), the databases of ten allow to conduct simple calculations, for instance, calculation of the line of an equal sound level, an isoseismic line (when carrying out measurements of the ground vibration, etc.).

When one does not use ready-made files the preparation of a digital map of the area (Fig. 3) is a laborious task relying, under a certain simplification, on the transporting of a photograph (e.g. scanning a printed map, use of satellite photos, etc.) into the computer; and then, using a special device (called digitiser or tablet) assigning the coordinates of points on the surface linked with a real network of geographical coordinates. The GIS programmes enable to process extensively the map prepared in this way. It follows from the authors' own experience that the most suitable form of processing is the creation of the above mentioned informative layers containing selected objects together with the related database [14, 15].

In the investigation of environmental noise, there is, more and more often a need to make a spatial visualisation of the acoustical field distribution. Modern GIS tools make also possible to create such maps and present them in various projections, three-dimensional maps an more complex ones both in preparatory and interpretation phases. These require also an highly efficient computer equipment.

Fig. 3.

4. Global positioning system (GPS)

In practice when using maps of the investigated area, there is a need of a fastlocation of the measurement data. In the procedure applied so far, either the approximate location in relation to the characteristic objects found in the considered area or, when conducting very accurate tests, the location of the points was made using surveying measurements.

Over the recent years, first in the geodesy and presently in other different domains, the GPS system has been used which utilises a group of special geodetic satellites emitting radio frequency signals determining their current position and the time of sending the signal. The GPS instrument being a radio receiver of these signals, after at least three satellites have been identified, solves the set of equations determining the coordinates of a given point. In practice however, this location is a little more complex since it requires taking into account a correction of the specially transmitted random error signal. The application of other calculation procedures makes possible to determine the spatial coordinates. The discussed possibility to calculate spatial coordinates can be used, for instance in determining the height of objects both in relation to sea level and locally in relation to ground. This also enables to carry out automation of the calculation of the area of the selected sites, and to estimate the volume of cubic structures.

Modern GPS receivers, often with preinstalled approximate maps of the area that enable to perform a preliminary location of points, providing that an electronic memory has been built-in, make also possible to draw, directly on the map, the route of a moving object (e.g. a car).

5. Databases for the effects of road traffic noise

The operations comprising the storage of measurement data, various types of assessment and comparison with a standard, and connections with the maps of the measured area are accomplished by the database software installed, most often, in a stationary computer. The base was designed in the MS Access 7.0 program. The functions of the base can be easily adjusted to the individual needs of the user. An original element of the base is the localisation of the measurement data and geographical position of each of them by using a separate GPS module together with a suitable software. The results are presented on a digital map of the area, made in our case, with the use of the GIS system of Map Info Professional 6.5 [8]. A typical customer is interested in obtaining complex and clearly prepared information on the effects of noise in the environment. The program is composed of a number of options, the most important ones being: option Wyniki badań (measurement results) that makes accessible the data base being a set of the expected information.

The conception of the database ensures the possibility to place the maps of defined localities or smaller areas in which measurement points were localised. Indicating a defined measuring point and selecting the option Wyniki pomiarów hałasu (Results of noise measurement) leads to the opening of the "folds" (Fig. 4) that give detailed information (by GPS and GIS) relating to the location of the measuring point. The second fold Ocena

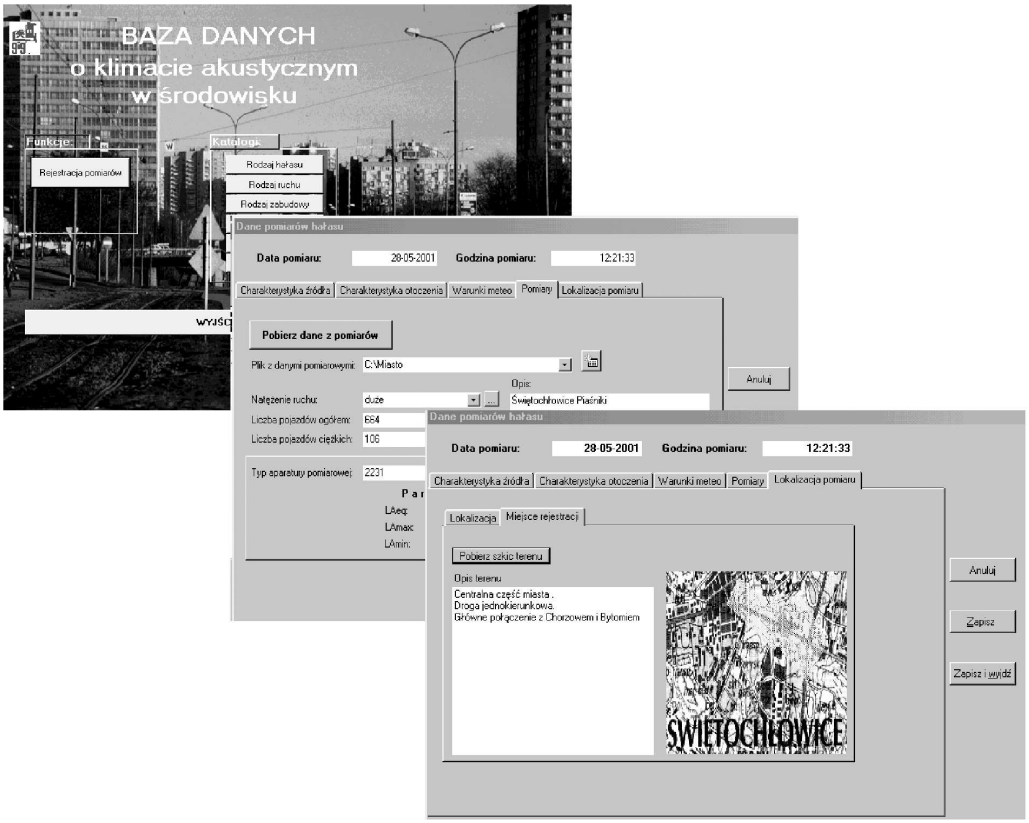

Fig. 4.

(evaluation) gives a current state in the domain of the effects of noise emitted for example by transport means in the outer environment. This option is to enables to utilise the results both into evaluation of the condition of the environment and settling the questions related to the localisation of new and modernised transport structures in the scope realised by the customer.

6. Conclusions

The possibilities of using the GIS and GPS techniques, as discussed earlier, in assessing vibroacoustical hazards in the environment, point at, following authors' own experience, a great usability, particularly in investigating larger areas (Housing estates, localities, etc.) in which a need arises to carry out measurements in a greater number of measuring points. Particular usability of the discussed techniques takes place when preparing acoustical maps of towns and transport routes. The possibility to connect the maps with relation databases makes possible to collect in a single place full information about the investigated area and objects located in it. This enables to carry out various

transformations and analyses of which most spectacular application is the optimisation of the course of transport routes to minimise the noise and mechanical vibration loads to the environment. The decreasing prices of the instrumentation (particularly GPS) and software encourage to wider implementation of the discussed methods, which gives much better and faster analytical and presentation capabilities of performed investigations.

References

[1] PN-ISO 14001 *Systemy zarządzania środowiskowego specyfikacja i wytyczne ich stosowania.*

[2] G. Myrta, *GIS czyli mapa w komputerze*, Wyd. Helion, 1997.

[3] J. Kompała, *Mapa akustyczna województwa katowickiego.* Część I: Hałas drogowy, Ekologia i Technika, 3, 18–21 (1994).

[4] J. Kompała, *Próba oceny hałasu przemysłowego na obszarach silnie zurbanizowanych*, Materiały XXIII Zimowej Szkoły Zwalczania Zagrożeń Wibroakustycznych – Wisła 1995, Wyd.: Oddział Górnośląski PTA, Gliwice 1995, s. 42–49.

[5] J. Kompała, *Ilościowa Ocena Klimatu Akustycznego Województwa Katowickiego* – Rozprawa doktorska GIG 1997.

[6] J. Kompała, J. Świder, A. Wandzioch, *Emisja hałasu przemysłowego do środowiska na terenie województwa katowickiego*, Materiały Międzynarodowej Konferencji Noise Control '95, Wyd. CIOP Warszawa 1995, 329–334.

[7] J. Kompała, *Mapa akustyczna gminy Bieruń*, Materiały XXIV Zimowej Szkoły Zwalczania Zagrożeń Wibroakustycznych – Ustroń 1996, Wyd. Oddział Górnośląski PTA, Gliwice 1996, 70–81.

[8] J. Kompała, *Mapa akustyczna województwa katowickiego.* Część II: Hałas kolejowy, Ekologia i Technika, Nr 6, 1994 r., s. 10–13.

[9] J. Kompała, *Pomiary hałasu w województwie katowickim*, Aura, 10, 2–7 (1995).

[10] A. Lipowczan, *Elementy akustyczne przeglądu ekologicznego województwa katowickiego*, Bezpieczeństwo Pracy. Nauka i Praktyka, 1, 2–7 (1995).

[11] A. Lipowczan, *Problemy ochrony przeciwhałasowej w komunikacji drogowej*, Ochrona powierza i problemy odpadów, 3(167), 67–73 (1995).

[12] A. Lipowczan, *Elementy akustyczne przeglądu ekologicznego dużej jednostki administracyjnej kraju, na przykładzie prac realizowanych w województwie katowickim*, Mat. XLI OSA 94 Prace Naukowe ITiA Polit. Wrocławskiej nr 78, 17– 26.

[13] A. Lipowczan, *Hałas a środowisko*, Biblioteka Fundacji Ekologicznej „Silesia", t. VIII, Wyd. Fundacja Ekologiczna „Silesia" 1995 r., s. 101.

[14] J. Kompała, I. Kubik, A. Lipowczan, *System doradczy wspomagania decyzji lokalizacyjnych inwestycji drogowych uwzględniający ekorozwój regionu*, Mat XLIV Otwartego Seminarium z Akustyki, OSA 97 Gdynia – Jastrzębia Góra 1997.

[15] J. Kompała, A. Lipowczan, *Preparation of the acoustic map of upper Silesia into account road traffic noise*, Proc. of International EAA/EEAA Symp. "Transport noise and vibration" Tallinn 08.06–10.06.98 pp. 327–334.

[16] R.J. Kucharski, M. Kraszewski, A. Kurpiewski, *Obliczeniowe metody oceny klimatu akustycznego w środowisku*, wyd. Geologiczne, Warszawa 1988.

[17] *Proposal for a directive of the European Parliament and of the Council relating to the Assessment and Management of Environmental Noise.*

[18] A. Lipowczan, *Podstawy pomiarów hałasu*, GIG LWzH Katowice-Warszawa 1987.

[19] Z. Engel, *Ochrona środowiska przed drganiami i hałasem*, PWN, Warszawa 1993.

[20] J. Sadowski, *Podstawy akustyki urbanistycznej*, ARKADY, Warszawa 1982.

[21] Instrukcja ITB nr 310. "*Metody sporządzania kompleksowych planów akustycznych miast i obszarów*".

[22] R. Makarewicz, *Hałas w środowisku*, Ośrodek Wydawnictw Naukowych, Poznań 1996,

[23] J. Kompała, A. Lipowczan, *Quantitative analysis of road noise for excessive urban area for example Katowice Voivodeship*. Proc. of Noise control 98 Krynica 2-4.06.1998.

[24] A. Lipowczan, J. Kompała, W. Mrukwa *et al.*, *Ocena oddziaływania na środowisko autostrady na przykładzie katowickiego odcinka trasy* A-4. Mat. sem. „Wpływ autostrad na klimat akustyczny środowiska" MOSZNiL – Liga Walki z Hałasem Wa-wa 1996, str. 99–112.

[25] J. Kompała, *Assessment of joint hazard to the outer environment from road and industrial noise by the example of the Katowice voivodeship*, Archives of Acustics, **23**, 3 (1998).

[26] *Order of the Ministry of Environmental Protection Natural Resources and Foresty of the 13th of May, 1998 on the protection of the environment against noise.*