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**Ecological foundations for the management of the natural environment
in urbanised conditions**

Abstract. The city as an urbanised system has an ecological structure with miscellaneous forms of functionality. The urban environment can be characterised as a terrain where the climate becomes increasingly dry, the atmosphere, water and soil is increasingly polluted and living organisms are affected by toxins. In the course of long term and complex studies carried out in Warsaw, 1986-1990, as a part of the Central Programme of Basic Research an attempt was made to determine to what extent the urban environment is being changed, how it affects the surrounding areas and how one should make use of this information in the process of urbanisation. The findings are briefly presented in this paper.

1. URBANISED AREAS

The urban environment has been changed so much, that the question arises whether the city may be called an ecological system. Ecologists' opinions on the city's ecological status are divided. Some do not consider the city an ecological structure, while the others maintain that only certain city structures, namely green spaces, may be recognised as ecological structures. There is also a theory according to which the city may be divided into various ecosystems that all together constitute a superecosystematic structure, the so called physiocenosis. Another theory, which is the closest to my view, treats the whole city organism as an ecological structure, including the main originator - man. The urban ecosystem is an ecological structure which has been transformed due to the limitation imposed on the elements of nature by industrial and urban structures. The only way of rational city management is to treat the whole city as an ecological structure.

1. 1. The city

On the whole, the urban environment can be described as terrain where there is increasing dryness of environment pollution of the atmosphere and soil and toxification of living organisms. The air and its degree of cleanliness is one of the basic factors determining the functioning of urban ecosystems. Due to the extensive building and

heavy traffic urbanised areas have high levels of dust and gas pollution. In the course of research into the problem, done in Warsaw in 1986, it was proved that dust and nitric oxide pollution were twice the recommended limits. As the measured values of pollution have been averaged they do not properly reflect the scale of atmospheric pollution in the areas located right by emission sources, e. g. in the streets. The highest values exceeded the ones measured in the main green areas, e. g. parks, by 85 to 90 per cent. City soil differs from natural soil in many respects, both physically and chemically. As a result of thorough studies a 1 : 25,000 soil map of Warsaw, comprising 19 soil subtypes according to the new anthropogenic soil system, has been drawn. Dust and gas pollutants also have unfavourable effects on soil in urbanised areas, which result in high concentrations of elements in the Warsaw soils. Lead contaminated soils constitutes 13.1 per cent of the city area and the terrain contaminated with zinc 4 per cent, copper 1.4 and nickel on 1.2 per cent respectively. Furthermore it was found that the concentration of heavy metals depends on the type of land use. The concentration of metals is relatively low in the suburban agricultural areas and forests, but increases in the more urbanised parts of the city. In built-up districts lead and zinc concentrations arise not only from traffic pollution, but also from the functioning of buildings and the chemical character of waste in the anthropogenic layer. Another distinct feature of urban soils is occurrence of calcium carbonate, especially in central parts of the city or new housing estates. The chemical compound considerably reduces soil acidity. A similar phenomenon is observed when measuring the concentration of soluble salts in soils. In comparison with woodlands and, to some extent, also agricultural areas, the top layers of soils in Warsaw's built-up districts contain apparently bigger amounts of soluble salts. The sources of soluble salts in Warsaw soils are, among others:

- a. chemical method of road snow removal with NaCl and CaCl₂;
- b. alkaline ash falls due to ash emission by heat and power generating plants;
- c. various chemical waste layers.

High salinity in urban areas is toxic to a great number of tree species – something frequently observed. Due to the engineering works, water conditions in the urban environment are continuously unbalanced, thus a conspicuous water table drop takes place and pollution of surface and open waters is observed as well. A common phenomenon of water in the Warsaw agglomeration is Cl⁻ and SO₄⁻² ion enrichment, which undoubtedly affects the development of vegetation, and trees in particular. Another specific attribute of the urban environment are the climatic conditions, so different from those of open terrain. Urban areas have higher average temperatures exceeding the norm by 0.5 to 1.5°C, and even 2 to 6°C on sunny days. Furthermore, when compared with the suburban zone the more urbanised parts have a lower air humidity (by 5–10 per cent). The conditions described for the urban environment are followed by the development of synanthropic vegetation that covers 55 per cent of the Warsaw municipal area, 15 per cent out of the 55 being occupied by ruderal communities. Moreover, in the developed parts of Warsaw, the central district among them, one cannot determine potential vegetation that would fall into categories recognised for the natural landscape of the Mazovian Lowlands. At present 30 per cent of the Warsaw area is covered with a hypothetically forest community, which is impossible to classify according to the well-known and binding phytosociological system. Poten-

tial system equivalents of the most altered and degraded sites covering 1.5 per cent of the Warsaw area are the relatively stable non-forest communities. The dry and warm climate enables species of fauna of South European origin, requiring higher temperatures than our native Polish animals, to settle in cities. Synanthropic species such as House Fly, Sparrow, Turtle dove and Rock Pigeon are typical examples of the group. Species like this found living conditions in the city so favourable that in a short time they became dominant in urban zoocenoses. To sum up I would like to stress that the city and its central zone in particular is characterised by specific conditions of climate, soil and water, and thus strongly influences the development of biocenoses.

1. 2. The urban fringe

The urban fringe countryside is specific space system, different from a village or the inner city typified by phenomena, processes and a distinct space structure peculiar to it. It is the most active natural, social and techno-economic system distinguished by unstable functioning. The sharp separation of ecological structures, presenting various levels of internal organisation, is an attribute of the urban fringe zone. The structures are typified by: the co-existence of natural and anthropogenic mechanisms; the prevalence of either natural or anthropogenic mechanisms; or exclusiveness of anthropogenic mechanisms. Usually they adjoin and have mutual influence on each other in an open structure. Since in most cases they cover small areas, a mosaic of diversified structures arises. Vegetation, the ecological structure most susceptible to changes, is an excellent indicator of environmental conditions and transformation of the whole natural environment, as well as of present and future anthropogenic processes, linked with the development of urban fringe areas.

The majority of plant communities situated in the vicinity of the city are labile and undergo constant quantitative and qualitative fluctuations. Evidence of the wide influence of anthropogenic factors is shown by an analysis of real and potential vegetation combined with comparison of relevant maps of the Warsaw fringe countryside comprising several model areas. This gives clear evidence of the importance of different methods of cultivation have on the shape of phytocenoses in the urban fringe. Diversity of ecological structures is expressed in the variety of species of flora as well as the spatial pattern of plant communities. The distinct character of plant assemblages is marked mainly by the specific phytosociological structure of plant communities with characteristic combinations of species. Topological variety and varied degrees of formation of communities; significant fragmentation of the area as well as the mosaic-like character of communities, which is a result of land use, are all principal characteristics of the spatial structure of urban fringe. In the study areas the existence of various stages of forest development was observed. Young, mature and veteran woodland was found as well as patches either resembling natural communities or distortions of them. Other communities were also noted in various stages of development, from initial to well-developed stages. Different stages of forest degeneration caused by rapid urbanisation were observed.

As a result of diversification of the vegetation there are neighbouring communities which belong to the same syntaxonomic unit but are in different stages of degeneration and differ from each other in respect of number and variety of species. An

important fragmentation of land takes place in an urban fringe zone, e. g. there are 5–10 times more communities than in a country zone and some 4–24 times more than in the centre of the city. A great number of local phytocenoses affected by land use and many replacement communities occur, e. g. in the urban fringe. The observations bear witness to the rapidity and variety in the transformation of these areas as well as the plasticity of the sites. There is a 50% increase in number of urban fringe phytocenoses and replacement communities in comparison with the agricultural landscape. There are also secondary plant complexes arising, which include ecologically diversified communities in various stages of transformation. The increasing extent of diversification in the real vegetation, combined with simultaneous decline in similarity to the potential vegetation was observed.

The prevalence of open areas with unstable plant groupings or ruderal communities is now becoming evident. The urban fringe zone is typified by the specific processes of synanthropization of vegetation. This can be observed at various organisational levels of vegetation. For example there is a decrease in the number of xerophilous and hygrophilous communities and subsequent replacement of them by mesophilous structures. Loosening the links between potential and real vegetation is apparent, particularly in ruderal communities, e. g. in the open areas and areas earmarked for various types of land development. Synanthropic communities in the study areas of Białołęka Dworska and Łomianki cover 70% of the area. Half the communities are sagittal and widespread in cities. The properties mentioned above characterise the biological structures of the urban fringe zone which perform a wide range of natural functions in this environment.

2. THE FUNCTIONING AND DIRECTIONS OF TRANSFORMATION OF ECOLOGICAL STRUCTURES IN THE CITY ENVIRONMENT

2.1. The city

As has been already mentioned in part 1, ecological systems have to function under difficult conditions specific to urban areas resulting in frequent disorders in their development. One of the indicators of physical and chemical transformations of soil are disorders in its biological activity. It is a well known fact that the correct biological activity of soil is a prerequisite for high biomass production of city vegetation. Sharp differences in decomposition of cellulose and in the presence of certain enzymes related to the extent of anthropopressure are evident. The decomposition of organic matter, which is expressed by decomposition of cellulose, is least efficient in the green patches along streets. However, these processes proceed much faster in bigger complexes such as parks. A similar interaction is observed so far as active dehydrogenases and ureases are concerned.

The decrease in productivity of green spaces, including lawns that on the average cover some 60 per cent of the total area, is an important indicator of urban environmental disorders. In the course of investigations of productivity it was discovered that grass patches situated under unfavourable conditions, as is the case in street zones, have substantially lower biomass production (nearly two fold) than similar patches located in parks and housing estates. On the other hand, all types of urban

grasslands have distinctly lower biomass production when compared with the productivity of similar plant structures in open landscapes, e. g. *Arrhenatherum elatioris* meadow. Moreover, it turned out that, despite the similarity of the planted seeds, the number of species occurring in the ground cover of park lawns is bigger than in street areas. The phenomenon is probably caused both by more varied site conditions and less stringent management, mainly a low frequency of mowing. It results in the development of multi-species plant structures in the sward, which is consistent with the principles of plant succession. Plants adopting "naturally" to the specific site conditions are found in areas of high soil salinity particularly in lawns located by streets. For example, two species belonging to so called "facultative halophytes", namely *Puccinella distans* and *Melilotus dentatus* were observed in Warsaw. When in natural communities the species mentioned above usually occur on saline sites.

The diversification of ecological efficiency in the urban environment does not only involve grasslands. Functional disorders of vegetation are expressed also by the length of time trees are in leaf. Research on this carried out in Warsaw showed the differences amount to a dozen or so days and depend on the species of tree as well as its location in relation to the source of anthropopressure. Generally speaking, trees growing in parks have a much longer period in leaf than the ones growing in street zones. Furthermore, variety was observed in the length of leafing period within the group of trees examined. For example, the shortest was found in *Acer pseudoplatanus*, *Acer platanoides*, and the longest in *Acer saccharinum*, *Populus nigra "Italica"* or *Salix alba*. In the course of plant development in urban greenspaces self-sown synanthropic vegetation comes up. This kind of vegetation, occurring in addition to the species sowed or planted on purpose as part of the area's management, is represented by ruderal communities in most cases. It functions in similar ways to those of stable "semi-natural" communities and does not require expensive management.

The research carried out in Warsaw proved the existence of as many as 24 individual plant groupings and 18 communities which were physiognomically distinct with a predictable and characteristic species composition. It is worth pointing out that these communities grow in various places sometimes even under extreme conditions where their existence is the only chance of vegetation surviving.

Municipal woods serve in most cases as recreation and holiday centres. In the areas of this type, e. g. Bielański Forest, the influence of anthropopressure on the vegetation initially results in a reduction in its characteristic species with simultaneous decrease in shrub cover. On the other hand, as perennials disappear, shade-tolerant terophytes, and annual synanthropic species, spread over light and disturbed woods.

Apart from the quantitative changes occurring as a result of the influence of urbanisation, there are functional disorders due to excessive chemical pollution. As has been already proved, chlorine and heavy metals are particularly noxious for plants. Also sulphur and fluorine accumulate in plants; their concentration depends mainly on the species and the distance from emission source.

Animals, one of the components of the city ecological structures, form a basic element in the cycle of matter and energy. Therefore ecosystems deprived of animals would not be able to function. The fauna in urbanised areas is substantially changed

in comparison with that of natural environments and depends on the type of urban greenspace. Plant structures of urban areas, both those characteristic of certain types of sites and simplified ones, allow populations of some herbivorous species such as aphids and red spiders to increase so much that certain species of trees become threatened. The greatest stability and capacity for self-regulation as well as the greatest variety of species is typical of park areas, while lower stability characterises housing estates. The functioning of ecological structures in the city depends apparently both on such factors as soil, water or air and on the degree of anthropopressure. Therefore, while managing urban areas one ought to be more aware of ecological processes in the specific urban systems than is currently the case.

2. 2. The urban fringe zone

The way in which ecological structures in the urban fringe zone function is determined by natural factors as well as a variety of anthropogenic influences. Various types of functioning coexist in these structures. Natural mechanisms prevail in parks and reserves; anthropogenic mechanisms act in agrocenoses; and in compact urban settlements anthropogenic mechanisms may be exclusive. Ecological structures develop due to plant succession and anthropogenic transformation of the sites. Both phenomena result in changed water regimes, alteration to the soil surface and methods of management. Changes to the vegetation arise from industrial and non-industrial activity. Mutually interrelated, anthropogenic activity and natural mechanisms bring about a variety of changes to ecological structures. Changes in vegetation structure may move in several directions. Degradation or degeneration follows when the structures do not perform the functions expected by man. Regression of structures result in structural transformation of phytocenoses, composition of species, qualitative and quantitative relationships. Changes in the range and area occupied by plant communities are seen in the urban fringe. For example, changes in the range of communities are noticed in damp and wet sites. The extent of *Phragmitio-Magnocaricion* communities was reduced and replaced by forest and bush communities, namely *Ficario-Ulmetum* and *Salici-Populetum*. In dry sites, the area of fields covered with sedge communities has been reduced and they have been replaced by *Arrhenatherion* meadows. The changes in distribution of communities are closely linked with the conversion from a range of island system to a mosaic-like range and range system; the first having a community series depending on site make-up, the latter less dependent on site composition and more determined by land use.

The described changes have varied dynamic quality. The progressive ones result in increased complexity followed by stabilisation of species composition and better adaptation to site conditions. They are represented by the development of forest and bush communities in place of grass and sedge communities, as well as man-made creation of orchard and meadow complexes in the place of fields, or the development of ruderal communities instead of fallow. At the same time, regressive changes take place. For example, *Molinion* meadows turn into areas simplified floristically. The urban fringe zone is dominated by regressive changes to ecological structures as a consequence of increasing synanthropization.

There is growth of spatial diversification contrast and mosaic-like shape of the plant assemblages that are linked with the processes specific for urban fringe zones in the city periphery. A comparison of the real vegetation map and the potential vegetation of sample areas, combined with an analysis of land-use shows sites holding *Ficario-Ulmetum*, *Quercu-Pinetum* and both fertile series of *Tilio-Carpinetum* dry-ground forests to be used in the most versatile ways. The same applies to the *Salici-Populetum* in Konstancin-Jeziorna. The biggest anthropogenic changes to vegetation are seen in the *Tilio-Carpinetum* in Konstancin Jeziorna, Nieporęt and *Quercu-Pinetum* in Łomianki, Komorów, and Karczew as well as *Ficario-Ulmetum* and *Salici-Populetum* in Konstancin-Jeziorna and Nieporęt. On the other hand vegetation is less altered in the *Peucedano-Pinetum*, *Cladonio-Pinetum*, *Ribo nigri-Alnetum* in Łomianki, Karczew and the *Vaccinio uliginosi-Pinetum*, *Leucobryo-Pinetum* in Konstancin-Jeziorna. The construction of drains and river embankments resulted in the drainage of the valley and the reduction in distribution of all alder and some marshy meadow sites, mainly of *Ficario-Ulmetum* with a simultaneous expansion of *Circaeo-Alnetum* and *Tilio-Carpinetum* sites. In contrast to the minor alterations to the sites, the real vegetation underwent quick and far-reaching changes. Over the last 200 years the areas covered with forest communities dwindled three-fold. The *Ficario-Ulmetum* has been almost totally deforested. The area of *Tilio-Carpinetum* has diminished nearly tenfold. The transformations affected swamp complexes as well, e. g. Łuże. Twenty years ago the natural complex of peatlands and rushes in Łuże did not differ much from its early 18th century appearance. Now, it is an over-drained and degraded area. Furthermore, it has been changed as a result into fields, meadows and allotments. In the study area of Komorów the transformation of the structure was less functionally dependent on the Warsaw area. The spatial structure of Komorów was established over one hundred years ago and since then only slight modifications have been introduced. It was just recently that faster changes, linked with the erection of a recreation centre and extension of orchard areas were observed. Over the last 40 years substantial changes have taken place in the terrain represented by the study areas of Karczew and Konstancin-Jeziorna, located south of Warsaw in the valley of the Vistula River. The changes have been most fundamental over the last 20 years, *Salicetum triandroviminalis* developed in the place of *Phragmition* and *Magnocaricion* rush communities. *Arrhenatherion* meadows have sprung up in the areas where ruderal communities of *Chenopodieta* and *Secalietea* used to dominate. Land-use changes and development of the land drainage resulted in a decrease in number of many sedge communities and low peatlands, and at the same time an increase has occurred in the area of damp meadows. The construction of a storage reservoir on the Narew River, in the Nieporęt study area and the recreational activity which followed the construction stimulated an extension of the built-up area.

The degree of anthropogenic transformation is different in various regions of the Warsaw urban fringe zone, being the highest east and north-east of Warsaw. The main cause of these differences is large-scale deforestation and the construction of new housing estates. In areas located west of Warsaw the degree of anthropogenic deformation has been on the increase for the last 160 years. The picture presented of the distribution of plant assemblages does not result merely from the direct

influence of the big city – it is also a reflection of the diverse character of sites in each region.

3. THE MANAGEMENT OF THE NATURAL ENVIRONMENT IN THE URBAN FRINGE ZONE

Site amelioration and best use of site properties are essential guidelines in the use of natural resources. In order to comply with these guidelines one should always examine the suitability of actual land use to the site in question. Therefore natural potential vegetation is determined which enables us to estimate with a sufficient degree of accuracy the economic usefulness and production capacity of the area. One may determine the direction of changes to the vegetation and decide what farming measures should be taken in order to carry out beneficial alterations in site conditions. It is a well known fact that sooner or later methods of farming incompatible with site conditions turn out to be destructive no matter how profitable they may seem at the beginning.

While altering the natural environment of a given area the influence of our management on the neighbouring sites should be considered. Before afforestation of waste land one ought to take into account trends in plant succession and site variability as well as existing natural communities, if there are any in the area. The comparison of the potential vegetation and the types of land use helped to find suitable replacement communities and determine the degree of site alteration and plasticity. On the basis of maps the choice of methods of land use in local site conditions was evaluated. Also the site usefulness was verified for land uses such as cereals, root-crop planting for soil improvement, meadow, pasture, forest and orchard cultivation.

The role of sites in the control of water quality and hydrology (including detoxification) were considered. The suitability of an area for building, agriculture or even a specific type of cultivation may be evaluated using the “fitness” scale. Its values are in order of “suitability” or in other words in “usefulness” classes, according to which one may plan space according to its economic optimum. This is a most important possibility in space planning. A 6-grade scale has been constructed. “O” means a type of site which is of no value for a given method of land use while “5” means a very good site. In the Warsaw voivodship urban fringe zone 12 types of smaller sites, not marked on the 1 : 1,000,000 map were distinguished. Plant communities, developed from natural communities as a consequence of man’s activity and called replacement communities are the measure of transformation capacity and elasticity of sites. The biggest number of replacement communities are in *Tilio-Carpinetum* valleys (fertile series) – 22, and *Potentillo albae-Quercetum* – 20; the smaller numbers are in *Tilio-Carpinetum* (fertile series) and *Pino-Quercetum* – 15, *Ribo nigrae-Alnetum* and *Circaeo-Alnetum* – 12, *Peucedano-Pinetum* – 10 and *Oxycocco-Sphagneteta* – 3. There are few replacement communities in small area natural communities.

The habitat of dry oak hornbeam forest is the most suitable site for the cultivation of cereals, root crops, vegetables, orchards, meadows and pastures. Peatlands, wet woodland, alder swamp and small area natural communities are definitely not suitable for agriculture. Nevertheless all these communities require special care and

protection since they play an important part in the water filtration and hydrology. Thus high pollution levels make these communities particularly important. Since their value as meadows is limited intensive drainage and improvement is of no avail. The dry *Cladonio-Pinetum* and damp *Molinio-Pinetum* forests play an important role in forest management. Dry-ground and oak forest sites should be assigned for agriculture, and not used for building.

Sites with pine or swamp forests or peatlands require the most cautious approach in spatial planning since they have the lowest elasticity. Therefore they are readily liable to irreversible damage. Sites with fertile dry-ground or oak forests may be used in a more versatile way: they may be transformed into plant assemblages of various types and purposes. On the grounds of potential natural capacity combined with structure and distribution of sites in the Warsaw voivodship, 10 regional units were distinguished. They differ in the composition and structure of plant communities. Each of the units is characterised by prevalence of a particular type of site and the method of land use. The latter is not always compatible with the site. It suggests that every regional unit requires slightly different space management and specific protective measures. For example, scarce sites of raised peatlands should be protected in unit 5, comprising the Łowicko-Błońska Plains, and unit 8, located in the Valley of the Vistula River.

Special emphasis should be put on the correct anthropogenic use of disturbed landscapes with numerous clay-pits, as in unit 10 comprising Radzymin, Wołomin, Zielonka, Marki. The long term evaluation of the landscape dynamic, e. g. in 40 year period, enables us to identify "conflict" areas with positive and negative oriented development. The "conflict" areas require special research and proper human intervention so that they would turn towards restoration, and not towards degradation. Vegetation helps us determine with relative speed and accuracy several parameters of the natural environment, which is essential for the optimal use of natural resources. The natural value, the "natural importance" may be estimated on the grounds of well developed plant communities that have a rich internal structure. Communities ought to be stable with a prevalence of natural control mechanisms and a varied internal structure.

The estimation of natural value, the "natural importance" factor that is used to evaluate the changes to the natural environment as well as selection of proper directions and measures for nature conservation and optimal land-use are both indispensable when devising local plans for space management.

Each type of potential natural vegetation is matched by a complex of abiotic environmental conditions. Thus a quite accurate recognition is possible, using bioindication, of site character, its ecological properties, economic usefulness and production capacity. Having obtained such information one may optimise farming measures. Firstly, in order to gain the biggest crop. Secondly, to determine the suitability of an area for various forms of land use.

The present condition of vegetation structure is a result of many factors. Therefore, one may predict in outline the reaction of the structure concerned to a given human activity. The predictions are relatively easy for more natural communities, being more difficult for secondary structures. The ability to foresee the results ought

to be an attribute of anyone who intends to create and manage the environment, especially in the very complex system of the urban fringe zone.

4. THE PRINCIPLES OF PLANNING FOR THE NATURAL ENVIRONMENT IN THE DESIGN OF CITY HOUSING DISTRICTS

The practice of town planning in the past shows a general lack of methods for registering and using the laws of nature. This is mainly due to:

- a. the high degree of complexity of nature and the way it functions, which is not reflected in proper documentation; the documentation serves merely for listing and describing the dynamics of ongoing processes and changes;
- b. a specific jargon barely understandable to non-specialists;
- c. a "scientific" approach according to which every element of the environment is considered separately, whereas the total picture is in reality more than a simple sum of the observations;
- d. the concentration on the abiotic part of nature, when it is this abiotic part that is being endangered by technology.

This results in planners neither being inspired by nor properly understanding the message. Thus the transfer of information is impeded and so sometimes designers treat nature as a side issue. However, nature as an intrinsic part and value of open space can and should inform the structure of contemporary cities. This structure can be created only with proper plans of town development.

If the plans are to be simultaneously instruments of preservation, of design and nature, then a new formula of approach towards the transmission of information about dynamic rules of nature is needed. The works of teams of naturalists and planners are based mostly on empirical research, but should not exclude theoretical studies. It is only simultaneous application of those two methods than enables us to achieve a proper level of generalisation.

The scope of our research covers the following points:

- comprehensive and concise expression of the information about the natural environment;
- management of the natural system – basis for spatial planning;
- economic approach towards living condition standards and the functioning of nature.

5. THE PRINCIPLES OF MANAGEMENT OF THE NATURAL ENVIRONMENT IN THE PROCESS OF DESIGNING A CITY HOUSING DISTRICT AT THE LOCAL PLANNING LEVEL

The basic principles of management of the natural system depend largely on the broad natural background. In general plans the background is defined at the city, district or regional level, and in the so-called detailed plans, in ie local plans – at the neighbourhood or housing district scale. The crucial clues for the choice of the specific way in which to manage nature are hidden at the levels described by the two above-mentioned types of plan. Therefore the plans were the main subject of research.

5. 1. The suggested scheme of procedure: our research proved that the initial stage of any plan should be better developed and not neglected, as it usually is in current town planning practice.

5. 2. The suggested documentation of the natural environment: the documentation ought to comprise a detailed description and diagnosis of the condition of the natural environment. It should cover biotic and abiotic parts of the environment – climatic conditions, pollution and degradation included.

In the empirical work concerning some of Warsaw districts, namely Dolny Mokołów and Wilanów Zachodni, a special emphasis was put on:

- a. definition of natural and anthropogenic determinants of the environment;
- b. location of the environmental changes that are arising or will arise due to present processes and future activities; initial warning prognosis;
- c. recognition of the crucial problems and conflicts between nature and the concepts of town planning;
- d. formulation of a programme of essential research, data collection or specialist expertise and supplementary studies.

The detailed documentation of the natural environment of a city or its region should cover the area concerned and its surroundings. Findings, diagnosis and evaluation of the state of the environment, including the relevant changes and processes, are important parts of the documentation. Information ought to be recorded on up-to-date contoured maps at several scales, the scale depending on the size of the natural functional areas concerned.

For example: 1 : 50,000 maps or 1 : 25,000 maps are suitable for the external zone of a small city, 1 : 10,000 and 1 : 5,000 maps for the areas within the town plan area. The areas having a considerable degree of natural complexity should be shown on 1 : 2,000 and 1 : 1,000 maps and should show more detailed information.

5. 3. The resultant synthesis

On the basis of the information mentioned above I suggest drawing up a complex synthesis of the natural conditions. This synthesis concerns a plan area and its characteristic natural boundaries extending into an external zone. This makes the picture of the functional natural areas easily readable. The concise and clear form of the synthesis enables their message to be transmitted directly into design works. The following points should be dealt with in the synthesis:

- a. natural characteristics of the given area;
- b. management of concepts for the natural systems;
- c. evaluation of suitability of the natural environment for the performance of specific functions – weighing the pros and cons;
- d. proposals for eliminating contamination of and unfavourable influences on the environment;
- e. location of the most suitable available areas for housing programmes.

5. 4. The principles for management of natural systems.

Four basic ecological principles were adopted for management of the environment:

- a. the principle of maintaining ecological diversity;
- b. the principle of maintaining continuity of the functional systems in time;
- c. the principle of continuity of the ecological systems in space;
- d. the principle of suitability of the ecological systems to the abiotic conditions.

Two basic systems were suggested:

- the system of regeneration, supply and change of air, which allows improvement of the aero-sanitary conditions;
- the system of provision and revival of animated nature, which checks the degeneration of nature.

This system involves biologically active areas forming a continuous structure. This facilitates natural self-regulation of the ecosystems. Such stimulation of homeostasis of city ecological systems carries not only theoretical but also practical consequences for conception of city green spaces. The concept ought to aim at:

- optimal conditions of man's biotic and abiotic natural environment;
- optimal conditions for ecosystem functioning.

Besides the above-mentioned systems an additional system should be created comprising areas important for protecting the natural heritage. The biologically important areas of this system would be supported by the other two. Unlike the two basic systems the third does not require either spatial continuity or varied structure.

5. 5. The natural core of the city.

The physical structure of these natural systems give a city its principal natural structure. It is this natural core that determines the potential for and condition of nature as well as the health and ecological status of the city. The core – a basic “living” structure of city nature ought to determine the spatial and functional structure of the city. The natural system may be an attractive inspiration for a varied spatial design. A special emphasis on the requirements of nature and the values of potential landscape is necessary for the spatial composition to be expressed properly. Forms of management and use of areas belonging to the natural core should not compromise efficient functioning of the natural system. Therefore the following instructions ought to be obeyed:

- a. eighty per cent of the areas included in the system for the regeneration, supply and movement of air should be occupied by vegetation or open water. The vegetation must not impede air flow. The other part of the area may serve as a location for services and technical installations, but green areas have to dominate;
- b. the areas included in the system for the supply and revival of animated nature ought to be occupied by vegetation of open water.

5. 6. The management of outer boundaries.

Junctions with outside systems constitute a dual purpose supply zone, the so called “ecological buffer” essential for the supply and revival of both nature and the air of the city. The ecological buffer is made up of forests, meadows and water bodies. These areas ought to be linked with the city by existing physiographic structures, such as valleys and biologically active areas. Use of the ecological buffer areas should not damage their natural functions. The management of the city's ecological buffer requires special legal regulations and we suggested the buffer zone be included in supra-local plans, such as regional or communal plans, which are concerned with natural functional areas.

5. 7. Elimination or limitation of contamination and unfavourable influences on the environment.

Having determined the background level of pollution the following measures should be taken to give an acceptable standard of air cleanliness:

- a. creation of a suitable infrastructure;
- b. limitation or elimination of sources emitting pollutants.

A special approach is recommended for areas where climatic conditions favour concentration of air pollutants. Supra-local communication routes and highways located within, or in the vicinity of a given area produce noise and combustion gases endangering the functioning of nature and the health of city-dwellers. The right protective measures included the design brief or elimination of the environmental hazard are recommended. The choice between the two options depends on the location of an area. The impact of the technological infrastructure should be predicted and evaluated, and pro-ecological solutions ought to be introduced. Hydrologic and hydro-geologic conditions are of special concern. Due to the likely contamination of ground water and surface water, the hydrologic and hydro-geologic conditions may preclude local sewage systems. The Warsaw district of West Wilanów may well serve as an example of such situation.

5. 8. The "commercial" approach towards standards of natural environment quality.

The basic neutral systems and combined groups of these systems should be managed in one of two ways:

- a. the alternative of **ecological optimum** which aims at the most effective functioning of the natural system. It requires relatively large and biologically rich areas;

- b. the alternative of **ecological minimum** that determines the threshold possibilities limiting the functioning of natural systems. In consequence this alternative also sets limits to the standard of living. It requires as small an area as possible of biologically active land and some specific steps to be taken, such as erection of housing estates in the areas least favourable in bio-climatic terms.

5. 9. The design scenarios.

Initial "design scenarios" based on ecological optima and minima decide on the future diversity and even conflicting influences between nature and the inhabitants lives. The optimal, minimal or intermediate alternatives included in spatial planning models help administrative authorities take decisions concerning future ecological standards. I am of the opinion these influence the participation of citizenry in city life, their social responsibility and ecological reflections.

The choice of the future ecological standard, followed by its inclusion in outline plans, is the beginning of a proper process.

5. 10. The natural verifying prognosis.

The spatial scenario that has been chosen for implementation is a subject of the so-called natural verifying prognosis. The prognosis is based on simulation of the anticipated reaction of nature to the suggested forms of land use, such as spatial structure, buildings or technical infrastructure. The estimation of the anticipated results of planning solutions, their influences on functioning of natural systems and conditions lets us negotiate reasonable decisions concerning physical planning. The use of the method mentioned above in the practice of housing district planning aims at:

- a. high ecological values for future human inhabitants and the biota of the designed area;

b. considerable reductions in unfavourable impacts of the planned spatial structure on ecological standards and the condition of city nature.

Furthermore, the method is of significant importance for:

- decision-taking processes at the planning stage;
- ecological inspiration and responsibility of the municipal government;
- development of new methods and formulae in local planning.

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