IAEA-TECDOC-292

GEOENVIRONMENT AND WASTE DISPOSAL

REPORT OF AN INTERDISCIPLINARY EXPERT MEETING
ON GEOENVIRONMENT AND WASTE DISPOSAL
JOINTLY ORGANIZED BY THE
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
AND THE
INTERNATIONAL ATOMIC ENERGY AGENCY
HELD IN VIENNA, 21–23 MARCH 1983

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PREFACE

Within the activities planned by Unesco in its Water and Earth Science programme, an interdisciplinary meeting on geology and environment was scheduled by this organization to be held by the beginning of 1983. At this meeting it was intended to consider geological processes in the light of their interaction and influence on the environment with special emphasis on the impact of various means of waste disposal on geological environment and on man-induced changes in the geological environment by mining, human settlements, etc.

Considering the increasing interest shown by the IAEA in the field, through environmental studies, site studies, and impact studies for nuclear facilities and particularly nuclear waste disposal, Unesco expressed the wish to organize the meeting jointly so as to take into account the experience gained by the Agency, and in order to avoid any duplication in the activities of the two organizations.

This request was agreed to by the IAEA Secretariat and as a result, the meeting was organized by both organizations and held at IAEA Headquarters in Vienna from 21-23 March 1983. The report of this meeting is herewith presented.

Jacques MOLINARI
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INTRODUCTION

The interdisciplinary meeting on Geoenvironment and Waste Disposal was initiated by Unesco within the framework of its project "Protection of the Lithosphere as a Component of the Environment" and jointly organized by Unesco and the International Atomic Energy Agency. The meeting was held at IAEA Headquarters in Vienna from 21-23 March 1983. Fifteen scientists participated in the meeting and eleven scientific papers were presented on three major themes:

I. General Aspects of Geoenvironmental Studies
II. Geological and Hydrological Factors Influencing the Environment
III. Waste Disposal and Protection of the Environment

Widespread awareness of environmental implications of human activities has been shown all over the world during the last two decades but only recently has more attention been devoted to the relationships between the different systems and subsystems of the total environment. An interdisciplinary approach is needed in order to understand the behaviour of the physical environment in the context of the environmental system as a whole, taking also into account man's impact on the geoenvironment.

The geoenvironment includes a number of factors and processes such as geological structure and composition, geodynamics, relief, hydrometeorological and geological conditions, and endogenic and exogenic geological processes. The interdependence of these factors and processes, their evolution and change under natural and man-induced actions is considered as a unified functional system.

Degradation of the geoenvironment is occurring at an unprecedented rate as a direct or indirect result of man's activities, and on a scale that requires international efforts in order to prevent serious long-term negative effects on mankind. To a great extent, the present conditions of accelerating degradation are a result of the intensive exploitation of the Earth's natural resources and other human activities in the absence of a clear scientific guidance or an adequate understanding of the consequences.

Geoenvironmental change is induced by anthropogenic pressure and this produces multiform effects on the total environment. One of the major causes contributing to the degradation of the geoenvironment is the disposal by man of wastes from industry, agriculture, municipal services and mining. These have created the unpredictable and variable behaviour of the geoenvironment which hampers the planning and management of georesources.

Real opportunities exist for the improvement of present undesirable conditions and for the avoidance, in the future, of past mistakes, but this can be achieved only through a better understanding of the

interrelationships between man's activities and geoenvironmental factors. With great scientific knowledge and properly armed with sophisticated technology, man can either destroy the geological equilibrium or develop natural resources in harmony with nature; this choice will be one of the most important factors in determining our standard and quality of living, our way of life and, ultimately, the survival of mankind. The rational use and protection of the geoenvironment requires a full understanding of the complexity of the environmental system, of the relationships between the lithosphere, the hydrosphere, the atmosphere and the biosphere, and of the influence of man's activities on each of these.

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1. THEME I: GENERAL ASPECTS OF GEOENVIRONMENTAL STUDIES

Chairman: Prof. György KOVACS
Scientific Secretary: Dr. Bedrich MOLDAN

1.1. PRESENTATION OF THE PAPERS

1.1.1. Geoenvironment: Concepts and Scientific Aspects, by Dr. Ivan I. Snezhko

In the paper the main activities of international organizations in the field of geoenvironment have been described.

The second section of the paper described main concepts of the components, factors and subsystems in their proper perspective. The author suggested treating the geoenvironmental aspects on the basis of an approach considering the "NATURAL RESOURCES AVAILABILITY - HUMAN NEEDS - ENVIRONMENTAL CONSEQUENCES ASSOCIATED WITH MEETING THE DEMANDS". Some definitions of geoenvironmental concepts were proposed. One of these definitions is:

> "The geoenvironment is a complex of geological components, factors and processes linked and regulated under certain relationships and being developed under the influence of natural factors and in accordance with natural laws and under the influence of human activities as well".

It was noted that the geoenvironmental concept is a very complex and broad system. This requires further development, research and scientific evaluation for a better understanding of its nature, and interactions and interrelationships between the different components of the environment.

The paper presents some global geoenvironmental information, urgent problems and consequences resulting from the use of natural resources by activities of human society.
Particular attention was given to the impact of man on geoenvironment caused by poor land use, mineral exploitation and energy use. It was noted that the growing load of human activities' pressure on the geoenvironment has already created many undesirable, unpredictable and multifaceted effects on the environment. Under these circumstances, the prediction of geological change and forecasting of long-term geological processes becomes much more difficult and some geological hazards are imminent. Urbanization and the use of natural resources have increased much more rapidly than the awareness and understanding of their effects.

The paper emphasizes the importance of further development of methodology on land-use planning through geoenvironmental mapping and lithomonitoring of separate regions. The author has made conclusions that such an approach will assist in environmental management and protection.

1.1.2. The Impact of Human Activity on the Geological Environment, presented by Prof. Genrich S. Vartanyan (report prepared in collaboration with G.V. Kulikov, G.N. Kashkovsky, V.A. Baron and V.T. Dubinchuk)

Some general approaches to the problem of geoenvironment were given in the report. As a result of mining and of large land reclamation projects, two important categories of anthropogenic impact were considered. In this context, mining activities in Donbas, Chelyabinsk and some other areas and their consequences on the water regime and engineering geological conditions were given. The effects of land reclamation projects in the Kasakhstan, Tobol-Irtysh mid-stream area on soil condition were considered. In the context of forecasting and preventing undesirable consequences, different procedures of isotopic survey and study were discussed.

1.1.3. Man's Activities and Their Influence on Geoenvironment in China, by Dr. Tang Ning-hua

Historically China has always been an agricultural country with a dense population. One may ask what influence on geoenvironment has been exerted by human activities in a country like China, ranking first in population, with nearly one-third of the world's people? What effect on human life has the changed geoenvironment brought? This paper tries to reflect the relationships between geoenvironment and human activities in China in the following three aspects:

I. Soil Erosion due to Forest Devastation.
According to the statistics of the early 1950s, the total area of soil erosion was up to 150,000 km^2, one sixth of the total cultivated land. Now the areas of soil erosion have increased rapidly in many places, even in the area which was rich in forest reserves. There are several factors causing soil erosion but the main factor is related to the deforestation which is intensified by the increase of population.

II. Land Deformation due to the Development of Natural Resources.
Because of inadequate understanding of the environmental problems induced by the development of natural resources and also because of out-of-date technology and poor management, many geological hazards have developed, such as land collapse in some limestone areas of South China and land subsidence in vast alluvial plains and coastal areas.

III. Groundwater Pollution Due to Waste Disposal.
With the high-speed development of industry and agriculture, bringing about arbitrary discharge of industrial and municipal wastes, and over-use of pesticides and fertilizers for a long time, China is now facing water pollution and water shortages in many places, especially in some big cities.
During recent years, the Chinese government has adopted a series of measures to protect the geoenvironment from degradation. But the relationship between geological hazards and human activities seems to be a great and everlasting struggle between man and nature. Through legislative, administrative, economic and scientific paths we have to study and solve in the long-term many problems created during this struggle. Only in this way may we renovate the ecologic environment for the benefit of future generations.

1.1.4. Geochemical Processes and Human Perturbation, by Dr. Bedrich Moldan

The author stressed that some of the most severe problems of the present global environmental situation have essentially a geochemical character. As examples, acidification of the environment and CO_2 buildup in the atmosphere were mentioned. In the paper, several important problems were discussed.

In the introduction, the natural cycles and fluxes of matter were compared with man-induced ones. The global carbon cycle was then mentioned as an example of the major element cycle. The problem of acidification caused by atmospheric deposition of acid substances was assessed. The global character of the pollution by heavy metals and other toxic elements was stressed. Attention was then devoted to the geochemical consequences of various anthropogenic activities. Waste disposal and related geochemical processes were discussed. Processes induced by agriculture were briefly examined. The significance of production of toxic organic chemicals and artificial ionizing radiation was mentioned. The final remarks were devoted to the general influence of geochemical environment on human health.

1.2. DISCUSSION AND COMMENTS

Geological, geophysical and geochemical phenomena represent important factors of our environment. Thus, geoenvironment is a complex of physical, geological and social components and processes being developed under the influence of natural factors and under the influence of man's activities as well. Geological factors have been rather neglected so far in environmental studies, and more attention has been devoted to biological factors and so ecological thinking has been dominated by biologically oriented ideas. Therefore, the importance of the geosphere as the principal part of our total living environment should be stressed.

The relatively little attention that so far has been paid to the geoenvironment is explained by the large capacity of geospheric systems to absorb man's wastes and to maintain a geological and geochemical balance. Moreover, the processes of the geosphere tend to be slow and difficult to assess to the point of evident and irreparable damage. Compare, for example, the direct effect of SO_2 in the air on coniferous trees with the "stealthy" process of acidification of the soil, which is no less, but perhaps more dangerous, persistent and irreparable. The impact of man's activities on the geosphere is now comparable to, and sometimes even exceeding, natural geologic processes.

We realize that the scope of the environmental problems is very great and that many programmes governed by various agencies are under way. So, the meeting focuses on a few issues selected not only for their own importance but also as an example of the complex interactions which could be demonstrated. These are, first, the issue of waste disposal and, in general, the influence of wastes on the various parts of the environment. The second task is the investigation of the influence of man's activities on geoenvironmental systems, including groundwater systems.

2. THEME II: GEOLOGICAL AND HYDROLOGICAL FACTORS INFLUENCING THE ENVIRONMENT

Chairman: Dr. Ferruccio GERA
Scientific Secretary: Prof. György KOVACS

2.1. PRESENTATION OF THE PAPERS

2.1.1. Geoenvironment and Water Management, by Prof. G. Kovacs

The paper starts by stating the principle, that water is an important part of the crust. It follows from this fact, that the availability of water depends on how geological structure and water react forming the geoenvironment. This interaction should be analysed from both quantitative and qualitative aspects extending the investigations always to the whole groundwater systems influenced by human activity.

To demonstrate the versatile connections, several examples are analysed in the paper representing the importance and the character of interactions between geoenvironment and water management.

2.1.2. Understanding the Groundwater System - A Key to Predicting Environmental Impacts, by Dr. B.L. Foxworthy

The close and fundamental interrelationships between groundwater systems, other parts of the geoenvironment, and many of man's activities are stressed in the paper. It is pointed out that trends of greater dependency on groundwater supplies and trends of accelerating degradation of groundwater quality are clearly on a collision course.

2.1.3. Changes of Groundwater Quality by Disposal of Non-radioactive Wastes, by Dr. G. Matthess

Disposal of non-radioactive gaseous, liquid and solid wastes causes changes of groundwater quality. The various geochemical reactions and the biochemical and physical processes which control the propagation of contaminants in groundwater are discussed in the paper.

2.1.4. Geoenvironmental Mapping, by Prof. M. Arnould

The geological environment can be analysed through its main factors: geology of the bedrock and of the surficial formations, engineering geological properties of soils and rocks, pedology, geomorphology, topography, landscapes, hydro-geology, natural hazards, and natural resources. Hydrology, climatology, land use, and effects of man's activity should be also added.

Almost all of these factors have a specific methodology for their mapping. When adding maps of vegetation, most of the so-called ecological mapping would be realized.

It is possible, therefore, to prepare general purpose maps of the natural environment in the form of an atlas. It is interesting to do this starting from the regular geological mapping for a better understanding of the interactions between the various factors.

2.2. DISCUSSION AND COMMENTS

After the presentation of the papers the participants discussed the environmental problems of groundwater systems. The main aspects raised during the discussion are summarized in this short report.

Water is an inseparable part of the lithosphere. It occupies a considerable ratio of the total volume of layers; the geological conditions have, therefore, a decisive influence on the availability of water. On the other hand, water acts also as a geological force, forming both the landsurface and the geological structure. These interactions should be considered, when the relationship between geoenvironment and hydrological factors is investigated.

It should be also considered, that water is one of the most movable components of the crust. Many environmental impacts are accumulated in the water as it transports them great distances. It is necessary, therefore, to investigate always larger geological systems to understand the processes governing the transport and storage of groundwater and its constituents as well as to determine the complete set of changes (main and secondary effects) caused by any quantitative or qualitative actions. Naturally both time- and space-scales depend not only on local (geological) conditions but also on the size and duration of the actions investigated.

It was emphasized that the physical-geological environment is the basis of any ecological systems developing on near the surface. The characterization of geoenvironment and the better understanding of the processes modifying it should be improved because presently the role of geoenvironment is almost neglected as compared to the ecological aspects in environmental studies. The coordinated preparation of various maps showing the elements of geoenvironment (geology, morphology, pedology, surface- and groundwater hydrology, land use, natural hazards, etc.) was mentioned as a useful tool, but attention was drawn to the fact that the misinterpretation of maps and their use out of scale may cause problems, and therefore, mapping methods should be internationally compared and improved. Similarly the usefulness of the establishment of data banks including harmonized and integrated information was discussed pointing out that not only the expected (mean) values of the parameters, but also their variances are required to judge the accuracy of various predictions.

Special attention was given to the qualitative parameters characterizing the geoenvironment. It was recognized that natural processes may also cause undesirable qualitative changes (migration of salty connate waters, development of alkaline soils due to high evaporation, etc.). The most harmful qualitative deterioration of the geoenvironment (and that of groundwater) is caused, however, by human activity, which includes not only the point source (waste disposal) and nonpoint source pollutions (fertilizers and other chemicals applied in agriculture) but in some cases, the quantitative changes may also initiate harmful qualitative consequences (sea-water intrusion). Considering the great importance of the quality of groundwater, which is one of the largest and safest sources to provide users with water (especially drinking water), the chemical, physical and biological (including biochemical and biophysical) processes assisting the natural self-purification of groundwaters should be investigated in detail.

Assessing the various harmful effects of human activity on geoenvironment, it was noted that some of them are irreversible (e.g. land subsidence due to water exploitation). Others are causing changes, the elimination of which is a very slow process and, therefore, the recovery of the system requires a long time (e.g. leaching out contaminants from aquifers). Another dangerous character of the pollution of groundwater is the fact that the contamination is observed only after a considerable time-lag, when a great amount of pollutants has already reached the system (especially when the slower propagation velocity of pollutants through the unsaturated zone is also involved). The regular observation of groundwater quality is, therefore, indispensable.

As a final conclusion, it was emphasized that the deposit of wastes underground does not represent a smaller hazard than using the atmosphere or surface waters as recipient of pollutants. This impression was created only by the buried character of pollution and the time-lag between the release of pollutants and the observation of the qualitative changes. On the other hand, some advantages can be mentioned also in connection with the deposit of wastes on and below the ground (treated sewage can be used as a water source in arid areas, or the organic content of sludge can be utilized in agriculture). The reasonable solution of the problems investigated can be provided only by careful waste and water management. This activity requires, however, the better understanding, the more complete exploration and simulation of geoenvironment, and especially groundwater systems.

3. THEME III: WASTE DISPOSAL AND PROTECTION OF ENVIRONMENT

Chairman: Prof. Marcel ARNOULD
Scientific Secretary: Dr. Franz MARCUS

3.1. PRESENTATION OF THE PAPERS

3.1.1. Safety Criteria Required for Waste Disposal, by Dr. Michael Langer

The author drew attention to the fact that many ideas about safety in the field of geological disposal could be transferred from the nuclear to other types of waste. He pointed out that site selection criteria are necessarily general, but that criteria could become more precise for specific combinations of waste types and disposal options. In view of the long-term perspective of disposal, it is necessary to include geological viewpoints in addition to purely engineering viewpoints. In this way, possible future interaction between the geological medium and the waste needs close examination, including the impact of possible modifying events.
The author proposed:

a) to collect and exchange data on existing waste disposal facilities;
b) to encourage research into the long-term interaction between toxic materials and barriers relied upon in waste disposal;
c) to perform work in the field of guidelines for the disposal of toxic materials, so that a safety concept can be arrived at, also involving earth science data.

3.1.2. Radioactive Waste Disposal, Technical Background, by Dr. Franz Marcus

In his lecture on the technical background for radioactive waste disposal, the author illustrated the relative size of the nuclear waste problem and the sophisticated safety philosophy developed. Only small volumes of radioactive waste are candidates for deep geological disposal and the multibarrier concept is followed strictly.

Relatively small quantities of radioactive waste are generated as a by-product of nuclear power production. For one GW.a - which is sufficient electricity to cover the needs of 2 million inhabitants in a moderately developed country - the waste amounts to 700 m^3.

Due to the toxicity of radioactive waste, its management must be planned carefully. Waste is concentrated, solidified and placed in containers. Disposal is planned in geological formations, at depths and under conditions which depend on the content of radioactivity and its decay with time. Waste of lower activities can be disposed of immediately, while waste from the spent fuel elements is kept in storage, taking advantage of the fast initial cooling. Routine geological disposal is planned to take place some decades from now. By the year 2000 there will be 200,000 tonnes of spent fuel and 3000 tonnes of solidified highly active waste.

Repositories are designed so that encapsulated waste will remain isolated from the geological formation during long time periods. The absence of water and the function of the host rock as a barrier will

further retard the return of any radioactivity to the biosphere. Intensive development is under way in order to further improve present design of repositories. Several underground test laboratories have been put in place in various geological formations.

The author pointed out that, during the last decade, different geosciences and techniques have been combined in an efficient manner to deal with the subject of radioactive waste disposal, that such co-operation should be continued and extended, and that a similar approach should be used in planning disposal of other toxic materials in view of a better understanding of the long-term consequences of waste disposal in society.

3.1.3. Influence of Radioactive Waste on Geological Environment and Geological Conditions Required for Disposal, by Dr. Jean Margat.

The author was unable to present his paper, which will be inserted in the collection of lectures to be prepared for publication.

3.1.4. Geological Disposal of Radioactive Waste. Environmental and Radiological Impact, Present and Future, by Dr. Ferruccio Gera

The author explained the pathways by which radionuclides from various repositories in different host rocks can reach man.
As examples of possible radiological impacts from high-level waste disposal, he quoted some studies where it is shown that the contribution to population doses from this source is extremely small in comparison with variations in background radiation due to such factors as the content of natural radioactive elements in the earth's crust or the variation of cosmic radiation with altitude.

3.2. DISCUSSION AND COMMENTS

After presentation of the papers, the session continued with a general discussion which covered several points. The most significant are briefly summarized below:

It was generally agreed that principles and criteria applied to the disposal of radioactive waste are much more rigorous and sophisticated than those utilized for other types of waste. The transfer of know-how developed in the nuclear field to the management of conventional waste appears to be a worthwhile exercise. The IAEA and UNESCO should promote such transfer and encourage further interdisciplinary exchanges.

In discussing the radiological impacts of power plants, it was mentioned that the natural radioactive elements released through coal burning give doses comparable to those from the normal operation of nuclear reactors. On the other hand, nuclear reactors produce large amounts of radioactive materials that are eventually found in solid waste and disposed of in the geosphere.

The principle that radioactive waste repositories should be regulated in terms of radionuclide releases and radiation exposures to individuals or populations was discussed. The alternative approach of regulating

concentrations of radionuclides in geological media was proposed and after extensive discussion, it was agreed that such an approach would be difficult to justify since no direct relationship exists between such concentrations and harmful radiation effects on various components of the geoenvironment and the biosphere.

In discussing the barriers that ensure long-term isolation of long-lived radioactive waste, it was pointed out that economics prohibit the use of these techniques for the isolation of non-radioactive waste because their volume is greater and their specific toxicity is usually lower. However, the principle of having barriers between waste and biosphere is worth retaining for all types of toxic waste. In many cases careful selection of disposal sites will allow taking advantage of natural barriers and of long transfer times and slow release rates for the pollutants.

Finally, it was reiterated that all waste disposal operations should be preceded by comprehensive assessments of their environmental and health impacts. Rational choices on waste disposal should be based on cost/benefit analysis as is the case for radioactive waste. The use of cost/benefit analysis could also be extended to other aspects of environmental management, for example to the use of natural resources.

RECOMMENDATIONS

In accordance with the major points discussed by the participants, we respectfully and thoughtfully offer the following recommendations:

1. Because the geoenvironment is a very complex set of systems which has an extremely intricate relationship with the environment as a whole, the international scientific community should undertake greater efforts towards a better understanding of the interrelationships between different divisions of the total environment. Such information would be very useful for the world's decision makers and planners to guide them toward making more precise and environmentally sound judgements about long-term change and consequences.

2. Approaches to the solution of problems resulting from human impacts on the environment should be made with the recognition of the very close interrelationship between the geoenvironment and other systems of the global environment. Information needs on these interrelationships should be further identified, and research should be undertaken to meet those needs.

3. As a major step in improving the availability of meaningful geoenvironmental guidance for the world's decision makers, UNESCO should take the lead in compiling an information bank consisting of technically sound documentation of experiences (case studies) throughout the world, that have high transfer value and that demonstrate relationships between man's activities and geoenvironmental consequences.
   For land-use planning and use by decision makers, the geomapping and modelling of geodevelopment of a given region on the basis of better monitoring might be very useful tools.

4. In order to build upon the significant beginning provided by this meeting, additional interdisciplinary meetings should be convened (a) to explore in greater depth some of the major issues raised at this meeting but not adequately treated, and (b) to bring together experts from other disciplines that are of critical importance in geoenvironmental evaluations but which were not represented here. In this regard the participants of this meeting expressed their satisfaction with the interdisciplinary nature of this conference. In addition, we recommend that UNESCO, UNEP and IAEA organize one or more experts meetings on selected aspects of:
   - the concept of geological environment,
   - the impact of geoenvironment on man's activities (land-use planning, urbanization, agriculture, industry...), and on
   - the interrelations of man's activities (including on waste management), with the geoenvironment,

   in order to select a programme of activities.

5. For improving the understanding of problems and processes involved in the disposal of toxic wastes, and for a better assessment of the mutual influences of wastes and the environment, the following are recommended:

   A. To collect data and experiences from existing, well-controlled waste disposal facilities.

B. To encourage research aimed at better understanding of the nature, behaviour and characteristics of different types of waste in order to better classify the wastes.

C. To encourage scientific investigations on the long-term behaviour of natural barriers to waste movement, including sealing materials such as clay layers.

D. To establish and promulgate recommendations and guidelines for:
   (1) safety concepts in waste disposal,
   (2) site selection criteria,
   (3) disposal performance criteria, and
   (4) the needs of earth-science data for site selection.

6. The transfer of research results, experience, and methodologies from the highly advanced field of nuclear waste disposal should be promoted for application to all aspects of toxic-waste disposal, for which much less reliable geotechnical information now exists.

ANNEX

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