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CHAPTER 4

Anthropogenic Factors

In 1953 some rural inhabitants of the island of Kyushu in Japan started to exhibit unusual symptoms: deafness and blindness were observed in many cases, and every fourth sufferer died. All those who died had eaten fish contaminated with mercury. It was discovered that a year earlier a factory began using mercury compounds in a technological process whose waste waters were disposed of in a nearby bay of the sea. The disease did not reoccur after the factory stopped getting rid of toxic waste in this way. Unfortunately, similar and more complex cases of anthropogenic action on the environment and human health have been recorded throughout nearly the whole of our planet.

The studies of many authors indicate that the causes of occurrence and wide dissemination of diseases such as cardiovascular pathology, malignant neoplasms, trauma, genetic anomalies, etc., are often linked with pollution and unfavorable environmental conditions, urbanization, and negative consequences of scientific - technological progress, which are characteristics of our reality. Polluting substances like pesticides, heavy metals, petroleum and its derivatives, and others set off a whole series of chain reactions in the environment, and their presence in it therefore cannot go unremarked.

Unfortunately, examples of severe foreseeable tragic effects of destructive action on the environment are becoming increasingly more numerous. To put it more precisely, the influence of man on the environment has acquired a planetary dimension, and the negative effects have become alarming. Here it is useful to cite the illustrative approach of I. Radovic and R. Mandic (1998): "*If we reduce the period of the Earth's existence to the length of human life, then every 100 million years of life on the planet would be equal to one year, and the planet on that time scale would now be 46 years old. Bacteria (or the first prokaryotic forms of life) would in* *that case be 35 years old, while the first unicellular eukaryotic forms of life would be about 15 years old. On that scale, dinosaurs disappeared before approximately eight months, and man appeared only seven days ago. The more intensive process of destruction and pollution of the environment started just three seconds ago. What are a mere three seconds in relation to the whole 46 years of life? Perhaps it is enough time for man to destroy both himself and his own civilization, but not to destroy nature itself taken as a whole*" (Radovic and Mandic, 1998).

The conditions of life on Earth have been altered by negative environmental effects caused by increase in the concentration of carbon dioxide and global warming of the climate; destruction of the ozone envelope; the advent of acid rain, a source of great damage in many regions of the world; wasteful exploitation of natural resources; the action of heavy metals, radionuclides, and pesticides in water, soil, plants, and animals; cutting down of forests; expansion of erosive and desertification processes; reduction of biodiversity as manifested in the daily disappearance of some 80 biological species; etc. The organism of man and other living beings on the Planet has for the most part exhausted its capacity for adaptation and adjusts with increasing difficulty to rapid changes in the environment. Influence has been especially strong on the physiological integrity and genetic structure of the living organism. Analyzing mutagens and breakdowns of genetic information, N. P. Dubinin reached the following conclusion already in 1975: "*On the whole, it can be stated that whereas much has been said up to now and is still being said about the threatening* ***ecological catastrophe****, today we face the problem of preventing a* ***genetic catastrophe***." According to Keller, Shchepin, and Chaklin (1993), three interrelated tasks are without doubt very pressing today: 1) *protection of the natural environment from further pollution*; 2) *protection of human health from adverse effects of environmental contamination*; and 3) *renewal and healing of the damaged environment.*

The literature on the many anthropogenic factors and causes of environmental pollution and degradation is very voluminous. Our treatment of these factors (in contrast to natural ones) will understandably be compressed. This does not mean that greater attention need not be paid to these problems (especially the response of the geological environment to anthropogenic factors) in future geomedical research. *In the newly arisen conditions, geological factors unquestionably play an important role through their defense mechanisms and ability to dictate both the process of pollution and effective measures for sanation of the environment.*

PROCESSES OF POLLUTION AND DESTRUCTION OF THE GEOLOGICAL ENVIRONMENT

Man as a geological force appeared relatively recently. However, the very short geological time of his action has not prevented man from destroying and altering many things in both the biosphere and the lithosphere. Among other things, he has extracted and processed the ores of ferrous and rare metals and dispensed enormous masses of potassium, phosphorus, and other compounds on fields throughout the globe. Anthropogenic redistribution of substances of the lithosphere, hydrosphere, and atmosphere has had increasingly negative consequences.

We note that life for billions of years avoided a whole series of elements with toxic and carcinogenic properties, whereas those elements today have already polluted a significant part of the geological environment and accumulated in agricultural soil, groundwater, and plants in amounts tens, hundreds, and thousands of times higher than maximal permissible concentrations. Moreover, unique anthropogenic (secondary) deposits of chemical elements have been formed in the vicinity of great industrial concerns, centers of mining, and thermal electrical power plants, and a circumstance to which we cannot remain indifferent.

Viewed geochemically, the consequences of human activity on the geological environment (surroundings) are both visible and manifold. According to M. Babovic (1992), changes associated with *destruction, transport, accumulation, and lithification can be distinguished.* Man takes part in *destruction* of the geological environment by digging, building, releasing various fluids, carrying out conscious interventions (tilling of agricultural land), etc. Through *transport* of rock masses, he has altered the natural relief and promoted processes of downfall (landslides and rockfalls). Changes of the geological environment caused by artificial *accumulation* take on significant dimensions in regions with hydrotechnological projects, where newly deposited sediments have been formed[75]. In a work published in 1978, F. V. Kotlov speaks of *anthropogenic lithogenesis* and singles out seven genetic comples of newly created formations (landfills, sedimentary deposits, embankments, etc.).

The given anthropogenic changes of the geological environment occur in the context of certain economic activities: agriculture, forestry, industry, construction, and mining.

From the standpoint of environment protection, geochemical changes of agricultural soil are the most important of all anthropogenic changes.

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[75] In the large Iron Gate (Djerdap) Reservoir, for example, the rate of sediment deposition in the past two decades on average comprised about 1 m annually. The sediment has very high concentrations of toxic elements (M. Perisic, 1997).

Such changes will be considered later on in the text. In addition to this, significant changes of the geological environment occur with the destruction of forests and other vegetation. It is estimated that the area of forested land on our planet has shrunk by two thirds just in the course of human history. Among other things, this has resulted in unchecked development of erosive processes, destruction of the soil cover, and expansion of deserts. Soil erosion has led to complete loss of fertility of more than half of all arable land in the world. Just between 1960 and 1970, about 6 million km^2 of fertile soil was transformed into desert in the region of the South Sahara[76]. This resulted in a million deaths and creation of approximately as many invalids due to inadequate nutrition.

Every day anthropogenic activity represents an increasingly important factor in the inception and development of landslides and other exogenous geological processes of all kinds. Human activity not only alters the appearance of the Earth's surface, but also causes significant changes in the upper part of the Earth's crust that in scale and consequences can be compared with geological processes. Significant activation of landslides and rockfalls has been known to occur during construction and exploitation of large reservoirs, road building, and other kinds of construction work.

Forms of destruction similar to those caused by construction projects are present in strip mining (enormous excavations on deposits of coal and copper, underground chambers, etc.). More will be said about this in the text to follow. We mention the exhaustibility of geological wealth as one of the most important problems facing mankind. The collapse of geological energy potentials could cause a great break in trends of human development. Pollution of drinking water and degradation of agricultural land are things that could be truly fatal for the human race.

The devaluation of geological wealth caused by urbanization probably occurs much more often than we know, since ore concealed by settlements is later hard to find. In conclusion, we mention dumping grounds of communal and industrial waste, which already result in considerable degradation of the geological environment.

[76] The scale of destruction can be illustrated by the phenomenon of "yellow" rain (snow) in regions of Northern Europe very far away. In just one episode of "yellow" snow, about 50,000 t of dust raised by sandstorms in the Sahara fell on the Scandinavian Peninsula. During the period 1989-1990, occurrences of elevated heavy metal concentrations were observed at Norwegian monitoring stations in episodes involving arrival of air masses from North Africa.

ARTIFICIAL PHYSICAL FIELDS - RISKS AND POSITIVE INFLUENCE

Artificial (Anthropogenic) Electromagnetic Fields

Of extraterrestrial origin, natural electromagnetic fields have different frequencies, behavior, and intensity, and all living beings are completely adapted to them. By way of contrast, artificial fields have greater coherence, a higher level of energy, and more stable frequency and duration. For this reason, they ert stronger influence on the biosphere. On the basis of frequency, electromagnetic fields are divided into electromagnetic fields (if their frequency is greater than commercial frequency - 50 Hz in Europe, 60 Hz in the United States) or electric and magnetic fields (if their frequency is less than the indicated values).

The influence of radio and TV transmitters is most frequently examined. Children are very sensitive to increased electromagnetic (EM) radiation and become irritable, cry, and feel the need to move from the place where they are. It has been established by measuring that horses, dogs, and humans react negatively to places with increased radiation, while cats, bees, and wasps seek out just such places. The sensitivity of organisms to the action of strong fields is attributable to the presence of elementary magnetite (Fe_3O_4) in them. Every living cell has its own EM frequencies and the human brain virates at the same frequency as the Earth. That is why all living beings respond differently to EM radiation. The result of harmful action is manifested in blood vessel shrinkage and greater tissue acidity, which facilitates penetration of heavy metals and microbes. Heavy metals attract EM waves in such a way that changes of cell gene structure occur after a period of several years, which leads to the development of chronic and malignant diseases (J. Kunosic, 2001). Although the organism struggles to re - establish the original state of equilibrium in its cells, defense mechanisms weaken in time and the person sickens.

The consequences include increased mortality from cancer (J. Matousek, 1987) and diseases of the nervous, reproductive, and cardiovascular systems with symptoms such as tachycardia, arrhythmia, reduction of arterial tension accompanied by decrease in voltage of the QRS complex on the ECG, slowing of circulation in veins of the internal organs, decrease of cholinesterase content in the serum, increase of histamine content, and changes of blood composition. These symptoms lead subsequently to headache, sweating, exhaustion, insomnia, dizziness, impaired memory, libido loss, muscle pain, asthma, increased frequency of chromosome aberrations (transmission of gene mutations to the progeny), etc. Also, personnel engaged in maintaining telecommunications and radar systems are prone to the "*microwave syndrome*" (with headaches, nervousness, and back pain reported by 60% of those tested; and conjunctivitis and fatigue by 40%) (D. Backovic, 1998). It should be mentioned here that artificial fields are used in medicine for therapeutic and diagnostic purposes (for electro - stimulation of the brain, heart, or muscles, as well as for destruction of tumors in oncology).

Artificial electric fields are associated with:

- *Electrostatic fields.* Like natural fields, they ert negative (unfavorable), positive (favorable), or neutral influence on the organism. The ideal ratio in living space is 60% negative ions (mainly oxygen ions) and 40% positive ions. Synthetic fibers in the textile industry lead to the disappearance of strong electric fields, which is reflected in worker depression and fatigue, as well as in changes of blood pressure. Artificial materials used in the building industry (synthetic paints and lacquers, artificial flooring, wallpapers, etc.) also affect ion content. These materials absorb negative ions, become charged, and create artificial fields with predominantly positive ions. This results in total weakening of the organism's immunity (R. Terzic, 1998); and
- *Long - distance power lines.* The phenomenon of so - called "*electromagnetic smog*" occurs here. The influence of such smog must not be underestimated and is manifested in various symptoms (disturbances of the central nervous system, insomnia, exhaustion, changes of pulse and blood pressure, etc.). Whereas fields of more than 1000 V/m are formed in the immediate proximity of electrical generators, motors, transformers, and distributive networks, the fields of household installations are in the range of 10 - 100 V/m (V. Stojanovic, 1998).

Artificial magnetic fields are created by industrial activity. In contrast to an electric field, a magnetic field passes easily through house walls, almost all metals, and tissues of the human body. It is a task for geophysicists to establish the existence and characteristics of such fields, on the basis of which they can ascertain any correlation between mortality of the population and artificial fields. According to the standards of Eastern European countries, it is permissible for the human body and head to be exposed to a magnetic field with a strength of 0.03 T and a gradient of 0.05 - 0.2 T/m, while the breasts and hands can be exposed to a field with a strength of 0.07 T and a gradient of 0.1 - 0.2 T/m. Fields in the range of 0.2 - 0.4 mT arise during use of household appliances.

It has also been established that an artificial field of terrestrial origin with a frequency of f = 0.01 - 5 Hz causes increase in frequency of the pulse and changes in the psycho - physiological state of humans (exhaustion above all), while a magnetic field with a frequency of f = 0.2 Hz and variable strength (5×10^5 to 1×10^6 nT) prolongs the reaction time of drivers. It should be noted that in the case of mobile telephones, the depth to which radiation penetrates the human body comprises 10 - 100 mm, whereas penetration is only 1 mm in the case of radar installations (whose frequency is as high as 10 GHz).

It is interesting to note here that researchers during the past 10 years have been intensively conducting experiments in which artificially created vertical geomagnetic field components are used to promote faster germination of the seeds of various cereals and improve their yields (E. Comino et al., 1995).

According to N. Trifunovic (1998), malignant diseases, myocardial infarct, and cerebral accidents (strokes) are caused in part by anomalous increase of the magnetic - electromagnetic (M - EM) field (the sum of the Earth's natural magnetic field and the artificial field consisting of induced and remnant magnetizations) in living and working space. The greater frequency of cancer in industrially developed countries and urban environments is attributed to the influence of electrification and automation in enclosed space (where man spends most of his time), which causes a significant increase in normal values of the M - EM field. Anomalous increases of these fields cause accumulation in tumor tissue of electrophiles (known in medicine to be risk factors, various substances that exist in neoplasms are electrophiles with increased ionic conductivity). In addition to inducing their formation, magnetic fields of anomalously high intensity thereby represent an environment favorable for the development of neoplasms.

Artificial ionizing radiation causes erythema of the skin and dermatitis, atrophy of skin glands, hyperkeratosis, and tumors (Dj. Sofrenovic, 1993).

Artificial non - ionizing radiation arises from different technological sources (B. Vulevic, 2000).

Ultraviolet (UV) radiation is emitted by lamps with inert gases and hydrogen lamps, halogen and fluorescent lamps, and lasers. Most exposed to it are welders, physiotherapists, cosmeticians (including ones who work with quartz lamps), printers, laboratory and medical personnel, etc. The consequences of excessive exposure to this kind of radiation have already been presented in the section of the book dealing with natural UV radiation.

Infrared (IR) radiation is emitted by hot and red - hot sources (industrial furnaces, apparatuses for gas welding, heaters, burner rooms), sources with electric discharge (arc lamps and arc - welding equipment), and lasers. Most exposed to IR radiation are blast furnace workers, workers involved in glass production, paper and cellulose factory workers, and workers employed in the textile, wood, and chemical industries. Physiotherapists are also at considerable risk. Harmful consequences of IR action were described in the chapter on natural IR radiation.

Radiofrequent (RF) radiation comes from modern - day apparatuses used in industry, medicine, research, etc. (TV, radios, radar devices, radio - navigation equipment, radio - telemetric devices, etc.). For this reason, most threatened by the given kind of radiation are persons who work around industrial RF heaters, industrial microwave (MW) furnaces, and installations for microwave and shortwave (SW) diathermia in medicine. Harmful action is registered as effects of overheating, with increase of body temperature, hyperthermia, and burns. The most sensitive are organs with weak circulation and weaker local thermoregulatory mechanisms (the lens of the eye, testes, etc.). Apart from thermal effects, there are also nonthermal ones: action on CNS, changes of the EEG, changes in synthesis and transduction of DNA, and altered flow of Ca ions from the brain cells.

Electromagnetic fields of extremely low frequencies (ELF) are created around aboveground and underground lines of high - tension (more than 35 kV), high - voltage apparatuses and installations, industrial machines and installations that operate on electricity, and electrical devices used in medicine, households, scientific research, etc. Workers who repair and maintain long - distance power lines are exposed to such fields, as are persons who work in or around substations, induction furnaces for smelting of metals, large electromotors, and transformers. Also at risk are installers and electricians who work on medium - and low - voltage circuits, radio and telecommunications installers, electrical engineers, etc.

The population is exposed to electric and magnetic fields of circuit frequencies that arise in the vicinity of transformers or around the electrical circuiting of houses, as well from household electrical appliances and light sources. Particularly threatened are persons who live near substations, long - distance power lines, and generators. The consequences of harmful action of ELF radiation include carcinogenesis, altered reproductive capacity (and disturbances in pregnancy), and neuro - behavioral disorders (electrical hypersensitivity). According to some authors, brain tumors (neuroblasts), leukemia, and breast cancer can occur during exposure to this kind of radiation.

Artificial Radioactive Fields

In America during the 1960's, elevated concentrations of radon were established in apartments built of materials made from the waste of uranium mines, as well as in buildings near dumps of highly radioactive waste. Investigations were initiated on the concentration of radon in enclosed spaces and its harmful action on human health. The pertinent data are presented in Table 4.1. (I. Petrovic, 1998). It was established that strength of the absorbed dose of gamma radiation is on average twice as great indoors as it is outdoors. Also, radiation is more intensive in zones with a colder climate. It is weakened by rain, snow, and increased atmospheric pressure. The concentration of radon is twice as great at night than by day, the minimum occurring at noon.

TABLE 4.1.
Radon concentration in rooms and their harmful effect on health.

Organ of human body	Professional workers		Citizens
	Quaternary	Annually	Annually
Whole body exposed to radiation, sexual glands, marrow	30	50	5
Skin, bones, thyroid gland	150	300	30
Arm, legs, knees	400	750	75
Other organs, tissues	80	150	15

The main sources of radon in enclosed spaces are the soil under and around the building, the materials that went into its construction, and the water used in it. Table 4.2. presents values of specific activity of Ra_{226}, Th_{232}, and K_{40} in different kinds of specially prepared samples of standard building materials.

External radiation of the population and penetration of the food chain occur as a result of contamination of the soil with radionuclides. Monitoring of radiation of both natural and artificial origin is resorted to for the purpose of implementing adequate protective measures.

Unfortunately, construction measures designed to reduce the energy needed to maintain buildings contribute to intensive concentration of radon. For example, measurements conducted in Sweden showed that the concentration of radon inside apartment buildings was as much as 5000 times greater than the level in the outside air. Resulting from energy - saving measures including overuse of thermoinsulation, this is precisely the reason why 14,000 new cases of cancer (primarily lung cancer due to accumulation of radon isotopes) and leukemia are recorded every year in Sweden.

Many human activities tend to strengthen radiation. They include mining (in the case of radon); production of energy from fossil fuels (accumulation and dispersion of radioactive elements with ash); setting off nuclear explosions; operation of nuclear power plants; application of mineral fertilizers (K and U in phosphates); use of radioactive isotopes in industry and medicine; etc.

Artificial Seismic Fields

Artificial seismic fields are formed as a result of chemical and nuclear explosions, mining activity, and seismic research. Their manifestations are the same as in the case of weaker earthquakes, and they have already been studied for some time by investigators in the field of engineering geophysics. Artificial earthquakes are known to have been induced by construction of hydroelectric structures (for example, the Kariba Dam in Central Africa), major chemical accidents, nuclear explosions, mining activity, or seismic research.

Instead of a **conclusion**, it remains only to be noted that the field of *ecological geophysics* constitutes the youngest branch of geophysics, one that began to be considered important only in recent years. The discipline known as sustainable civil engineering has developed rapidly in counterpoint to the kind civil engineering practiced up to now (which has been responsible for great environmental disturbances due to use of extensive land areas, excessive consumption of raw materials and energy, production of large quantities of waste materials, and degradation of the natural environment). For all these considerations, it can be concluded that research in the area of ecological geophysics is capable of making a significant contribution (S. Komatina, 1998). Naturally, this presumes a more elastic (and responsible) approach to problem solving and awareness of the fact that *experts of different profiles must be simultaneously involved in every task if we hope to achieve the goal of sustainable development.*

POLLUTION OF AGRICULTURAL SOIL

Due to the presence of humins and clays, soil can bind very high concentrations of harmful materials or elements. The distribution of elements is itself determined primarily by the ion - altering characteristics of soils, their adsorptive properties, and the presence of independent compounds of certain harmful components. Transport of harmful substances through soil is accomplished mainly by water and partly by air currents (winds) carrying with them dust or aerosols enriched with these substances.

Soil possesses the capacity for biological self - purification: decomposition of fallen detritus and its mineralization occur in the soil. In the final analysis, soil compensates at its own expense for lost mineral substances. If any component important for mineralization processes is lost due to overburdening of the soil, then the mechanisms of its self - purification are inevitably disturbed and complete degradation occurs as a result. Conversely, creation of optimal conditions for self - purification of

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the soil promotes preservation of ecological equilibrium and conditions for the existence of all living organisms, including man.

TABLE 4.2.
Minimal, average and maximal values of Ra_{226}, Th_{232} and K_{40} specific activity in samples of various building materials (G. Pantelic, I. Petrovic, 2000).

Type and number of samples		Minimal activity	Average activity	Maximal activity
Ra_{226}				
Block	6	29.0	50.7	125
Cement	14	6.3	53.2	119
Brick	17	8.5	48.0	167
Gypsum	11	9.1	278	
Granite	83		64.4	213
Stone	26		44.2	236
Lime	11		8.3	17.2
Marble	26		44.7	299
Ash + Slag	6	62.2	194	323
Sand	10	6.8	12.8	25.7
Gravel	6	7.6	10.8	21.3
Th_{232}				
Block	6	9.9	40.2	59.1
Cement	14	1.4	22.6	41.1
Brick	17	8.9	62.0	163
Gypsum	11		13.9	25.6
Granite	83		112	432
Stone	26		56.6	306
Lime	11		1.2	3.8
Marble	26		63.0	297
Ash + Slag	16		53.2	118
Sand	10	6.2	14.9	24.1
Gravel	6	8.6	13.0	18.6
K_{40}				
Block	6	83	411	632
Cement	14	24.9	209	438
Brick	17	100	650	903
Gypsum	11		10.7	27.6
Granite	83	1.3	1058	2067
Stone	26	6.1	746	1616
Lime	11		11.4	28.8
Marble	26		868	1620
Ash + Slag	16	54.3	284	416
Sand	10	100	308	515
Gravel	6	100	259	421

On the other hand, high - intensity food production requires that plants be protected from a number of pests, diseases, and weeds. For this reason, utilization of agricultural soil is today almost unthinkable without the use of *pesticides* (insecticides, fungicides, herbicides, etc.), substances toxic even in small doses[77]. Herbicides have gained widespread application in the process of chemization of agriculture, and their manufacture has increased appreciably throughout the world. Man has even used them as a biological weapon. In one of their aggressions (the aggression against Vietnam), the Americans "succeeded" in completely destroying with the aid of herbicides the rich vegetation and animal life on vast areas of jungle in Vietnam, contaminated the country's soil with them, and threatened the lives of its people. The ecological consequences of this imprudent human action were disastrous, with long - term negative effects.

Contamination of vital food products by pesticides represents an ever - present problem. There have been described in the literature nearly 3 thousand cases of non - professional poisoning occurring after consumption of plants treated with organochlorine and organophosphorus preparations, as well as ones based on arsenic and mercury. Among mercury preparations, fungicides are widely used for seed protection. Their use caused poisoning on a large scale in Iraq at the end of 1971 and beginning of 1972, when 6530 persons were poisoned and 459 died. The clinical picture of this poisoning - which was caused by Mexican seed wheat treated with an organomercury fungicide - was characterized by the following symptoms: paresthesia, ataxia, reduction of coordination, loss of vision to the point of blindness, dysartria, and hearing loss. Similar mass poisoning occurred on a state farm in Ghana in May of 1967.

Tests have shown that among pesticides, such well - known preparations as DDT, tifios, and other organochlorine preparations have the most toxic and dangerous ecological properties. The insecticide properties of DDT were discovered before the Second World War, and enormous amounts (about 4.5 million tons) of this very toxic compound were used over the next two decades on fields, in forests, and even in living space throughout the world. Owing to the fact that it possesses exceptional stability and a remarkable capacity for migration, DDT has been recorded over vast areas of the biosphere: in the organisms of penguins in Antarctica, in seals of Lake Baikal, and even in mother's milk. A known characteristic of DDT is its tendency to accumulate in fatty tissue of the human organism, where it acts as a carcinogenic agent.

Fertilizers applied to agricultural soil contain the following four harmful ingredients: nitrogen compounds (nitrates, nitrites, ammonia, and organic nitrogen), sulfates, chlorides, and phosphates. In addition to the

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[77] Experiments have also demonstrated carcinogenic effects in certain kinds of pesticides.

ingredients listed, heavy metals are also present in fertilizers. A constant increase of nitrate content in both soil and groundwater has been recorded in most agricultural regions over the course of the past quarter century. For example, this is the case with nearly all of Northwest and Western France. Nitrates are undesirable in food and drinking water because they cause decline in the level of hemoglobin in the blood, which is fatal for the progeny. Moreover, they promote formation of carcinogenic nitrosamines, which represent a danger to living organisms at all stages of development. Phosphates in soil bind various microelements, and uranium (one of the most undesirable of pollutants) can also be introduced into soils.

Although the level of *heavy metals* in most agricultural soils is not yet high enough to cause acute problems of toxicity, their heightened presence in certain regions has been increasingly often reflected in mass poisonings of the population. Heavy metals are introduced into agricultural soil in some of the following ways: 1) with chemical protective agents; 2) through application of fertilizers; 3) with waste water (industrial waste water, sewage, and water from livestock farms) used for irrigation purposes; and 4) with emissions from the air. As time passes, pollution of soil by chemical elements is becoming an increasingly pressing problem. This refers primarily to ecologically dangerous elements capable of accumulating in organisms with definite consequences to them, elements such as mercury, arsenic, cadmium, lead, chromium, nickel, zinc, antimony, fluorine, strontium, and some others. Due to their ability to accumulate in the organism, heavy metals can be toxic even in weak doses. For example, arsenic accumulating in the human organism can produce a carcinogenic effect on the skin. Mercury, on the other hand, causes disturbances of the gastro - intestinal tract, nervous disorders, and kidney damage. Heavy metals in soil are treated in greater detail in the book "**Heavy Metals in the Environment**" by D. Bogdanovic, M. Ubavic, and V. Hadzic (1997).

WATER POLLUTION

By pollution of water, we mean deterioration of its quality under the influence of chemical components, heat, or bacteria to an extent that it unfavorably affects (without necessarily creating a threat to human health) water use in everyday life, for agricultural and communal purposes, and in industry. Surface water and water in shallow horizons are most predisposed to pollution. Such water is directly exposed to the unfavorable influence of various anthropogenic factors, above all waste water and contaminated atmospheric water. The question of its protection is therefore especially pressing (M. Komatina, 1990).

The reasons for water pollution are to be found in the intensive urbanization and industrialization that have characterized the last two centuries of development of human society. The main pollutants are industrial waste water and communal sewage; pollutants linked with agriculture; ones arising in mining regions; and petroleum and petroleum products.

Among all groups of pollutants, a leading role can unquestionably be assigned to *industrial waste water*, primarily because of the great quantity of such water and high content of toxic components in it. Dregs of such metals as lead, mercury, cadmium, vanadium, nickel, zinc, cobalt, molybdenum, manganese, etc., on entering water even in insignificant quantities become toxic. Active ions of the compounds of these elements can cause serious damage to the health of persons who drink water containing them. In the United States, for example, more than 100 thousand sectors have been recorded where industrial waste water and communal sewage are disposed of on the Earth's surface, and there are 50 thousand registered dumps of toxic chemical waste, 75% of them being located in regions with important water resources. Industrial waste water is rich in various inorganic and organic compounds. Moreover, it can contain radioactive substances or be hot. Much of this water is highly toxic and highly mineralized. Experience indicates that in cases of larger basins of waste water disposal, the dispersion aureole of pollutants in groundwater can measure tens of square kilometers.

Marked by a number of polluting components (various microorganisms, nitrogen compounds, organic acids, chlorides, etc.), fecal matter represents the basic form of waste in urban centers. However, the presence of bacterial pollutants constitutes the main characteristic of *communal sewage.*

Water pollution in agricultural regions is caused by pesticides, fertilizers, drainage from livestock farms, waste from poultry processing plants, etc. (Fig. 4.1.). Especially dangerous is pollution caused by pesticides, followed by contamination with nitrates and heavy metals from fertilizers. Mineralized water represents a potential pollutant of groundwater on territories with soil improvement.

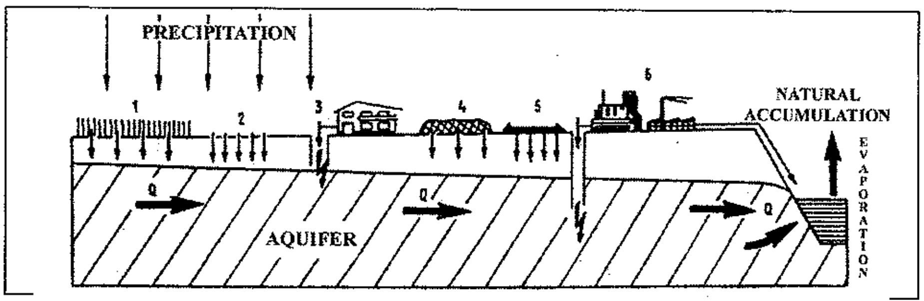

Fig. 4.1. Sources of groundwater contamination caused by agricultural activity. *Fertilizers and pesticides:* 1. during irrigation; 2. during fertilizing; *Waste waters*: 3. Municipal; 4. Industrial; *Disposals*: 5. Hard; 6. Liquid.

Exploitation of *large mineral deposits* often leads to deterioration of water quality on the wider area around mines and strip mines. Large amounts of water are generally evacuated during drainage of the deposit, and this disturbs the regime of groundwater and upsets the hydrochemical equilibrium.

Large foci of pollution by *petroleum and petroleum products* are linked with regions where oil wells and refineries are located. It is estimated that total losses of this liquid form of energy raw material constitute about 2% of world production, which represents a serious threat to underground and surface water. The problem is complicated by disasters occurring during transport of oil, such as happened, for example, in 1967, when about 100 thousand tons of oil leaked into the sea from the tanker Torrey Canyon, completely contaminating beaches on the coasts of England and Normandy and destroying fish life in the region. Not to mention the even greater damage to human health and the natural environment caused by the bombing of Serbian oil refineries and petrochemical installations by the United States and its Western European allies during the spring of 1999.

The listed pollutants cause the following *basic forms of water pollution*: chemical (inorganic and organic), hydrocarbon, biological (bacteriological), radioactive, and thermal. *Chemical pollution* of water is associated primarily with industrial waste water, escape of technological solutions, chemization of agriculture, etc. Such polluted water can have high content of heavy metals, aromatic hydrocarbons, phenols, detergents, cyanide, sulfates, chlorides, phosphates, etc. *Hydrocarbon pollution* is characterized by increased content of petroleum hydrocarbons of varying composition, which become very toxic as soon as their content exceeds the limits of perceptible smell and taste. *Biological (bacteriological) pollution* is caused by various organisms: viruses, bacteria, algae, etc. The most dangerous consequences (epidemics) are caused by pathogenic bacteria and viruses[78]. *Radioactive pollution* occurs when uranium, radium, strontium, cesium, tritium, or some other radioactive elements enter the atmosphere and reach the Earth's surface after nuclear tests or with certain kinds of industrial waste. *Heat (thermal) pollution* is manifested in a change of temperature under the influence of technogenic factors, for example during evacuation of water from thermoelectric power plants.

From the standpoint of influence, it is significant whether the introduced pollution is:

- *biodegradable,*
- *bioresistant,* or
- *toxic.*

When it enters water, *biodegradable pollution* undergoes intensive processes of biological decomposition, the strongest action here being erted by microorganisms. *Bioresistant pollution* in principle presents less of a problem if it is biologically inactive, inert inorganic material forming sludge that is a suitable environment for creation of benthos and development of biological processes in it. *Toxic pollution* of inorganic (heavy metals)

[78]Pathogenic bacteria transported by water are one of the main causes of illness and death in many countries, especially developing ones.

or organic (pesticides, etc.) nature represents the most harmful kind of bioresistant pollution.

The risk to health from harmful and dangerous chemical substances present in drinking water is most often defined as the probability that an adverse effect on health will appear after exposure to such substances. Depending on their effects on health, chemical polluting substances are divided into ones that are:

- *toxic (acute and chronic),*
- *carcinogenic,*
- *teratogenic,* and
- *mutagenic.*

Metabolic processes transpire mainly in the liver and to some extent in the spleen and kidneys, but the bulk of toxic substances are deposited in the bones.

In the matter of transport and interaction of microelements (especially heavy metals), *river courses* represent the most complex aquatic systems. We take the Rhein in the 1970's as an example of the extent to which a river can be overburdened with such elements. As a result of chemization of agriculture, this river received annually about 800 kg of mercury, 30,000 kg of arsenic, and 900 kg of herbicides. With waste water of industrial concerns on its banks, the river took in 11,000 t of zinc, 2,000 t of chromium, 1,400 t of copper, 1,850 t of iron, 500 t of nickel, 2.2 million t of sulfates, 400 thousand t of nitrates, 1,200 t of chromic acid, and 200 t of cadmium. Navigation also contributed to heavy pollution of the river, which received about 75 thousand t of petroleum and petroleum products annually.

In comparison with rivers, the degree of pollution of *groundwater* - which in many regions represents the only source of drinking water - is appreciably lower. That this is the case is primarily due to its better natural protection. For example, artesian water - bearing horizons are generally well protected from sources of pollution because they are covered by a thick clay overlayer. In the case of an alluvial medium, apart from possible lateral influence of a polluted surface stream, sectors with a thin clay overlayer can be directly threatened from the surface. A karst water - bearing medium is undoubtedly the most sensitive because the risk of infiltration of pollutants through ponors and karst collectors is ever present, while the capacity for self - purification is perceptibly lower due to the great speed of underground currents.

AIR POLLUTION

From the time of the Industrial Revolution to the present day, air in the vicinity of settlements, industrial concerns, and mining basins has differed to a constantly growing extent from air of the natural environment. To be specific, the atmospheric envelope in the indicated places is increasingly becoming a dump for the products of combustion of all kinds of coals, oil, and oil derivatives, as well as for many synthetic and other compounds evaporated into the air. According to certain data, 240 billion tons of the *gas of life* was destroyed in the past 100 years, in exchange for which the atmosphere received 360 billion tons of toxic carbon dioxide, 53 million tons of nitric oxide, 200 - 250 million tons of dust, and 120 million tons of ash. In this way, life in many cities has for decades been growing less and less bearable.

We call to mind the smog that engulfed London from the 5th to 9th of December in 1952, when the hospitals overflowed with patients suffering from respiratory and cardiac ailments and there were 4 thousand deaths, which was not the only time something like this happened in the city. Or Los Angeles, also a *city of smog*, where the incidence of lung cancer increased by 40% in areas with high content of carcinogenic hydrocarbons (20% in other parts of town). Later, the center of smog - induced catastrophes shifted to the densely populated industrial regions of Japan, where disastrous situations occurred in 1968 in Osaka and in 1970 in Tokyo.

Skipping over global changes, we note that the biological effect of air pollution can be local or regional. In the case of *local action*, the quantity of toxic ingredients is such that it causes rapid local sickening of the respiratory pathways and lungs. Thus, for example, dangerous poisoning by SO_2 from an industrial concern occurred in 817 citizens of Yokohama (Japan) in January of 1972. A *regional effect* is manifested, for example, on the territory of England, where mortality from chronic bronchitis - which comprises 30 thousand deaths a year - exceeds the mortality from tuberculosis and lung cancer combined and is ten times higher than in agricultural countries.

According to the data of H. Heimann, about 1.5 million t of SO_2 enters the air every year from burning of 32 million tons of coal in New York alone. This results in an increase in the incidence not only of bronchitis and other lung ailments, but of heart diseases as well[79]. The extent of air pollution with hydrogen sulfide is high in a good many cities of the USA

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[79] The biological consequences of pollution are also very evident in the case of plant life. It has been demonstrated that the process of pollution, even at low concentrations of SO_2, can lead to serious physiological changes in plants. Apart from its harmful effect on vegetation, sulfur dioxide erts destructive influence on stone and concrete buildings, as well as cultural and historical monuments.

and Europe, while air pollution with SO_2 (*acid rain*) leads to increase in acidity of the soil.

With the development of *metallurgy*, a number of problems have arisen in the area of air hygiene. In the process of ore processing, dust rich in metal particles enters the air as a side product. As a result of both its quantity and quality, such dust can cause lasting deterioration of health due to its direct influence on the organs of respiration. In non - ferrous metallurgy, for example, dust from copper smelteries is the most dangerous, since extremely poisonous volatile substances can be formed from released elements under the influence of atmospheric humidity. The situation is similar in regions with lead and zinc smelteries.

The majority of undesirable ingredients act on the process of metabolism. Some of them enter the bloodstream through the lungs and become involved in metabolism in that way. Others (mainly ionizing radiation) do this without going through the lungs. A negative effect also results from the fact that a *cap* of dust and smoke over cities retains the biologically most useful ultraviolet rays, which can lead to various metabolic disturbances and the onset of sickness (for example, D avitaminosis). Toxic substances entering the organism through the lungs and bloodstream can cause serious metabolic disturbances more dangerous than when they are introduced with food because they bypass the liver, in which initial detoxication takes place.

Automobile traffic represents the main source of harmful emissions in developed countries today. It is estimated that in the United States at the beginning of the 1980's, 94 million tons of carbon monoxide entered the air, three fourths of it having been produced by automobile traffic. This presents a special danger to children and the sick (persons suffering from insufficient circulation of blood in the brain or myocardial infarct, as well as patients with enhanced thyroid function and anemia). Unfortunately, exhaust fumes contain increasing amounts of carcinogenic 3 - 4 benzopyrene. This accounts for the direct relationship between increase of lung cancer in inhabitants of large cities and growth of automobile traffic, which has been demonstrated by a number of investigators (T. Bakacs, 1977). Of elements present in the air, molybdenum, arsenic, zinc, vanadium, and cadmium contribute to the occurrence lung cancer in males and bronchitis in persons of both ses. In many countries, a special problem is presented by high concentrations of lead (from high - octane gasoline), and investigators have established increase in the amount of this metal to harmful levels in the blood of urban drivers. According to B. P. Dark (1970), the content of lead in tissues and organs of Americans was elevated 120 - fold.

Radioactive air pollution will be discussed later in the text.

ARTIFICIAL RADIOACTIVE POLLUTION

The first diseases that that we know today were caused by radioactive radiation were lung diseases. They were caused by internal sources of radiation, radioactive substances that people introduced by inhaling radioactive dust. To be specific, data from the year 1500 indicate that a large number of miners in a European mine died from a then unknown lung disease. At the beginning of the last century, it was concluded that they died of lung cancer: the cancer was caused by radiation of uranium and products of its decay that the miners inhaled while extracting cobalt ore (P. Bojovic, 1981).

The modern *atomic era*, meanwhile, has been marked by the sudden mass appearance of various anthropogenic sources of radiation. We now have nuclear weapons, various nuclear installations, radioactive isotopes, nuclear machines in laboratories and clinics, and along with them radiation accidents of greater and smaller dimensions that have increasingly affected man, animals, and plants.

Contamination of the environment by radioactive materials has become one of the most significant problems of modern civilization. The technological revolution brought about by application of nuclear energy for peaceful purposes is indisputably leading to increase in radioactive contamination of the biosphere, in spite of great advances in the matter of environment protection that have been made in this field. The dangers of nuclear weapons use and accidents occurring at nuclear installations make this problem even more pressing.

Artificial (fabricated) radionuclides enter the biosphere for the most part in the following three ways:

- As a consequence of radioactive fallout after experimental nuclear explosions;
- Through escape of radioactive substances due to breakdown of nuclear reactors or other nuclear installations; and
- Due to use of radioactive isotopes for medical, technological, and other purposes.

Regarded from the radioecological standpoint, *radioactive fallout* must be considered the most significant form of contamination of the biosphere, since it is rapidly dispersed over extremely great areas of our planet following nuclear explosions.

The first mass pollution of the atmosphere occurred in 1945 at the time of the atomic bombings of Hiroshima and Nagasaki in Japan, which caused radiation sickness on a large scale (with severe immediate or chronic consequences). Nuclear tests have been performed without interruption from 1945 to the present day. Altogether, 1,418 tests of nuclear weapons were carried out during the period of 1945 - 1983, the culmination occurring in 1961 - 1962 (Fig. 4.2.). The given tests released enormous quantities of fission products into the biosphere. Still, the share of radioactive fallout in overall irradiation of the population has declined since 1962, when nuclear explosions in the atmosphere were almost completely stopped.

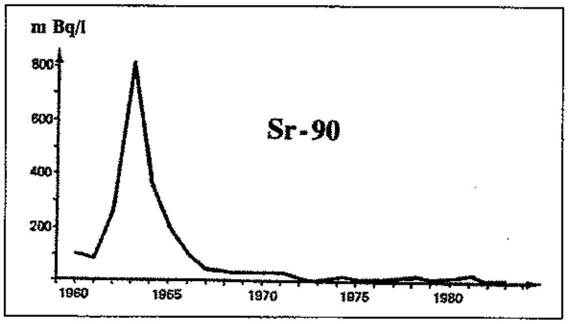

Fig. 4.2. Graph of Sr_{90} local distribution in atmosphere for 1960 - 1985 period (B. Petrovic, R. Mitrovic, 1991).

How great can be the *radiation risk to the population* from breakdowns at nuclear installations for peaceful use of atomic energy is demonstrated by the accident that occurred at the "Lenin" Nuclear Power Plant in Chernobyl (Ukraine) on 26 April 1986. It turned out that released radionuclides can pollute large areas, with consequent accumulation of radionuclides such as I_{131}, Cs_{134}, and Cs_{137} in the biosphere[80]. A great many nuclear accidents of varying degrees of gravity have been recorded to date at nuclear installations throughout the world.

Of the more than 200 radionuclides formed during nuclear fission, Sr_{89}, Sr_{90}, Cs_{134}, Cs_{137}, Cs_{144}, Pu_{239}, Ru_{103}, Ru_{106}, Ba_{140}, I_{131}, and Zn_{65} can be singled out as being biologically significant. We shall dwell on radioactive strontium (Sr_{89} and Sr_{90}), radioactive cesium (Cs_{134} and Cs_{137}), and the iodine radionuclide I_{131}, and the plutonium radionuclide P_{239}. These radionuclides did not exist in nature before atomic tests. During the past half century, they have acquired a special role in the radioactive contamination of drinking water and foods of plant and animal origin.

[80] During operation of a nuclear power plant, about 99% of radioactive material remains in the fuel elements in the form of radioactive waste. The disposal of such accumulated waste and radioactive isotopes formed in laboratories and at medical institutions for the time being presents a problem with no easy solution.

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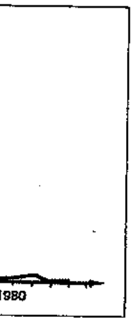

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1. The *radionuclides* Sr_{89} and Sr_{90} have a significant fission return (about 5.5%). Their main biological specificity is that they behave in the organism like calcium, Sr ions being deposited in the bone system. The bones of young individuals bind 5 - 10 times more Sr than do the bones of adults due to the organism's great need for calcium during the period of bone growth, a fact that must be remembered in planning the diet of children. The biological half - life of Sr - 90 in an adult man is 1000 days (spongy tissue) or 1500 days (compact tissue);
2. Unlike Cs_{134}, the *radionuclide* Cs_{137} has a high fission return (about 6.2%) (Fig. 4.3.). The main biological specificity of these two radionuclides is that they behave in the organism like potassium and are found in every cell of the organism. The biological half - life of Cs_{137} is 10 - 70 days in animals (depending on the species of animal) and 10 - 110 days in man (depending on age of the organism);
3. The *radionuclide* I_{131} has a high fission return (about 7%). It enters the organism of humans and animals primarily with lettuce and other vegetables radioactively contaminated by atmospheric precipitation. The physical half - life of I_{131} is 8 days and comprises 80 - 120 days in an adult man. Deposition of I_{131} in the human thyroid gland depends on age of the organism and is greatest in newborn infants;
4. Among *radionuclides of plutonium*, Pu_{239} is best represented in the biosphere, although even it is present in relatively small amounts. However, because it has a very long physical (24,100 years) and biological (200 years in the human skeleton) half - life, the biological significance of this radionuclide is enhanced. On account of their exceptionally strong carcinogenic action, radionuclides of plutonium present one of the greatest threats to survival of man on Earth.

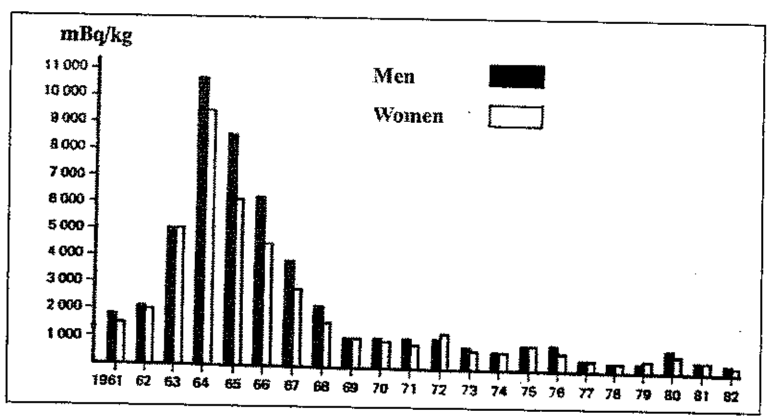

Fig. 4.3. Level of Cs_{137} activity in human beings during 1961 - 1982 periods.

Research on the biological action of ionizing radiation was initiated already during the first decades of the last century, at which time its harmful influence on the human organism was established. Interest in such research grew especially in the 1950's, when nuclear energy started to be used for peaceful purposes in different fields. Together with radiation as a cause of a number of human diseases, accumulation of strontium - 90, cesium - 137, and other newly created isotopes in various minerals, water, soil, animals, and plants was seen to be a problem of great significance in connection with pollution of the Earth's biosphere with radioactive substances. For man, radionuclides in the food chain are especially dangerous. We have in mind here the phenomenon of radionuclide concentration in animal organisms, especially in certain organs and tissues[81]. For example, cows that consume large amounts of contaminated grass concentrate radionuclides in the thyroid gland or in the milk. A similar effect is achieved in fish and shellfish after passage of a large amount of contaminated water through their bodies.

As a result of experiments on animals and study of the consequences of radiation in persons who survived the atomic explosions in Hiroshima and Nagasaki and survivors of nuclear accidents, one - time exposures to lethal doses causing *acute radiation sickness* have been investigated the most thoroughly. Bone - marrow, intestinal, tomic, and cerebral forms of acute radiation sickness can be distinguished, depending on the sensitivity of cells and tissues and the dose of irradiation (D. Markovic, S. Djarmati, I. Grzetic, and D. Veselinovic, 1996). The biological effects of radiation have been treated more extensively by J. Martinovic (1981).

Chronic radiation sickness occurs following multiple or long - term external irradiation or long - term internal irradiation (when radioactive substances are introduced with food or water over a long period of time). Some of the radioactive material entering the organism is eliminated from it, but some of it is absorbed and accumulated in organs and tissues (isotopes of iodine in the thyroid gland, strontium - 90 and radium in the bones). Mucous of the intestines, liver, thyroid gland, and other organs is sensitive to strong irradiation.

Depending on the dose of radiation, effects that do not appear at once, but instead set in some time after irradiation can be: 1) *somatic* (malignant tumors); and 2) *genetic* (birth defects and disturbances that are transmitted to future generations). Moderate and high doses of radiation for the most part induce somatic effects, while low doses induce genetic effects.

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[81] Norwegian investigators in 1988 recorded a level of Cs_{137} activity in venisen of the order of 90,000 Bq/kg (K. Hove and A. Ekern, 1988). The deer fed exclusively on forest vegetation and fruits with a level of contamination considerably higher than that of arable land. In Yugoslavia, activity of the indicated radionuclide in meat of these ruminents comprised something under 100 Bq/kg just after the Chernobil accident (S. Stankovic et al., 1993).

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Pathological changes in different tissues and organs can occur with the passage of time in organisms recovering from acute injuries caused by radiation, as well as after chronic exposure to it. There is not the slightest doubt as to the carcinogenic effect of ionizing radiation. This effect was observed in man already during the first days of radiology and was subsequently confirmed by many examples in humans and by experiments on animals. On the basis of these data, it is believed that radiation can induce any type of cancer.

The occurrence of malignant tumors in different organs and tissues largely depends on the specific ability of a radionuclide to be stored in a certain organ or tissue.

Leucosis occupy an important place in the pathology of tumorous forms with delayed action. Leukemia appears many months after the action of leukomogenic factors, but pre - leukemic cells are found in the bone marrow soon after irradiation. During the period of 1948 - 1950, for example, five times as many people died of leukemia in Hiroshima than in other regions of Japan.

POLLUTION AND DISTURBANCE OF THE ENVIRONMENT CAUSED BY ORE EXPLOITATION AND PROCESSING

Mining stretches back into distant pre - history and already in the Middle Ages constituted part of the foundation of every state. In the course of its long history, mining started with a phase of ore and rock gathering. The technology for exploitation of only rich deposits of metals and non - metals near the surface was developed in the next phase. With accelerated industrialization and far greater needs for energy raw materials in addition to metals and non - metals, the transition was made to strip mining and underground mining on a massive scale (with breaking of ores and accessory rocks). For all practical purposes, it was in this phase that man embarked on massive degradation of the geological environment. The depth of some mines in Africa and India attains 4,000 m, while great strip mines of coal can be more than 1,000 m deep. The enormous "hunger" for more and more inexpensive new raw materials can be illustrated by the fact that 35 to 40 tons of ore and slag per capita is excavated (detached from the geological environment) annually throughout the planet. Of that quantity, only about 2% represents useful material.

Together with the indicated problems caused by disturbance of the geological environment, problems of environmental pollution are equal in rank. Such pollution can be associated with surface processing of coal deposits; the presence of sulfur in ores, coal, and oil; drilling for oil at sea and its transport; fluorine loss at aluminum plants; radioactive waste; etc.

Potentially, any deposit can be a powerful complex source of pollution. The reason for this is that elevated concentrations of a wide assortment of toxic chemical elements are inevitably present in extracted and processed ores, as well as in slag. The complex nature of a deposit as a source of pollution also stems from diversity of the natural environment in which it is found. Negative effects in the form of toxic chemical accumulation can be seen in all vitally important resources: water, air, soil, and food. As numerous data indicate, this produces negative biological reactions in all living organisms, including man (increase in occurrence of general and specific diseases, decline of biological productivity, far - reaching mutagenic consequences, and finally death).

During the course of exploitation and processing of mineral and energy raw materials, the lithosphere, atmosphere, biosphere, and hydrosphere are all disturbed to a greater or lesser extent. In the case of *strip mines*, there are many visible disturbances:

- *Changes in morphological properties of the terrain*;
- *Changes in the rate of exogenous processes* (landslides, rockfalls, gulley erosion in the slag, etc.);
- *Changes in hydrological and hydrogeological properties of the terrain* (patterns of drainage, pollution of surface streams and groundwater, thermal pollution of water, etc.);
- *Changes of flora and fauna* in the case of non - ferrous metallurgy, such changes being noticeable over a radius of up to 100 km (elevated content of trace elements in vegetation, fruits, vegetables, and other agricultural crops, disappearance or migration of plants and animals, etc.);
- *Changes in the atmosphere* (mechanical pollution by different kinds of dust, chemical pollution by gases and fumes, etc.); and
- *Changes in the living and working conditions of man* (decline of work capability, health problems, shortening of life expectancy, etc.).

Operation of *underground mines* is accompanied by terrain subsidence, appearance of cracks, stability problems, and formation of slag on the surface. Very serious problems arise when water is pumped and evacuated from many shafts and abandoned underground chambers, operations that often result in pollution of surface and groundwater. Special problems are presented by the difficult conditions of underground work, with many attending risks (methane formation, pit fires, etc.). Mining is plagued by incurable professional diseases, work injuries, and shortening of the miners' life expectancy.

Strip mining of coal on the territory of Appalachia in the United States transformed a picturesque natural setting into a desert with gaping holes, slag heaps, and infertile barren earth. Masses of materials are thrown out in the process of extraction and refinement of ore. Some of it is washed by rain into rivers, where it has a serious effect on the organic life in them and their water regime. It is an especially difficult task to evacuate polluted mine water without polluting surface and groundwater (A. Allison and D. Palmer, 1980). The situation is similar in many other countries of the world. It is a fact that large strip mines of coal with dumps and installations for its preparation are located near settlements and in flatlands, where they ert additional influence on the environment, especially disturbing agroecosystems and the groundwater regime.

Methods of gasification are being increasingly used in an attempt to resolve the problem of effective exploitation of the world's enormous coal reserves with minimal damage to the environment[82].

Mining basins with exploitation of metallic mineral raw materials and their metalworks are great polluters of air, water, soil, and plant and animal life, above all with numerous toxic elements[83]. For example, the unrestored strip mine on Mt. Kopaonik has become a permanent source of mineral particles rich in heavy metals. Wind action has led to increase in the concentration of heavy metals in the soil, the following levels (mg/kg) having been recorded at Suvo Rudiste (map reference 1,960): Fe, 208,000; Mn, 3700; Cu, 340; Zn, 240; Pb, 210; Cr, 67; and Cd, 2 (Z. Vukmirovic and M. Curic, 1993). In the vicinity of the Trepca lead smeltery near the town of Kosovska Mitrovica - a major source of environmental pollution - the following levels of heavy metals were found in soil (in mg/kg): Pb, 4000 - 7500; Zn, 2000 - 7000; Ni, 4 - 14; and Co, 0.2 - 1.2 (Z. Vukmirovic, 1997). As for metalworks, roasting of ore minerals results in the release of significant amounts of sulfur dioxide, a poisonous gas that has a harmful effect on plants and animals. Fluorine is released in the technological process employed in aluminum plants, and it also erts harmful influence on vegetation, plowed fields, and domestic animals.

The ecological action of *secondary geochemical anomalies* created by man is defined by the levels of chemical elements in living organisms (i.e., biogeochemical linkage in the environment - organism system) and the

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[82] World coal reserves are so great that it can be stated with certainty that man will be able to count on stable production and consumption of coal for the next 200 years. Inasmuch as more than 4 billion tons of this fossil fuel is extracted from the bowels of the Earth every year, it is clear that the use of *clean coal technologies* (*CCT*) needs to be expanded and combined with recultivation of exhausted strip mines in order to protect the environment.

[83] *Transgressive technogenic diseases* of a chemical nature are linked with movement of chemical pollutants of the environment over great distances by means of atmospheric or hydrological circulation (A. P. Avtsin et al., 1983). A classical example of transgressive phenomena in the biosphere is the case of *acid rain*, which is caused by massive emission of sulfur and nitric oxides and other toxic ingredients (including trace elements) into the atmosphere. The sources of pollution are industrial concerns in the United States, England, France, Germany, and other industrially developed countries.

biological consequences of that phenomenon. Research on the biogeochemical and biological consequences of environmental pollution by chemical elements has been carried out with increasing intensity over the past quarter century, mainly through experimental study of the response of living organisms to elevated concentrations of chemical elements entering the organism in various ways (with food, air, or water). These studies have resulted in the discovery of a broad and diversified scale of negative consequences, expressed both in the form of unhealthy reactions specific for a certain chemical element and in the form of reactions of a non - specific nature, when the action of elements contributes to increase in the frequency of deviations from normal physiological development of the organism or increase of overall illness (Fig. 4.4.). This is illustrated by the following examples:

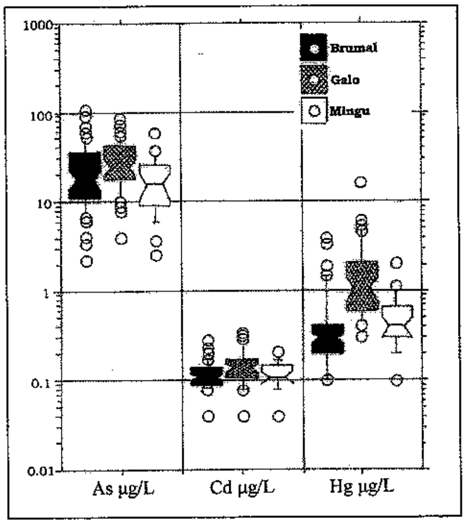

Fig. 4.4. Concentration of arsenic, cadmium and mercury in children urine in settlements: Brumal, Galo and Mingu (J. Matschullat et al., 2000).

1. First registered in the middle of the 20th Century, the widely known *Minamata sickness (mercuriosis)* was caused by water pollution with industrial waste water rich in mercury. The clinical picture of poisoning of many persons was complex, with significant morphological changes in the central nervous system (Keller, Shchepin, and Chaklin, 1993);
2. Also recorded for the first time in Japan during the 1950's, *itai - itai disease* resulted from increased intake of cadmium into the organism with rice. The rice fields responsible were irrigated from a river that received cadmium from a nearby mine. This disease basically involves specific affliction of the kidneys (*cadmium nephropathy*) and is characterized by severe damage to the skeleton;

3. Gold fever is especially present in Amazonia, where about million gold rinsers handle mercury in order to separate the precious metal. The local population was confronted with a serious threat of intoxication in this way. Investigations showed that the average level of mercury as a poison was equal to that recorded in developed countries with high consumption of fish (Japan, Australia, and the West Coast of the United States). For example, analysis of skin of the inhabitants established that mercury content was highest (6.6 µg/g) in Amero Indians, and in one village the poison was found in more than 80% of children and 60% of adults. A similar situation prevails in Guyana;
4. According to E.B. Davies (1983), there are numerous data indicating that a correlation exists between the distribution of lead in soil and the incidence of *atherosclerosis* and *caries* in regions with polymetal mines. Moreover, near the dump of an old mine in West Wales (with the following levels of metals in soils, in mg/kg: lead, 1,760 - 14,910; copper, 32 - 42; and cadmium, 1.4 - 2.9), animals died of lead poisoning, and elevated Pb content was recorded in the blood of children;
5. Increasingly present problems of *industrial berylliosis* have been found to cause mass sickness among workers and also affect children in neighboring houses. It is most often manifested in the form of lung sickness, for which no specific methods of treatment have been discovered to date.

Thermal electric power plants and *installations for coke production* as a rule are heavy polluters of air, water, and soil. They are above all the greatest anthropogenic sources of heavy metals. The most negative consequences arise due to simultaneous emission of oxides of sulfur and nitrogen, which in the presence of atmospheric water vapor are transformed into strong acids. For example, soil acidity caused by the smoke from many coke furnaces using coal with high sulfur content destroyed vegetation and intensified gulley erosion on hill slopes in the state of Pennsylvania in the United States (A.D. Howard and I. Remson, 1978). Together with pollution of the atmosphere by smoke fumes, surface and groundwaters are also contaminated. Thus, in the neighborhood of Yugoslav thermal electric power plants that use brown coal containing a series of dangerous elements, from 12 to 14% of the primary mass of coal remains in the form of ash following combustion. With the exception of mercury, some of the arsenic and cadmium, etc., the majority of elements remain in the solid phase (in ash and smoke sediment). It was established by S. Matic et al. (1993) that smoke sediment from the Morava thermal electric power plant near the town of Svilajnac contains the following elements (in mg/kg): Cr, 48.7; Mn, 497, Fe, 69,700; Co, 7.5; Ni, 43.6; Cu, 65.2; As, 39.0; Cd, 2.0; and Pb, 59.0. Ash in the firebox itself was estimated to contain 4.7 to 10.9 mg/kg of uranium (soluble in water).

COMPLEX HARMFUL INFLUENCES OF URBANIZATION ON THE NATURAL ENVIRONMENT

The first alarming signs of environmental pollution coincide with the process of urbanization, which is with the Industrial Revolution. Although the first cities were founded in Mesopotamia 5 - 6 thousand years ago, there was no urbanization on a more significant scale in any country of the world until the middle of the 19th Century. Thus, for example, in 1800 only 2.4% of the population lived in cities, and only four cities had a population of more than a million. There were 19 such cities at the beginning of the 20th Century and 141 in 1965. By the end of the year 2000, more than half of the world's population lived in urban environments. City dwellers today constitute 90% of the total population in Holland, Belgium, the Ruhr, Silesia, etc., and we are witness to the formation of enormous cities - megapolises - in a number of industrially developed countries.

Limited space with constant growth in the number of inhabitants per unit of area and consequent increase in the amount of communal waste has contributed to ever greater pollution of the environment. On entering the environment, waste participates in biological circulation, weakens the capacity for self - purification, and causes breakdown of ecological equilibrium. The soil loses its capacity for self - purification, and the biological value of groundwater deteriorates. Polluted drinking water in cities became a source of serious intestinal diseases in the past, with the result that inadequate communal hygiene in Europe at the end of the 18th Century gave rise to the famous era of great destructive epidemics (typhus, plague, smallpox, and - at the beginning of the 19th Century - cholera as well) (T. Bakacs, 1980).

Industrialization was a significant factor in stimulating the rate of environmental pollution in the 19th Century. Pollution of the environment took on a new character: whereas it had previously been a local phenomenon, pollution by toxic substances and various end products came to be present on an alarming scale with the development of industry[84]. The amount of atmospheric dust is hundreds of times greater and that of exhaust fumes 5 to 25 times greater in cities than in the country. Atmospheric pollution in cities absorbs about 20% of sunlight and more than

[84] Increase in the rate of industrialization, development of new technological processes, and improvement of the standard of living have caused rapid growth in the amount of industrial and communal waste. The task of sanitary and controlled waste disposal has thereby become a major problem, and waste control is now an imperative of the modern world. It should be noted that environmental concerns were also characteristic of pre-Christian history. Of great interest here is the city dump that existed in the Sumerian city of Ur (about 2500 B.C.). This dump is a treasury of significant finds that enable us to trace the city's development and history over the course of three centuries.

50% when the sun is low in the sky. All of this affects public health by increasing the number of respiratory, cardiovascular, malignant, and other diseases.

The number of diseases increases precipitously in times of smog. Automobile exhaust fumes are the main cause of an especially dangerous type of smog, so - called *photochemical* or *Los Angeles* smog[85]. On the streets of Paris alone, more than 1.3 million automobiles move daily on an area of 105 km^2. More than 4 million automobiles in Los Angeles release about 1100 t of nitric oxide, the concentration of ozone is 100 - 200 times greater than in clean air, various organic compounds are formed (toxic formaldehydes and organic peroxides), and several hundred chemical compounds enter the air. Generally speaking, air takes on an unpleasant smell during photochemical smog, visibility worsens, the mucousa in humans is irritated, and the condition of sufferers from lung and other diseases deteriorates. Domestic animals and plants also suffer.

The constant *street noise* of city traffic has a harmful effect on hearing. Moreover, noise causes tension, a feeling of fear, and insomnia. It also frequently contributes to serious disorders of the nervous system, somatic changes, and stress - linked diseases such as hypertension, impaired secretory work of the stomach and intestines, hormonal disturbances (diabetes for instance), etc. (T. Bakacs, 1980). The following pathological states (after Bakacs) can arise due to strong stress influences:

- Gastritises and enteritises, gastric and duodenal ulcers;
- Cardiovascular diseases, including coronary disease and hypertension;
- Diabetes and certain other metabolic diseases of hormonal etiology, disturbances of thyroid function, etc.;
- General irritability and nervousness, all the way to mental illness.

Apart from noise, constant and ever growing nervous tension (caused by the fast pace of life) and industrial and traffic - induced air pollution represent important pathogenic and etiological factors characteristic of large cities. A typical disease of urban areas is hypertension, in whose pathogenesis nervous strain plays a significant part. In addition, stress factors are increasingly blamed for the incidence of coronary illnesses, which among members of certain professions (intellectual workers, doctors, managers, etc.) have acquired the nature of professional diseases.

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[85] Growth of traffic has caused an enormous increase in the number of road accidents. According to data from the late 1980's, the total number of persons injured in traffic accidents in West Germany attained an average of 1.7 million annually. In countries with more highly developed automobile and rail traffic, road accidents ranked third to fourth among all causes of death and first in the case of children up to five years old.

We note in conclusion other professional diseases (according to A. P. Avtsin, 1972):

- Cancer of the urinary bladder in workers who come into contact with products of aniline and hydroquinones;
- Cancer of the respiratory pathways in employees of electrolysis works and persons involved in production of nickel, such cancer being characterized by long - term development; and
- Cancer among chimney sweeps in England.

CONSEQUENCES OF THE ACTION OF POLLUTANTS ON MAN

As we have seen, anthropogenic influence on living organisms - humans, animals, and plants - is diverse and for the most part entails negative consequences. The following key consequences of pollutant action are singled out in the book "**Physico - chemical Basis of Environment Protection**" (D. Markovic et al., 1996):

- Threat to life on the Planet, probably enhanced by possible decrease of oxygen in the atmosphere;
- Threat to the survival of individual species of living organisms and indirectly to that of other organisms dependent on them;
- Genetic changes of living species, especially man, that can lead to his demise as an intelligent and the currently reigning species;
- Hindering of the existence and threat to the survival of individuals and the groups to which they belong; and
- Direct and rapid negative action on individuals or narrower groupations.

All of the indicated consequences are a result of the combination of a large number of greater or smaller changes on the Earth that have acted to disturb the unity of organisms and the environment.

The action of chemical pollutants depends on a number of factors such as *physico - chemical and toxicological characteristics, particle size, concentration, time of action (exposure), and the manner of entry into the organism.* Where the human organism is concerned, such action can be classified as *irritating, fibrogenic, allergic, dermal, toxic, mutagenic, carcinogenic, and embryotoxic.*

- Many substances irritate the eyes, nose, upper respiratory pathways, lungs, or skin, and their action can be expressed in varying degrees;
- Many forms of dust (coal dust, asbestos dust) cause fibrosis, the advance of which leads to pneumoconiosis, a serious disease that every year kills several thousand people throughout the world;

- A polluted environment contains many allergens that are taken into the organism by breathing, with food products, or through contact;
- Skin diseases can be caused by a whole series of substances such as acids or bases, solvents, or detergents;
- Entry of poisons into the organism causes poisoning (intoxication) with possible acute, subacute, and chronic forms of action;
- Mutations are chemical (molecular) changes of genes that are inherited (passed on to the next generation), and a whole series of more conspicuous mutations are known today to have occurred in plants, animals, and man;
- Two kinds of agents ert carcinogenic action: *endogenous carcinogens* (certain hormones, vitamin D_2, cholesterol, and bile acids); and *exogenous carcinogens* (chemical substances; physical agents; ionizing and non - ionizing radiation; biological agents such as viruses, bacteria, and parasites; and combinations of the indicated carcinogens);
- During pregnancy, chemical substances can cause various disturbances in development of the fetus, two types of effects - *teratogenic* and *embryotoxic* - being distinguished here.

In order to prevent or suppress the harm done by chemical agents on living organisms, it is necessary to have a closer knowledge of the modes and mechanisms of unfavorable action and ascertain the connection between the amount and concentration of a substance and the adverse effects it produces[86]. Some mechanisms of harmful action are considered below.

Mechanisms of Toxic Action. Classical toxicology deals with the effects of chemicals on humans and domestic animals under conditions of their direct exposure. Experiments have shown that poisoning requires interaction between poisons and the organism, i.e., their entry into the organism, poisoning occurring only when the dose of a harmful substance attains a value at which deleterious effects appear. Depending on the amount of a given substance, it can be indifferent, medicinal, or poisonous in its action on the organism. For example, the well - known poison arsenic is used as a medicine in small doses, while many medicines become poisons with a significant increase of dose.

Poisons enter the organism by means of inhalation and ingestion or through the skin. On penetrating a living cell, poisons alter physico - chemical characteristics of the cytoplasm, destroy the membranes of organelles, change the reaction of the cell medium, and disturb the conditions needed for normal functioning of cell proteins. Enzymes - cell biocatalysts - are especially sensitive to the action of poi-

[86] *Risk estimation* is a basic element in the complex plan of human health protection on an area under examination. This involves estimation of influence erted by environmental health factors (factors classed as very significant and most significant from the standpoint of health). Estimation of the level of morbidity and mortality under the influence of anthropogenic factors is carried out according to the concept of *environmental health impact assessment (EHIA)*.

sons. Poisoning of some enzyme that takes part in an important metabolic process in the final analysis has a lethal outcome. Poisons act as enzyme inhibitors, either *general* (salts of heavy metals such as Ag, Cu, Hg, and Pb) or *specific* (cyanides, H_2S, sulfides, azides, and CO, which act on metals).

Entry of a poison into the organism evokes defensive responses that attempt to limit the poison's toxic action. Such responses include elimination of the foreign substance in unchanged form from the organism; deposition (storage) of the foreign substance in tissues of the organism; and decomposition of the poison to simpler substances that are eliminated or involved in general processes of metabolism. The most widespread response of every organism to an introduced foreign substance is its decomposition, processes of biotransformation occurring primarily in the liver, but also in the gastro - intestinal tract, kidneys, and fatty tissue.

Ecotoxic Action. When a chemical substance causes damage to the ecosystem, we say that it erts ecotoxic action. A chemical can alter the total quantity of living organisms (biomass) of the ecosystem or change the ratio of individual elements of biomass. Bioinhibitory action (resulting in decline of reproduction and growth and increase of mortality) and biostimulatory action (eutrophication) can be equally harmful to the ecosystem. In ecotoxicology, any action that introduces changes in functioning and structure of the ecosystem is important.

In estimating the relationship between the real concentration of a pollutant and its effect, we need to take into account the substance's chemical persistence, mobility, and bioconcentration (bioaccumulation). Persistence refers to long - term retention of toxic substances in the environment. Here it is very important to establish whether the substance remains in its original form or undergoes processes of degradation. Degradation of a substance in the environment can be accomplished chemically, photochemically, and biologically, usually with formation of inorganic substances as end products. It should be stressed that there are a large number of compounds which retain unaltered high toxicity over a longer period of time (compounds of heavy metals and metalloids, certain organic compounds).

Combined Action of Pollutants. Inasmuch as the environment simultaneously houses pollutants of very complex composition with different mechanisms of action, the combined action of such substances represents a central problem of ecotoxicology. The problem is complicated by their combination with climatic, biological, and geological factors.

Depending on whether the effect is strengthened or weakened during simultaneous action of poisons, the concepts of *synergism* and *antagonism* were introduced at an early stage in study of the combined action of toxic substances. More recently, the term synergism has been used to express the state where the effect of combined action of toxic substances surpasses the sum of effects of each individual poison. The term additive action is used if the given effect is equal to this sum, while antagonism refers to the case where it is weaker than it.

Natural factors that act in combination with harmful substances include the following:

- *High air temperature*, which usually accelerates development of the toxic process and increases sensitivity of the organism to the action of toxic substances, while toxic substances lower resistance of the organism to overheating;

- *High atmospheric humidity*, which significantly alters the irritating and general toxic action of substances that are readily hydrolyzed; and
- *Reduced air temperature*, which strengthens the toxic action of pollutants, a circumstance attributable to alteration of conditioned refles and disturbance of the body's thermoregulation.

Basic Mechanisms of Mutagenesis. Man is subject to the same laws of inheritance as every other organism on Earth, and mutations can arise in him also. Thus, it is known that 46 chromosomes are found in the nucleus of cells of a normal man, although there are individuals with 47. Such people have organic damage and are usually characterized by reduced mental capacity. According to data of the World Health Organization, 20% of childhood diseases and 15 - 20% of deaths among children are linked with birth defects (physical, mental, and psychic) resulting from somatic or generative (germinal) mutations, i.e., damage to genetic material.

Numerous data indicate that the genetic material of man has recently undergone increasing damage, the number of harmful mutations in the human population growing at an ever faster rate. According to data presented at a meeting of the Soviet Academy of Sciences in 1989, the genetic danger to humanity is rising and becoming alarming. It is believed that genetic processes in somatic cells cause (among other things) malignant tumors, which are responsible for the deaths of a fifth of the population. If the rate of gene mutations under the influence of environmental pollution continues to increase, the biological consequences to man will be catastrophic when the frequency of mutations is doubled.

Research results show that many chemical pollutants are harmful agents, since they affect gene structure and function and cause somatic and generative mutations. Cancer, autoimmune aggressions, degenerative diseases (physical, mental, and psychic), accelerated aging, etc., are held to be caused by somatic mutations, while various congenital diseases, many birth defects, and early fetal death are believed to result from generative mutations.

Causes of Malignant Diseases. Professional cancer has been known since 1775, when P. Pott described cancer of the scrotum in young chimney sweeps that pulled themselves through factory chimneys in order to clean them more thoroughly and thereby came into direct contact with considerable amounts of soot. Although many similar cases were recorded subsequently, it was only in 1933 that benzo(a)pyrene was identified as the most significant carcinogenic component in soot. Cancer in Scottish miners employed in exploitation of oil shales was described by A. Scott, while cancer of the urinary bladder was recorded in 1895 among workers employed in the chemical industry in Germany.

According to data of the World Heath Organization, environmental pollutants are the cause of more than 70% of cancers in humans. A direct dependence has been established with certainty for lung cancer, which occurs more frequently in the inhabitants of polluted cities than in country dwellers. Also, changes of benzo(a)pyrene concentration in the air always affect mortality from lung cancer.

The number of carcinogenic substances is relatively great, although there are no precise data as to the final figure. The list of carcinogens published by the International Agency for Research on Cancer (IARC) includes 783 substances.

Chemical carcinogens are divided into two groups, *inorganic* (certain heavy metals and their compounds, minerals, and radionuclides) and *organic* (polycyclic aromatic hydrocarbons, alkylating agents, aromatic nitrogen compounds, and various other organic compounds). The greatest number of chemical carcinogens belongs to the group of polycyclic aromatic hydrocarbons, which induce tumors locally after one month to two years. A second significant group is composed of alkylating compounds (ethylene, ethylmethane sulfate), which unite readily with proteins, DNA, and RNA, causing changes in their composition that alter genetic material of the chromosomes.

ROLE OF ECOLOGICAL MINERAL SUBSTANCES IN ENVIRONMENT PROTECTION

Many mineral raw materials and rocks in general - in the raw state or after a certain degree of processing - play a significant part in environment protection. For this reason, such raw materials can be called ecological raw materials.

Most significant from the standpoint of environment protection are various non - metals: zeolites, different kinds of clays and silicates, glauconites, granites, serpentinites, dolomites, limestones (lime) and marbles, etc. They are being increasingly used as natural sorbents to remove suspended particles or dissolved substances from industrial waste water (a major pollutant of water resources and soil) and for other purposes. Based on the paper of R. Tomanec, D. Milovanovic, and D. Vucinic (2001), a brief survey of the uses of such raw materials is given below.

Among different kinds of clays, it is possible to single out bentonite clays, kaolinite, palygorskite clays, and sepiolite. Use of *bentonite clays* is based on the fact that they possess a high capacity for cation exchange and can be effectively employed for selective adsorption of certain ions of heavy metals (Cu, Zn, Ni, and Cd for instance) from waste (contaminated) water. They are also used to remove alkaloids and insecticides from fruit extracts, in production of fodder for livestock, in recultivation of degraded soils, etc. More effective as an anion exchanger, *kaolinite* is also used for purification of water. *Palygorskite clays* are used for melioration and improvement of the structure of sandy soils, as an excellent adsorbent in the oil and gas industry, as a fixative of lead accumulated in soil near highways, etc. A complex mixture composed of several minerals - bentonite, zeolite, perlite, and vermiculite - in addition to water - soluble fluorides is used to remove a whole spectrum of heavy metals present in solutions for preparation of mineral raw materials or in mine waters.

Employed in practice for a long time now, *quartz sand* is one of the mineral raw materials used most frequently for relatively inexpensive filtration of water. Of siliceous sedimentary rocks, we mention *diatomite*, *opoka*, and *trepele*, which are excellent adsorbents and substances for filtration. Diatomite is also used to remove radioactive isotopes from contaminated soil, as a carrier of microelements, for improvement of soil quality, etc.

Zeolites constitute an extremely important group of ecological mineral raw materials, since they possess the capacity for ion exchange and exhibit adsorptive characteristics. They are used in many ways: in treatment of relatively low - radioactive waste and contaminated water; to remove heavy metals from waste; to eliminate Fe, Mn, and Sr from groundwater; for recultivation of soil; etc.

Vermiculites are being employed to an increasing extent in the field of environment protection. They have been used to neutralize Cs_{137} of radioactive waste water; to remove heavy metals (Pb, Zn, Cu, and Cd) and ammonium ions from surface water; and as the bed of different filters for purification of mine, industrial, and other kinds of contaminated water.

Owing to its adsorptive properties and ion - exchange capacity, *glauconite* (glauconitic sand) has many applications in the domain of environment protection. When covered with a layer of glauconitic sand 0.5 m thick, recultivated soils in areas of abandoned strip mines give a very high yield of various crops. Other possible applications are for purification of radioactive and other waste water; to improve soil quality (through improvement of aeration, maintenance of soil humidity, and adsorption of pesticides from the soil); to increase the bioproductivity of aquatic basins (by stimulating accumulation of phytoplankton and increasing the productivity of fish in them); etc.

Serpentinites represent a cheap and widely disseminated mineral raw material. In the first place, finely ground serpentinite is extremely useful as an adsorbent of anion collectors such as xanthates and oleates (which are very frequent and dangerous pollutants of river courses in zones with industrial installations for preparation of mineral raw materials). It can also be used for purification of mine water, etc.

It is felt that *garnets* will have a significant role to play in the field of water purification in the near future.

Transformed into MgO, *magnesite* represents a very useful product in treatment of contaminated water of different origin (for removal of heavy metals from dilute solutions and elimination of algae, organic substances, phosphorus and ammonia, boron, and other pollutants).

As the main product of limestone, *lime* is used in many areas of environment protection: for treatment of drinking water, wastes, and sludge; to neutralize certain kinds of industrial waste; and for desulphurization of gases from thermal electric power plants. Use of lime in the form of calcium oxide in farming for calcification of agricultural soil is today practiced on a scale smaller than might be expected.

Due to limitation of space, it is impossible to present other ecological mineral raw materials such as *barite*, *gypsum*, and *peat* (useful for blotting of waste water from livestock farms, as an adsorbent in the case of water and soil polluted by petroleum and petroleum derivatives, etc.), *peat vivianite*, *tremolite* (a substitute for asbestos), *dawsonite*, etc.

The wide range of possible uses of ecological mineral raw materials or repair of degraded land or environment protection has not yet received the attention it deserves.