Sergey Govorushko

Human Impact on the Environment

An Illustrated World Atlas

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ISBN 978-3-319-24955-1 ISBN 978-3-319-24957-5 (eBook)
DOI 10.1007/978-3-319-24957-5

Library of Congress Control Number: 2015951778

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

This book has a dual purpose. On the one hand, it is a *geographic atlas*, a collection of geographical maps united by a common theme. In this case, the theme is human impacts on nature. All of the maps in this atlas show either distribution of different kinds of human activities or geographical aspects of their effects on natural components. As for territorial coverage, it is an atlas of the world because all the aspects of human impact on the environment are considered on a global basis.

On the other hand, this volume is a *reference book*. It contains short descriptions of the various kinds of human activity and their effects on specific natural components. It reflects scientific knowledge on these problems as it stood during the late twentieth to early twenty-first century. The extremely limited volume of text allowed us to provide only minimal necessary information. More detailed information can be found in the references listed at the end of each chapter.

At the same time, this volume is an *illustrated atlas*, meaning that text and maps are accompanied by photographs showing specific examples of human effects on the environment. As the saying goes, "One picture is worth a thousand words". In the atlas, there are 300 photographs taken in 70 countries and all oceans.

As to the *sources*, they can be divided into three *categories*: (1) some citizens of different countries—chiefly, scientific associates who sent me the needed illustrations in the form of slides, photographs, or separate electronic files; (2) some organizations; and (3) sites of different international, national, and local organizations. I am grateful to the authors and organizations granting permissions for the use of the photographs in this book. It seems to me sometimes that collecting permissions was more difficult than writing the text of the book. Lists of copyright holders for maps and photographs are given in an appendix.

The book also includes about 65 maps. They were obtained for the atlas in a variety of ways: (1) maps found in different sources (books, articles, Internet sites); (2) maps synthesized on basis of two, three, and more sources; and (3) maps prepared by the author specifically for this book. In this case, a search of list of objects was carried out at first, the coordinates were determined, and, after that, the objects were automatically plotted on the map using the program ArcGIS for

Desktop. All of maps in the atlas are presented in the same projection (Robinson projection).

The author wishes to express his gratitude to Academician P.Ya. Baklanov, Director of the Pacific Geographical Institute, FEB of RAS (Far-Eastern Branch of the Russian Academy of Sciences), for every possible support over many years in conducting the investigations.

The support and assistance of current and former colleagues at the Pacific Geographical Institute are also gratefully acknowledged; included are Mr. V.B. Primak, Dr. S.M. Krasnopeev, Prof. A.M. Panichev, Dr. V.V. Aramilev, Prof. A.V. Moshkov, Mr. A.V. Vlasov, and Mr. V.A. Solkin.

Numerous colleagues from Russia have also contributed indirectly to this book, including Mr. V.A. Kantor, Prof. S.P. Gorshkov (Moscow State University, Moscow), Prof. S.A. Bulanov, Dr. E.V. Trofimova, Prof. A.A. Tishkov (all from the Institute of Geography, Moscow), Ms. E.I. Udilova (Greenpeace/Russia, Moscow), Dr. M.V. Khotuleva (Ecoline EA Centre, Moscow, Russia), Mr. E.V. Kovalev, Ms. L.O. Kudryavtseva, Mr. A.A. Lapin, and others.

The author has had the unique opportunity of becoming acquainted and collaborating with numerous international colleagues. Of particular note are Dr. I. Kelman (Centre for International Climate and Environment Research, Oslo, Norway), Prof. C. Tisdell (University of Queensland, Brisbane, Australia), Prof. H.J. Walker (Louisiana State University, United States), Dr. S.F. Trush (National Institute of Water and Atmospheric Research, Hamilton, New Zealand), and Prof. B. Braun (Geographical Institute of Köln University, Germany).

Of major importance to the author are the positive attitude and helpfulness of Ms. L.P. Slavinskaya for assistance in preparation of the manuscript for publication, and Ms. E.V. Oleinikova for preparation of electronic versions of maps.

Special thanks to Ms. D.M. Miller (Boulder, Colorado, USA) for close editing of the manuscript and her persistence in overcoming differences between the Russian and English, which, as I hope, allowed the book to become clearer for the Western reader. The author would like to thank the translator, V.M. Karpets (Pacific Geographical Institute, Vladivostok, Russia).

The author will be very grateful to all who, after discovering errors, uncertainties, etc., in the book, send information concerning them to me at **sgovor@tig.dvo.ru**. In addition, e-mailed photographs illustrating impacts of humanity on the environment also would be helpful.

Contents

About the Author

Sergey Govorushko is a chief research scholar at the Pacific Geographical Institute, Russian Academy of Sciences (Vladivostok, Russia). He is also professor at the Far Eastern Federal University (Vladivostok). His research activities focus on the interaction between humanity and the environment, including the impact of natural processes on humanity; the impact of humanity on the environment; and assessment of the interaction (environmental impact assessment, environmental audit, etc.). He has authored ten and co-authored 14 monographs.

Introduction

The effects of society on nature began when people first appeared and have a long history. At the early stages of the survival of the human race, the human population was relatively small, and the impact of people on nature was minimal. The situation has changed since people embraced the use of fire more than a hundred thousand years ago.

At the beginning, humans cleared forests with the aid of fire in the course of bushmeat hunting. Later on (8000–3000 BC), forests were cleared with the aid of fire for the purposes of agriculture and military operations (at first in the course of conflicts between tribes, and then between states) rather than hunting. The slash-and-burn system resulted in one of the most essential environmental consequences: the desertification of 2 billion ha of fertile lands, which is greater than the area of presently cultivated lands.

The distribution of different kinds of human activities in 1000 BC—i.e., about 3000 years ago—is shown in Fig. 1. The numbers indicate the following:

America: (1) Arctic marine mammal hunters; (2) Subarctic forest hunter-gatherers; (3) North American Pacific foraging, hunting, and fishing peoples; (4) Plateau fishers and hunter-gatherers; (5) Desert hunter-gatherers; (6) Plains bison hunters; (7) Poverty Point culture; (8) Eastern North American woodland hunter-gatherers; (9) Maize farmers; (10) Olmec civilization; (11) Caribbean hunter-gatherers; (12) Manioc farmers (replacing hunter-gatherers); (13) Chorrera culture; (14) El Paraiso culture; (15) Amazon forest hunter-gatherers; (16) Chinchoros culture; (17) Savanna hunter-gatherers; (18) Shellfish gatherers; (19) Andean hunter-gatherers; (20) Pampas cultures; and (21) Patagonian shellfish and marine mammal hunters.

Eurasia: (1) Saami; (2) Finno-Ugric taiga hunter-gatherers; (3) Paleo-Siberian taiga hunter-gatherers; (4) Arctic marine mammal hunters; (5) N. European Bronze Age cultures; (6) Karasuk culture (transhumant pastoralist chiefdoms); (7) Proto-Altaic pastoralists; (8) Urnfield cultures; (9) Cimmerians; (10) Celtiberians; (11) Illyrians; (12) Thrace; (13) Greeks; (14) Phrygians; (15) Hittites; (16) Urartu; (17) Iranian pastoralists; (18) Tibetans (transhumant pastoralists); (19) Sinic peoples; (20) Koreans; (21) Ainu; (22) Levantine Kingdoms; (23) Aramaeans; (24) Elam;

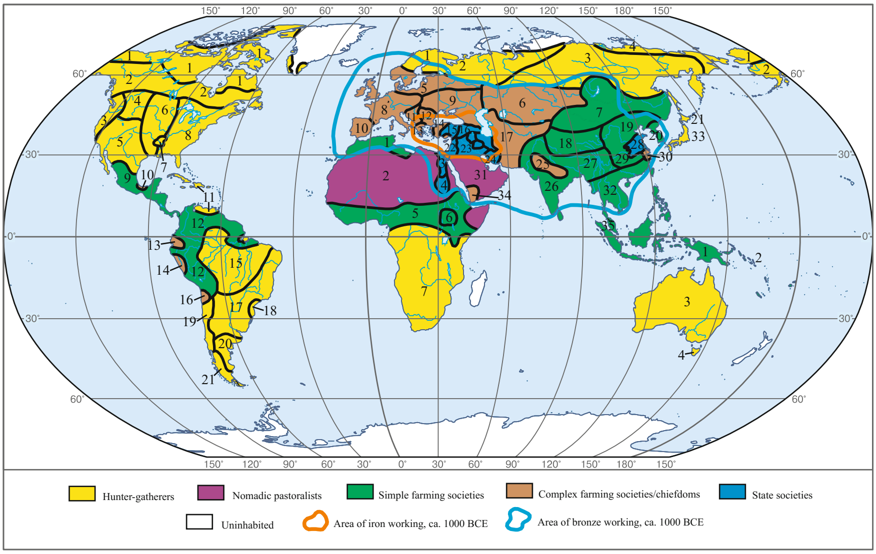

Fig. 1 The world in 1000 BCE (http://en.wikipedia.org/wiki/File:World_1000_BCE.png) [CC BY 2.5 (http://creativecommons.org/licenses/by/2.5)], via Wikimedia Commons

(25) Vedic Aryans; (26) Dravidians; (27) Burmese; (28) Zhou; (29) Thais; (30) Wu; (31) Arabian pastoral nomads; (32) Austro-Asiatic rice farmers; (33) Late Jomon culture; (34) Saba; and (35) Austronesians.

Africa: (1) Berbers; (2) Saharan pastoral nomads; (3) Egypt; (4) Kush; (5) West African cereal farmers; (6) Ethiopian highland farmers; and (7) Khoisan.

Australia and Oceania: (1) Papuan Neolithic farmers; (2) Lapita culture (proto-Polynesians); (3) Australian Aboriginal hunter-gatherers; (4) Tasmanian hunter-gatherers.

Three thousand years ago, the world's population was approximately 50 million people. Naturally, hunting, gathering, and primitive agriculture and livestock farming prevailed in those days. However, in the most developed civilizations, the spectrum of activities was much wider. In some cases, we may speak of housing and communal services.

For example, in the early third millennium BC in Mohenjo Daro, the largest ancient city of the Indus River valley (within the territory of the present-day Pakistan), each house had a canal for discharge of sewage into large main channels. The first waterworks also emerged many millenniums ago. For example, a permanent system of plated pipelines arranged on slopes for providing gravity flow of water existed in ancient Iran 3000 years ago. The water was provided at the expense of groundwater. At that time, water supply lines were also used in the interfluves of the Tigris and the Euphrates Rivers and in the valleys of the Nile and Indus.

Diversion of runoff was also used at that time. For example, an efficient system of drainage–irrigation channels within the Euphrates River basin (south

Mesopotamia) was created as early as the middle of the fourth millennium BC. It consisted of channels, floodgates, dams surrounding the fields, and shadoofs. Using each of them, one can lift about 2 t of water an hour time to a height of 6 m.

At that time, a primitive cement was already produced in Egypt, while burnt loam bricks were used in the above-mentioned Mohenjo Daro. The oldest known dam has been dated at 3000 BC. It was situated within 100 km of Amman (today's Jordan); it was a stone wall 4.5 m high and 1 m thick. According to data from archaeological finds, shipbuilding was used 7200 years ago.

However, technological development has made a gigantic step forward over the last few millenniums. A vast number of new kinds of activities have developed, and industrialization and scientific–technological progress have intensified environmental destruction. On the one hand, the development of industry and its infrastructure required additional destruction of natural ecosystems; on the other hand, a new kind of the impact on the environment and on humans has been seen—pollution of natural constituents by anthropogenic wastes and their effects on living organisms.

Human influences on the environment have reached critical scales, and the existence of a global ecological crisis is generally recognized. Some idea of this crisis is given by this atlas.

Chapter 1
Electric Power Industry

The electric power industry is the branch of power engineering that includes the generation and transmission of electric energy. The key role of this branch is explained by the advantages of electric energy over other kinds of energy—advantages such as the relative easiness of its long-distance transmission, distribution between consumers, and conversion to other kinds of energy (mechanical, thermal, chemical, optical, and so on). A distinctive feature of electric energy is that its generation and consumption are relatively simultaneous, because the electric current propagates through the network with a speed close to the speed of light. In the foreseeable future, it will remain a principal kind of energy, providing engineering progress in all spheres of the lives of people. Electricity is generated by power plants through the use of energy carriers or the conversion of other kinds of energy. For example, heat in thermal power stations transforms water into steam, forcing the rotors of steam turbines. These turbines are connected to the rotors of generators, in which the mechanical energy of the turbines is transformed into electrical energy. Solar power stations transform the energy of sun-rays into electrical or thermal energy, for example.

The distribution of different kinds of electric power engineering is illustrated in Table 1.1.

Table 1.1 Contribution of power plants of different types to global electric power production (percent) in 2011

Thermal power engineering	Hydropower engineering	Nuclear power engineering	Non-traditional power engineering	Total (%)
67.2	16.5	11.9	4.4	100

From http://www.c2es.org/technology/overview/electricity

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_1

1.1 Hydropower Structures

Hydropower engineering is a power industry based on the use of hydraulic power for generation of electric energy in hydroelectric power plants (HPPs).

The HPPs are widely distributed (Fig. 1.1). Hydropower is a fully mature technology, use in 159 countries (Technology Roadmap 2012). Worldwide hydroelectric power production in 2010 amounted to 3427 terawatt-hours (TWh) (Use and capacity of global hydropower increases 2012). Worldwide total installed hydropower capacity in 2009 was 926 GW, generating 3551 TWh/year (12.8 EJ/year), and representing a global average capacity factor of 44 % (Kumar et al. 2011). World leaders (share of hydropower global capacity, percent) at the end of 2013 were China (26.0), Brazil (8.6), the United States (7.8), Canada (7.6), and Russia (4.7) (REN21 2014).

The **major structures** of an HPP include a dam, a storage reservoir, channels, pressure pipelines, distribution devices, and other structures; however, the major changes in the environment are caused by the construction of storage reservoirs (Fig. 1.2).

The **major damage** associated with hydropower engineering is caused by flooding of the land, changes in river run-off below a dam, and the backwater effect, which, in turn, involve effects on practically all natural components. Basically, these **components** include the following (Govorushko 2014): (1) condemned land; (2) surface waters; (3) vegetation; (4) soils; (5) animal kingdom; (6) atmosphere; and (7) geologic environment.

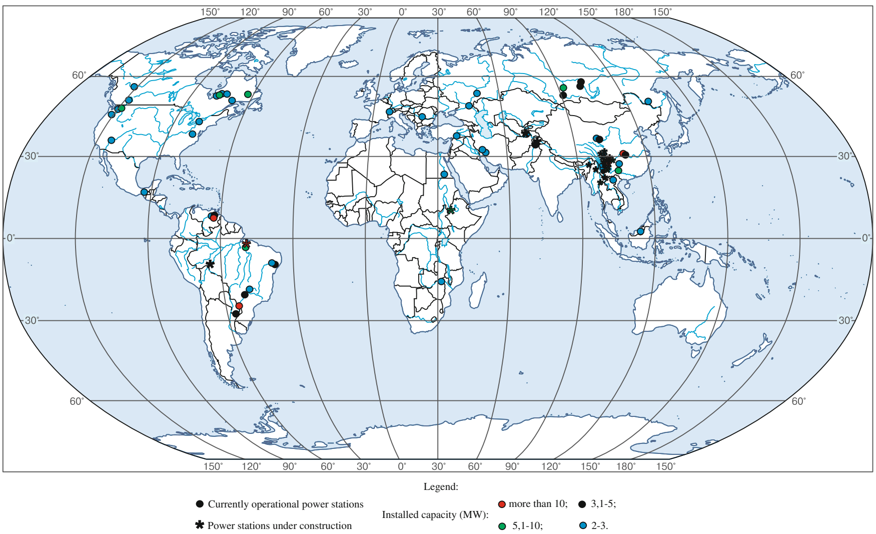

Fig. 1.1 Largest hydropower stations in the world. Prepared by author based on data at http://en.wikipedia.org/wiki/List_of_largest_hydroelectric_power_stations

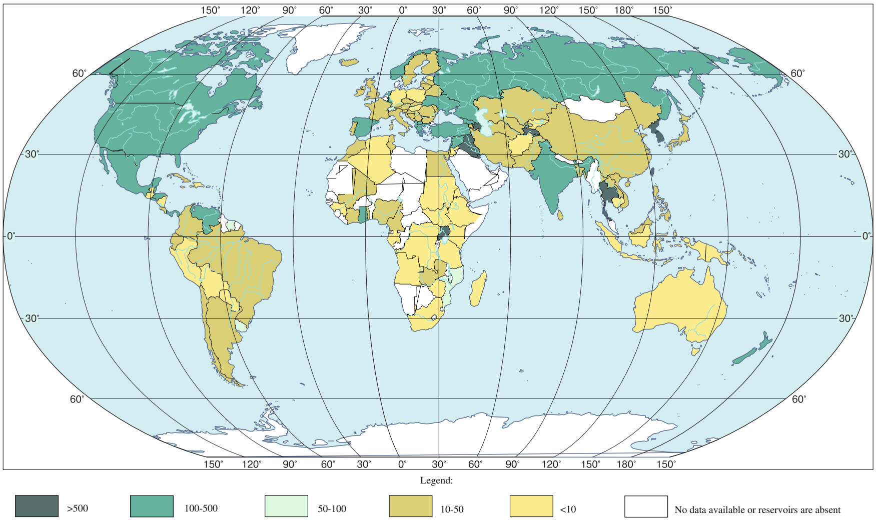

Fig. 1.2 Reservoirs of the world. Summary total capacity (by countries, million cubic metres per 1000 km^2) (Resources and Environment 1998). Reproduced with permission of Institute of Geography of the Russian Academy of Sciences

More than 95 % of the land area used for energy facilities is used by HPPs (Electrical power engineering and nature 1995). Such significant condemnation of lands creates strong *socioeconomic* impacts related chiefly to forced resettlement. For example, construction of the **Aswan High Dam** required the resettlement of 120,000 local residents (Ibrahim 1983); the **Pa-Mong Dam** in Vietnam led to the resettlement of 450,000 (Canter 1996); and construction of the **Three Gorges Dam** in China resulted in the resettlement of 1.2 million people (Steil and Yuefang 2007). The total number of displaced people is estimated at 80 million (Gorkina 2013). As a result of flooding of land, historical, architectural, and archeological monuments often disappear.

The influences on **surface waters** are diverse. A storage reservoir changes the *thermic regime* of a river downstream as warmer water than that the river flows into it in autumn and colder water flows into it in spring; differences reach, on average, 2–4 °C. Sometimes, affected zones are several hundred kilometers long (Avakyan et al. 1987).

Irregularities in daily and weekly water flow rates result in abrupt variations in the *ice regime*. In regions with cold climates, this often causes autumn and spring ice jams and, thereby, water level rises. Hydrochemical conditions change with the seasons as well as the drainage of *biogenic substances*.

Variations in hydrological, hydrochemical, and thermal conditions result in changes in the conditions under which **ichthyofauna** develop, because the biomass of forage organisms decreases and the conditions of spawning, fattening, and hibernation of fish deteriorate (Avakyan et al. 1987). In turn, these changes

influence the **vegetative** ground cover and the **animal** inhabitants of the river valleys and deltas.

In storage reservoirs, there is an abrupt **drop in water exchange** as compared with that in rivers. Reductions in flow velocities cause the sedimentation of nearly all *tractional* load and a large portion of *suspended* solid particles on the bottom. A World Bank study (Mahmood 1987) estimated that about 0.5–1 % of the total freshwater storage capacity of existing reservoirs is lost each year due to sedimentation. These figures correspond to an annual loss of reservoir storage capacity of some 45 billion m^3 (estimated based on a rate of 0.75 %) (Zhide and Tong 2010).

Depending on the conditions in a storage reservoir, the **water quality** may be either higher or lower than that in a river. The processes of natural *purification*—including sedimentation, settling, dilution, disintegration of organic substances, and so on—can lead to improvements in water quality. In tropical areas, the *water quality* is, as a rule, worse. The carriers of many diseases (such as malaria and schistosomiasis) experience favorable living conditions, which results in increases in the morbidity and mortality of people (Golubev 2006).

Transformation of the banks of storage reservoirs is especially intense over the first years after they are filled. The losses of land due to bank transformation may be considerable. For example, about 5000 ha—that is, approximately 2 % of the flooded area—were lost near the Tsimlansky storage reservoir (Russia) (Electrical power engineering and nature 1995). One more consequence of constructing storage reservoirs is an **under flooding** of lands due to rising groundwater levels. The under flooding, in turn, causes changes in the species composition of vegetation within the coastal zone.

Influences on **vegetation** are expressed as flooding of forests when a storage reservoir is being filled. For example, more than 20 million m^3 of wood appeared to be under water after construction of the Ust-Ilimsky hydropower station (Russia) (Engineering ecology 2003). The creation of storage reservoirs also results in fundamental changes in higher *aquatic vegetation and phytoplankton*. For many storage reservoirs, the rapid development of blue–green algae is a serious problem (‘water bloom’).

Soils are affected due to their under flooding around the reservoir and lowering of the groundwater line downstream of the dam due to decreases in the area of the flood plain (Reservoir storages 1986).

Filling a reservoir has adverse effects on **fauna**. Often, the fast flooding of a territory causes the loss of many animals. Many species of animals (snakes, shrews, moles, hedgehogs, and so on) move too slowly to escape the rising water. Because lands that previously were inundated primarily in spring may become flooded permanently, the richest biogeocenoses are destroyed, which results in *disappearance of the habitats* of many animals. Unfavorable water levels cause a decrease in the quantity of *waterfowl and wading birds* as well as of *semiaquatic animals*.

The construction of storage reservoirs significantly affects the *ichthyofauna*. Changes occur in things such as the rates of fish growth, the number and structure of populations, lifetimes, and reproduction and maturing conditions. The erection of dams on the majority of large rivers in the world disturbed the *migration paths* of

valuable diadromous and catadromous fish (sturgeon, salmon, herring). Their spawning grounds proved to be inaccessible for spawners.

Effects on the **atmosphere** are expressed as changes in the climate of adjacent territories. On the great plain storage reservoirs, the climatic variations affect the territory commensurable with the water surface area; mountain storage reservoirs exert little effect on the climate. In essence, the variations consist of a decline in the climate *continentality*.

Storage reservoirs affect the climate through the discharge of *greenhouse gases* into the atmosphere. The global annual emissions from hydroelectric reservoirs are estimated around 301.3 Tg carbon dioxide and 18.7 Tg methane (Li and Zhang 2014). This effect is maximal in northern areas where great areas of peatlands are within the flooded area (Louis et al. 2000).

The influence on the **geological environment** is expressed as increases in seismicity. It is well known that the construction of great storage reservoirs in areas of tectonic activity results in *earthquakes*. Some *examples* of the interrelationships between storage reservoirs and earthquakes are as follows: Kremasta in Greece, Koyna in India, Kariba in Zimbabwe and Zambia, Monteynard in France, and Nurek in Tajikistan. Earthquakes with magnitudes of 6.0 or greater have been observed in these areas (Mekkawi and Schnegg 2004; Nikolayev and Vereshchagina 2006).

Most probably, the effects of storage reservoirs on *surface waters*, as well as on *ichthyofauna*, *soils*, *and vegetation* of adjacent territories, should be recognized as most important.

HPPs are quite safe sources of electric energy, but emergency situations related to them are not uncommon. The **failure of dams** is most dangerous. The *largest catastrophic failure* of a dam was that of the Banqiao Dam (Henan Province, China) in 1975; the disaster killed 26,000 people (http://en.wikipedia.org/wiki/Dam_removal). The *greatest financial loss* (almost US$2 billion) was recorded in the course of the 1976 Teton Dam failure in the Colorado River basin (Idaho, United States) (Malik 2005).

The effects of HPPs on the environment are illustrated by Photos 1.1–1.10.

Photo 1.1 Dams are classified into four major categories based on the type of construction and materials used: (1) embankment; (2) gravity; (3) arch; and (4) buttress dams. This image shows the Kariba Dam. It is a concrete arch dam constructed between 1955 and 1959 on the Zambezi River. The height of the dam is 128 m (420 ft.) and the length is 579 m (1900 ft.). It creates a reservoir (Lake Kariba) with a total capacity of 180 km^3 (43 cu mi). Photo credit: FAO Aquaculture Photo Library

Photo 1.2 Besides the dam hydroelectric stations (with artificial control of the river levels through the use of a dam), there are diversion power stations (with supply of water from the watercourse through a special channel to the point where there are large differences in levels). These stations are often constructed in the area of waterfalls. In this case, the water is taken from the watercourse upstream of the waterfall and fed to the turbines downstream of the waterfall. In this aerial photograph taken at a height of about 1 km, the American (to the left) and Canadian (to the right) parts of Niagara Falls are shown. Photo credit: http://en.wikipedia.org/wiki/Waterfall by user IDuke on en.wikipedia (Photo by Duke) [CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5) or CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons

Photo 1.3 Now from 50 to 75 % of all water passing through Niagara Falls is carried away through four great tunnels that are far upstream of the falls themselves. Then the water passes through hydroelectric turbines that provide energy to the immediate areas of the United States and Canada before it returns into the river downstream of the waterfalls. The aggregate capacity of the electric power plants is 4.4 gigawatts (GW). The photo shows the Canadian electric power plant Adam Beck II. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 18 November 2011

Photo 1.4 The creation of reservoirs has strong socioeconomic impacts related chiefly to forced resettlement. In total, the number of displaced people is estimated at 40–80 million. After construction of the Uglich Hydroelectric Station dam in 1939, the Uglich Reservoir was created (surface area of 249 km^2 and a water volume of 1.2 km^3; its length is 143 km, and the maximum depth is 23 m), which resulted in partial flooding of the town of Kalyazin. The photo shows the submerged Kalyazin Bell Tower, located only partially above the water level. Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 14 June 2013

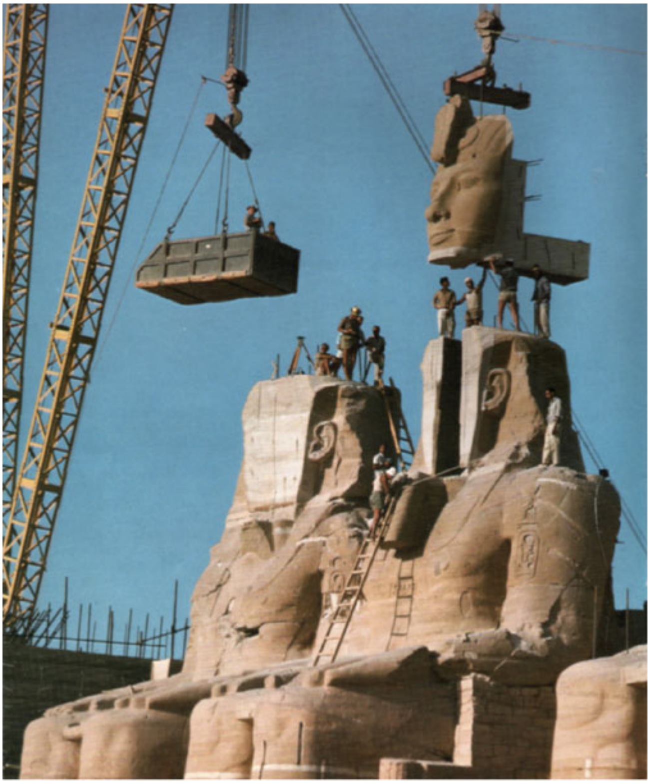

Photo 1.5 Flooding of land can also result in the disappearance of historical monuments. Recovery operations concerning masterpieces of Nubian architectonics found in the area flooded by the Aswan hydropower station (Egypt) are widely known. The operation “Recovery of Abu-Simbel temples” is known worldwide; two temples (those of Pharaoh Ramses II and his beloved wife Nefertari) were cut into 2168 blocks weighing as much as 30 tons and moved upwards by 64 m. A mounting of the face of Pharaoh Ramses II is shown.The face weighs 19.6 tons. Photo credit: Per-Olow Anderson, 1967

Photo 1.6 Reservoirs affect vegetation as forests are flooded when a storage reservoir is being filled. The forest flooded in the course of filling the Kopylkov hydroelectric power station (Velikaya River, Pskov Oblast, Russia) reservoir is shown. The construction of this hydroelectric station was completed in 1952. The area of water storage is 23 km^2, while the maximum depth is 29 m. Photo credit: A. Zabulonov, 26 July 2013

Photo 1.7 Creation of water storage reservoirs results in lateral erosion. The process of shore transformation is especially intense during the first years after a reservoir is filled. Losses of lands due to shoreline erosion can be great. The transformed section of the Bratsk Reservoir shore at the location of the Artumey settlement is shown. For the first six years after the reservoir was filled, the average rate of shore retreat reached 139.5 m/year. Photo credit: A.L. Ragozin, 1990

Photo 1.8 Large water reservoirs accumulate up to 95–98 % of all alluvia brought down by a river. The photo shows the Three Gorges Dam (upgrade-stream side) in China. At current levels, 80 % of the land in the catchment of its reservoir is experiencing erosion, depositing about 40 million tons of sediment into the Yangtze annually. Because the flow is slower above the dam, much of this sediment will now settle there instead of flowing downstream, and there will be less sediment downstream. Photo credit: A.N. Makhinov (Institute of Water and Ecological Problems, Khabarovsk, Russia), 21 February 2009

Photo 1.9 Water quality in reservoirs may deteriorate due to slowdowns in water exchange, development of living organisms, and processes of oxygen and thermal stratification. Storage reservoirs are more subject to contamination as compared with rivers. The picture shows the Tsimlyansk Reservoir in the lower course of the Don River (Russia). The green color of the water indicates high levels of eutrophication due to an oversupply of nutrients, which induces explosive growth of plants and algae. Photo credit: Russian Space Agency

Photo 1.10 Fish ladders are built on or around dams to aid the migration of diadromous fish. The fish swim and leap up a series of relatively low steps to reach the waters on the other side of the dam. The water must fall over the steps fast enough to attract the fish to the ladder, but it should not flow so fast that it washes the fish back downstream or exhausts them to the point that they are unable to continue their journey upriver. Photo credit: https://en.wikipedia.org/wiki/Fish_ladder by USACE (USACE) [Public domain], via Wikimedia Commons

1.2 Thermal Power Structures

A **thermal power station** is a power station that uses the energy of combustion of any fuel to generate electric energy. The prevalent fuel is coal (59.5 %), followed by gas (31.3 %), black oil (8.2 %), peat (0.8 %), and oil shales (0.2 %) (Fig. 1.3).

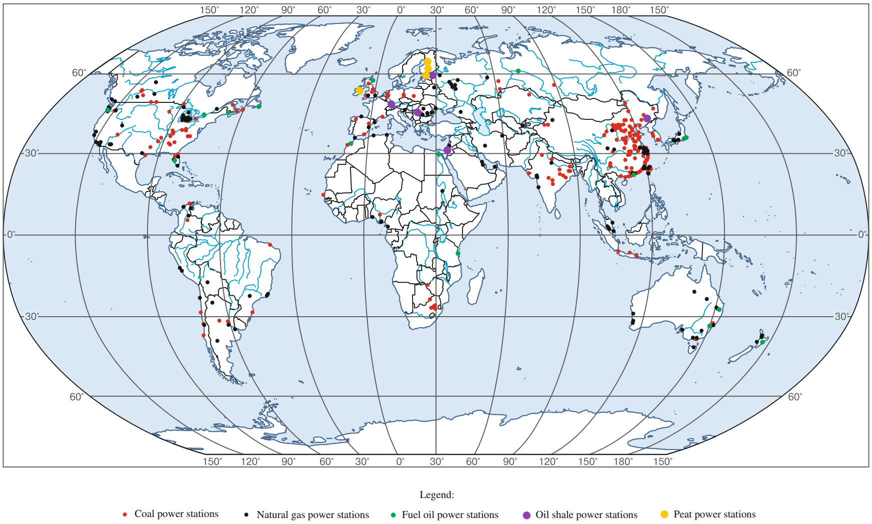

Fig. 1.3 Thermal power stations. Prepared by author based on data from numerous internet sources

Thermal power stations influence the following environmental **components** (Govorushko 2013): (1) air; (2) surface waters; and (3) soils. Thermal and noise effects are also of some importance. Thermal power stations exert indirect effects on other components of the environment (e.g., vegetation, underground waters).

The effects on the **atmosphere** are expressed as consumption of enormous amounts of oxygen and contamination of the air. The *major contaminants* discharged to the atmosphere include flying dust (ash), sulfur oxides, nitrogen oxides, and carbon dioxide. The contribution of thermal power engineering to air basin contamination is estimated at 27 %. Solid particles account for 31 % of the total amount of discharges, while sulfur dioxide and nitrogen oxides account for 42 and 24 %, respectively (Golubev 2006).

Some **elements** are discharged into the atmosphere in amounts exceeding their extraction from deposits. For example, emission of molybdenum from coal-fired power plants is more than 3 times the amounts extracted from deposits; arsenic, 7 times; uranium and titanium, 10; aluminum, iodine, and cobalt, 15; mercury, 50; lithium, vanadium, strontium, beryllium, and zirconium, in the hundreds; and gallium and germanium, in the thousands (Engineering ecology 2003).

It should be noted that the volume released determines only the amount of fallout contaminants. Reactions taking place in the atmosphere alter the emitted compounds.

Some emissions react with each other or natural elements in the atmosphere and are transformed into more *dangerous* compounds, while others, on the contrary, become *safe*. For example, nitrogen oxides, after oxidation to dioxides, fall to the ground in the form of fixed nitrogen, replacing common fertilizers in super alkaline soils.

The effects on **surface waters** include the following: (1) changes in the qualitative condition of water bodies and (2) influence on the amount of surface water. Changes in the qualitative condition occur in the case of discharge to water bodies of waste water with increased concentrations of contaminants.

The major contaminants released into water bodies are *mineral salts* (mainly sulphates and chlorides) and *oil products* (e.g., sulfur fuel oils and kerosene) and other pollutants (such as corrosion products, solutions of inorganic acids, and other compounds). A danger of contamination of surface waters with *soluble salts* is that they, in contrast to other pollutants (e.g., solid particles and organic, toxic, and surfactant species), are not subjected to the effects of environmental processes (e.g., deposition, decomposition, and uptake by living organisms); therefore, they can be extracted only by artificial techniques (Rudsky and Sturman 2014).

Pollution by oil products is characteristic mainly of *oil-fired thermal power plants*, and it is insignificant on the whole. Other pollutants are delivered to water bodies with waters of cooling and hydraulic ash removal systems, spent solutions after the chemical treatment of heat and power equipment, and so on. On the whole, the effects of thermal power engineering on the qualitative condition of water bodies are not too great.

The *quantitative effects* are expressed as an irrevocable withdrawal of water resources. The major water losses take place in the operation of cooling systems (water cooling towers, cooling ponds, and cooling passages). For example, about 2.5 % of the water circulating in a water cooling tower is lost due to evaporation (ReVelle and ReVelle 1995).

The influences of thermal power engineering on **soils** also can be subdivided into quantitative and qualitative. The *former* are expressed as a condemnation of land for construction of the power plants (basic structures, cooling storage reservoirs, ash disposal areas, etc.). For example, in the United States alone, coal-fired power plants generate nearly 140 million tons of fly ash, scrubber sludge, and other combustion wastes every year (Stant 2010).

Changes in *soil quality* are caused by dust rising from the ash disposal area surface, settling of atmospheric emissions directly on the soil, and washout of toxic matter from vegetation when it rains.

As for **thermal pollution**, only 30–35 % of the energy generated by fuel combustion in a coal-fired power plant is delivered to consumers. About 10 % of the heat goes to the atmosphere, while 50–55 % of the energy is removed in the course of water cooling of condensers (Rudsky and Sturman 2014). The discharge of warm water may result in changes in the species composition of the aquatic flora and fauna, because conditions become favorable for the reproduction of thermophiles.

The effects on **vegetation** are caused mainly by the contact of green parts of plants with atmospheric pollutants and soil degradation. Soil contamination has marked effects on crop capacity.

The effects of thermal power engineering on natural components are illustrated by Photos 1.11–1.14.

Photo 1.11 The effects of electric power plants on the atmosphere include consumption of enormous amounts of oxygen and contamination of the air. The major contaminants discharged to the atmosphere include flying dust (ash), sulfur oxides, nitrogen oxides, and carbon dioxide. From the environmental viewpoint, coal combustion is the most dangerous process. When natural gas is burned, the volume of released carbon dioxide is nearly two times less as compared with combustion of coal. The releases from a coal electric power station (Luchegorsk, Primorsky krai, Russia) into the atmosphere are shown. Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 14 June 2013

Photo 1.12 During the burning of peat, carbon dioxide emissions are lower by 4–24 times, and suspended solid particles are lower by 2–19 times as compared with the burning of coal. One of the world's largest peat-fueled power plants, the Toppila Power Station, in Oulu, Finland, is shown. Its capacity is 190,000 kW. It consists of two electric power units with capacities of 77,000 and 113,000 kW. Photo credit: http://en.wikipedia.org/wiki/Toppila_Power_Station

Photo 1.13 The prevailing type of fuel in thermal electric power plants is coal, followed by gas, fuel oil, peat, and oil shale. The Buck Steam Station (North Carolina, United States) is a two-unit coal-fired generating station situated on the Yadkin River. Operating since 1926, this station has a 256 MW generating capacity and emitted 680,009 tons of carbon dioxide in 2011. Photo credit: Les Stone (Greenpeace), 13 December 2011

Photo 1.14 The Kingston Fossil Plant coal fly ash slurry spill occurred on 22 December 2008. An ash dike ruptured at an 84-acre (0.34 km^2) solid waste containment area at the Kingston Fossil Plant in Roane County, Tennessee, United States. 1.1 billion gallons (4.2 million m^3) of coal fly ash slurry was released. The sludge traveled downhill, covering up to 400 acres (160 ha) of the surrounding land, damaging homes and flowing into nearby waterways such as the Emory River and Clinch River (tributaries of the Tennessee River). It was the largest fly ash release in U.S. history. A collapsed house inundated by the spill is shown. Photo credit: Tennessee Valley Authority, 23 December 2008

1.3 Nuclear Power Plants

A **nuclear power plant** (NPP) is a power plant that transforms the energy of nuclear disintegration in a reactor into electricity. In 2014, there were 435 civil nuclear power reactors operating in 31 countries, with a further 71 under construction (http://www.world-nuclear.org/Nuclear-Basics/Global-number-of-nuclear-reactors/). Global nuclear power capacity was 392 GW in 2013 (World energy outlook 2014). The leaders in total generation are the United States, France, Russia, South Korea, and Germany (http://www.businessinsider.com/countries-generating-the-most-nuclear-energy-2014-3?op=1). As for percentage of total national electric power generation, the countries rank in the following order (2013): France (74.8 %), Slovakia (51.7 %), Belgium (51.0 %), Hungary (50.7 %), and Ukraine (46.2 %) (http://en.wikipedia.org/wiki/Nuclear_power_by_country). Global distribution of NPPs is shown in Fig. 1.4.

While NPPs are operating, the following effects are observed (Semikolennykh and Zharkova 2013): (1) radioactive pollution of natural components (especially the atmosphere and surface waters); (2) thermal pollution of the water cooling reservoir and underground waters; (3) chemical pollution of the atmosphere, soils, and water bodies; (4) underflooding of territory; and (5) impacts on hydrobionts.

The major sources of **atmospheric** pollution with radioactive substances are as **follows**: (1) combustible material nuclear fission (supplies inert gases such as xenon and krypton as well as radioactive iodine); (2) impact of neutron currents on the heat carrier of the primary coolant system and ambient air; and (3) disturbance of the fuel element cans. A number of auxiliary facilities are also sources of radioactivity.

The contribution to **hydrospheric** pollution is made by subactive waters (waters of low radioactivity) of the **following systems**: (1) primary coolant circuit (waters

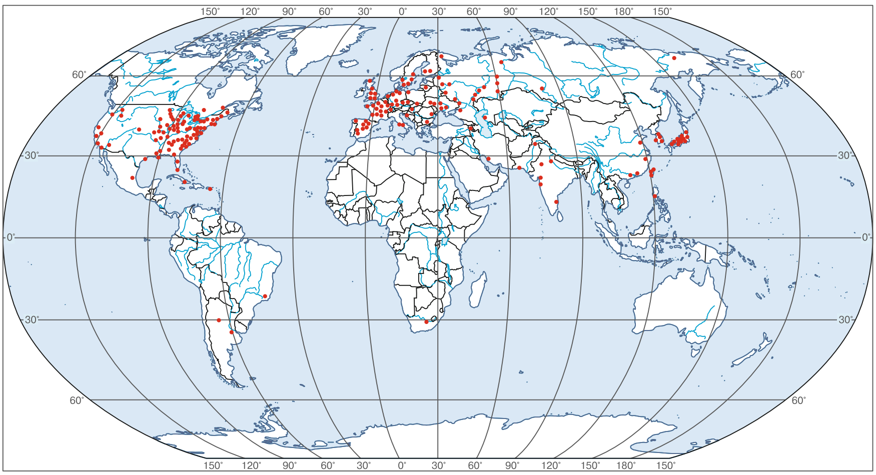

Fig. 1.4 Nuclear power plants of the world (Maksakovsky 2006, vol. 1). Reproduced with permission of V.P. Maksakovsky

of cooling and fuel assembly transfer ponds); (2) control and protection system loop; (3) waters forming during decontamination of the reactor plant rooms; (4) flushing waters used in equipment deactivation; (5) waters of sanitary inspection rooms and special laundries; and (6) waters discharged by radiochemical laboratories. During normal NPP operation, the volume of tritium in the water body silts increases 20–50 times as a result of water discharge (Alekseenko 2005).

Radioactive contamination of **soils** and **vegetation** occurs when radionuclides fall out to the Earth surface from the atmosphere. Depending on the landscape biochemical conditions, the radioactive contamination may accumulate or disperse.

During NPP operation, radioactive wastes of three **kinds** are produced: (1) spent fuel (fuel elements filled with compressed, sintered pellets of uranium dioxide); (2) waste products of reactor operation (wastes from cleaning of heat transfer agents from radioactivity, control rods, and so on); and (3) dismantled waste products. Depending on the disposal method, contamination of different natural media (surface and underground waters, geological environment, etc.) is possible.

Thermal pollution from NPPs, which is greater than that from thermal power stations, is important (Yablokov 2001). In addition, the heat released by an NPP is created through the condensation system with cooling water and only partially with ventilation air; therefore, this thermal contamination does not significantly affect the atmosphere and instead extends to surface and underground waters.

For example, 4 million m^3 of fresh and sea water per minute are discharged from NPP water cooling systems in the United States, and temperatures of process water exceed the **temperatures** of natural waters by 5–15 °C (Dynamics of marine ecosystems 2007). At the Kola NPP (Russia), located within the Arctic Circle, the temperature of underground waters increased from 6 to 19 °C near the main building (Vronsky 2007).

NPPs also cause **chemical** pollution of surface waters. The pollutants can be subdivided into three **groups** (Electrical power engineering and nature 1995): (1) inorganic matter not exceeding the maximum permissible concentrations (MPCs) in waters (sulphates and chlorides of calcium, magnesium, and sodium); (2) toxic substances whose concentrations exceed their MPCs in water bodies (salts of iron, copper, and zinc, fluorine compounds, etc.); and (3) matter affecting biological oxygen demand values (ammonium salts, nitrates, sulfides, etc.).

The contamination of **air** in the course of NPP operation is minor, caused by volatile substances and dust emitted from different processing solutions and stored solid waste, and combustion of organic fuels (gas, fuel oil, coal) used in heaters and other plants (Semikolennykh and Zharkova 2013).

Hydrobionts are affected by thermal contamination of the aquatic environment and their passage through water intakes. For example, the total number of fish involved in the water intakes in an NPP on Lake Erie (with water flow of about 85 m^3/s) can exceed 500 million individuals a year. In the Leningrad NPP (Russia), 50 % of zooplankton is killed when it enters the water intakes (Kryshev and Ryazantsev 2000).

The influence of NPPs on natural components that occurs during **dismantling** is not clearly understood, because we have little experience in decommissioning.

The effects of NPPs on the environment are illustrated by Photos 1.15–1.20.

Photo 1.15 The thermal pollution from nuclear power plants is greater than that from thermal power stations. The heat is released by an NPP through the condensation system with cooling water and through ventilation air. The photo shows cooling towers of a nuclear power plant in Cattenom, France. It ranks seventh in capacity among nuclear power station in the world, generating 5200 MW of electric energy (four reactors with capacities of 1300 MW each). Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 24 August 2012

Photo 1.16 The photo shows the Onagawa Nuclear Power Plant, located in Miyagi Prefecture, Japan. It was the most quickly constructed NPP in the world. The plant's waste heat water leaves 7 °C higher than it came in and it released 10 m under the surface of the water, in order to reduce adverse effects on the environment. Photo credit: http://en.wikipedia.org/wiki/Onagawa_Nuclear_Power_Plant by user Nekosuki600 on en.wikipedia [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

Photo 1.17 The Vermont Yankee is a NPP located in Vernon, Vermont, United States. The Connecticut River provides cooling water for its two major water systems: the circulating water system and the service water system. The circulating water system is used to cool the plant's main condenser. The service water system is used to cool auxiliary components in the nuclear facility and the turbine facility; it is also used to absorb decay heat from the reactor's cooling systems during emergencies or when the reactor is shut down. Photo credit: https://en.wikipedia.org/wiki/Vermont_Yankee_Nuclear_Power_Plant by Nuclear Regulatory Commission

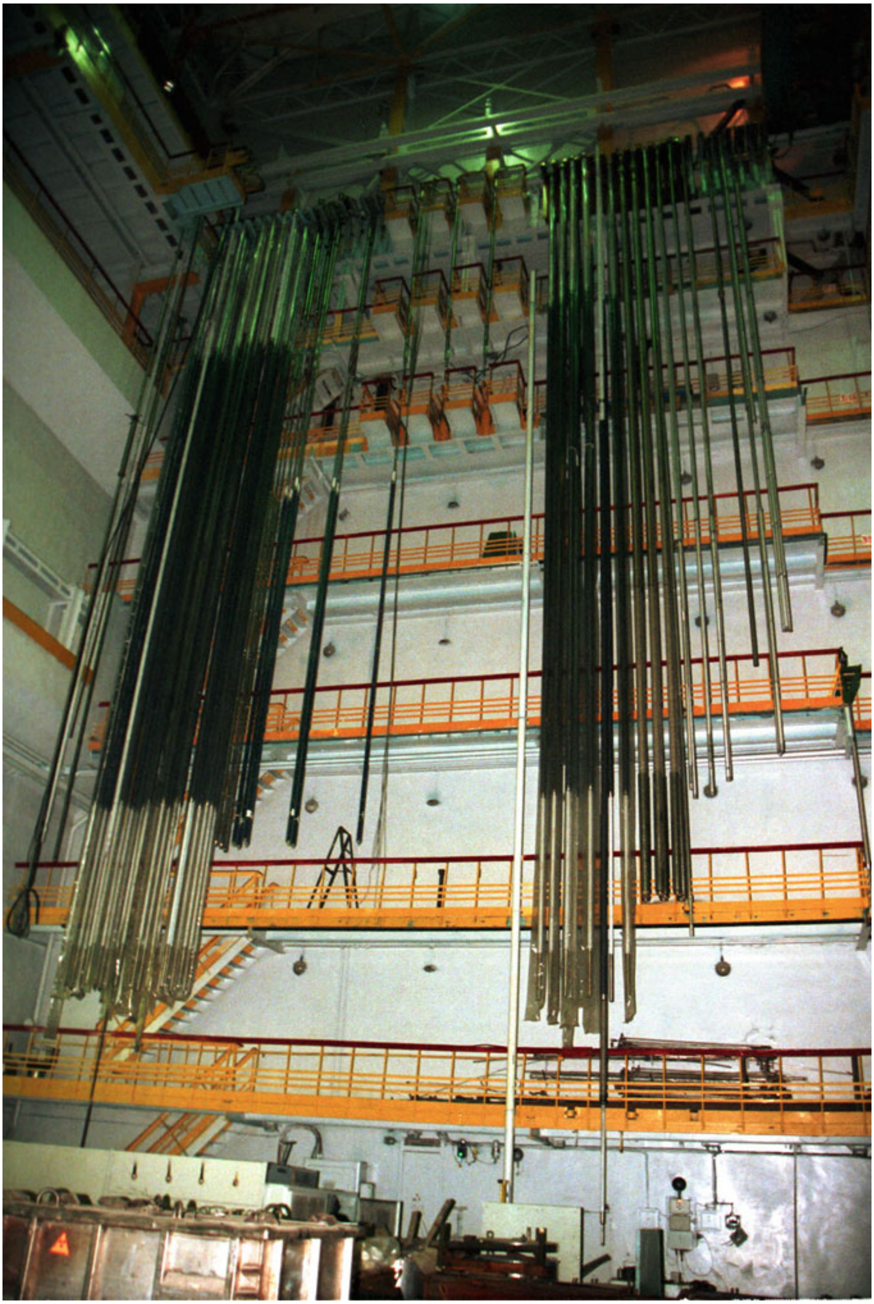

Photo 1.18 NPPs produce three kinds of radioactive wastes: (1) spent fuel (fuel elements filled with compressed, sintered pellets of uranium dioxide); (2) waste products of reactor operation (wastes from cleaning of radioactive materials from heat transfer agents, control rods, and others); and (3) dismantled waste products. The fuel elements in the reactor hall of the Leningrad NPP (Russia) are shown. Photo credit: V. Kantor (Greenpeace Russia), October 1997

Photo 1.19 The photo shows technicians placing transuranic waste at the Waste Isolation Pilot Plant near Carlsbad, New Mexico. Mishaps that occurred at the plant during 2014 brought attention to the problem of how to deal with increasing stockpiles of spent fuel from commercial nuclear reactors, which are currently stored at the reactor sites. In 2010, the U.S. Department of Energy shelved plans to develop the Yucca Mountain nuclear waste repository in Nevada. Photo credit: http://en.wikipedia.org/wiki/Deep_geological_repository by DOE Photo [Public domain], via Wikimedia Commons, 31 August 2005

Photo 1.20 Different groups of organisms can be ranked according to their degree of susceptibility to radioactive irradiation as follows: beasts; birds; higher plants; fishes; reptiles; amphibians; crustaceans; insects; mosses; lichens and algae; bacteria; protozoa; mollusks; and viruses. A piggy-mutant having one head and two trunks is shown. This mutation was due to the Chernobyl NPP accident, which took place on 26 April 1986. Photo credit: http://en.wikipedia.org/wiki/Chernobyl_disaster_effects by Vincent de Groot—http://www.videgro.net (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY 3.0 (http://creativecommons.org/licenses/by/3.0)], via Wikimedia Commons

1.4 Non-traditional or Alternative Power Structures

Non-traditional or **alternative power structures** include power plants that use renewable energy sources. Strictly speaking, hydraulic power is also a renewable source, but it, along with thermal and nuclear power, is generally categorized as traditional power engineering. The shares of different types of power generation are shown in Table 1.2.

Table 1.2 Global renewable energy capacity production, 2013

	Geothermal	Solar PV	Solar thermal	Wind	Tide	Biomass	Total
Capacity (GW)	12	139	3.4	318	0.5	88	560.9
Share (%)	2.14	24.78	0.61	56.69	0.09	15.69	100

Calculated by author with using data from REN21 (2014)

By the end of 2013 the five countries that were **leaders** in the generation of electric power from these sources were China, the United States, Germany, Spain, Italy, and India (REN21 2014).

1.4.1 Solar Power Structures

A **solar power plant** (SPP) is an engineering structure used to convert solar radiation into electric power. Sunlight can be converted into electricity by using *photovoltaics* (PV). More than 100 countries use solar PV. In 2013, Germany (35.9 GW), China (19.9 GW), Italy (17.6 GW), Japan (13.6 GW), and the United States (12.1 GW) were the leaders in this field. The global solar PV market at the end of 2013 exceeded 139 GW (REN21 2014).

Photovoltaics have mainly been used to power small and medium-sized applications, from the calculator powered by a single solar cell to off-grid homes powered by photovoltaic arrays. For **large-scale generation**, SPPs are used (Fig. 1.5). As of April 2013, the largest PV power plants in the world were the Agua Caliente Solar Project (Arizona, United States, 250 MW), California Valley Solar Ranch (United States, 250 MW), the Golmud Solar Park (China, 200 MW), the Welspun Energy Neemuch Project (India, 150 MW), and the Mesquite Solar project (Arizona, United States, 150 MW) (http://en.wikipedia.org/wiki/Solar_power_by_country).

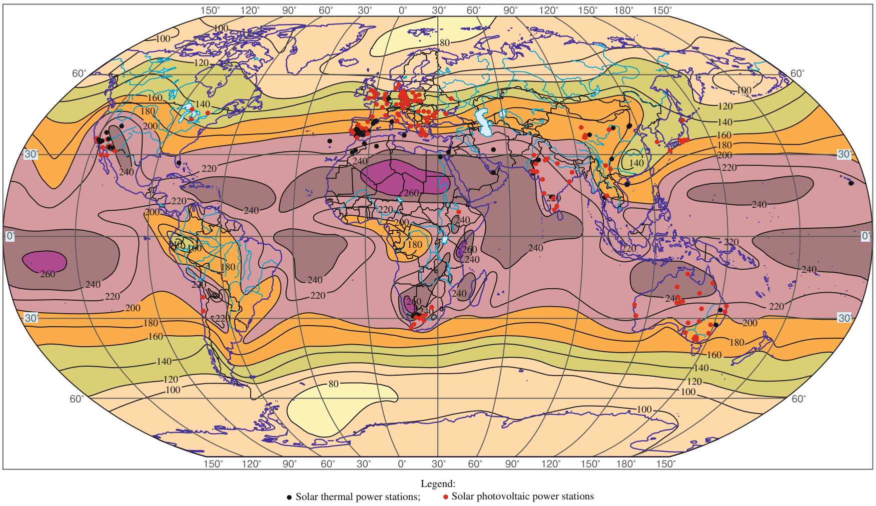

Fig. 1.5 Average annual amount of solar radiation reaching the Earth surface in watts per square meter (Resources and environment 1998). Reproduced with permission of the Institute of Geography of the Russian Academy of Sciences. Main solar power stations. Prepared by author based on data from numerous internet sources

Electricity and heat are produced from solar radiation in the following **ways**: (1) generation of electric power by using photocells; (2) conversion of solar energy into electricity by means of thermal machines, such as (a) steam engines (piston or turbine) using steam, carbon dioxide gas, propane-butane, or Freon and (b) Stirling engines (a kind of external combustion engine that may operate on any heat source); (3) solar power engineering (heating of a surface absorbing sun-rays and subsequent distribution and use of the heat; focusing of solar radiation on a vessel containing water for subsequent application of the heated water in heating systems or steam electric generators); (4) thermo-air power plants (conversion of solar energy into the energy of an air stream directed to a turbo-generator); and (5) solar balloon power plants (generation of steam inside a balloon covered with a selectively absorbing coating that is heated by solar radiation).

The methods of solar radiation **conversion** are different and depend on the power plant construction. All SPPs are subdivided into several **types**: (1) tower-base SPPs; (2) dish-shaped SPPs; (3) SPPs using photovoltaic cells; (4) SPPs using parabolic concentrators; (5) combined SPPs; and (6) balloon SPPs.

The often-declared environmental cleanness of solar power engineering is an **illusion**. From an environmental point of view, only the operation stage can be considered relatively clean, and even that assertion is made with reservations.

The **negative effects** of solar power engineering become apparent in the **following**: (1) condemnation of land; (2) contamination of natural media in manufacturing materials for plants; (3) contamination of the environment with highly toxic chlorates and nitrites from working fluid leaks; (4) influence on vegetation and

soils when they are shaded by solar concentrators; (5) changes in the heat balance and humidity near plants; (6) death of birds at power-base solar plants; (7) climatic effects of SPPs in space; (8) television and radio noises; and (9) thermal effects on the environment of cooling a condensate.

The construction of solar power stations needs large **areas** of land. A power plant producing 1000 MW in a hot, dry locality (such as west or central Australia) will need a total collector area of 13–25 km^2. This area is more than that occupied by an ordinary thermal power plant but less than the territory used for a plant and coal open-cut (Govorushko 2011a).

The **indirect environmental impact** of solar power engineering lies in the fact that it demands considerable resources. Enterprises manufacturing concrete, glass, steel, and other materials are needed to support the construction of SPPs. The making of photoelectric cells for solar batteries demands substances (silicon, cadmium, arsenide-gallium) that are hazardous to produce. In the case of wide development of solar power engineering, such indirect effects on the natural environment could be considerable.

The effects of solar power stations on the environment are illustrated by Photos 1.21–1.28.

Photo 1.21 Power-base SPPs consist of numerous mirrors. They direct the sun-rays to containers filled with water that are mounted on towers In this process, a great deal of thermal energy is generated. The water is heated and transformed into vapor, which is transferred to turbine-generator units. Birds flying over the surfaces of such power plants are roasted alive on the fly due to the high temperatures, which can reach 1000 °F (about 537 °C). The photo shows Solucar PS10, the first solar thermal power plant based on a tower in the world that generates electricity for commercial use. Photo credit: http://en.wikipedia.org/wiki/List_of_solar_thermal_power_stations by afloresm (SOLUCAR PS10) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons, 27 September 2007

Photo 1.22 The construction of solar power stations requires large areas of land. A power plant producing 1000 MW of electricity in a hot, dry locality (such as west or central Australia) will need a total collector area of 13–25 km^2. This area is more than that occupied by an ordinary thermal power plant but less than the territory used for a plant and coal open-cut. The photo shows the Nellis Solar Power Plant, located in Nevada, United States. The power plant occupies 140 acres, contains about 70,000 solar panels, and generates 14 MW of solar power for Nellis Air Force Base. Photo credit: U.S. Air Force photo, Airman 1st Class Nadine Y. Barclay, 9 October 2007

Photo 1.23 Solar thermal energetics is not designed to generate electric energy. As a result of heating of surfaces absorbing sunlight, water can be heated and used for hot water supplies or heating systems. The photo shows solar collecting panels used to provide a hot water supply in north-eastern China. China accounts for 64 % of the globe's solar water heating collectors, followed by the United States (5.8 %), Germany (4.2 %), Turkey (3.9 %), and Brazil (2.1 %). Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia) 25 August 2007

Photo 1.24 One of the environmental problems associated with photovoltaic solar panels is the use of cadmium in cadmium telluride solar cells. Metallic cadmium is a toxic substance that tends to accumulate in ecological food chains. The amount of cadmium used in thin-film PV modules is relatively small (5–10 g/m^2), and cadmium emissions during module production can be reduced to almost zero with proper pollution control methods. Current PV technologies result in cadmium emissions of 0.3–0.9 µg/kWh over the whole life cycle. The photo shows solar panels on the roof of a house in the town of Bad Dürkheim (Rhineland-Palatinate, Germany). Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia) 26 August 2012

Photo 1.25 Solar power is used in a numerous mechanisms and devices. A solar panel cooker is displayed. It is a corrugated board box coated on inside with foil; the open side is situated to face the sun. The foil surface reflects the sunlight, heating a vessel containing water to pasteurization temperatures at a certain point inside the box. Villagers like this woman in Zouzugu, Ghana, prevent dracunculiasis and other water-borne diseases by pasteurizing water in solar cookers. Photo credit: Tom Sponheim

Photo 1.26 Yet another similar example of the use of solar power is a starboard lateral post marking the channel of Otago Harbor in New Zealand. It glows during hours of darkness by using energy accumulated by a solar cell battery during daylight hours. Photo credit: http://en.wikipedia.org/wiki/Solar_power_in_New_Zealand, 26 November 2010

Photo 1.27 A solar-powered trash compactor in Hertogenbosch (Netherlands) is shown here. By compressing its contents, the unit gains capacity, so it does not have to be emptied as often. Fewer trash collections mean cost savings for labor, fuel, and maintenance, and reduced greenhouse gas emissions. Solar-powered trash compactors are perfect for cities, community centers, parks, beaches, or other high-traffic areas. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 10 August 2014

Photo 1.28 A solar pump used to deliver water to a pasture is shown. A hose is submerged in the water body, and the pump, through a system of flexible pipelines, conveys water to where it is used. A solar cell battery is used as the electric power source. Photo credit: U.S. Department of Agriculture

1.4.2 Wind Power Structures

Wind power stations convert wind energy into electric power. They consist of several wind turbines constructed in one locality. Worldwide, at least 806,000 small-scale turbines were operating at the end of 2012, exceeding 678 MW (REN21 2014) (Figs. 1.6 and 1.7).

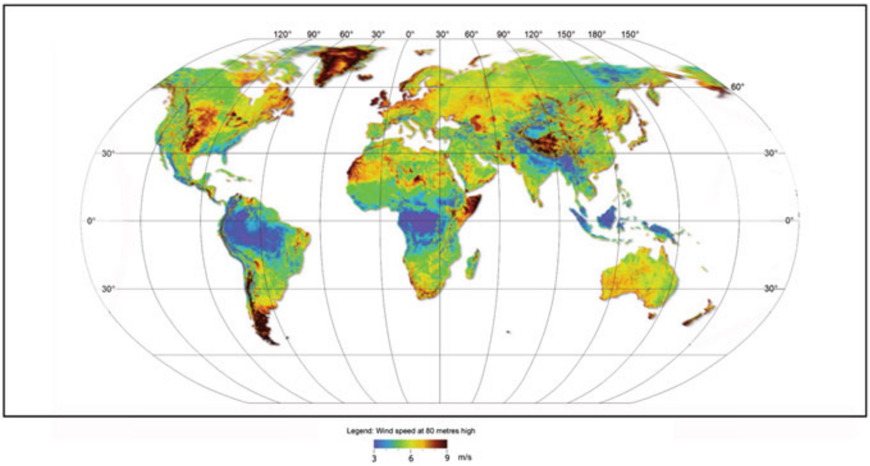

Fig. 1.6 Global wind power potential (http://blog.fabric.ch/index.php?/archives/1309-Where-Wind-and-Solar-Power-Make-Sense.html; http://news.cnet.com/i/bto/20080304/3t_global_wind_540x420.jpg; http://www.windpoweringamerica.gov/wind_maps.asp)

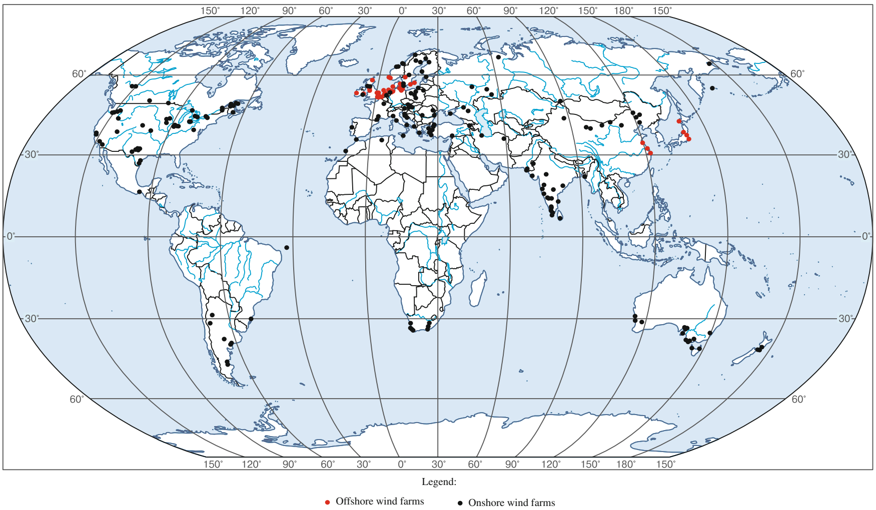

Fig. 1.7 Wind farms. Prepared by author based on data from numerous internet sources

By the end of 2013 wind energy was used in 103 countries. The **leaders** in the generation and use of wind power were China (91.4 GW), the United States (61.1 GW), Germany (34.7 GW), Spain (23.0 GW), and India (20.2 GW). The worldwide wind capacity reached 336,327 GW by the end of June 2014 (http://www.wwindea.org/webimages/WWEA_half_year_report_2014.pdf).

Wind power plants are categorized according to where they are placed: (1) ground (wind turbines are usually installed in the hills); (2) coastal, or onshore (a small distance from the sea coast); (3) offshore (constructed at sea, within 10–12 km of shore); and (4) floating.

So far, ground wind power plants are the most common. The *greatest* of them is the Jiuquan Wind Power Base in Gansu Province (China). It has a capacity of 5160 MW (http://en.wikipedia.org/wiki/Gansu_Wind_Farm). The largest **onshore** wind farm is the Alta Wind Energy Center located in Tehachapi Pass in California, with an installed capacity of 1320 MW (http://en.wikipedia.org/wiki/Alta_Wind_Energy_Center).

The greatest **offshore** wind power plant is the London Array (outer Thames Estuary in United Kingdom), with an installed capacity of 630 MW (http://en.wikipedia.org/wiki/London_Array). The world's first operational deep-water floating *large-capacity* wind turbine is the Hywind (52.3 MW turbine) in the Åmøy Fjord near Stavanger, Norway (http://en.wikipedia.org/wiki/Floating_wind_turbine).

The **adverse effects** of wind power engineering include the **following** (Govorushko 2011b): (1) condemnation of land; (2) influence on the animal world; (3) noise impact; (4) visual impact; and (5) electrical, radio, and television noises.

Wind turbines cannot be too close to each other, because their capacities will be reduced due to **wind flow interference**. The result is considerable withdrawal of land. Wind power plants require approximately 0.1 km^2 of free space per megawatt.

Wind power plants pose dangers to birds, insects, and aquatic organisms. The impact on the *ichthyofauna* is most dangerous during *WPP construction*: disturbances in their habitats result in fish migration and fish kill. During the *operational period*, the effects of noises and vibrations are not great, while cessation of navigation and fishing between the turbine supports may even have positive consequences. The effects on marine mammals (dolphins, seals, whales) are also minor.

During *construction*, the bottom deposits and structure of turbulent currents change, which has an adverse effect, first of all, on **benthic organisms**. The extent of the impact depends on the substrate; it is minimal in the case of bottom rock (Kiseleva and Nefedova 2006). During *operation* when electric power is transmitted through a submarine cable, strong electric and magnetic fields may cause fright reactions among fish and bottom-dwelling organisms, and, in this case, the cable will be a barrier to fish migration (Kadomskaya et al. 2006).

The effect on **birds** is minimal according to data obtained by European ornithologists. Birds feel wind turbines at a distance of more than 1 km and avoid them (Kiseleva and Nefedova 2006). According to data obtained by Sovacool (2009), 0.3–0.4 fatalities per gigawatt-hour of electricity have been recorded, which

corresponds to about 70,000 birds a year for the United States. There are also data on the death of **bats**. A study in 2004 estimated that over 2200 bats were killed by 63 onshore turbines in just 6 weeks at two sites in the eastern United States (Arnett et al. 2005).

The **noise impacts** caused by wind turbines include mechanical and aerodynamic. The components responsible for the greatest noise are the generator; the swing actuator, which turns the top part of the wind power plant toward the wind; the gearbox; and the blades. Noise from some of these components is continuous, while that from the others occurs from time to time; however, noise is produced only when the turbine is operating. All in all, the noise of spinning turbines is relatively low as compared with that of other industrial sources.

Visual impacts also occur, but they are subjective. Many people believe that wind power stations improve the esthetic qualities of the landscape; however, there are people who consider them to be unacceptable.

Wind power stations are a source of **radio** and **television interference**. In particular, the reflection of radio waves in the ultrashort band (USB) and microwave range by the rotating blades of wind power plants disturbs normal operation of airlines' navigational instruments and complicates television transmissions (Engineering ecology 2003).

The effects of wind power stations on the environment are illustrated by Photos 1.29–1.32.

Photo 1.29 Windmills, along with watermills, have been used by humanity for a long time. Such mills have been used largely for grain milling and woodworking (lumber mills), and as pumping or lift stations. Other uses have included tree bark milling for use in the leather industry, for cutting of rolled metal products, for degradation of ores of some nonferrous metals, and for milling of oil seeds. They were also used in textile manufacturing, and in the production of carpets, gunpowder, paints, and other products. A windmill in Belgium is shown. Photo credit: V.V. Rudsky (Moscow State Regional University, Russia), 10 August 2014

Photo 1.30 According to the where they are placed, the following types of wind power plants can be categorized: (1) ground (wind turbines are usually installed in the hills); (2) coastal, or onshore (a small distance from the sea-coast); (3) offshore (constructed at sea, within 10–12 km of shore); and (4) floating. Ground wind turbines in North Rhine-Westphalia, Germany, are shown here. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 4 August 2014

Photo 1.31 The Lillgrund offshore wind farm in Sweden is shown here. Global installed wind power capacity reached 282.5 GW in 2012, a 19 % increase over that in the previous year. Photo credit: Tomasz Sienicki, 2 September 2011

Photo 1.32 The effect of wind farms on birds is not very great. Birds feel wind turbines at a distance of more than 1 km and avoid them. However, 0.3–0.4 fatalities per gigawatt-hour of electricity have been recorded, which corresponds to about 70,000 birds a year in the United States. Some wind power stations discontinue operation during seasonal migration of birds. The picture shows birds navigating near wind turbines. Photo credit: http://commons.wikimedia.org/wiki/Sterna_paradisaea by Dirk Ingo Franke (Own work) [CC BY-SA 2.0 de (http://creativecommons.org/licenses/by-sa/2.0/de/deed.en)], via Wikimedia Commons

1.4.3 Geothermal Power Structures

A **geothermal power plant** is a power station that converts the heat in the Earth into electric power. World high-temperature geothermal provinces are shown in Fig. 1.8. At present, geothermal resources have been *identified* in some 90 countries, and there are *quantified records* of geothermal utilization in 78 countries (Lund 2010). Geothermal electricity generation is currently used in 24 countries, while geothermal heating is used in 70 countries.

Based on the rated electrical power (in gigawatts), the following countries occupied the leading positions at the end of 2013: (1) United States, 3.4; (2) the Philippines, 1.9; (3) Indonesia, 1.3; (4) Mexico, 1.0; and (5–6) Italy and New Zealand, 0.9 (REN21 2014).

A geothermal power plant **operates** as follows. Water is pumped through wells deep in the Earth where the rocks are very hot. Infiltrating into the rock joints and cavities, water gets warm with steam formation and rises back through the other, parallel wells. Thereafter, the hot water is delivered immediately to the power plant, where its energy is transformed into electricity by one or more turbines and generators.

At present, three **types** of geothermal power plants are used: (1) those using *superheated steam* [geothermal steam is directly used for rotation of turbines (dry steam)]; (2) those using steam-hydrotherms [hot, deep water under high pressure is pumped into reservoirs at reduced pressure; the steam that is formed rotates a turbine (flash steam)]; and (3) those with a *binary cycle* (moderately hot water comes into contact with a second liquid having a lower boiling point; the heat of the

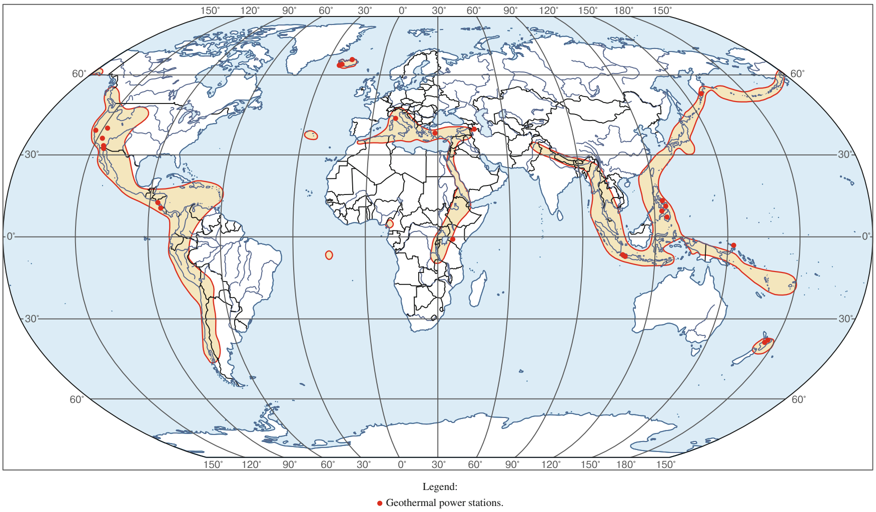

Fig. 1.8 World high-temperature geothermal provinces (Maksakovsky 2006, vol. 1). Reproduced with permission of V.P. Maksakovsky

geothermal water evaporates the second liquid, and the resulting vapours drive the turbines) (Kagel et al. 2007).

Geothermal power stations have major adverse effects on the following environmental **components** (Kubo 2003; Arnorsson 2004): (1) atmosphere; (2) geological environment; (3) surface and underground waters; (4) animal world; (5) condemnation of land; and (6) noise pollution.

The major air pollutants include hydrogen sulfide, carbon dioxide, methane, ammonia, hydrogen, nitrogen, mercury vapor, radium, and radon (Gupta and Aggarwal 2001). These pollutants contribute to global warming and acid rain, and produce noxious smells if released. Hydrogen sulfide is the most hazardous.

Existing geothermal power plants emit an average of 122 kg of carbon dioxide per megawatt-hour of electricity (http://en.wikipedia.org/wiki/Geothermal_power). The atmospheric contamination per gigawatt-hour is believed to be as small as compared with that for coal-fired power plants. The power plants using binary cycles do not contaminate the atmosphere (Govorushko 2011c).

The effects on the **geological environment** include increases in seismicity and subsidence of the Earth surface. A project in Basel, Switzerland, was suspended because more than 10,000 seismic events measuring up to 3.4 on the Richter scale occurred over the first 6 days of water injection (Deichmann et al. 2007).

The construction of geothermal power plants can adversely affect *land stability*. Subsidence has occurred in the Wairakei field in New Zealand (Lund 2007) and in Staufen, southern Germany (Waffel 2008).

Surface waters are polluted when waste waters are discharged. The most toxic pollutants are arsenic, boron, and hydrogen sulfide, elements and compounds that are frequently present in poisonous concentrations in geothermal waters. Other pollutants that may be present in harmful concentrations include aluminum, fluorine, ammonia, salts, and various heavy metals.

High concentrations of *heavy metals* are associated with high-temperature brines such as those at the Salton Sea in California. High *bromine* and *arsenic* concentrations are found in many geothermal systems associated with andesitic volcanism. Examples include Mount Apo in the Philippines and Achuapan in El Salvador. Boron-rich geothermal waters form upon reaction with marine sediments, such as at Ngwaha in New Zealand (Arnorsson 2005).

Consumption of water by geothermal power plants is insignificant. They use 20 l of fresh water per megawatt-hour versus over 1000 l per megawatt-hour for coal plants (Lund 2007). Cases are known of contamination of **underground water** due to leakages in reservoirs and pipelines (Birkle and Merkel 2000).

Animal inhabitants of surface waters are affected by these plants. For example, the geothermal heat carrier used in the New Zealand geothermal power plant Wairakei is discharged to the river of the same name. Concentrations of a number of heavy metals (e.g., mercury) in trout muscular tissue exceed many times the norm (Tomarov 1997).

The **condemnation of land** for utilizing geothermal power is minor. A geothermal facility uses 404 m^2 of land per gigawatt-hour, while a coal facility uses 3632 m^2/GWh (Kagel et al. 2007). The **noise impact** is also minor. At the well

drilling stage, it does not exceed 54 db, while during operation, levels are only 15–28 db (Kagel et al. 2007).

The effects of geothermal power stations on the environment are illustrated by Photos 1.33 and 1.34.

Photo 1.33 This picture shows the Larderello geothermal power station (Italy), the world's first such plant built for commercial use. The history of the plant began on 4 July 1904 when the first geothermal power generator was tested there. Geothermal reservoirs must reach or exceed 180 °C in order to be useful for energy production. The geology of Larderello makes it uniquely conducive to geothermal power production, with hot granite rocks lying unusually close to the surface, producing steam as hot as 202 °C (396 °F). Now it produces 10 % of the world's entire supply of geothermal electricity, amounting to 4800 GWh per year and powering about a million Italian households. Photo credit: http://en.wikipedia.org/wiki/Larderello, August 2009

Photo 1.34 Existing geothermal electric power plants emit an average of 122 kg of carbon dioxide per megawatt-hour of electricity. The atmospheric contamination per gigawatt-hour of electricity is small as compared with that for coal-fired power plants. The photo shows the Reykjanes Power Station. It uses steam and brine from a reservoir at 290–320 °C, which is extracted from 12 wells that are 2700 m deep. This is the first time that geothermal steam of such high temperatures has been used for electricity generation. Photo credit: Steve Morgan (Greenpeace), 5 December 2010

1.4.4 *Use of Oceanic Energy*

1.4.4.1 Wave Power Structures

The **wave power** of the world ocean is estimated at 2.7 billion KW (Engineering ecology 2003). For electricity generation, one can use wind-generated waves and surge. A peculiarity of sea disturbances is their **inhomogeneity over time**: maximum values are 5–11 times higher than average values (Govorushko 2011d).

Spatial inhomogeneity is also characteristic of ocean disturbances. Wave power flows are greatest in coastal zones at high latitudes, and the wave energy density in the southern hemisphere is much higher than that in the northern hemisphere. The coasts in the low latitudes show comparatively small energy flows. The boundaries of sharp changes in the wave energy flow values for the Pacific coasts of North and South America, as well as for the American coasts of the Atlantic Ocean, pass along 30°N and 30°S. For the eastern Atlantic coasts, the boundary of abrupt change in the energy flow in the southern hemisphere shifts to 10°S (Modern global changes 2006, vol. 2) (Fig. 1.9).

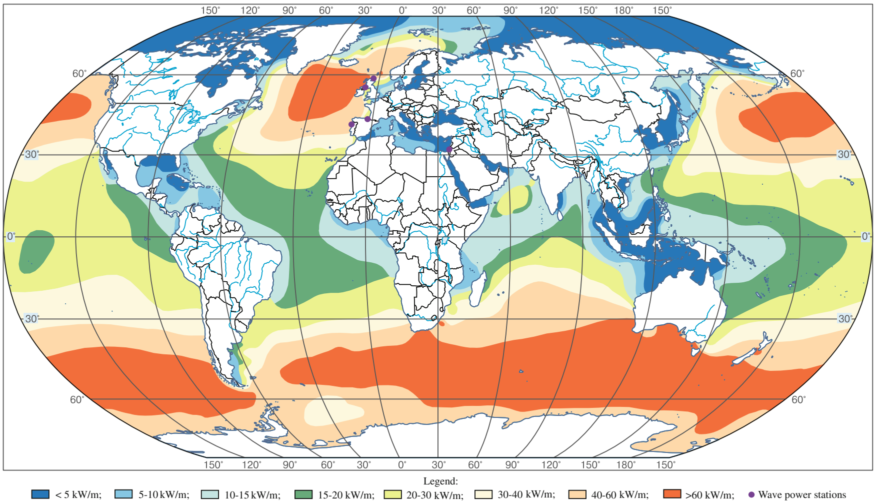

Fig. 1.9 Wave energy flux in kilowatts per meter wave front (http://en.wikipedia.org/wiki/Wave_power)

The average maximal **density** of wave energy is 40 MW/km of coastline (Griffiths 2003). The *extreme values* are characteristic of the north-western coast of Great Britain in the vicinity of the Hebrides, where the wave energy density reaches 80 MW/km (Engineering ecology 2003). Wave energy levels are shown in Fig. 1.9. On the whole, increased energy density is characteristic of the Pacific coastal zone,

which is also extremely long. This index is slightly lower for the Atlantic and Indian Oceans (Modern global changes 2006, V. 2).

There are three basic **methods** for converting wave energy to electricity:

1. **Float** or **buoy systems** that use the rise and fall of ocean swells to drive hydraulic pumps. The object can be mounted to a floating raft or to a device fixed on the ocean floor. A series of anchored buoys rise and fall with the waves. The movement "strokes" an electric generator and produces electricity, which is then transmitted ashore by underwater power cables.
2. **Oscillating water column devices** in which the in-and-out motions of waves at the shore enter a column and force air to turn a turbine. The column fills with water as the wave rises and empties as it descends. In the process, air inside the column is compressed and heats up, creating energy the way a piston does. That energy is then harnessed and sent ashore by electric cable.
3. "**Tapered channel**," or "**tapchan**," systems rely on a shore-mounted structure to channel and concentrate the waves, driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity, using standard hydropower technologies (http://www.oceanenergycouncil.com/index.php/Wave-Energy/Wave-Energy.html).

The world's **first** commercial wave energy plant was put into service in the Portuguese area of Aguçadoura on 23 September 2008. Its turbines provide a power of 2.25 MW. It is believed that the number of turbines (generators) in this plant can be increased in the future and raise the capacity to 21 MW (http://en.wikipedia.org/wiki/Wave_farm).

The influence of wave power engineering on the environment is not great and is expressed as **follows**: (1) animal world; (2) surface waters; (3) variations in the dynamics of deposit movement within the coastal zone; (4) visual impact; and (5) indirect impact caused by high materials consumption.

Wave power stations create hazards for some **animals** near them. Large machines have to be put near and in the water to gather energy from the waves. These machines disturb the sea floor, change the habitat of near-shore creatures (like crabs and starfish), and create noise that disturbs the sea life.

Impacts on **surface waters** involve spillage and pollution by toxic chemicals that are used on wave energy platforms (http://www.conserve-energy-future.com/Advantages_Disadvantages_WaveEnergy.php).

The effects on **deposit movement dynamics** occur when the wave energy plants are constructed within the coastal zone. The structures serve as breakwaters, disrupting the balance between erosion and accumulation of deposits. If the energy converters are placed in the deep waters of the open sea, the energy plants do not affect coastal stability (Ageev 2004).

The **visual impact** lies in the fact that, when wave energy plants are installed near a coastline, problems of esthetics arise because the plants are visible from shore. The **indirect impacts** occur because significant quantities of metals are melted to construct the wave energy plants, which is ecologically harmful.

In addition, the presence of a continuous line of wave energy plants may become a barrier for *navigation* and prove to be hazardous for ships under stormy conditions. On the whole, wave power engineering is characterized by the least environmental impact of all the energy industries (Govorushko 2003).

The effects of wave power plants on the environment are illustrated by Photos 1.35–1.37.

Photo 1.35 The indirect impact of wave farms occurs because significant quantities of metals are melted to construct the wave energy plants, which is ecologically harmful. The photo shows one of three Pelamis machines bursting through a wave at the Aguçadoura Wave Park off Portugal. Each Pelamis machine is 140 m long and 3.5 m in diameter and comprises four sections. Photo credit: http://commons.wikimedia.org/wiki/Electricity, September 2008

Photo 1.36 OPT's PB150 is a power station for generating electrical energy from wave power. It is a point absorber or buoy, currently in use or in planning at nine locations around the world, but primarily within Australia and the United States. It generates power using a hydroelectric turbine. Power Buoys can be connected to the electrical grid by power transmission cables, or they can operate autonomously in a deep-water environment. The rising and falling of the waves offshore causes the buoy to move freely up and down. The resultant mechanical stroking drives an electrical generator. The generated wave power is transmitted ashore via an underwater cable. Photo credit: http://en.wikipedia.org/wiki/PowerBuoy, 1 April 2011

Photo 1.37 The Wello Penguin is truly organic and unique in design. It captures kinetic energy, turning it into usable power while riding the waves. The 1600 ton vessel, approximately 30 m long, is held in place by three wires anchored to the seabed below. The Penguin fleet may consist of anything from one or more units, depending on the desired energy production capacity. The Penguin is designed to be simple, reliable, and extremely durable in order to withstand the harsh conditions of the ocean environment. All operational parts are placed inside its protective cover. The Penguin represents great value over its lifetime, as it requires very little maintenance. Overall it has a longer life cycle than an average wind power plant. Photo credit: Steve Morgan (Greenpeace), 29 September 2011, Orkney Islands

1.4.4.2 Tidal Power Stations

Tidal power is a form of hydropower that converts the energy of tides into electricity. There are three basic **types** of tidal power plants: (1) tidal stream systems make use of the kinetic energy of moving water to power turbines, in a way that is similar to windmills using moving air; (2) barrages make use of the potential energy in the difference in height between high and low tides; they are essentially dams across the full width of a tidal estuary; (3) dynamic tidal power exploits a combination of potential and kinetic energy, by constructing dams 30–50 km long from the coast straight out into the sea or ocean, without enclosing an area (http://en.wikipedia.org/wiki/Tidal_power) (Fig. 1.10).

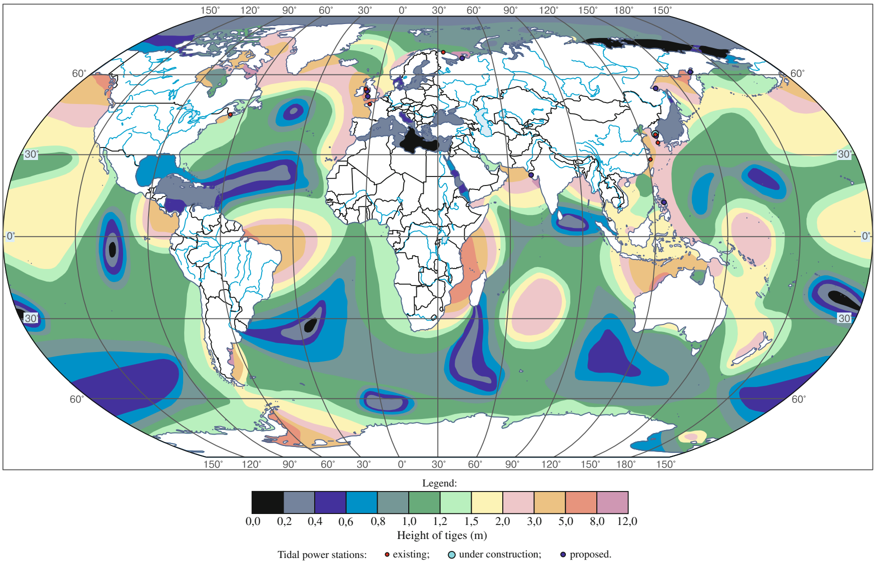

Fig. 1.10 Global tide range (http://www.meted.ucar.edu/oceans/tides_intro/print.html. Reproduced with permission of Bureau of Meteorology, Australia)

The SeaGen tidal stream power station built in Strangford Lough (Northern Ireland) in 2007 is an example of power stations of the **first** type. A 1.2 MW underwater tidal electricity generator was installed here. The rates of tidal streams at this location reach 4 m/s (http://en.wikipedia.org/wiki/Strangford_Lough). Such turbines have a minimal effect on the environment.

As for power stations of the **second** type, the tidal water is fed to a baffled-off basin. When the water levels in it and in the sea become equal, the gates at discharge openings are closed. With the onset of ebb tide, the sea water level drops and, at that time, turbines and electric generators connected to them come into action and water leaves the basin gradually (Nekrasov 1990).

Such tidal power plants can be *double-acting*. In this case, turbines work when water moves from the sea to the basin and vice versa. The double-acting tidal power plants are able to generate electric power for periods of 4–5 h with interruptions of 1–2 h for four times a day (Marfenin et al. 1995).

The number of power stations using barrage tidal power is not great. The largest ocean energy facilities in operation are all tidal projects and are used for electricity generation. They include the 254 MW Sihwa plant in South Korea (completed in 2011); the 240 MW La Rance station in France (1966); the 20 MW Annapolis plant in the Bay of Fundy, Nova Scotia, Canada (1984); and the 3.9 MW Jiangxia plant in China (1980) (REN21 2014).

The effects of the tidal power plant at the **Bay of Fundy** were analyzed in great detail, because of the **following** factors: (1) long duration of discussion of its construction suitability (more than 70 years); (2) intense development of environmental legislation in the United States and Canada; (3) economic opportunities in these states; (4) considerable interest of the community in nature conservation; and (5) location of the bay on the border of two states that have responsibilities with regard to the plant (Marfenin et al. 1995).

The **principal** effect of tidal energy stations on the environment is a reduction of **natural water exchange** between the cut-off water body and the sea, which results in the following **consequences**: (1) changes in the distribution of current speeds in the bay; (2) redistribution of bottom sediments; (3) decreases in the aqueous medium stability in the bay (desalination, temperature rise, contamination, etc.) under the action of land processes; (4) decreases in the amplitudes of the bay's water level variations; and (5) reductions in water turbidity (Govorushko 2011d).

First of all, a tidal power plant affects hydrobionts because the exchange of salt and fresh waters is disturbed, and redistribution of bottom sediments results in changes in the living conditions for sea flora and fauna. The investigations carried out in the La Rance tidal power plant showed an essential change in the composition of bottom **hydrobionts,** but they did not record a drop in their numbers (Charlier 2007). At the same time, a sharp reduction in bioproductivity, a twofold decrease in the numbers of species of flora and fauna, and decreases in the total numbers of individuals were observed at Kislaya Guba (Russia) (Preobrazhensky et al. 2000).

A reduction of water turbidity increases the penetration of sunlight and the productivity of **phytoplankton**. Passage of fish through turbines results in their **loss** due to pressure drop, contact with blades, cavitation, and other causes. Even with the most fish-friendly turbine design, fish mortality per pass is approximately 15 %. The loss of large marine **mammals** (whales, seals, dolphins, etc.) is possible (http://en.wikipedia.org/wiki/Tidal_power). In addition, the dams not infrequently prevent the renewal of fish resources, since the species that travel to the bays to spawn (salmon, herring, smelt, etc.) cannot enter (Preobrazhensky et al. 2000).

The environmental effects of tidal power plants are much less as compared with those of hydropower plants with similar **output capacities**.

The effects of tidal power stations on the environment are illustrated by Photos 1.38 and 1.39.

Photo 1.38 Tidal stream generators make use of the kinetic energy of moving water to powerturbines, in a way similar to wind turbines that use moving air. This method is gaining inpopularity because of the lower cost and lower ecological impact compared to tidal barrages. SeaGen, the world's first commercial tidal generator, in Strangford Lough, Northern Ireland, is shown here. It was installed in April 2008 and was connected to the grid in July 2008. It generates 1.2 MW of electricity for between 18 and 20 h a day. Photo credit: http://en.wikipedia.org/wiki/SeaGen, 1 April 2011

Photo 1.39 The major environmental effect of tidal hydroelectric stations is a reduction in the natural water exchange between the cut-off part of the water area and the sea. First of all, this influences hydrobionts. The Kislaya Guba Tidal Power Station (Kola Peninsula near Murmansk, Russia) is the world's sixth largest tidal power plant, with an output of 1.7 MW. It began operating in 1968. The site was originally chosen because the long and deep ford had a fairly narrow outlet to the sea, which could easily be dammed for the project. Photo credit: http://en.wikipedia.org/wiki/Kislaya_Guba_Tidal_Power_Station by Сайга20К (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

1.4.4.3 Other Sources

Production engineering and costs of electric power generation from different renewable energy sources differ markedly. Some of them do not at present find *practical application*, although their potential is very high.

In particular, huge reserves of energy that can be transformed into electric power are concentrated in **ocean currents** Fig. (1.11). For example, the Gulf Stream carries a water volume exceeding 50 times the volume transported by all the rivers of the world. Based on the Gulf Stream, one could produce more than 100 million kW of power. There are projects of such power plants in the Straits of Florida and Gibraltar and off the eastern shore of Japan (Kuroshio Current). However, the cost of such electric power is so far too high (Govorushko 2011d).

Of all kinds of oceanic energy, the reserves of **osmotic energy** are the highest. The global potential is estimated to be 1600–1700 TWh—equivalent to 50 % of the European Community's total annual power generation today (Osmotic power 2009).

Osmosis is the transport of water from a place where dissolved substances (e.g. salt) are present at low concentrations through a semipermeable membrane to a place with higher concentrations. A semipermeable membrane allows some substances to pass through, but stops other substances. The concentrations on both sides of the membrane will tend to equalize. As water passes through the membrane only one way, osmotic pressure builds up "inside;" in an osmotic power plant this pressure can be used to generate electricity.

An osmotic power plant can be located anywhere freshwater meets the sea, provided that the seawater is sufficiently saline. Osmotic power plants are not affected by weather changes as solar and wind power plants are, and they can

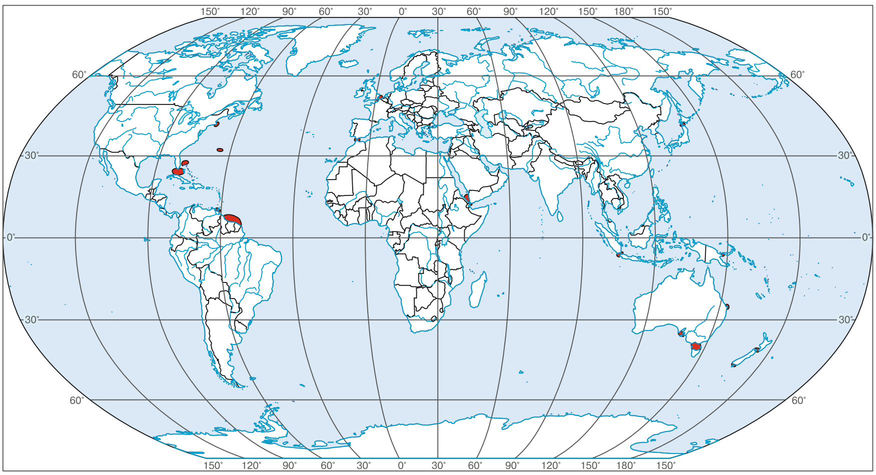

Fig. 1.11 Areas of the world ocean most favorable for ocean current electricity generation. Prepared by author based on data from Kenny (2007)

continuously generate electricity. Most river outlets are suitable locations for such power plants, although some river water must be cleaned more than others. The world's first osmotic plant, with a capacity of 4 kW, was opened by Statkraft on 24 November 2009 in Tofte, Norway (http://en.wikipedia.org/wiki/Statkraft_osmotic_power_prototype_in_Hurum).

The environmental consequences of operation of **salt power plants** are as follows (http://en.wikipedia.org/wiki/Osmotic_power): (1) damage to living organisms in the course of water extraction or on membranes; (2) influence on freshwater species when waters of greater salinity are discharged; (3) variations in water circulation, which affect the motion of nutrients and oxygen concentrations; and (4) penetration of toxic biocides used to prevent membrane contamination into the trophic chains.

Another important potential **source of energy** is the temperature drop caused by the facts that solar radiation does not penetrate deep into ocean waters and, therefore, cold waters are at shallow depths below the warm layer. Power plants that take advantage of these temperature differences may use the heat of surface waters to transform cooling fluid into steam (vapor). The cold water from depths of some hundred meters will cool and condense this steam (vapor), forming a low-pressure zone to which new portions of steam (vapor) will move, rotating the turbines (http://energy.gov/eere/energybasics/articles/ocean-thermal-energy-conversion-basics).

Ocean thermal energy conversion (OTEC) utilizes the temperature differences between the warm surface seawater and cold deep ocean water to generate electricity (Fig. 1.12). As long as a sufficient temperature difference (20 °C or 68 °F)

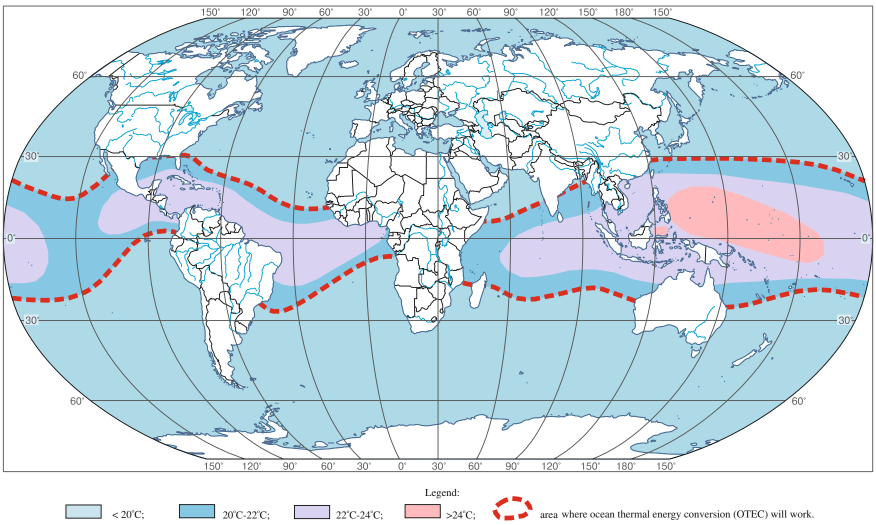

Fig. 1.12 Differences in temperature between the ocean surface and water a kilometer down (http://www.otecnews.org/what-is-otec/resource/; http://physics.ucsd.edu/do-the-math/2012/01/the-motion-of-the-ocean/; http://www.energyland.emsd.gov.hk/en/energy/renewable/otec.html)

exists between the warm upper layer of water and the cold deep water, net power can be generated.

There are three types of OTEC processes: closed-cycle, open-cycle, and hybrid-cycle. In the closed-cycle system, heat transferred from the warm surface seawater causes a "working fluid" (such as ammonia, which boils at a temperature of about 25 °C, or 78 °F, at atmospheric pressure) to turn to vapor. The expanding vapor drives a turbine attached to a generator that produces electricity.

Open-cycle OTEC uses the warm surface water itself as the working fluid. The water vaporizes in a near vacuum at surface water temperatures. The expanding water vapor drives a turbine attached to a generator and produces electricity. The water vapor, which has lost its salt and is almost pure fresh water, is condensed back into a liquid by exposure to cold temperatures from deep ocean water. Hybrid systems use parts of both open-cycle and closed-cycle systems to optimize production of electricity and fresh water.

The use of similar power plants can result **in changes** in water circulation, disturbances in the biological balance, and climate change. In order to construct such power plants, large quantities of non-ferrous metals (magnesium, titanium, etc.) and new synthetic materials whose production is related to serious environmental contamination will be needed. The rise of deep waters rich in nutrients may have a favorable effect on organisms in surface waters.

The environmental effects of these power stations are illustrated by Photos 1.40 and 1.41.

Photo 1.40 An important potential source of energy is the temperature drop caused by the fact that solar radiation does not penetrate deep into ocean waters; therefore, cold waters are present at shallow depths below the warm layer. Power plants that take advantage of these temperature differences may use the heat of surface waters to transform cooling fluid into steam (vapor). The cold water from depths of some hundred meters will cool and condense this steam (vapor), forming a low-pressure zone to which new portions of steam (vapor) will move, rotating the turbines. A view of the ocean thermal energy conversion facility at Keahole Point on the Kona coast of Hawaii is shown. Photo credit: http://commons.wikimedia.org/wiki/File:OTEC_in_Hawaii.jpg, 30 October 2011

Photo 1.41 For such power stations to work, differences in temperature between the ocean surface and water a kilometer down must be more than 20 °C. So the areas where ocean thermal energy conversion will work are situated in equatorial and tropical zones of the World Ocean. Left pipes used for OTEC. Right floating OTEC plant constructed in India in 2000. Photo credit: http://commons.wikimedia.org/wiki/File:Otec2.jpg, Harishmukundan at the English language Wikipedia

1.4.5 *Electricity Production from Biomass*

Biomass is organic matter that retains the energy of the Sun owing to the process of photosynthesis. Its initial form is plants. Further along the food chain, biomass can be transferred to herbivorous animals, and then to carnivores when the herbivorous animals are eaten. In turn, humans also eat plants and animals (Fig. 1.13).

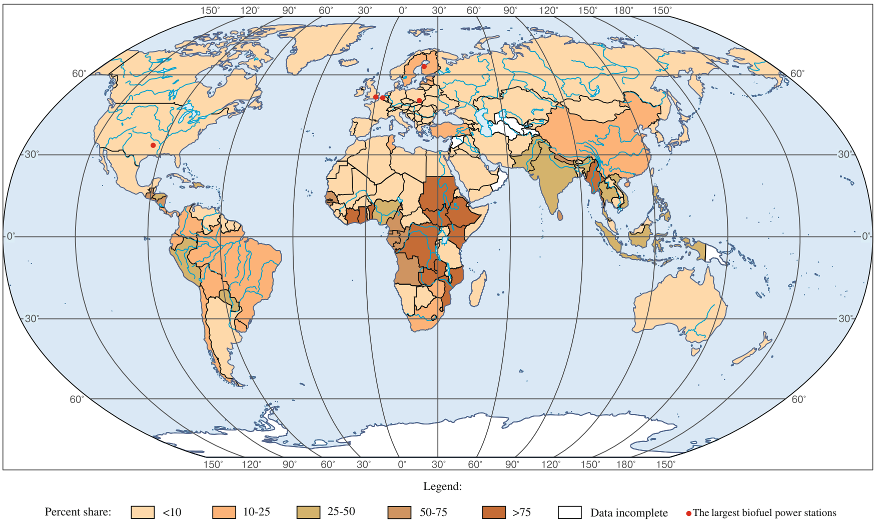

Fig. 1.13 Share of wood fuels in national energy consumption. Wood energy includes fuel wood, charcoal, and black liqor, measured in thousand metric tons of oil equivalent (TOE). Wood energy consumption is expressed as a percentage of total final energy consumption from all energy sources in thousand TOE (Matthews et al. 2000; http://forests.wri.org/pubs_dataset.cfm?PubID=3055; http://en.wikipedia.org/wiki/List_of_largest_power_stations_in_the_world)

The further **transformation of biomass** occurs in many ways. It can be present in the form of manure, bird droppings, fecal deposits, and domestic waste. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, and sugarcane (http://en.wikipedia.org/wiki/Biomass). According to data from different sources, biomass reserves are equivalent to 1.0 (Hall 2002) to 1.2 billion tons of petroleum (Solovyanov 2008). Bio-power generated around 405 TWh of the world's electricity in 2013. The five countries that **led** in biofuel production (billion liters) in 2013 were (1) the United States, 55.4; (2) Brazil, 28.4; (3) Germany, 3.9; (4) France, 3.0; and (5) Argentina, 2.7 (REN21 2014).

So far, biomass is mainly used for production of heat energy by three basic **processes**: (1) direct combustion; (2) biomass fermentation; and (3) use of energy carriers produced during biomass transformation (biogas, spirits, etc.) (Engineering ecology 2003).

In the **first** process, biomass is directly used as a fuel. For example, approximately 2.5 billion people in the world use fire-wood for heating and cooking. Fire-wood accounts for 15 % of the world's energy supply and up to 35 % of the supply in the developing countries (Govorushko 2011e). The share of wood fuels in national energy consumption is shown in Fig. 1.13.

In the **second** process, heat released in the course of fermentation by organic waste (manure, droppings, sawdust, etc.) is harnessed. This heat is most often used for heating greenhouses, hotbeds, and other structures. In the **third** process, such energy carriers as biogas and spirits are extracted from biomass. **Electric energy** can be generated from biomass with the third process.

Biogas, which is produced by the fermentation of biomass, consists of methane, carbon dioxide, and small amounts of other gases such as hydrogen sulfide. Different organic wastes are suitable for this process, including waste of fish and slaughtering workshops (blood, fat, guts); wastes of starch and treacle production (fiber and syrup, wastes of potato processing and production of chips—peelings, rinds, rotten tubers); wastes of juice manufacturing (fruit, berry, vegetable marc, grape refuse); waste of milk plants (lactoserum as well as manure); and bird droppings and feces (http://ru.wikipedia.org/wiki/).

Decomposition of biomass occurs under the influence of **three kinds** of bacteria. In the food chain, the subsequent bacteria are supplied with products of the vital functions of the preceding ones. The **first** kind is *hydrolytic*, the **second** is *acid-forming*, and the **third** is *methane-forming* bacteria.

At present, about 60 **technologies** of biogas production are used or are being developed. The most routine method is anerobic fermentation in metatanks or anerobic columns (http://www.biogasinfo.ru/about/).

Biogas consists of 55–75 % methane and 25–45 % carbon dioxide. **Gas yield** depends on the content of dry substance and the kind of raw materials used. One ton of cattle manure may provide 50–65 m^3 of biogas with a methane content of 60 %. By using different kinds of plants, one can produce 150–500 m^3 of biogas with methane contents of up to 70 %. The maximal quantity of biogas (1300 m^3), with methane contents of up to 87 %, can be obtained from fat.

Landfill gas, a kind of biogas, is obtained from municipal waste dumps. Global production of landfill gas is about 1.2 billion m^3/year (Production 2009). From 1 m^3 of biogas, one can obtain from 2 to 3 kWh of electric power. There are several **techniques** for generating electric power from biomass through its gasification. For electric power generation, the following equipment can be used: gas turbine units, steam turbine plants, gas-diesel plants, or internal combustion engines with spark ignition (Geletukha and Zheleznaya 1998).

Power generation from biomass is considered to be the one of *most environmentally friendly branches* of power engineering, as it helps reduce contamination of the environment with every possible waste (stock raising, domestic activities, forestry, woodworking, etc.).

At the same time, during biomass fermentation for producing ethanol, considerable amounts of byproducts (flushing waters and distillation residue) are produced that pollute the environment (Govorushko 2011e). For example, in the extraction of

1 l of ethanol, 13 l of **waste** liquids are produced (Pimentel 2001). In addition, other impacts include **thermal pollution**, depletion of soil organic materials, and exhaustion and **erosion** of the soil (Ageev 2004).

The environmental effects of power generation from biomass are illustrated by Photos 1.42–1.47.

Photo 1.42 Biomass is organic matter that retains the energy of the sun owing to the process of photosynthesis. Its initial form is plants; it is largely used for generation of thermal energy. A sugarcane plantation in Brazil (state of São Paulo) is shown here. Cane is used for biomass energy. Photo credit: Jose Reynaldo da Fonseca, 9 June 2007

Photo 1.43 Further along the food chain, biomass can be transferred to herbivorous animals and transformed into manure. In turn, manure can be used for generation of thermal energy. The photo shows piles of dried manure, used as fuel for fire in Mongolian households, on a farm near the Khargistai-Bayanburd Forest (near Tsagaan Nuur, Mongolia). Photo credit: Sean Gallagher (FAO), 7 October 2011

Photo 1.44 Firewood and woody coal provide 12 % of the world's energy, largely in the developing countries. The photo shows splitting chocks for firing furnaces in the settlement of Krasny Yar (Primorsky Krai, Russia). Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 7 February 2014

Photo 1.45 About 1.2 billion people do not have access to electricity, and 2.8 billion have to rely on wood or other biomass to cook and heat their homes. Burning of wood contributes to atmospheric contamination and to the greenhouse effect. The photo shows smoke from fired stoves in the settlement of Krasny Yar (Primorsky Krai, Russia). Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 7 February 2014

Photo 1.46 A wood chip factory near Mapua, Nelson, New Zealand, is shown. In the bottom left corner, the logs delivered to the factory are shown. These logs fall into the important group of woody biomass (this group includes firewood, pellets, and briquettes). The chipped wood is used for generation of thermal and electric energy. In order to produce the chips, the moisture content of the raw material should not exceed 30 %. Photo credit: Lorette Dorreboom (Greenpeace), 7 February 1991

Photo 1.47 A combined heat and power plant in Metz, France. The 45 MW boiler uses waste wood biomass from the surrounding forests as a renewable energy source and provides electricity and heat for 30,000 dwellings. Photo credit: http://en.wikipedia.org/wiki/Biomass, Bava Alcide57 at English Wikipedia [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

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Chapter 2
Industry

In an extended sense, the term *industry* means the totality of enterprises occupied with the production of instruments of labor, extraction of raw materials and minerals, and power generation. It also includes the further processing of products manufactured in industry or in other activities (agriculture and forestry, fishing). Electric power generation and transmission were considered earlier in Chap. 1, while extraction of raw and other materials is described in Chap. 3. The branches considered here belong to the manufacturing industry. They include the enterprises occupied with processing raw and other materials. The characteristic features of these industrial enterprises are serial production, division of labor, and the use of highly productive machines and equipment and their maximum specialization.

During industrial production, raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as aircraft, household appliances, or automobiles, or sold to wholesalers. Industrial regions of the world are shown in Fig. 2.1.

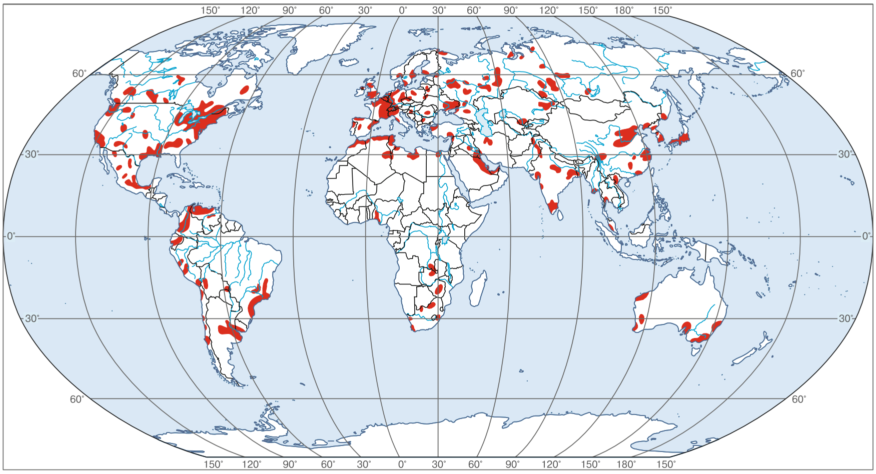


Fig. 2.1 Industrial regions of the world (Maksakovsky 2006, vol. 1). Reproduced with permission of V.P. Maksakovsky

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_2

2.1 Chemical Industry

In the **chemical industry**, raw materials of oil and mineral origin are used to produce chemical intermediates or finished products through chemical reactions. The **major products** of this branch are fertilizers, oil products, solvents, acids, bases, and chemical intermediates.

The **complexity** of the chemical industry is confirmed by the fact that 500 industrial chemical substances are produced as a result of 400 processes, using 1 of 10 kinds of charge stock: benzene, butylene, cresol, ethylene, methane, naphthalene, paraffin, propylene, toluene, and xylene.

These organic intermediates, together with 100 inorganic acids, salts, and bases manufactured by the chemical industry, are used to produce more than 70,000 kinds of products. Polymers and plastics, especially polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, polystyrene, and polycarbonate, comprise about 80 % of the industry's output worldwide (http://en.wikipedia.org/wiki/Chemical_industry).

There are now over 20 million synthetic chemicals, and that number is increasing by more than 1 million a year (http://www.worldwatch.org/node/485). This industrial sector is **most developed** in the United States, Japan, Germany, Great Britain, France, Italy, and the Netherlands (Maksakovsky 2006, vol. 1).

The environmental impacts of this industry are **extremely diverse**, which is explained by the enormous number of technological processes and manufacturing operations, composition of raw materials, physicogeographical features of affected regions, and so on.

The major **reasons** for the atmospheric pollution released by chemical enterprises are the **following**: (1) incomplete product yield; (2) discharge of admixtures and pollutants in the processing of raw materials; (3) losses of substances used for manufacturing processes; and (4) emission of odorous substances and oxidation and destruction products into the air.

The most **significant gaseous pollutants** of the atmosphere with regard to the volume of their production and toxicity are (1) chlorine; (2) nitrogen oxides; (3) sulfur dioxide and sulfur trioxide; (4) hydrogen chloride (hydrochloric acid); (5) hydrosulfide; (6) hydrogen fluoride; (7) carbon disulfide; and (8) fluorine and its compounds.

The chemical industry is a powerful source of effects on **surface waters**. The considerable withdrawal of water that is used in the manufacturing processes for purposes such as cooling and flushing is characteristic of this branch. During the manufacturing of chemical substances, pollution of water with chemicals and by-products takes place.

Some of the **factors** causing hydrospheric pollution are rainfall run-off from territories where structures for storage of raw materials and finished products are

located; and discharges of bleed waters from cooling systems, flushing waters, and manufactured product. **Typical pollutants** of surface waters include phenols, spirits, resins, chlorides, sulfates, sodium, and calcium (Arzhanov 1994).

In chemical production, more than 800 types of solid **waste** are formed, and only one-third of them are fully or partially used. The solid wastes include residues of raw materials and polymers, and sludge and sediments formed in treatment facilities and feed systems of steam generating units as well as in the course of washing tanks and reservoirs. Considerable ash-and-slag waste is also formed as a result of the operation of coal-dust steam generating units (Chizhov and Shekhovtsov 2004).

Considerable **noise** is also characteristic of many chemical enterprises, and sources include **such production equipment** as compressors, gas turbines, pumps, control valves, furnaces, flares, heat exchangers with air cooling, evaporative cooling towers, and ventilation systems (Environmental assessment sourcebook 1992).

It also should be noted that many materials and substances involved in the production of chemicals are **dangerously explosive** and constitute **fire hazards**. Taking into account the fact that the application of high pressure as well as the use of substances with high reactivity are characteristic of manufacturing technologies, they result in serious danger of explosions and drastic consequences.

2.1.1 Petrochemical Industry

The **petrochemical industry** is a part of the chemical complex based on the products of oil, gas condensate, and associated petroleum and natural gas processing.

The raw materials and manufacturable products of this industry can be divided into four **groups**: (1) raw materials (two kinds: oil and gas); (2) base intermediate products (about 10 kinds; e.g., ethylene, propylene, benzene, methanol); (3) petrochemicals (about 100 kinds: spirits, glycols, oxides, anhydrides, and others); and (4) final petrochemical products (about 1000 kinds, such as plastics, resins, synthetic fibers, synthetic rubbers, synthetic detergents, varnishes). In transitions from one group to the other, the number of products increases by an order of magnitude (Braginsky 2009).

The petrochemical industry involves more than 100 **technological processes**. **Major processes** include rectification, cracking, reforming, alkylation, isomerization, carbonization, pyrolysis, dehydrogenation (including oxidizing processes), hydrogenation, hydration, ammonolysis, oxidation, and nitration (Ratanova 1999).

Among the **countries leading** in volumes of oil and gas processing are the United States and countries of Western Europe (particularly Italy, Germany, France, and Great Britain). This industry is developing at a swift rate in China (Maksakovsky 2006, vol. 1) (Fig. 2.2).

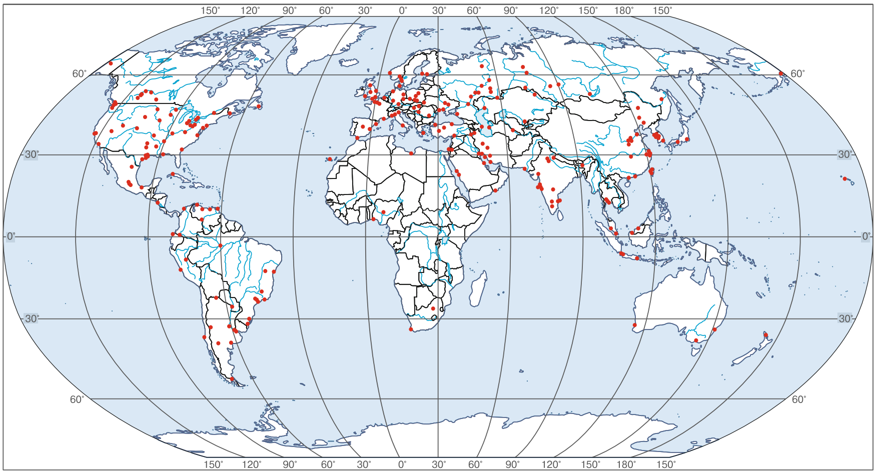


Fig. 2.2 Main petrochemical companies. Prepared by author based on data from numerous Internet sources

There are essential **differences** in the types of **raw materials** used in different countries. In the United States, Canada, Mexico, Saudi Arabia, a number of Asiatic countries, Brazil, and Venezuela, the major kinds of raw materials are products of *gas processing* plants (ethane, propane, butane, etc.), while in European countries, Russia, China, India, Japan, and Korea, fractions from *oil processing* are used as raw materials (Braginsky 2009).

In Russia, petrochemical enterprises account for about 48 % of the emissions of harmful substances into the atmosphere, 27 % of contaminated waste waters, more than 30 % of detectable solid waste, and up to 70 % of the overall volume of greenhouse gas emissions (Mukhamatdinova et al. 2012). The petrochemical industry affects, first of all, the following natural **components**: (1) atmospheric air; (2) surface waters; and (3) withdrawal of lands. The effects on other components are indirect. It also affects public health and results in considerable mortality and trauma.

The **most significant pollutants** of the atmosphere (*in the order of decreasing priority*) are hydrogen sulfide, sulfur dioxide, phenol, carbohydrates, nitrogen oxides, carbon oxides, and dust (Karlovich 2005). The major **sources** of pollution are plants for sulfur extraction and catalytic crackers (Environmental problems of the petroleum industry 2005).

Gas processing also makes its contribution to atmospheric pollution. In the operation of one of the gas processing plants in western Siberia (Russia), 230,000 tons of pollutants are released into the atmosphere every year (Mukhamatdinova et al. 2012).

The effects on **surface waters** are caused by the withdrawal of great volumes of water that is needed for participation in the chemical reactions, cooling, process steam generation, and washout of foreign substances from oil products. Per 1 ton of refined oil, 2.0–3.5 m^3 of water are used (Vladimirov and Izmalkov 2000).

Considerable quantities of oil products, sulfates, chlorides, nitrogen compounds, phenols, and salts of heavy metals enter surface waters with the waste waters of refineries (the annual quantity is 500 km^3) (Ratanova 1999).

The wastes discharged, besides polluting water bodies, also result in variations in such factors as pH and biochemical consumption of oxygen. These changes, in turn, affect **hydrobionts** (Loughery et al. 2014). The withdrawal of **lands** occurs in the construction of petrochemical enterprises and in storage of the waste products. Every year, the petrochemical industry generates 3 billion tons of *solid waste* (Mukhamatdinova et al. 2012).

The atmospheric pollution has indirect effects on **soils** and **vegetation**. The combustion of *petroleum gas* damages vegetation, for example; within a radius of 200–250 m of a flare, the vegetation is fully destroyed, while within 3 km of it, trees suffer and cast leaves. Trees and bushes suffer from necroses, while twisted needles and shorter sprouts are characteristic of conifers (Shuitsev 1982).

This kind of economic activity influences the life and health of **people**. In the petrochemical industry, explosive mixtures arise during technological processes. More frequently, they are generated by escaping gases, vapors, or fogs.

The first severe **fire** caused by leakage of liquefied natural **gas** took place on 20 October 1944, in the city of Cleveland, Ohio (United States), and killed 130 people. The first major incident related to liquefied **petroleum gas** occurred on 28 July 1959, in the state of Georgia (United States), and resulted in the loss of 23 lives (Petrova 2014). In 2011, about 15,000 incidents were recorded in the world's petrochemical industry, although during 2002–2011 accidents defined as temporary and without permanent consequences, declined dramatically. However, cases with permanent disability were up to 5 %; cases with permanent disability were up to more than 5 %, and the fatal cases were almost constant (Giacobbe et al. 2013).

The environmental effects of the petrochemical industry are illustrated by Photos 2.1–2.5.

Photo 2.1 The petrochemical industry delivers into the atmosphere about 1 billion tons of different aerosols per year, making a considerable contribution to global warming. The most significant pollutants of the atmosphere are hydrogen sulfide, sulfur dioxide, phenol, carbohydrates, nitrogen oxides, carbon oxides, and dust. The photo shows emissions at the Shell Puget Sound Refinery, Anacortes, Washington, United States. Photo credit: Walter Siegmund

Photo 2.2 Considerable quantities of oil products, sulfates, chlorides, nitrogen compounds, phenols, and salts of heavy metals enter surface waters with the waste waters of refineries (the annual quantity is 500 km^3). The photo shows waste oil discharged onto the ground from a lubricant factory in the state of Khartoum, Sudan. Photo credit: United Nations Environment Program from *UNEP Sudan Post-Conflict Environmental Assessment Report*, 22 June 2007

Photo 2.3 The withdrawal of lands occurs in the construction of petrochemical enterprises and in storage of the waste products. Every year, the petrochemical industry generates 3 billion tons of solid waste. Mountains of PVC incineration waste in Lisbjerg, Denmark, are shown. Poly (vinyl chloride), commonly abbreviated PVC, is the third-most widely produced polymer, after polyethylene and polypropylene. Photo credit: Thomas Mark (Greenpeace), 1 January 1997

Photo 2.4 The combustion of petroleum gas fully destroys vegetation within a radius of 200–250 m of a flare, while within 3 km of it, trees suffer and cast leaves. Trees and bushes suffer from necroses, while twisted needles and shorter sprouts are characteristic of conifers. Gas flaring in a petrochemical complex at Skikda, Algeria, is shown. Photo credit: E.V. Kovalev, 25 April 2013

Photo 2.5 Every year, about 1500 accidents and catastrophes occur in the petrochemical industry, and 4 % of them are accompanied by the deaths of 100–150 people and property damage of up to US$100 million. Fire-extinguishing operations after a Texas City refinery explosion are shown. Photo credit: http://en.wikipedia.org/wiki/Oil_refinery by Chemical safety and hazards investigation board [Public domain], via Wikimedia Commons, 23 March 2005

2.1.2 *Mining and Chemical Industry*

The **mining and chemical industry** is a complex of enterprises engaged in production, concentration, and preprocessing of apatite and phosphatic rocks, natural potassium salts, and ores containing sulfur, boron, arsenic, barium, and barite, as well as iodine and bromine.

This industry produces **fertilizers**, which are subdivided into phosphoric, potash, and nitrogenous fertilizers (Fig. 2.3). There are also *compound* mineral fertilizers, which contain two or three nutritive substances. Strictly speaking, the manufacturing of nitrogenous fertilizer does not belong to the mining and chemical industry, but we will consider it here for the sake of convenience.

The largest nitrogen-producing countries are China, India, the United States, and Russia. The largest phosphate-producing countries are China, the United States, India, and Russia, while the largest potash-producing countries are Canada, Russia, and Belarus (http://www.tfi.org/statistics/statistics-faqs). The world fertilizer manufacturing in 2013 reached 178.6 million tons, including 108.8 million tons of nitrogen fertilizers, 41.1 million tons of phosphate fertilizers, and 28.7 million tons of potash fertilizers (Heffer and Prud'homme 2014).

The prevalent **phosphoric fertilizers** are superphosphate, double superphosphate, ammophos, precipitate, and ground phosphate rock. Phosphorites (sedimentary rocks containing phosphoric anhydride, P_2O_5) and apatite (mineral, calcium phosphate) serve as raw materials for their production.

About 90–95 % of the world output of phosphoric ores is used to produce mineral fertilizers (Ivanov et al. 2014). In the mining of **phosphoric ores** in the world, the phosphorites predominate over apatite ores (91 % vs. 9 %). The sole

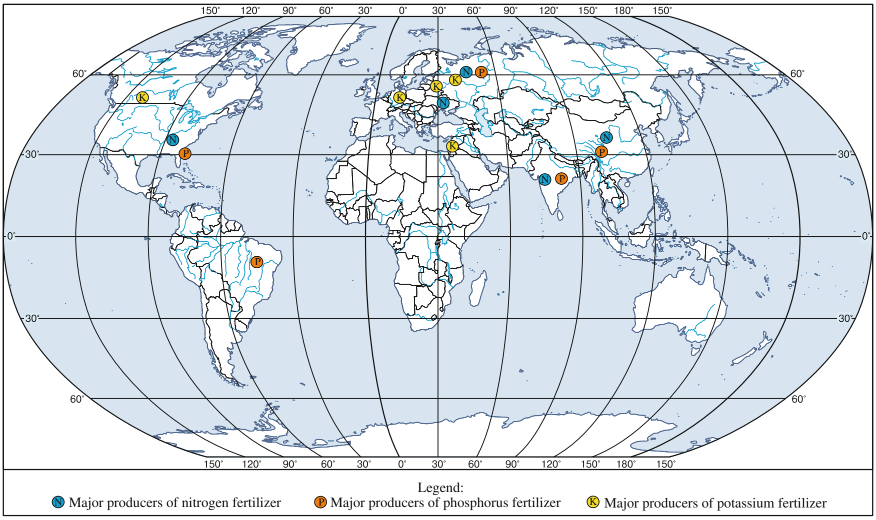


Fig. 2.3 Largest fertilizer producers (http://www.fertilizer101.org/sources/?seq=2; http://www.potashcorp.com/annual_reports/2010/graph_gallery/19/)

exception is in Russia, where the inverse ratio is observed: the ratio for ore reserves is 18–82 %, while that for production output is 5–95 %. The **leading nations in the extraction** of phosphatic rocks in 2012 were (1) China; (2) the United States; (3) Morocco; (4) Brazil; and (5) Russia (http://en.wikipedia.org/wiki/Phosphorite).

Potash fertilizers (potassium chloride, potassium sulfate, and double manure salt) are produced from natural salts, primarily carnallite and sylvinite. The world reserves of potassium salts are about 50 billion tons. More than 80 % of reserves of ore used for potassium production fall in only three countries: Canada, Russia, and Belarus. The **major countries** producing potassium ores are Canada, France, Germany, the United States, Belarus, and Russia. The production of potash fertilizers includes the separation of calcium chloride from associated salts by selective solution or flotation methods (Ratanova 1999).

The raw feedstock for production of **nitrogen fertilizers** (ammonium nitrate, carbamide, ammonium sulfate, etc.) is ammonia. Earlier, ammonia was produced from coke and coke oven gas, while now it is produced from natural gas.

The mining and chemical industry affects the following natural **components**: (1) atmospheric air; (2) surface waters; (3) soils; (4) animal world; and (5) vegetation.

The composition of **atmospheric** emissions depends strongly on the charge stock and technique of operation. In the production of phosphate fertilizers, the major pollutants are fluorides, which are present in gaseous and aerosol emissions. In addition, the air is polluted with arsenic, copper, zinc, strontium, thorium, and rare-earth elements (Gorbunov et al. 2001). Everyday, plants manufacturing nitrogen fertilizers emit 5–12 t of nitric oxides and nitric acid, as well as ammonia and formaldehyde (Fig. 2.4).

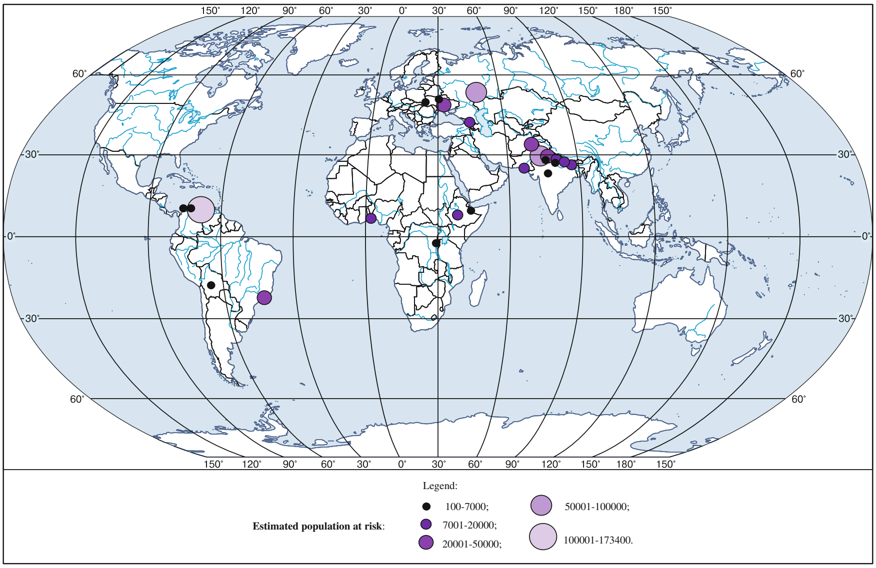


Fig. 2.4 Pesticide pollution from pesticide manufacturing facilities (http://www.worstpolluted.org/projects_reports/display/93). Reproduced by permission of Blacksmith Institute for a Pure Earth

Surface waters are contaminated with waste waters containing sulfates, phosphates, fluorine, copper, and zinc (Gorbunov et al. 2001). The influences on **soils** are caused by storage of waste. For example, in the production of potash fertilizers, the stocking of halite waste results in considerable salinization of soils (Baboshko 2005). Dust particles in high concentrations can considerably decrease soils' permeability to water (Environmental considerations during potash production 1987).

Indirect effects on **vegetation** and the **animal world** are related to contamination of water and air. In Qatar, for example, fertilizer production releases about 3 million tons of ammonia and 5 million tons of urea every year to the Persian Gulf in the form of liquid wastes, which have extremely unfavorable effects on hydrobionts (Abdel-Moati and Al-Ansari 2000). Industrial sewage released from the Stebnikovsky potash fertilizer plant (Ukraine) in September 1983 led to the total disappearance of hydrobionts in the upper Dniester River (Cheredarik and Shnarevich 1988).

The mining and chemical industry has a high risk of **casualties**. The production of fertilizers involves high risks of explosions. For example, on 17 April 2013, an explosion occurred at the West Fertilizer Company storage and distribution facility in West, Texas, 18 miles (29 km) north of Waco, while emergency services personnel were responding to a fire at the facility. At least 14 people were killed, more than 160 were injured, and more than 150 buildings were damaged or destroyed (http://en.wikipedia.org/wiki/West_Fertilizer_Company_explosion).

The environmental effects of the mining and chemical industry are illustrated by Photos 2.6–2.10.

Photo 2.6 The Dead Sea area is characterized by a combination of two natural factors—high water mineralization and excess solar energy. Each kilogram of water contains 190 g of magnesium and calcium chlorides (Mg+Ca) Cl_2, 67 g of sodium chloride (NaCl), 12.7 g of potash chloride, and many other salts. The average annual amount of solar radiation approaches 200 kcal/cm^2. This is an orbital image of the Dead Sea. Jordanian and Israeli mineral evaporation ponds can be seen at the south end, separated by a central dike that runs roughly north-south along the international border. Photo credit: Russian Space Agency, 9 August 2008

Photo 2.7 The production of salts from sea water is based on differences in the solubilities of natural salts, depending on concentrations in brines. Water from the Dead Sea is delivered to ponds. As the water evaporates, one or another salt precipitates. The retained water is drained off to the neighboring pond-evaporator, where the other salt is crystallized by further evaporation. The precipitated salt along with the bottom brine is transferred by means of specialized dredgers through a floating pipeline to shore for further processing and refining. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 18 July 2010

Photo 2.8 The composition of atmospheric emissions from fertilizer plants depends largely on the charge stock and techniques of operation. In the production of phosphate fertilizers, the major pollutants are fluorides, which are present in gaseous and aerosol emissions. In addition, the air is polluted with arsenic, copper, zinc, strontium, thorium, and rare-earth elements. The picture shows high pollution of the atmosphere by the Yingfeng Chemical Plant (Sichuan, China), which manufactures phosphate fertilizers. Pollution causes distress for residents in the vicinity of the production facilities. Photo credit: Wen Wenyu (Greenpeace), 25 November 2012

Photo 2.9 The effects of manufacturing fertilizers on surface waters are related to increased content in waste waters of sulfates, phosphates, fluorine, copper, and zinc. The photo shows outflow pipes from the Lebanese Chemical Company fertilizer plant in Selaata, Lebanon. Photo credit: Greenpeace, 1 October 1997

Photo 2.10 The mining and chemical industries involve high risks of casualties. The production of fertilizers involves high risks of explosions. Aerial views are shown of buildings surrounding a Texas fertilizer plant that erupted in a thunderous explosion, killing 14 people, including 12 firefighters battling a blaze at the facility. Photo credit: Ron Heflin (Greenpeace), 19 April 2013

2.1.3 Other Chemical Industries

There are several important industries in addition to the petrochemical and mining and chemical industries. These include the resin and chemical and pharmaceutical industries and the manufacturers of acids (Figs. 2.5 and 2.6).

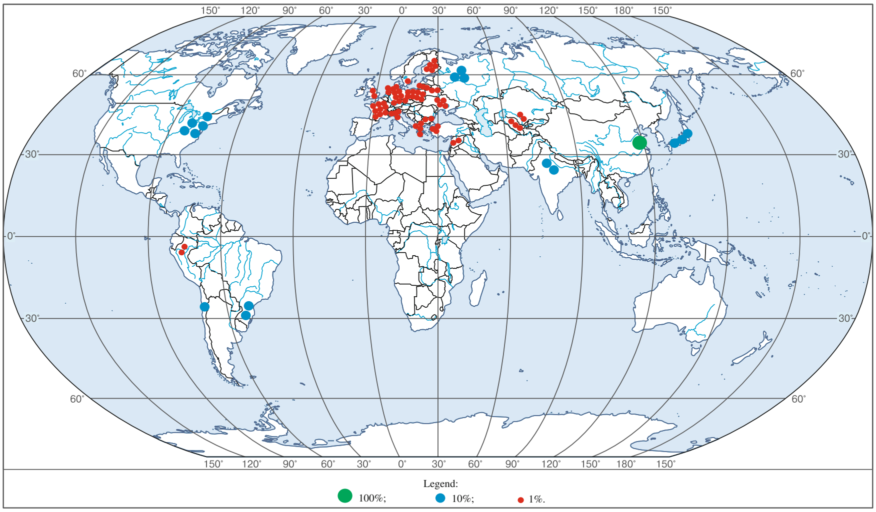


Fig. 2.5 Sulfuric acid output in 2000 shown as percentage of that of the top producer (China—24,720,000 tons) (adapted from Anwar saadat at English Wikipedia http://en.wikipedia.org/wiki/Sulfuric_acid)

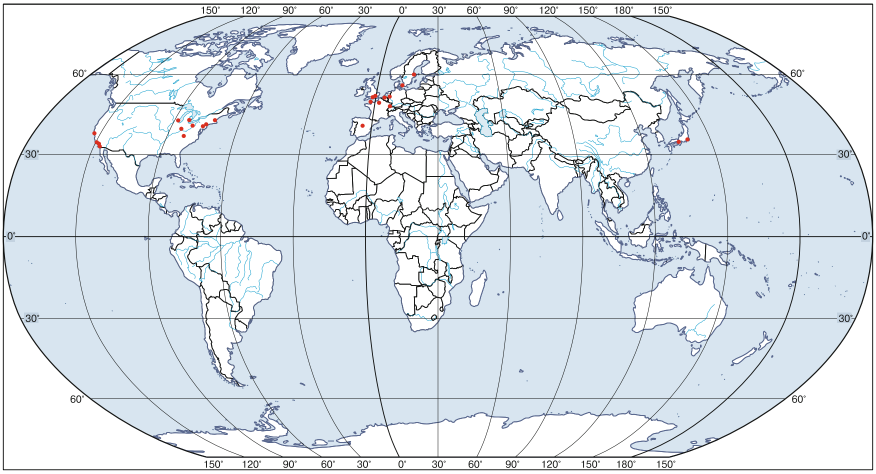


Fig. 2.6 Main pharmaceutical companies in the world. Prepared by author based on data from numerous Internet sources

The **resin industry** is developed to the **greatest extent** in the United States, Canada, Sweden, and Finland. It is based on chemical processing of forest raw materials (timber, bark, needles, dip, etc.).

The **chemical and pharmaceutical industry** is engaged in the production of pharmaceutical products, including synthetic and phytochemical preparations, antibiotics, vitamins, blood substitutes and organic preparations, and different types of medicaments. The pharmaceutical industry accounts for 25 % of the total cost of production of the chemical industry (Krotkov 2013).

The major products in the **manufacture of acids** are sulfuric and nitric acids. In the past, the use of sulfuric acid was so widespread that its production was considered for a long time to indicate the overall level of development of the chemical industry (Marshall 1989).

Sulfur, sulfides of metals, hydrogen sulfide, waste gases of thermal power plants, and sulfates of iron, calcium, etc., serve as raw materials for the production of *sulfuric acid*. The basic **stages** of its manufacture are (1) burning of raw materials with the production of sulfur dioxide; (2) oxidation of sulfur dioxide into sulfur trioxide; and (3) absorption of sulfur trioxide. World sulfuric acid production in 2012 was 230.7 million tons. The top five countries are China, the United States, India, Russia, and Morocco (Sulphuric acid 2014).

Sulfuric acid is used for the following **purposes**: (1) in the production of mineral fertilizers; (2) as an electrolyte in lead-acid batteries; (3) for the manufacture of different mineral acids and salts; (4) in the production of artificial fibers, coloring agents, smoke-forming substances, and explosive materials; (5) in the petroleum, metalworking, textile, tanning, and other industries; and (6) in reactions of industrial organic synthesis: (a) dehydration (production of diethyl ether, esters); (b) hydration (ethanol from ethylene); (c) sulfurization (synthetic cleaning agents and intermediate products in the manufacture of coloring agents); and (d) alkylation (manufacture of isooctane, polyethylene glycol, caprolactam) (Rodionov and Chang Wang Kui 2003).

Nitric acid ranks next to sulfuric acid in production volume. The raw material used in its production is ammonia. This acid is **used** in the production of mineral fertilizers; in the military industry; in the publishing business (etching of printing forms); and for other purposes.

The above-mentioned industries influence the following natural **components**: (1) atmospheric air; (2) surface waters; (3) underground waters; and (4) vegetation.

Contaminants of **atmospheric air** include dust and gases. In the chemical and pharmaceutical industry, *dust* is formed mainly during crushing and milling of feedstock. Crushing is carried out in jaw, roll, cone, hammer, and other crushers. Milling is performed using ball and porcelain mills and disintegrators.

In the production of acids, gases are the predominant atmospheric emissions. For example, in *sulfuric acid* manufacture, the basic components of atmospheric emissions are nitrogen oxide, nitrogen dioxide, and sulfur dioxide. In *nitric acid* manufacture, nitrogen oxide and ammonia are emitted; in the manufacture of *hydrochloric acid*, chlorine is emitted; and in the manufacture of *phosphoric acid*, anhydrous hydrogen fluoride is emitted (Stadnitsky and Rodionov 1996).

In the production of 1 kg of *sulfuric acid* in the Federal Republic of Germany, discharges of sulfur dioxide reach 2.6 kg, which corresponds to total sulfur dioxide emissions of 8000 tons per year in that country (Environment 1999b, vol. 2). In *wood-chemical* enterprises, discharges include oxides of nitrogen, sulfur, and carbon; and sulfurous anhydride (Bobkova et al. 1999). For plants producing *soda*, ammonia, phosphoric anhydride, sulfur trioxide, and nitrogen oxides are emitted.

Surface waters are contaminated by discharges of sewage. The production of 1 ton of sulfuric acid results in the formation of 45–70 m^3 of sewage. In the production of pigment (*titanium dioxide*), waste waters containing large quantities of sulfuric acid are discharged (Environment 1999b, vol. 2). The waste waters of *pharmaceutical enterprises* contain a large variety of materials, including alkalis, different organic substances, and components of the products manufactured.

Influences on **underground waters** are often related to waste storage. For example, the sludge collectors of factories manufacturing *soda* occupy territories of 3–4 ha. If the hydraulic seals of collectors' foundations are damaged, polluted waters get filtered to the underground horizons (Ratanova 1999).

Vegetation is affected mainly by atmospheric pollution. For example, forests are depressed by emissions of a wood-chemical complex in the north of European Russia: the lifetime of needles is reduced (particularly for pines), and there is deterioration and dieback of forest species (Bobkova et al. 1999).

The environmental effects of these chemical industries are illustrated by Photos 2.11–2.13.

Photo 2.11 Charcoal is a light black residue consisting of carbon and any remaining ash, obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually produced by slow pyrolysis, the heating of wood or other substances in the absence of oxygen. The photo is an aerial view of a charcoal camp in the state of Pará, Brazil. Thousands of remote charcoal camps in Brazil have pillaged huge areas of natural rain forest to smoulder into wood charcoal. The charcoal is burnt in blast furnaces that convert iron ore to pig iron, an intermediate product in the steel-making process. Photo credit: Rodrigo Baléia (Greenpeace), 30 November 2011

Photo 2.12 In the industrial production of chemicals and pharmaceuticals, different raw materials obtained from plant and animal products, as well as products extracted by chemical synthesis, are widely used. This photo shows a platform where canisters containing pharmaceuticals are loaded into an automatic dispensing machine at a mail order pharmacy. Photo credit: National Institute for Occupational Safety and Health, 7 April 2010

Photo 2.13 The chemical and pharmaceutical industries include the enterprises involved in manufacturing synthetic and phytochemical preparations, antibiotics, vitamins, blood substitutes and organic preparations, and different types of medicaments (such as injection in ampoules, tablets, dragée, capsules, pills, suppositories, liniments, emulsions, aerosols, and plasters). A vervet monkey with a box of aspirin stolen from campers in the Augrabies Falls National Park, South Africa, is shown. Photo credit: http://en.wikipedia.org/wiki/Environmental_impact_of_pharmaceuticals_and_personal_care_products by NJR ZA (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons, 16 September 2009

2.2 Metallurgy

2.2.1 Iron and Steel Manufacturing

The **countries** that are **leaders** in *steel*-making include the following (million tons, in 2013): (1) China, 779.0; (2) Japan, 110.6; (3) the United States, 87.0; (4) India, 81.2; and (5) Russia, 69.4. The **worldwide production** in 2013 was 1607 million tons (World Crude Steel Production 2014). As for *cast iron*, the following countries **lead** (million tons, in 2012): (1) China, 654; (2) Japan, 81; (3) Russia, 50; (4) India, 42; and (5) South Korea, 41. In all, 1.1 billion tons were smelted in the world in that year (http://www.metaltorg.ru/n/99CDDE).

Ferrous metallurgy influences the following natural **components** and parameters: (1) atmosphere; (2) surface waters; (3) soils; (4) anthropogenic physical effects (thermal, noise, vibration, etc.); (5) geological environment; (6) withdrawal of land; and (7) visual impact. Indirect effects are also exerted on other components (vegetation, animal world, underground waters, etc.).

The effects on **atmospheric air** are expressed as pollution with solid and gaseous substances. The *former* are subdivided into coarse-grained dust particles that settle on the ground near the plants and micron and submicron particles (‘suspended dust’) that can be transported for long distances (Zhuchkov et al. 2002).

Dust is formed at practically all stages of production, but especially in the course of operation of blast, steel-making, ferroalloy, and coke-fired furnaces; agglomeration plants; and lime burning plants (Yanin 2004). The following substances are prevalent in the composition of **gaseous pollutants** (Sultanguzin et al. 2002): (1) sulfur dioxide related to a presence of sulfur in fuels or ores; (2) nitrogen oxides emitted to the atmosphere as combustion products; (3) carbon monoxide; and (4) gaseous fluorides and chlorides. The **most serious** gaseous emission is *sulfur dioxide*. Its major **sources** are (1) ore agglomeration lines; (2) coke-oven batteries; (3) blast furnaces; and (4) steel-making units.

The **share** of ferrous metallurgy in the pollution of the atmosphere with gases is 15.5 % in Russia (Yanin 2004) and 10 % in Japan (An approach to recycling of resources in Japan 2004). Integrated iron-and-steel works, with capacities of 2–10 million tons of steel a year, emit 10,000–42,000 tons of sulfur dioxide; 7000–32,000 tons of nitrogen oxides; and 80,000–430,000 tons of carbon monoxide every year (Sultanguzin et al. 2002).

The influence of ferrous metallurgy on **surface waters** is quite strong. Ferrous metallurgy works are significant sources of waste waters. The average specific volume of waste waters is 11.3 m^3 per ton of steel. Metallurgical works, with capacities of 1 million tons of steel a year, discharge 18,000 m^3 of sewage every day; high contents of suspended matter are characteristic of this sewage (exceeding background levels by a factor of 10). The discharges of a number of works are highly toxic alkalis with pH levels of 12–13 (Doncheva and Pokrovsky 1999).

Soils are contaminated in the course of storage of raw materials and waste. The smelting of 1 ton of cast iron and steel is accompanied by the formation of

0.2–1 ton of slag. Blast-furnace slag consists of oxides of the following elements: silicon (40–44 %), calcium (30–50 %), aluminum (5–16 %), magnesium (1–7 %), iron (0.2–4.5 %), and manganese (0.5–3 %). Steel-smelting slag differs from blast-furnace slag in its higher content of iron and manganese oxides (Rudsky and Sturman 2014). Pollution is caused by both *wind transport of dust* from areas where solid waste is stored and by *precipitation scavenging* of harmful substances from waste storage facilities and from dust and gaseous discharges.

The effects on the **geological environment** are caused by large volumes of earth works during the constructing of enterprises. In the course of construction of a rolling-mill shop with five rolling mills and a yield of 4 million tons of rolled metal a year, 9.8 million cubic meters of ground are extracted (Khazanov 1975). Ferrous metallurgy also exerts different **anthropogenic physical actions** (*thermal pollution* that generally affects surface waters; *noise pollution,* and *vibration).*

Iron and steel plants rank among the greatest industrial complexes, and they require significant **withdrawal of land**. In order to produce 1 ton of cast iron, 20–30 tons of rocks are extracted from deep in the earth, and certain areas are used on the ground surface for opencast mines, waste banks, and tailing dumps (Pevzner 2003).

Vegetation is subjected to indirect impacts. According to data obtained by Rudsky and Sturman (2014), within the ferrous metallurgy enterprise zone, the productivity of corn used for silage preparation decreases by 43 %; that of horse beans decreases by 36 %; that of cereal crops, by 26–27 %; and that of sugar beets, by 55 %. In the steppes of southern Russia, pollution with heavy metals, especially zinc, copper, and nickel, is observed (Dyakonov and Doncheva 2002).

The effects of ferrous metallurgy on the environment are illustrated by Photos 2.14–2.16.

Photo 2.14 The effects of ferrous metallurgy industrial plants on atmospheric air are expressed as pollution with solid and gaseous substances. The former are subdivided into coarse-grained dust particles that settle on the ground near the plants, and micron and submicron particles (‘suspended dust’), which can be transported for long distances. Dust is formed at practically all stages of production, but especially during the operation of blast, steel-making, ferro-alloy, and coke-fired furnaces; agglomeration plants; and lime-burning plants. The photo shows an iron and steel plant in Sheffield, United Kingdom. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), February 1977

Photo 2.15 Gaseous pollutants of ferrous metallurgy enterprises include the following substances: (1) sulfur dioxide related to the presence of sulfur in fuels or ores; (2) nitrogen oxides emitted to the atmosphere as combustion products; (3) carbon monoxide; and (4) gaseous fluorides and chlorides. The most serious gaseous emission is sulfur dioxide. Emissions from the Cherepovets iron and steel plant (Russia) are shown here. Photo credit: V. Kantor (Greenpeace Russia), 31 May 2010

Photo 2.16 Some of the major sources of the environmental effects of ferrous metallurgy include blast and open-hearth furnaces, blast-furnace slag granulation plants, converters, ferro-alloy complexes, steel continuous casting plants, etching rooms, sintering machines, pellet firing machines, and crushing-milling equipment. Slag run-off from one of the open-hearth furnaces at a Republic Steel Corporation steel mill in Youngstown, Ohio, United States, is shown here. Slag drawn off the furnace just before the molten steel is poured into ladles for ingoting. Photo credit: http://en.wikipedia.org/wiki/Slag_heap, November 1941

2.2.2 Non-ferrous Metal Manufacturing

Non-ferrous metallurgy is a much more complex branch than ferrous metallurgy. A vast variety of different facilities, methods, and processes is characteristic of this branch of industry. Accordingly, the compositions of discharges to the atmosphere and water bodies are also different, related, first of all, to the raw materials that are used.

One of the peculiarities of non-ferrous metal **ores** is that they contain relatively small amounts of the base metal. For example, the **content** of copper in ores infrequently exceeds 5 %; zinc and lead, 6–7 %; and molybdenum, only 0.1–0.2 %. The **exception** is ores of aluminum, which contain not less than 30 % of the base metal (Rudsky and Sturman 2014).

The **major polluters** in non-ferrous metallurgy are sintering furnaces and calcining kilns; electrolyzers; crushing-milling equipment; continuous transport mechanisms; and areas of materials loading, unloading, and overturning. The **major smelted metals** are copper, lead, zinc, nickel, and aluminum (Fig. 2.7).

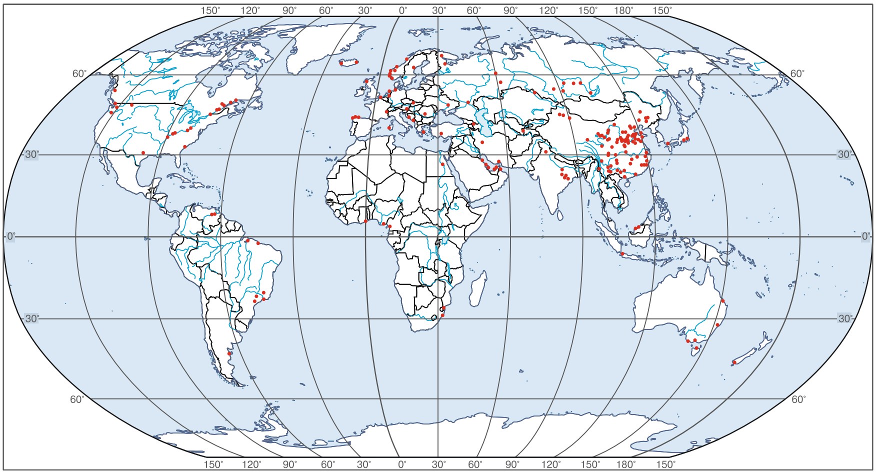


Fig. 2.7 Main aluminum smelters in the world. Prepared by author based on data from numerous Internet sources

This industry affects the following natural **components**: (1) atmospheric air; (2) surface waters; (3) condemnation of land; (4) soils; (5) vegetation; and (6) the animal world.

Air pollutants associated with this industry include sulfurous anhydride (75 % of total emissions into the atmosphere), carbon monoxide (10.5 %), and dust

(10.4 %). Pollution of the air with *sulfur dioxide* is generally observed when lead, antimony, copper, and zinc are smelted from sulfide ores (Novikov 1999).

For example, in the course of producing 1 ton of *copper,* 8.3 tons of sulfur dioxide are emitted into the atmosphere. On the whole, the production of copper is responsible for approximately 13 % of anthropogenic sulfur dioxide emitted into the atmosphere (Modern global changes 2006, vol. 1). In the production of *magnesium*, in addition to sulfurous anhydride, chlorine and hydrogen chloride (hydrochloric acid) are released. The *aluminum* industry also discharges anhydrous hydrogen fluoride and carbonic oxide (Burkat and Smola 2006).

The major **sources** of *dust* are furnaces of different types, concentrate dryers, and crushing-milling equipment. Very high concentrations of heavy metals and other chemical elements, reaching some tens of percents of the dust mass and exceeding many times their content in ores, are characteristic of the dust emissions (Yanin 2004).

Non-ferrous metallurgy is the greatest polluter of **surface waters**. The waste waters of the enterprises contain particulate pollutants, oil products, ions of heavy metals, sulfates, chlorides, fluorides, and other substances (Ratanova 1999).

The smelting of non-ferrous metals consumes a great deal of water. For example, the *following volumes of water* are used for production of the following metals: nickel, 4000 m^3/t; tungsten and molybdenum, 2500; titanium, 1; aluminum, 1500; copper, 5000; lead and zinc, 360; and tin, 750 (Rudsky and Sturman 2014).

The enterprises of non-ferrous metallurgy are among the largest industrial complexes, and they require considerable **withdrawal of land**. For example, non-ferrous metals are extracted from ores that generally contain several grams to several kilograms of commercial component per ton, thus large areas are occupied for waste storage.

In the vicinity of metallurgical combines, intense pollution of **soils** is recorded that is generally related to admixtures coming from the atmosphere. For example, investigations near the Irkutsk aluminium smelter (Russia) showed more than 100-fold increases in contents of fluorine, aluminum, manganese, barium, and sodium as compared with their background levels in soils (Belozertseva 2002). As a rule, increases in soil acidity occur near aluminum smelters.

The effects on **vegetation** are related to pollution of air and soils. For example, within 16 km of a metallurgical complex in Ontario (Canada), 25 species of plants were found to be growing under normal conditions. As one grew closer to the complex, the number of plant species decreased, and at a distance of less than 1.6 km, none of the plants were found (Strauss and Mainwaring 1989).

The effects on the **animal world** are also indirect and are related to contamination of the soil and vegetation. Around the Monchegorsk metallurgical complex, the numbers of soil invertebrates were 6–14 times lower as compared with uncontaminated territories, while the total biomass was 10–12.6 times smaller (Effect of metallurgical production 1995).

The effects on natural resources are expressed indirectly, through the great *power* and *fuel consumption*. The production of aluminum (16,000–18,000 kWh of electric power per ton), magnesium, and titanium requires especially large amounts of power. The production of nickel (50–55 tons of equivalent fuel per ton), alumina of nepheline raw materials, black copper, and other non-ferrous metals also consumes large amounts of fuel (Geographical encyclopaedic dictionary 1988).

As compared with *ferrous* metallurgy, non-ferrous metallurgy is a **much more adverse industry** from an environmental viewpoint.

The environmental effects of non-ferrous metallurgy are illustrated by Photos 2.17–2.20.

Photo 2.17 Non-ferrous metallurgy is a heavy polluter of the atmosphere. The picture shows emissions from a facility of the Mining and Metallurgical Company "Norilsk Nickel" (Russia). This is one of largest companies involved in the production of precious and non-ferrous metals. Share of world production are as follows: palladium, 50 %; nickel and platinum, 20 %; and cobalt, 10 %. Smelting is directly responsible for severe pollution, including acid rain and smog. By some estimates, 1 % of the entire global emissions of sulfur dioxide originates here. Heavy-metal pollution in the area is so severe that the soil itself has platinum and palladium contents that are feasible to mine. Photo credit: S.P. Gorshkov (Moscow State University, Russia), July 1990

Photo 2.18 The effects of non-ferrous metallurgy on vegetation are related to pollution of air and soils. Dead larches in the Ergalakh River basin near the Mining and Metallurgical Company "Norilsk Nickel" (Russia) are shown. Pollution levels (sulfur dioxide, hydrogen sulfide, phenol, formaldehyde, dust, nickel, and copper) are extremely high here. Norilsk is one of the most polluted places on Earth. Photo credit: S.P. Gorshkov (Moscow State University, Russia)

Photo 2.19 Within the non-ferrous metallurgy enterprise zone, the productivity of corn used for silage preparation decreases by 43 %; that of horse beans decreases by 36 %; that of cereal crops, by 26–27 %; and that of sugar beets, by 55 %. A potato field on the right-bank terrace of the river Yenisei (Russia) is shown here. The Krasnoyarsk aluminum plant is visible in the background. Photo credit: S.P. Gorshkov (Moscow State University, Russia), August 1994

Photo 2.20 A large amount of toxic waste is characteristic of many non-ferrous metallurgy enterprises. Accidents occur frequently in related storage facilities. For example, one such accident occurred on aluminum plant in Ajka, Hungary. This is a natural color image of the area surrounding a toxic sludge spill. The aluminum plant appears along the right edge of the image and incorporates both bright blue and brick-red reservoirs. The sludge forms a red-orange streak running west from the plant. This view shows the spill thinning but remaining discernible for several kilometers to the west. Villages of Kolontar and Devecser were affected by this toxic spill. Photo credit: Jesse Allen (NASA Earth Observatory), 9 October 2010

2.3 Mechanical Engineering

Mechanical engineering is developed to the **greatest extent** in the United States (almost 30 % of total engineering products), Japan (15 %), the Federal Republic of Germany (10 %), France, Great Britain, Italy, and Canada (Maksakovsky 2006, Book 1).

Large-scale engineering works generally include the following **departments** (Rodionova 2013): (1) power producing; (2) foundry; (3) rolling; (4) machining; (5) galvanizing; (6) assembling; and (7) painting.

Based on their environmental **effects**, the power-producing departments (boiler plants) do not differ from thermal power plants, while the environmental effects of foundries and rolling plants are not as great as those of iron and steel plants. Therefore, they are not considered here.

In **machining** shops, metalworking is performed, which includes turning, milling, grinding, drilling, forge-and-press, welding, and other kinds of work. The most complex activity is metal cutting; it accounts for about 40 % of the finished product value (Ratanova 1999).

The **electroplating** industry involves the deposition of metal, alloy, and chemical conversion (phosphate, oxide, etc.) coatings. According to *kinds of coatings*, the volume of output is subdivided as follows (percent): zinc plating, 58.8; nickel plating, 10.0; copper coating, 8.4; chromium plating, 8.4; cadmium plating, 4.6; and tinning, 2.7. Every year, several billion square meters of metal surfaces are processed; 50 % of the cadmium produced, 25 % of the tin, and 15 % of the nickel is spent for these purposes (Bek 1991).

In applying coatings, the following **operations** are performed: (1) etching; (2) degreasing; (3) activation; (4) applying special electroconductive layers; (5) applying metal coatings; and (6) special treatment of coatings.

There are two **types** of **assembling** works: (1) stationary (all components and units are fed to one place, the assembly stand) and (2) mobile (yet-to-be-assembled units move successively through all stands). In **paint** shops, the paint-and-lacquer coatings are applied to the finished products.

In the **electrical manufacturing** segment of mechanical engineering, various units are made for energy generation, transmission, conversion, and consumption; means of communication and electrical measuring instruments; and different manufacturing equipment. The production of batteries, fluorescent lamps, and mercury thermometers has the greatest effect on the environment (Yanin 1998).

Mechanical engineering affects the following environmental **components** and parameters: (1) atmospheric air; (2) surface waters (3) underground waters; (4) soils; and (5) noise pollution (Figs. 2.8 and 2.9).

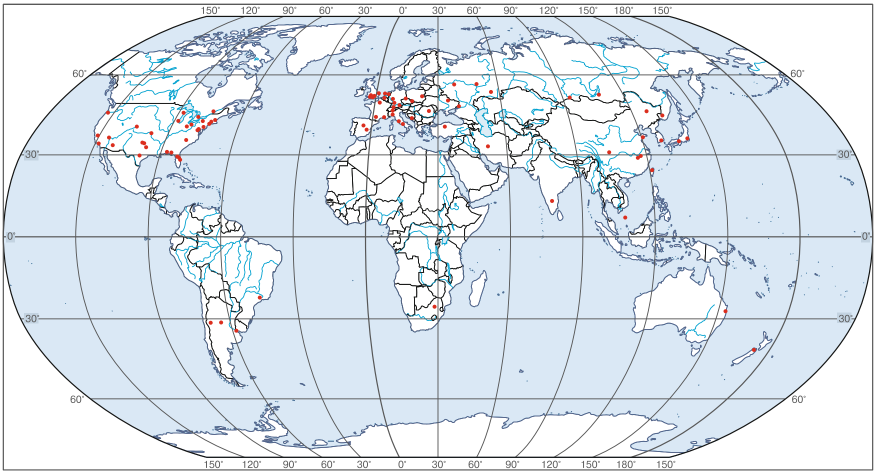


Fig. 2.8 Helicopter plants in the world. Prepared by author based on data from numerous Internet sources

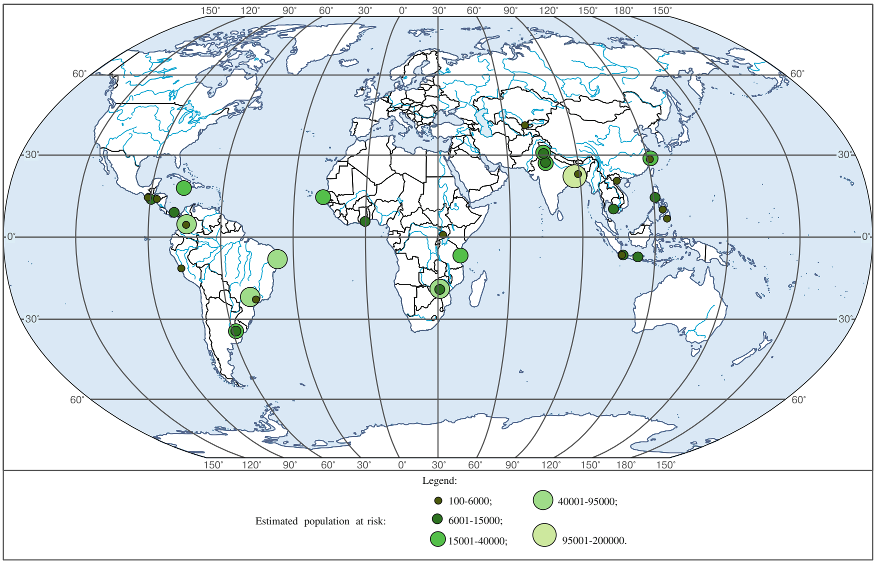


Fig. 2.9 Lead pollution from used lead-acid accumulator recycling (http://www.worstpolluted.org/projects_reports/display/90). Reproduced by permission of Blacksmith Institute for a Pure Earth

The effects of mechanical engineering on **atmospheric air** are significant. Atmospheric pollution takes place during *machine working* of metals; particles of worked materials, and sublimates and fumes of lubrication-cooling fluids which enter the air. Pollutants that enter the atmosphere include oxides of sulfur, nitrogen, and carbon, as well as chlorine, abrasive dust, aerosols, and vapors (Popova 2006).

The harmful substances entering the air from *galvanizing* plants are in the form of dust, fine fog, vapors, and gases. The processes of acid and caustic etching, as well as plating (blackening, anodizing, phosphating, etc.), are most unfavorable.

In *paint* shops, the fumes of organic solvents, paint-and-lacquer materials, and pigment aerosols predominate (Ratanova 1999). In *battery* factories, the air is contaminated with dust containing lead, nickel, cadmium, arsenic, bismuth, antimony, and tin (Yanin 2004).

The major source of pollution of **surface waters** in *metalworking* is the discharge of used lubricant-cooling agents, electrolytes and washing agents containing oil products, soluble metal compounds, suspensions, and harmful chemical elements.

The waste waters of *galvanizing* activities generally contain cations (copper, zinc, nickel, cadmium, chromium, lead, mercury, iron, aluminum, tin, bismuth, cobalt, manganese, etc.) and their hydroxides (in the form of suspensions and colloidal particles), and anions (chlorides, sulfates, fluorides, cyanides, nitrates, nitrites, phosphates, etc.), as well as surfactant species (Bek 1991; Environment 1999a, b, vol. 1).

Galvanizing activities show the **greatest water consumption**. They account for 20–50 % of the total water usage of mechanical engineering enterprises. Of particular importance is the workpiece flushing process performed after most manufacturing operations. This process accounts for about 70–80 % of water consumption and 30 % of water contamination by this industry. The second most important source of contamination is the "used" electrolytes, which account for 30 % of the contamination but only 1–2 % of the waste water volume (Bek 1991).

The pollution of **soils** is generally related to solid waste storage. The waste is mainly composed of chips and fillings of ferrous and non-ferrous metals, and scale and sludge from the electroplating industry. The sludge of settling boxes contains toxic compounds of lead, chromium, copper, and zinc (Engineering ecology 2003).

Effects on **underground waters** are common. For example, 35 % of the total mercury in underground waters in Sweden is from burned batteries (Yanin 1998). **Noise pollution** is especially high in the machine working of metals. For example, it reaches 115–130 db in press shops (Rudsky and Sturman 2014).

The environmental effects of mechanical engineering are illustrated by Photos 2.21–2.23.

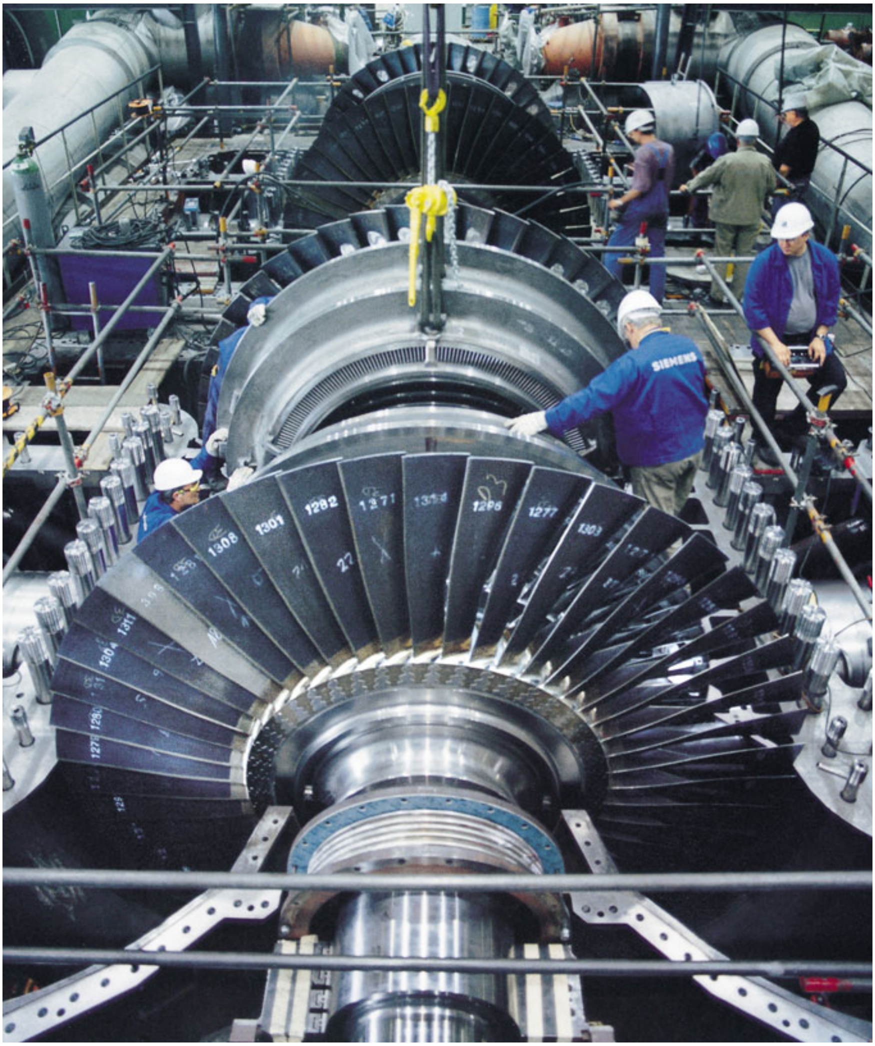


Photo 2.21 Mechanical engineering is the most complex and differentiated branch of industry. Based on the product range, mechanical engineering is subdivided into the following activities: (1) general engineering; (2) transport engineering; (3) electrical manufacturing industry; (4) agricultural engineering; (5) instrument engineering; (5) arms production; and others. Assembly of a steam turbine rotor produced by Siemens, in Germany, is shown here. Photo credit: Siemens Pressebild

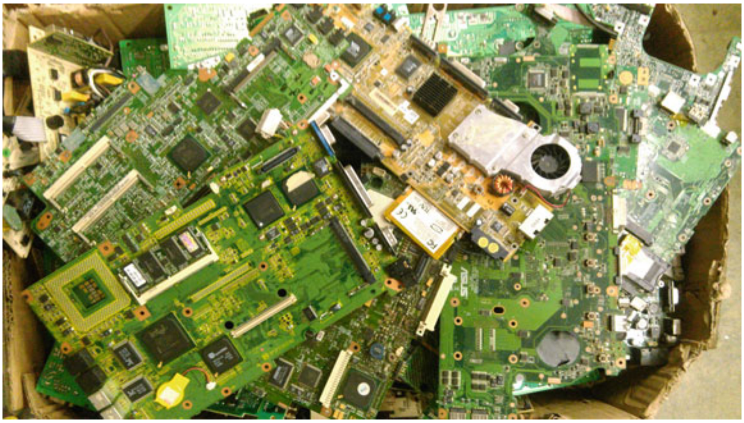


Photo 2.22 Electronic waste includes discarded electrical or electronic devices (computers, electronic office equipment, electronic entertainment devices, mobile phones, television sets, etc.). All electronic scrap components may contain contaminants such as lead, cadmium, beryllium, or brominated flame retardants. An estimated 50 million tons of E-waste are produced each year. Electrical waste contains hazardous but also valuable and scarce materials. Up to 60 elements can be found in complex electronics. In the United States, an estimated 70 % of heavy metals in landfills comes from discarded electronics. The photo shows electronic cards in one of the computer companies in Vladivostok. Photo credit: A.S. Govorushko, 1 December 2014

Photo 2.23 The harmful substances entering the air from galvanizing plants are in the form of dust, fine fog, vapors, and gases. The processes of acid and caustic etching, as well as plating (blackening, anodizing, phosphating, etc.), are most unfavorable. The photo shows a hot-dip zinc galvanizing plant in an industrial sector (Kot Lakhpat, Lahore) in Pakistan. Photo credit: Syed Zillay Ali

2.4 Building Materials Industry

The products of the **building materials industry** are natural and manmade materials and articles applied in the construction and repair of buildings and other structures. This industry affects the following environmental **components** and parameters: (1) atmospheric air; (2) soils and vegetation; (3) surface waters; (4) geologic environment; (5) condemnation of land; (6) thermal pollution; and (7) radioactive contamination.

The adverse effects on the **atmosphere** are generally caused by *dust* discharges. The major *sources* of its delivery to the atmosphere are cement mills, lime kilns, carbonate of magnesia production plants, brick kilns, and asphalt processing units.

For example, raw materials for *cement* production include limestone, chalk, and, more rarely, marbles, marls, travertine, and fusible clays and clay loams. For the production of 1 ton of cement, about 3 tons of lump material must be crushed, milled, burnt, and carried. This material is almost completely transformed into fine dust consisting of a mixture of calcium carbonate ($CaCO_3$), calcium oxide (lime, CaO), and other substances (Vainshtein and Vainshtein 2003).

Dust that is extremely detrimental to health arises in the manufacture of goods from *natural rock materials* (Starikov 2013). The major manufacturing operations producing dust include (Bretschneider and Kurfurst 1989) (1) crushing; (2) cracking; (3) transfer to charging grid; (4) transportation; and (5) storage. Production of *lime* is accompanied by discharge of about 200 kg of dust per ton of output products, while 140 kg is discharged in the production of 1 ton of gypsum plaster (Rudsky and Sturman 2014).

In the manufacture of *lime sand brick*, the “dirtiest” operations are charging of limestone and sand by cranes, transportation, sorting with sifters, and pressing (Primak and Baltrenas 1991). In the course of producing *ceramics* and *clay brick*, the maximum escape of dust is characteristic of the chamotte milling division and batch preparation shops (Vakunin and Koryakov 2005).

Some factories manufacturing building materials emit, in addition to dust, large quantities of *gaseous pollutants*. For example, the world’s cement industry accounts for 1.5 % of anthropogenic discharges of carbon dioxide (Yudovich et al. 2005). The cement industry ranks third in this characteristic in the European Community (Szabo et al. 2006).

Increased gas emissions are also characteristic of *asphalt* production. In this case, the major source of emissions is drums for asphalt-concrete mix preparation, to which the mineral components are delivered and where they are mixed with a binding component, bitumen (Dorozhukova and Yanin 2004).

The manufacture of *sanitary ware* is accompanied by emissions of up to 200 kg of carbon oxides per ton of product (UNEP 2013 Annual Report 2014). The smoke fumes caused by glass making contain the following (milligrams per cubic meter): fluorides, 150; arsenic oxides, 55; boron oxides, 1300; and sulfur oxides, 375 (Menzelintseva and Artemova 2006). The *other harmful components* of waste gases emitted during the production of building materials are nitrogen oxides and carbohydrates.

Effects on **soils** are observed particularly in the course of coating plant operation and transportation of asphalt. A number of chemical elements enter the soil, including zinc, copper, mercury, molybdenum, chromium, and lead (Dorozhukova and Yanin 2004). Cement dust causes adverse effects for vegetation (Mehraj et al. 2013). Plant growth parameters, yield components of crops which can be considerably influenced by excessive metal accumulation in soil (Mehraj and Bhat 2014).

Surface waters are polluted by the following **processes** (Environmental assessment sourcebook 1992): (1) fluid drainage from settling boxes used for dust soaking; (2) scattering of kiln charge; and (3) storage of raw materials and processing wastes. These processes result in pH increases and pollution with suspended and dissolved substances, predominately potassium and sulfates.

The influences on the **geological environment** are related to two **factors** (Govorushko 2009): (1) processing of huge volumes of natural materials (sand, clay, crushed stone, limestone, etc.) and (2) excavation of large amounts of subsoil. For example, the volume of earthworks in the course of construction of a cement mill with a capacity of 1.2 million tons a year is approximately 1.3 million cubic meters (Khazanov 1975).

Condemnation of land is caused by the considerable quantities of waste. However, as a rule, these wastes are nontoxic or low in toxicity. In addition, a large portion is returned to production (Rudsky and Sturman 2014).

Thermal pollution is related to the fact that the manufacture of many kinds of products requires considerable expenditures of energy. For example, 1 % of world energy consumption is used for the production of cement. In order to produce one ceramic brick, about 0.27 kg of the equivalent fuel is needed (Filatov 2005). Generally, energy is consumed in processes of hard firing (e.g., brick, tile, Dutch tile, and faience and porcelain sanitary ware items).

Radioactive contamination is caused by the fact that some natural rock materials (granites, syenites, porphyrites) are characterized by increased background radiation (Filatov 2005). On the whole, its role is not great.

The influences of the building materials industry on the environment are illustrated by Photos 2.24 and 2.25.

Photo 2.24 The production of bricks results in environmental degradation due to emissions of gaseous and particulate pollutants. All the brick kiln operations, from digging earth to unloading fired bricks from the kiln, are accompanied by the generation of dust. Air pollution in a brick kiln is produced through both stack emissions and fugitive emissions. The use of thermally low-efficiency kilns, outdated technology, and inefficient firing technologies contributes to particulate and gaseous emissions. Emissions from brick kilns consist mainly of fine particles of coal, dust particles, organic matter, and small amounts of gases such as sulfur dioxide, nitrogen oxides, hydrogen sulfide, carbon monoxide, and others. The photo shows numerous brick kilns near Dhaka, Bangladesh. Photo credit: Boris Braun (University of Cologne, Germany), 21 February 2009

Photo 2.25 In order to produce 1 ton of cement, about 3 tons of lump material must be crushed, milled, burnt, and carried. This material is almost completely transformed into fine dust consisting of a mixture of calcium carbonate, calcium oxide, and other substances. The cement industry also accounts for 1.5 % of anthropogenic discharges of carbon dioxide. The chimney of a cement factory in Slite, Gotland, Sweden, is shown. Photo credit: John Cunningham (Greenpeace), 23 May 2001

2.5 Woodworking Industry

The **woodworking industry** manufactures sawn goods, plywood, wood-based panels, furniture, matches, sleepers, and other products. The basic **kinds** of woodworking machines and processes are: (1) sawing (band, circular, power-saw benches, trimming, multi-edgers, butting, panel); (2) milling; (3) jointers; (4) panel planers; (5) turning; (6) four cutters; (7) drilling; (8) polisher; and (9) dovetail jointers.

Mechanical processing of wood is generally based on four **operations**: (1) sawing; (2) planing; (3) drilling; and (4) polishing. As a result, sawn goods are produced that are used in construction, manufacture of furniture, finishing agents, musical instruments, sports goods, crafts, and so on.

Chemical treatment of timber-based materials is used to make *wood fiberboard* (sheet material made of plexiform wood fibers by drying or hot-pressing) and *wood chipboard* (sheet material made by hot-pressing wood chips with binding materials).

As for environmental pollution, the woodworking industry is not a leading source. For example, it ranks 10th among all industrial branches in Russia by volumes of atmospheric emissions and accounts for 2.9 % of their total amount (Yanin 2004). Woodworking has effects mainly on the following natural **components**: (1) atmospheric air; (2) soils; and (3) underground waters. In addition, it has serious impacts on human health.

Effects on **atmospheric air** are generally related to dust emitted during the mechanical treatment of timber, and gas discharges in the case of chemical treatment. In 1991, the emissions of harmful substances by the Russian woodworking industry into the atmosphere reached 855,300 tons (Lapkayev and Rogov 2005).

Dust is fine, solid particles suspended in the air. It is **subdivided** into (1) *coarse* dust, which is visible to the naked eye; (2) *finer* dust, which is visible when passing through sun-rays in the air; and (3) dust that is *invisible* to the naked eye.

The most intense dust formation is characteristic of radial saw, panel saw, band saw, and belt-grinding machines (Lomakin et al. 2005). For example, grinding machines produce from 24 to 2040 kg of dust per shift (Lapkayev and Rogov 2005).

Fine dust with particle sizes of less than 10 μm is most dangerous. In mechanical treatment of timber, this dust comprises about 65 % of the total amount (Yanin 2004). Among all kinds of mechanical processing, **grinding** (polishing) operations are most significant from this point of view. As to toxicity, the dust of the East ***Indian redwood***, or sappanwood tree, is most dangerous, followed by ash, larch, pine, birch, and oak dust (Lapkayev and Rogov 2005).

The **waste** volumes of the mechanical processing of timber are relatively small. For example, they are 3–6 % in the timber works of British Columbia (Canada) (Orban et al. 2002). They contain generally 34.5 % bark, 15.4 % sawdust, 8.5 % cuttings, 21.9 % chips, and 19.6 % other waste (Yanin 2004). When this waste is milled with the objective of further processing, more dust escapes.

Gaseous emissions are largely related to the production of chipboard and include redolent terpene hydrocarbons and formaldehydes. For example, about 40 plants in the Federal Republic of Germany manufacturing chipboard discharged 4600 tons of these organic compounds into the atmosphere in 1979 (Environment 1999a, vol. 1).

The influences on **soils** and **underground waters** are generally related to leaching from waste wood that is buried in the ground (Bassett 1996). Some contribution is made by penetration into the soil of toxic preservatives in the course of impregnation and drying of timber, as well as their washout when preserved timber is used (Popova and Kharuk 1991).

The effects on human **health** are related to the release of dust. Three **types** of reactions of humans to wood dust have been identified: (1) primary irritations; (2) allergic reactions; and (3) systemic diseases (Lapkayev and Rogov 2005).

The **first group** is related to the irritation of mucous membranes, which is accompanied by rhinitis, lachrymation, nasal hemorrhage, and other reactions. **Allergic** reactions are more often expressed as itching, but whole-body dermatitis is possible. Many known skin diseases are caused by the wood dust of a number of tropical species. However, it is now known that the wood dust of many species of the temperate zone (spruce, pine, larch, linden, birch, maple, beech, and oak) has similar effects (Lapkayev and Rogov 2005).

The **third group** includes diseases of the respiratory tract, eyes, and other parts of the body. Wood dust causes the occupational disease pneumoconiosis (Golovunina 2001). The oncogenic effect of beech and oak dust is considered to be proven (Environment 1999a, vol. 1).

An additional threat to people is related to the ability of wood dust to *ignite* and *explode* under certain conditions (Voronova and Avlokhova 2005).

The environmental effects of the woodworking industry are illustrated by Photos 2.26–2.28.

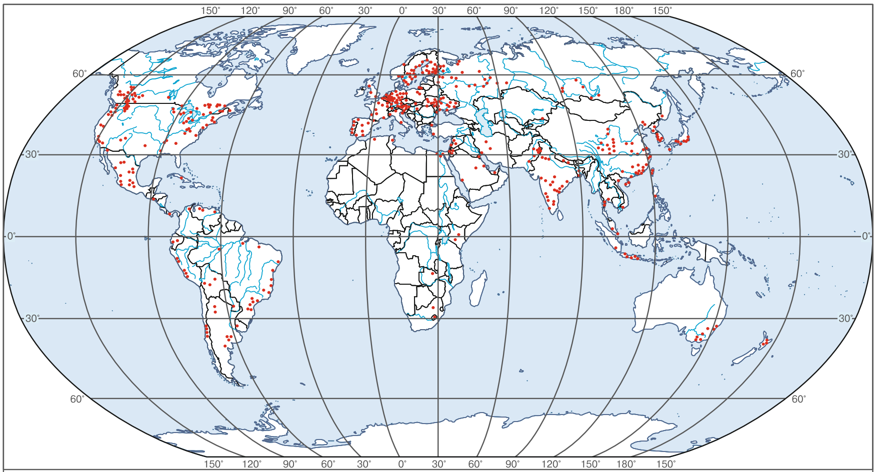
Photo 2.26 Chemical treatment of timber-based materials is used to make wood fiberboard (sheet material made of plexiform wood fibers by drying or hot-pressing) and wood chipboard (sheet material made by hot-pressing wood chips with binding materials). The photo shows wood fiberboard and wood chipboard. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 16 November 2013

Photo 2.27 The wastes produced in the mechanical processing of timber contain generally 34.5 % bark, 15.4 % sawdust, 8.5 % cuttings, 21.9 % chips, and 19.6 % other wastes. The photo shows the operation of a belt sawmill in Idaho, United States. Photo credit: Chris Schnepf (University of Idaho, United States)

Photo 2.28 Illegal logging contributes to deforestation and by extension global warming, and it also causes loss of biodiversity. The identification of illegally logged timber is technically difficult. Illegal logging accounts for up to 30 % of the global logging trade and contributes to more than 50 % of tropical deforestation in central Africa, the Amazon Basin, and South-East Asia. The photo shows the Odani sawmill, located in Placas (Pará state, Brazil), linked with logging and processing of illegal timber. Photo credit: Lunae Parracho (Greenpeace), 28 September 2014

2.6 Wood Pulp and Paper Industry

The following five countries **lead** in paper and paperboard production (million tons, 2011): (1) China, 99.3; (2), the United States, 75.1; (3) Japan, 26.6; (4) the Federal Republic of Germany, 22.7; and (5) Canada, 12.1 (http://en.wikipedia.org/wiki/Pulp_and_paper_industry) (Fig. 2.10).



(http://www.paperonweb.com/ppmanfaa.htm; http://www.risiinfo.com/risi-store/do/product/detail/north-american-pulp-and-paper-mill-map.html; http://www.nscorp.com/nscportal/nscorp/Customers/Industrial-Products/Paper-Clay-Forest/; http://en.wikipedia.org/wiki/List_of_paper_mills)

Fig. 2.10 Main pulp and paper mills. Prepared by author based on data from numerous Internet sources

Cellulose produced from the wood *of coniferous trees* is stronger, and its fibers are longer; however, cellulose can be manufactured from any plant. The **technological process** can be described simply as follows. Cuttings of logs (1–3 m long) are freed from bark and abraded into wood pulp. The wood pulp is bleached with hydrogen peroxide or sodium peroxide. Then the non-cellulosic substances (lignin, gums, mineral substances, etc.) are removed from the wood pulp.

There are two **methods** of cellulose production: (1) sulfite and (2) sulfate. In the **sulfite** method, the wood pulp is processed with a solution of calcium bisulfate and sulfuric acid. The processing is carried out in autoclaves at temperatures of 130–160 °C and pressures of up to 6 atmospheres. Within 10–16 h, most of the non-cellulosic substances have been dissolved, and, as a result, we have 95 % cellulose. Then the cellulose is washed with water, dehydrated, and compressed (Ratanova 1999).

The **sulfate** method of cellulose production includes the boiling of wood chips in white liquor (a mixture of sodium hydroxide [NaOH] and sulphureous sodium [Na_2S]) at 165–175 °C for 3–5 h. The cellulose produced is washed, disintegrated, dried, and bleached. As in the sulfite method, a major pollution source is the bleaching shop (Ratanova 1999).

The pulp-and-paper industry influences the following natural **components**: (1) surface waters; (2) atmospheric air; (3) animal world; (4) soils; (5) underground waters; and (6) thermal pollution.

The effects on **surface waters** are basically observed in the *sulfite* method of production. The waste waters in this case can be divided into the following **types**: (1) bark-containing waters (polluted with bark, which degrades water quality by releasing tarry matter); (2) fiber-containing waters (polluted with wood fibers and dyes that are deposited on the bottoms of water bodies; the fibers rot, emitting carbon dioxide and ammonia); (3) leachate-containing waters (contain lignin, tarry matter; disturb the oxygen regime of water bodies); (4) acid waters (contain mineral acids, including sulfric acid; reduce pH and dissolved oxygen content); and (5) chlorine-containing waters (polluted with chlorine, alkali, and sulfuric and hydrochloric acids) (Shabalova and Tarasyavichute 2006).

In the *sulfate* method of production, the major effect is also related to leachate-containing waste waters. They include gums, phenols, hydrogen sulfide, methyl mercaptane, turpentine, methanol, and other substances. Sludge-containing waters show very high alkalinity (Ratanova 1999).

The pulp-and-paper industry consumes large quantities of water: for production of 1 ton of cellulose, from 200 m^3 (Ince et al. 2011) to 400–500 m^3 (Rudsky and Sturman 2014) of water are needed.

Atmospheric pollution results from emissions of dust and gaseous substances. The *solid particles* include sodium and calcium compounds, and particles of starch, talc, lime, clay, and pigments. The volumes of emissions may reach 283 kg per ton of the final product (Yanin 2004). The *gaseous pollutants* include hydrogen sulfide, oxides of nitrogen and carbon, methyl mercaptane, dimethyl sulfide, terebenthene, and methanol (Romanova and Bratseva 2004; Turanchiyeva 2005).

Effects on the **animal world** are indirect and related to the pollution of water bodies with waste waters. The discharge of leachate-containing waste waters reduces the water transparency, which decreases available sunlight and thus phytoplankton formation. Pulp-and-paper mill effluents affect fish reproduction (Milestone et al. 2012; Kovacs et al. 2013).

Effects on **soils** are caused by dust that falls from the atmosphere and leakage of high-alkalinity waste. Data on soil changes near a paper-making plant in the Assam State (India) are given in a paper by Phukan and Bhattacharyya (2003). In soils near the plant, aluminum oxide, iron (III) oxide, and manganese (II) oxide, as well as calcium, sodium, magnesium, and lead, accumulate; soil becomes alkaline, and its water retentivity and density decrease.

Effects on **underground waters** are also related to leakages. For example, 23 years after a Baykal pulp-and-paper plant was put into operation, underground waters between the industrial site and the edge of Lake Baykal were found to be polluted with sulfate ion, hydrocarbonates, and other substances. In order to resolve this problem, 12 interceptive wells were drilled. Pumped underground waters were cleaned; in 1999, 474 m^3 were pumped (Gorkina 2009).

Thermal pollution is caused by the use of large volumes of water (flushing of cellulose, using water for cooling systems, etc.) and then discharge of the heated water to water bodies.

The environmental effects of the pulp-and-paper industry are illustrated by Photos 2.29–2.31.

Photo 2.29 Cellulose can be manufactured from any plant. However, cellulose produced from the wood of coniferous trees is stronger, and its fibers are longer. Stockpiles of rain-forest logs at APP's Indah Kiat Perawang pulp mill in Riau, Sumatra, Indonesia, are shown. Photo credit: Greenpeace, 2012

Photo 2.30 The effects of wood pulp and paper plants on surface waters are basically associated with the sulphite method of production. The waste waters are polluted with bark, wood fibers, lignin, tarry matter, mineral acids, chlorine, alkali, sulfuric and hydrochloric acids, and other substances. The photo shows a waste disposal basin at a paper company in Minnesota, United States. Photo credit: U.S. EPA Great Lakes Program Office

Photo 2.31 Atmospheric pollution from pulp and paper plants results from emissions of dust and gaseous substances. The solid particles include sodium and calcium compounds, and particles of starch, talc, lime, clay, and pigments. The gaseous pollutants include hydrogen sulfide, oxides of nitrogen and carbon, methyl mercaptane, dimethyl sulfide, terebenthene, and methanol. The Baykalsky wood pulp and paper works (Russia) are shown here. On 25 December 2013, it was closed. Photo credit: V. Kantor (Greenpeace Russia)

2.7 Light Industry

Light industry includes such *branches* as the textile industry, clothing manufacture, tanning, shoemaking, the fur industry, and toy manufacture. The most important branch is the **textile** industry, which provides about half of the entire production volume and ranks first in the number of employed people.

The textile and tanning branches have the greatest effects on the environment. The basic **technological processes** of the textile branch are (1) raw material preparation; (2) spinning; (3) weaving; (4) painting and coloring; and (5) other finishing (addition of materials that decrease combustibility and improve color fastness and extension resistance, and so on).

In the production of **leather**, the animal fells are subjected to the following **operating steps**: (1) preparatory processes (skin with hairs is changed into untanned, semi-finished goods; rawhide, at this step, is preserved with salts, dried, and washed with solutions of chemicals, and the hairs are removed); (2) tanning (in order to increase resistance and elasticity, a skin is treated with chromium sulfate, sodium sulfate, and sodium carbonate); (3) trimming (foliation) of skin (natural skin has a thickness of about 1 cm; it is split into three to six layers); and (4) finishing operations (dyeing, malaxation, and greasing) (Poyarkov 2002) (Fig. 2.11).

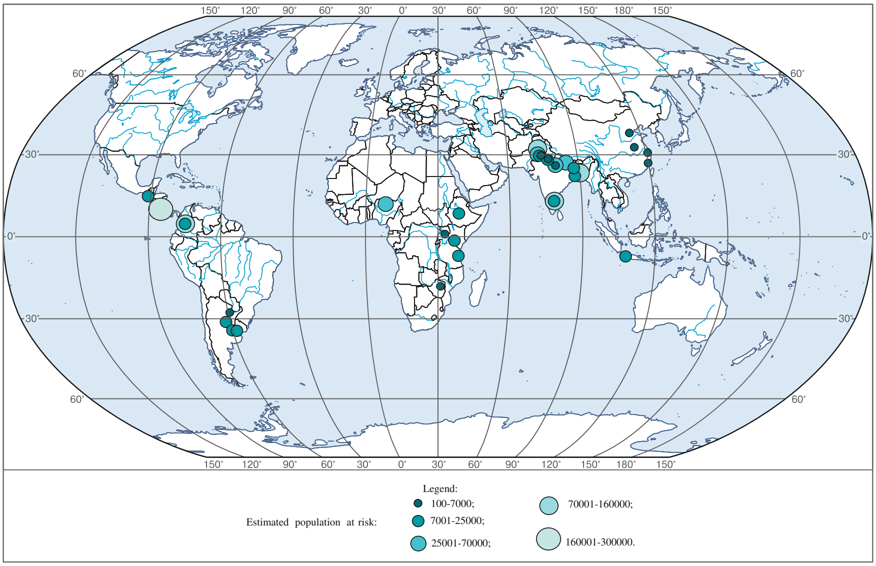


Fig. 2.11 Chromium pollution from tanneries (http://www.worstpolluted.org/projects_reports/display/88). Reproduced by permission of Blacksmith Institute for a Pure Earth

Light industry affects the following natural **components**: (1) surface waters; (2) atmospheric air; (3) soils; and (4) the animal world. It also exerts serious influences on human health.

Surface waters are polluted with different substances. As for water consumption, light industry is among the leading branches of industry. Water use in the *textile branch* is basically related to *cloth* washing at different stages of finishing. Water consumption is 100–330 m^3/t for different cloths (Marinich et al. 2000; Sadova et al. 2002). Water consumption in *leather making* is much lower: in the treatment of 1 ton of raw tanning products, 35 m^3 of waste waters are formed (Van Groenestijn et al. 2002).

Water pollution caused by operating textile production units is basically related to cloth washing, coloring, and finishing. Waste waters are contaminated with *pesticides* (used for sanitizing sheep) and *soil particles* (Rogachev 2000), and they contain particles of fat, soap, soda, surface-active materials, and wool (Smirnov et al. 2000).

Much of the initial solutions are contained in the waste of *dye-finishing* production. For example, the amounts of thickeners, Glauber's salts, starch, and surface-active materials in the waste waters are up to 90 % of their initial content in the finishing liqors; for sodium hydroxide, it is 50 %; for dispersed and cationic dyes, 40 %; for sulfur dyes, 30 %; and for potassium dichromate, 25 % (Kiselev 2002).

The major contaminants in the *tanning* industry are chromium salts used for tanning, and cobalt, copper, and nickel, which are components of coloring agents (Rodrigues and Formoso 2013; Rudsky and Sturman 2014). In the treatment of 1 ton of raw stock, 200 kg of chlorides, 100 kg of sulfates, and 10 kg of trivalent chromium are formed (Van Groenestijn et al. 2002).

Emissions into the **atmosphere** include dust and gases. Wool dust consists of particles of mineral and organic origin. Silicon dioxide, part of the mineral component, is the most dangerous (Smirnov et al. 2000). The composition of *gaseous pollutants* in the textile branch depends on the technological operation. They are carbon monoxide; nitrogen dioxide; sodium hydroxide; hydrogen peroxide; hydrogen sulfide; sulfur dioxide; ammonia; nitrogen dioxide; formaldehyde; and nitric, hydrochloric, and sulfuric acids (Sadova et al. 2002; Marinich et al. 2000).

In *leather* manufacture, the air is polluted with hydrogen sulfide, ammonia, and vapors of sulfuric and formic acids (Pisareva et al. 2003). Because polymeric materials are used for the manufacture of leather goods, and different glues (including those based on organic solvents) and dyes are widely applied, considerable amounts of toxic pollutants are released into the atmosphere (Mikhailyuk et al. 2003).

Soils are contaminated when pollutants settle out from the atmosphere, and in waste storage. In *leather making,* chromium and lead are major pollutants. The **animal world** is affected through pollution of habitat. Discharges of waste waters cause living conditions for hydrobionts to deteriorate. For example, discharges of phenols and synthetic detergents poison fish (Kiselev 2002).

Many occupational **diseases** are characteristic of light industry; for example, allergic asthma caused by pollen covering the wings of the **silkworm moth**, and ursolic asthma of furriers. Byssinosis, a lung disease caused by inhalation of organic dust containing textile fibers, is found in workers in cotton and flax spinning mills (Environment 1999b, vol. 2). Also, tanneries are contaminated by bacteria and fungi that create occupational inhalation risks to workers (Skora et al. 2014).

The environmental effects of light industry are illustrated by Photos 2.32–2.37.

Photo 2.32 Sheep hair is one of the major kinds of raw material used in the textile industry. Sheep shearing is the process by which the woolen fleece of a sheep is cut off. The person who removes the sheep's wool is called a shearer. Typically, each adult sheep is shorn once each year. The annual shearing most often occurs in a shearing shed, a facility especially designed to process often hundreds, and sometimes more than 3000, sheep per day. The photo shows a sheep shearer at the Shearing Shed, Yallingup, Western Australia. Photo credit: http://en.wikipedia.org/wiki/Sheep_shearing, Martin Pot (Martybugs at en.wikipedia) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY 3.0 (http://creativecommons.org/licenses/by/3.0)], via Wikimedia Commons

Photo 2.33 In the production of leather, the animal fells are subjected to the following operations: (1) preparatory processes (skin with hairs is changed into untanned, semi-finished goods; rawhide, at this step, is preserved with salts, dried, and washed with solutions of chemicals, and the hairs are removed); (2) tanning (in order to increase resistance and elasticity, a skin is treated with chromium sulfate, sodium sulfate, and sodium carbonate); (3) trimming (foliation) of skin (natural skin has a thickness of about 1 cm; it is split into three to six layers); and (4) finishing operations (dyeing, malaxation, and greasing). The photo shows workers handling hides to produce leather at a tannery in Cáceres, Mato Grosso, Brazil. Photo credit: Ricardo Funari (Lineair/ Greenpeace), 8 April 2009

Photo 2.34 The major contaminants in the tanning industry are chromium salts used for tanning, and cobalt, copper, and nickel, which are components of the coloring agents. In the treatment of 1 ton of raw stock, 200 kg of chlorides, 100 kg of sulfates, and 10 kg of trivalent chromium are formed. The photo shows the flow of contaminated water from tanneries to the Ganges in Kanpur, India. Photo credit: Boris Braun (University of Cologne, Germany), 16 September 2007

Photo 2.35 A total of 75 % of tanneries are located in South Asia (especially in Nepal, Bangladesh, and India). In the largest tannery region of Bangladesh, Hazaribagh, more than 200 tanneries generate 7.7 million liters of liquid waste and 88 million tons of solid waste every day. The direct discharge of these wastes has contaminated the ground and surface water with dangerously high concentrations of chromium, as well as cadmium, arsenic, and lead. The photo shows a dump site containing chromium sulfate in Rania, Northern India. Photo credit: Boris Braun (University of Cologne, Germany), 17 January 2010

Photo 2.36 Tanning is the stage in which raw leather is processed and made more durable so that it can be made into various products in the subsequent segment of the industry. The types and concentrations of the chemicals used in different stages of production are varied. Chromium is one of the most widely used chemicals throughout this process. The primary health impacts from chromium are damage to the gastrointestinal, respiratory, and immunological systems, as well as reproductive and developmental problems. Tanners at work treating hides in Fez, Morocco, are shown here. Photo credit: A. Gandolfi (FAO)

Photo 2.37 Byssinosis, a disease of the lungs caused by inhalation of organic dust containing textile fibers, is characteristic of workers in shops conducting preliminary treatment in cotton and flax spinning mills. The photo shows baskets with cotton being unloaded at a cotton factory in Asifabad, Adilabad district, Andhra Pradesh, India. Photo credit: Peter Caton (Greenpeace), 18 November 2009

2.8 Food Processing Industry

The **food processing industry** comprises facilities for producing ready-to-eat products and prepared foods, as well as tobacco goods, soap and other cleaning agents, perfumes, and cosmetics.

The food industry affects the following natural **components**: (1) surface waters; (2) atmospheric air; (3) the animal world; and (4) condemnation of land. In addition, it seriously affects human health and results in high mortality.

Surface waters are polluted with different substances. The compositions of pollutants are very different, depending on the enterprise. Organic compounds (fats, proteins), mineral suspensions, and chlorides are present in the waste waters of *meat processing* plants. The discharges of cattle slaughterhouses are polluted the most (Uglov 2006).

The waste waters of *margarine* production plants show high acidity and high contents of fats and sulfates (Willey 2001). A large volume of nitrogen-containing waste forms in the production of *cheese* (Tusseau-Vuillemin 2001). Preparation of 1 kg of cheese yields 9 kg of whey. About a *half* of its global production is not processed, but instead is discharged in the form of waste waters (Siso 1996); in this case, the biological oxygen demand (BOD_5) reaches 3000 mg/l (Kionga-Kamau 1995).

The *sugar industry* (Fig. 2.12) exerts a considerable influence on surface waters. In the Gorakhpur district of Nepal, for instance, improperly treated water

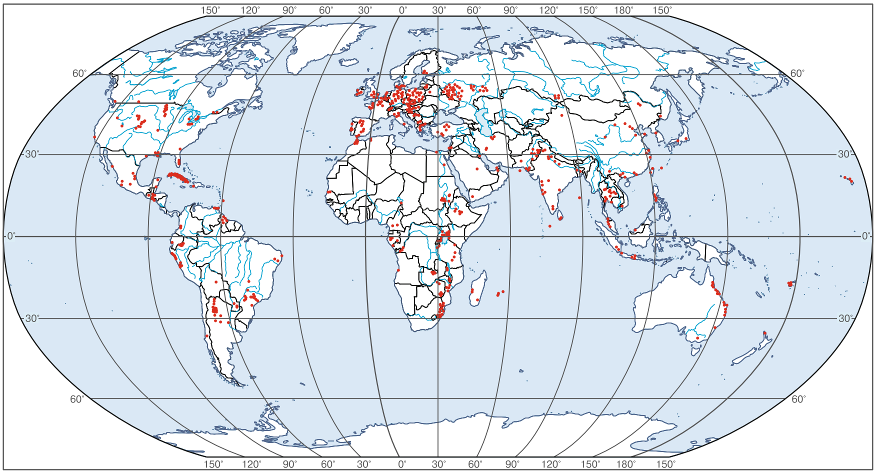


Fig. 2.12 Main sugar mills. Prepared by author based on data from numerous Internet sources

discharged from two sugar factories into a stream rendered the stream's water unfit for drinking, bathing, or irrigation (Hess et al. 2014). The waste waters of *olive processing plants* are highly toxic due to their content of phenols (D'Anibale et al. 2004).

Air is polluted with dust and different gaseous contaminants. *Dust* emissions usually originate from dry, loose products (sugar, salt, grain, flour, coffee, tea, starch, etc.). In most cases, the dust particles are released during mechanical fragmentation. The food industry in Russia releases to the atmosphere 1.4 % of the total volume of solid particles for all industrial sectors (Yanin 2004).

This industrial branch emits *odorous gaseous substances*. They may be *visible* (as for instance, in vegetable oil expression, coffee bean roasting, smoking of meat and fish, drying of fish, and broiling of peanuts and hamburgers). Sometimes, the odors are emitted without *visible* pollution, such as in the cooking of tomatoes, processing of spices, and fish dressing and processing (Protection of the atmosphere against industrial pollution 1988, vol. 2).

The production of *smoked products* results in serious atmospheric pollution with gases. All types of smoking chambers generate phenols, carbonyl compounds, acids, and benzopyrene (Kim and Filippov 2003). Benzopyrene is of great importance because it accounts for 97 % of the environmental danger related to the production of smoked products (Kim et al. 2004; Kim and Kim 2005). For production of 1 l of beer, about 30 kg of carbon dioxide enters the atmosphere (The geography of beer 2014).

In the **animal world**, hydrobionts suffer the most from pollution of this industry, related to reduction in dissolved oxygen in water and to the toxicity of a number of pollutants. Examples of these effects include mass fish mortality due to discharges of waste waters from a brewery in Iraq (Khayat 1986) and a sugar mill in Latvia (Sugar plant ordered to close 2005). Another example is the sharp decrease in species diversity of zooperiphyton due to waste waters from a cheese dairy in Russia (Skalskaya 2002).

The condemnation of land is related to accumulation of considerable amounts of waste in some enterprises. When different *cereals* are processed, huge masses of husks, fine vegetable particles, and other debris are generated (Rudyka et al. 1999). For example, production of *flour* and *rice flour* and *cotton* cleaning yield 17.7 tons, 66 tons, and 63 tons of waste per worker a year, respectively (Yanin 2004). In some factories producing potato starch, from 100,000 to 250,000 m^3 of starch-containing sludge are generated every year (Facts and figures: food processing and the environment 1995).

In the making of *baked goods* and *confectionery*, the waste basically consists of reject pastry and egg-shells. For example, 34 tons of reject pastry and shells of 4 million eggs (approximately 28–38 tons per year) are generated in a plant producing 6000 tons of goods every year (Nayman 2006). Serious problems also arise

with *packaging materials*, which constitute a considerable portion of domestic waste (Brown 1993).

Dust that forms in flour milling plants, sugar mills, and plants producing cocoa powder, dried milk, and other products is able to spontaneously explode (Yanin 2004). For example, dust exploded at a sugar refinery in Port Wentworth, Georgia (United States) on 7 February 2008. As a result, 13 people were killed and 42 were injured (http://en.wikipedia.org/wiki/List_of_industrial_disasters#Food_industry).

The environmental effects of the food industry are illustrated by Photos 2.38–2.42.

Photo 2.38 The enterprises of the food processing industry are divided into three categories according to the raw material used: (1) those that run on raw stock of vegetable origin; (2) those that run on raw stock of animal origin; and (3) those that use non-agricultural raw materials. Checking of carcasses in a slaughterhouse in Chad is shown here. Large differences in meat consumption exist both within and between countries, ranging from an average of 83 kg per person per year in North America and Europe to 11 kg per person per year in Africa. Photo credit: Roberto Faidutti (FAO)

Photo 2.39 Many enterprises of the food industry are sources of considerable water pollution. Hydrobionts suffer from this pollution to the greatest extent; ill effects are related to reduction in dissolved oxygen in water and to the toxicity of a number of pollutants. In addition, 0.5 ton of water is spent in slaughterhouses for each killed animal in the course of slaughter and butchering. Offal and effluent flowing from the slaughter yard past a well toward the White Nile are shown here. Photo credit: United Nations Environment Program (UNEP), from *UNEP Sudan Post-Conflict Environmental Assessment Report*, 22 June 2007

Photo 2.40 A large volume of nitrogen-containing waste forms during the production of cheese. Preparation of 1 kg of cheese yields 9 kg of whey. About a half of the global production of cheese is not processed, but instead is discharged in the form of waste waters. Cheese production located at the foot of Künzelspitze, between the towns of Schoppernau and Schröcken, in the Bregenzerwald, Austria, is shown here. Photo credit: http://commons.wikimedia.org/wiki/File:Production_of_cheese_in_Hopfreben_19.JPG by Böhringer Friedrich (Own work) [CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons, 28 May 2011

Photo 2.41 Dust that forms in flour milling plants, sugar mills, and plants producing cocoa powder and dried milk and other products is able to spontaneously explode. The photo shows the damage caused by a sugar dust explosion on February 7, 2008, at the Imperial Sugar refinery at Port Wentworth in Georgia, United States. Photo credit: U.S. Chemical Safety and Hazard Investigation Board, 10 February 2008

Photo 2.42 The influences of the food industry on atmospheric air are related to pollution with dust and different gaseous contaminants. The emissions of dust usually originate from dry, loose products (sugar, salt, grain, flour, coffee, tea, starch, etc.). In most cases, the dust particles arise in the course of mechanical fragmentation. A chimney at the Puunene sugar mill, Puunene, Maui, Hawaii, is shown here. Photo credit: https://en.wikipedia.org/wiki/Pu%CA%BBunene,_Hawaii by joanna orpia from QLD, Australia (sugar cane factory in maui) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

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Chapter 3
Mining and Mineral Processing

3.1 Opencast Mines

Opencast mining is extraction of commercial minerals from the Earth's surface using open-pit workings. About 60 % of metallic ores, 85 % of non-metallic ores, 100 % of non-metallics, and 35 % of coal are produced by this method. The distribution of mineral resources of the world is shown in Fig. 3.1.

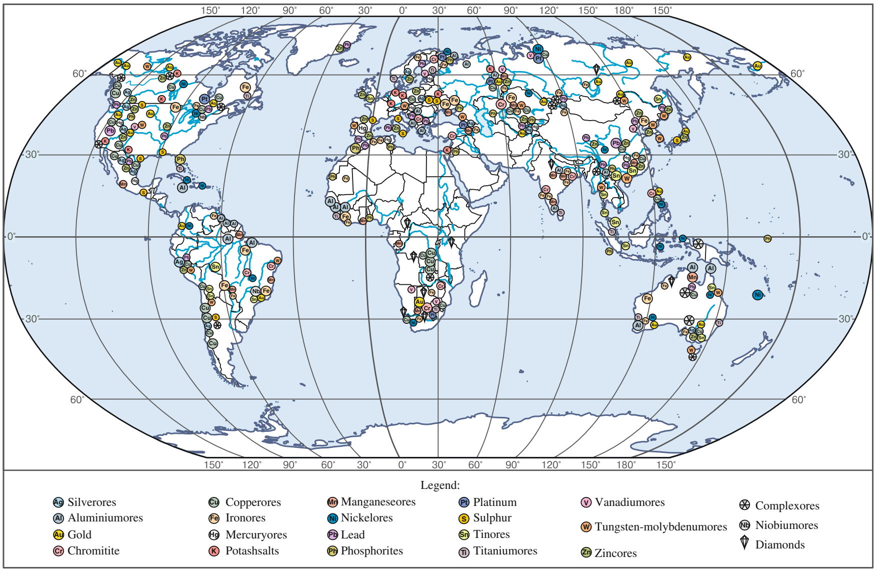

Fig. 3.1 Mineral resources of the world (not including fuels) (Kholina et al. 2009). Reproduced with permission of V.N. Kholina

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_3

Opencast mining impacts the following **natural components**: (1) condemnation of land; (2) soils; (3) vegetation; (4) animal world; (5) atmospheric air; (6) surface and underground waters; and (7) relief.

Regarding the **area of condemned land**, the mining industry is a leading branch of industry. Extraction of 1 million tons of coal disturbs 3–43 ha; iron ore, 14–640 ha; manganese ore, 76–600 ha; ores for production of mineral fertilizers, 22–97 ha; limestone, 60–120 ha; and phosphorites, 22–77 ha (Pevzner 2003; Mirzekhanova 2008).

Soils are contaminated with fuels and lubricants, flushing liquids, sludge, and other materials. The accumulation of dust from dumps and open casts on the soil surface reduces a soil's fertility. During reclamation activities, the physical properties of soils are disturbed and other impacts occur (Lukanin and Trofimenko 2001).

The natural state of **plant** cover is disturbed both around open casts and in the land plots where production sites are established. These disturbances include destruction of trees and shrubbery, and degradation and loss of grass cover. The effects on vegetation may be indirect and caused by air and soil pollution, which have negative effects on plants.

Effects on the **animal world** are also indirect and are caused by contamination of other media. Soil invertebrates are affected to the greatest degree; amphibians and small mammals follow; and birds are affected to a lesser degree. The effects on ichthyofauna are generally caused by increases in the acidity of surface waters, and they often are considerable. Freshwater fish usually do well at pHs of 5.0–8.5. A sudden change in pH within this range can have adverse effects on them, while when the range expands to 4.0–9.5, the fish usually perish (Govorushko 2009).

The **basic sources** of air pollution are open casts and grinding-sorting factories (Ovseychuk 2006). **Specific sources** of dust and gas emissions include (1) explosions; (2) motor transport; (3) handling operations; (4) drilling operations; and (5) dust-forming surfaces (dumps, slopes, tailing dumps, etc.).

Mineral dust is the **main component** of aerosol atmospheric contamination. In ore quarries, more than 90 % of the rock mass is extracted by using drilling and blasting operations. The amounts of dust formed are 0.043–0.254 kg of dust per kilogram of explosive material (Lukanin and Trofimenko 2001).

The **total volume** of dust discharged as a result of opencast mining in the Russian Federation is 460,000 tons a year (Goncharov et al. 2005). As compared with other branches of industry (power engineering, petrochemistry, etc.), the spatial scales of this pollution are not great.

Surface waters are subjected to geochemical transformation to the greatest extent. Generally, pollutants enter surface waters from three **sources**: (1) dewatering of mine workings; (2) drainage effluent from "waste" rock dumps; and (3) drainage of concentrating mill tailing dumps (Yanin 2005).

As for contamination of surface waters, **sulfide minerals** are of great significance. When deposits are being developed, the rocks are crushed and, as a result, there are large increases in their reactive surface areas. The abrupt increase in accessibility to oxygen intensifies oxidation processes of sulfide minerals and growth in discharges of ore components. From the ore-bearing rocks, considerable

quantities of heavy metals, aluminum, iron, manganese, etc., are released, which are also toxic for aquatic organisms (Yellishetty et al. 2013).

Dewatering of quarries causes **underground water** levels to drop, forming a depressed funnel area, which may be 2–3 orders of magnitude larger than the area of the quarry. Around the Kursk magnetic anomaly (Russia), drops in levels reach 50–113 m and increase at rates of 1–3 m per year, while the funnel area is about 40,000 km^2. Around the Donets Basin (Ukraine), it exceeds 100,000 km^2 (Kovalevsky 1994).

An opencast operation is a powerful factor in **relief** transformation. The mining of each ton of ore is accompanied by several cubic meters of overburden. The area of positive topographic forms (dumps) is usually slightly larger than that of negative forms (quarries). In the Mikhailovsky mining and concentration complex (Kursk magnetic anomaly), for example, the area of dumps is 2000 ha, while that of quarries is only 1500 ha.

On the whole, opencast operations exert marked adverse effects on the environment; **surface waters** and **ichthyofauna** are among the components that are affected the most.

The environmental effects of opencast operations are illustrated by Photos 3.1–3.8.

Photo 3.1 The mining industry is among the leading branches of industry with respect to the area of condemned land. The photo shows trucks loading coal at the Cerrejón coal mine, located in Colombia on the border with Venezuela. It is an open-pit mine, one of the largest mines of that type in the world. The mine extends over 69,000 ha (170,000 acres). By the end of 2011, the Cerrejón mine had reached a production figure of 32.03 million tons. It represents 4.6 % of global coal sales. Cerrejón has a mining fleet comprising 493 pieces of equipment: 258 trucks with load capacities of 190, 240, and 320 tons; 50 hydraulic shovels; and 185 pieces of auxiliary equipment. Photo credit: https://commons.wikimedia.org/wiki/File:Cerrejonmine2.png by en:User:Zero Gravity [Public domain, GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

Photo 3.2 The impacts of any mining enterprise are not limited to any one natural component. For example, the Bingham Canyon Mine has had adverse environmental effects on the habitats of fish and wild animals; it also is a source of air and water pollution, creating health hazards to the surrounding public. Since the early 1990s, the mine has spent more than $400 million on clean-up efforts in the affected areas. The Bingham Canyon Mine has been in production since 1906, and it has created a pit over 0.6 miles (0.97 km) deep and 2.5 miles (4 km) wide, covering 1900 acres (770 ha). Every year, it produces approximately 300,000 short tons of copper. In addition to copper, the mine produces about 400,000 oz of gold, 4 million ounces of silver, and 25 million pounds of molybdenum. Photo credit: http://en.wikipedia.org/wiki/Bingham_Canyon_Mine

Photo 3.3 The important sources of air pollution in mining activities are motor transport and handling operations. The main component of atmospheric contamination is mineral dust. The open-cast of the *Gafsa Phosphates* Company (CPG) in south-western Tunisia is shown. CPG, with a current production exceeding 8 million metric tons, is the world's fifth largest phosphate producer. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 23 August 2008

Photo 3.4 Drilling operations are an additional source of dust and gas emissions in the mining industry. When drilling is carried out, carbon oxides, nitrogen oxides, hydrocarbons, soot, sulfur dioxide, benzo[*a*]pyrene, hydrogen sulfide, and silicate dust enter the atmosphere. Considerable preparation work related to territory leveling and construction of temporary approach roads is required for transportation of the drilling equipment within the exploration area. Exploratory well drilling in a gold ore field in Khabarovsk Krai, Russia, is shown. Photo credit: V.M. Govorushko, 21 July 2013

Photo 3.5 Surface waters are the component of the natural environment that is subjected to geochemical transformation to the greatest extent in the mining industry. Generally, pollutants enter surface waters from three sources: (1) dewatering of mine workings; (2) drainage effluent from "waste" rock dumps; and (3) drainage of concentrating mill tailing dumps. The photo shows a 32.9-acre phosphogypsum slag heap in Sichuan, China. The fluoride content of the leaching solution is 277 mg/l. According to state regulations, any figure over 100 mg/l is hazardous and should be subject to strict regulation. No residential area should be built within 800 m, and no water source should be used within 150 m. Photo credit: Wen Wenyu (Greenpeace), 25 November 2012

Photo 3.6 On 30 January 2000, the dam containing toxic waste material from the Baia Mare Aurul gold mine in northwestern Romania burst and released 100,000 m^3 of waste water, heavily contaminated with cyanide, into the Lapus and Somes tributaries of the river Tisza, one of the largest in Hungary. An estimated 80 % of all fish in the Tisza River died as a result of the spill. Numerous other animals such as foxes, otters, and ospreys, died after eating contaminated fish. The photo shows cyanide pipes coming from the Aurul gold mine, leaking cyanide into the environment. Photo credit: Jim Hodson (Greenpeace), 1 February 2000

Photo 3.7 Dewatering of quarries causes underground water levels to drop, forming a depressed funnel area, which may be 2–3 orders of magnitude (100–1000 times) larger than the area of the quarry. The Khingansky tin quarry in the Jewish Autonomous Oblast, Russia, is shown. Photo credit: I.D. Debelaya (Institute of Water and Ecological Problems, Khabarovsk, Russia), 20 August 2013

Photo 3.8 An opencast operation is a powerful factor in relief transformation. The mining of each ton of ore is accompanied by several cubic meters of overburden. In this case, a variety of heavy machinery is used, such as excavators and bulldozers. A Bagger 288 bucket-wheel excavator is shown. It was built to remove overburden before coal mining at the Hambach strip mine in Germany. It can excavate 240,000 tons of coal or 240,000 m^3 of overburden daily—the equivalent of a soccer field dug to 30 m (98 ft.) deep. The excavator is up to 220 m (721 ft.) long and approximately 96 m (315 ft.) high. The excavating head itself is 21.6 m (70.9 ft.) in diameter and has 18 buckets, each holding 6.6 m^3 (8.6 yd^3) of overburden. Photo credit: http://en.wikipedia.org/wiki/Surface_mining by User:Martinroell [CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons

3.2 Underground Mines

Underground mining is extraction of minerals from the Earth's interior without disturbance of the Earth's surface. Underground mining accounts for about one-**third** of the minerals that are mined in the world. The *deepest* mines in the world are the TauTona and Mponeng gold mines in the Republic of South Africa, which are currently working at depths exceeding 3900 m (http://www.mining-technology.com/features/feature-top-ten-deepest-mines-world-south-africa/).

Two basic **techniques** are used in underground mining: (1) blast-hole drilling (periodic explosion of the rock, loading and transportation of loose rock, support setting; it is a cyclic technology); and (2) combined techniques, in which the basic technological processes are combined in time (Gorodnichenko and Dmitriyev 2008).

Underground mining affects the following natural **components**: (1) surface waters; (2) underground waters; (3) animal world; (4) vegetation; (5) geological environment; (6) condemnation of land; and (7) atmospheric air.

Surface waters are polluted with contaminated mine drainage waters. In underground coal mining alone, 1.4 billion m^3 of water are pumped every year from mines. This water is contaminated with suspended substances, including fine particles of coal and rock, colloidal particles, and different bacteria; it is enriched with dissolved chemical substances, and it contains surface-active materials (Rudsky and Sturman 2014).

Mine drainage waters are often characterized by their *acidity*. For example, a discharge of mine drainage waters in the Donets Basin (Ukraine) having a volume of 55 million m^3 causes pH in the watercourses to drop from 7.9 to 3.6. In addition, mineralization doubles, while content of sulfates triples (Gorshkov 2001). In the Republic of South Africa, river waters infrequently not contain increased concentrations of *uranium* from drainage waters of gold mines (Winde and Sandham 2004).

The carryover of chemical elements in mine drainage waters continues after a mine has been closed (Semikobyla 2007). For example, hundreds of tons of non-ferrous metals are carried every year by mine waters from an abandoned sulfide deposit complex near Freiberg (Germany); these metals settle partially in the river deposits, while the remainder is carried to the sea (Kulikova 2005).

Underground waters are affected by drainage of the water-bearing horizons by mine workings. In the course of water pumping, cones of depression are formed. Their dimensions depend on geological and hydrogeological conditions in the area and the duration of drainage works. Their radii can reach 10 km. Mines not only dehydrate adjacent territories, but also contaminate the drained underground waters (Kulikova 2005).

Underground mining requires less **condemnation of land** than opencast mining. Nevertheless, the surface complex of buildings and structures (mine site) occupies considerable land and includes administration buildings, dumps, slime pits, warehouses for the natural drying of slime, coal storage facilities, quarry mine workings, and other facilities (Semikobyla 2007; Zhao et al. 2013).

The **geological environment** is affected by the formation of underground mined-out space due to extraction of rocks and the minerals they contain. In the course of mining, rock bursts—sudden fracture failure of the strained part of the mineral mass adjacent to the underground mine working—sometimes arise.

Rock bursts complicate mining activities owing to disturbances of mine working supports, and damage to and moving of machines, mechanisms, and equipment. The most powerful outburst ever recorded occurred in 1968, when 14,000 tons of coal and 600,000 m^3 of methane were displaced in the Donets Basin at a depth of 750 m (Yasamanov 2003).

The major sources of **atmospheric** pollution associated with underground mines are the gas-dust emissions. An estimated 27 billion m^3 of methane, 16.8 billion m^3 of carbon dioxide, and 200,000 tons of dust are discharged every year into the Earth atmosphere from underground mine workings (Glukhov et al. 1997). Approximately 20–21 billion m^3 of methane are released from coal mines, while the remaining amount is provided predominantly by mines producing iron, copper, gold, nickel, mercury, diamonds, and potassium salts (Mining engineering and environment 2001).

Gases and dust are also released from the surfaces of waste dumps and mineral storage areas. In coal mines, conic dumps or pit refuse heaps are commonly encountered, many of which may **ignite spontaneously**. The burning rock dumps discharge much smoke and harmful gases (Protection of the environment against anthropogenic impacts 1993). Underground mining of mineral resources is a dangerous activity. In the twentieth century, about 100,000 mine workers died in accidents related to blasts of gas in coal mines alone (Ivanov et al. 2014).

For example, on 13 May 2014 the Soma mine disaster occurred in Turkey. An explosion occurred 2 km below the surface; 787 workers were present during the disaster, and 301 of them died (http://en.wikipedia.org/wiki/List_of_industrial_disasters).

The environmental effects of underground mining operations are illustrated by Photos 3.9–3.12.

Photo 3.9 World coal resources can be quantified as follows: 15 % of world land is occupied by 3600 coal-mining fields. Coal resources occur in 75 countries and comprise 14.810 billion tons. In some regions coal is the base of the economy. For instance, the economy of the Svalbard archipelago of Norway relies mainly on coal production. Most of the coal is exported to Germany, Denmark, Portugal, and Spain. The Svalbard coal mine is shown here. Photo credit: Ilan Kelman, http://www.ilankelman.org/aircraft.html, June 2009

Photo 3.10 The major factor influencing surface waters is discharge of contaminated mine drainage waters. The photo shows highly contaminated acidic mine drainage coming from a copper mine into the Rio Tinto, Spain. As a result of the mining, Rio Tinto is notable for being very acidic (pH 2), and its deep reddish hue is due to iron dissolved in the water. Acid mine drainage from the mines leads to severe environmental problems due to the heavy metal concentrations in the river. Photo credit: Carol Stoker (NASA), July 2002

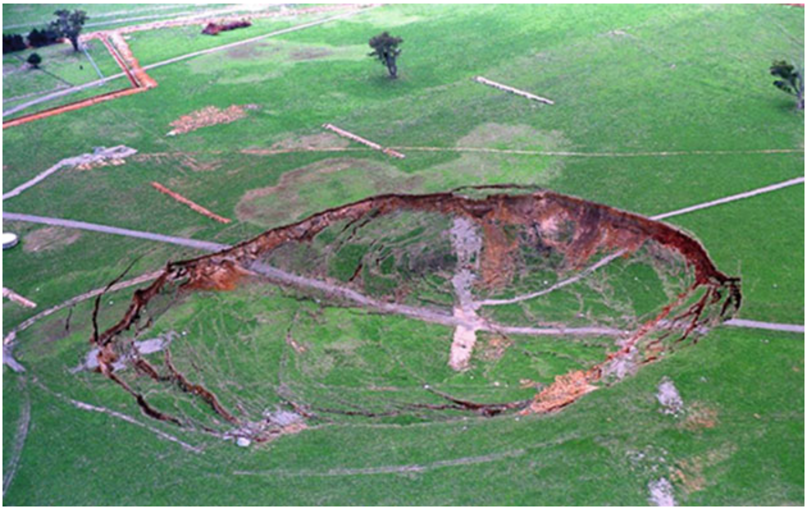

Photo 3.11 As a result of extraction of great volumes of rock during mining, there are gradual subsidence or crush bursts of the overlying rock roof. The image shows the results of a collapse at the Elura lead-zinc underground mine after removal of stope material, Australia. Photo credit: http://en.wikipedia.org/wiki/Underground_mining_(hard_rock), 27 January 2006

Photo 3.12 Some mining enterprises, on completion of mining operations, are transformed into tourist attractions. For example, the Wieliczka Salt Mine lies within the Krakow metropolitan area (Poland). The mine, built in the thirteenth century, produced table salt continuously until 2007. The Wieliczka Salt Mine reaches a depth of 327 m (1073 ft.) and is over 287 km (178 mi) long. About 1.2 million people visit the Wieliczka Salt Mine annually. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 21 August 2014

3.3 Drag and Hydraulic Extraction of Deposits

Drag and **hydraulic methods** are used to develop **placer** deposits. Placer deposits form due to the destruction of *primary* deposits by weathering processes and further movement of the matter. The concentrations of the commercial component depend on differences in the densities of the component and surrounding loose sediments. There are many **types** of placers, but the two most important are (1) river and (2) coastal-marine.

Placer deposits provide gold, platinum, diamonds, optical-grade quartz, amber, different accessory minerals (ilmenite, rutile, zircon, and monazite; materials containing titanium, zirconium, and hafnium), building materials (gravel, sand), and other materials. The greatest *coastal-marine* placer deposits are within water areas of Australia, India, the United States (Alaska, California), and the Republic of South Africa (Mironenko and Sorokin 2007).

The development of placers is a specific **form of opencast** mining. In the case of **river** placers, *cleaning* the surface of vegetation, *development mining* (removal of the upper non-productive stratum), *watering*, and *production* (extraction of the commercial component from the productive stratum) are necessary. In the course of production, flushing and concentrating sands are conducted based on differences in the physical properties of commercial minerals and barren rocks (Mirzekhanova et al. 2014).

Coastal-marine placers are developed in different *ways*. Within inshore belts, sands are extracted by scrapers, bulldozers, excavators, and hydraulic guns. At great depths (up to 160 m), **dredges** equipped with hoist winches and wireline bucket-grapplers are applied. The bucket is dropped into the sea, cut into the ground, and lifted up after the material is captured. There are also dredges with *sludge pumps* (Fig. 3.2).

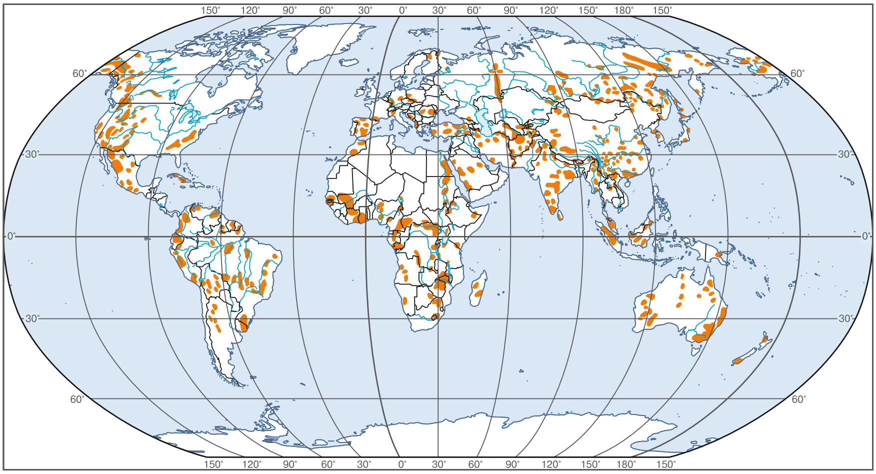

Fig. 3.2 Areas of alluvial gold deposits in the world (http://www.minelinks.com/alluvial/gold_map_5.html)

The **drag** and **hydraulic** development of placers **mainly influences** surface waters and hydrobionts. The condemnation of land is also important. Impacts on underground waters, atmospheric air, soils, vegetation, and terrestrial animals are much less (Fig. 3.3).

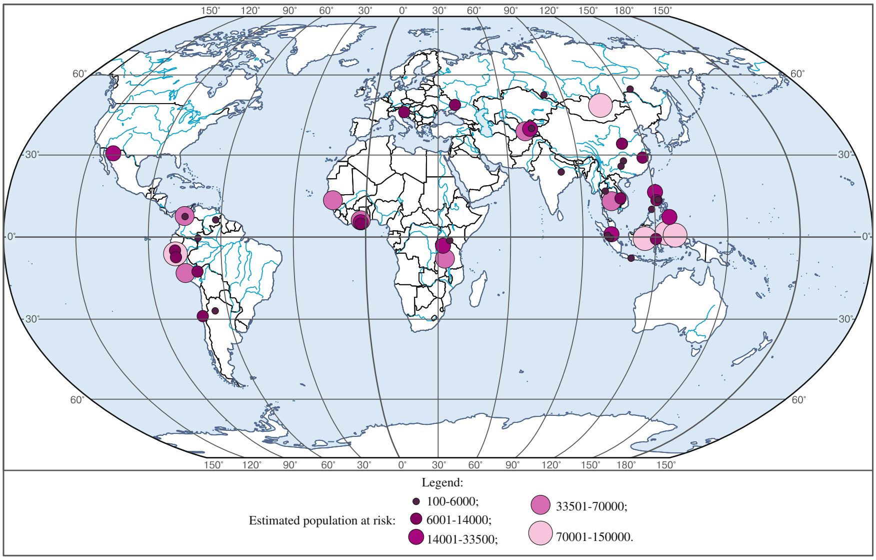

Fig. 3.3 Mercury pollution from gold mining and ore processing (http://www.worstpolluted.org/projects_reports/display/87). Reproduced by permission of Blacksmith Institute for a Pure Earth

The influences of river placer development on surface and underground waters are related to the following **factors**: (1) operations are carried out in the overflow lands and valleys of rivers; (2) technology provided for the displacement of watercourse channels, and their blocking by dams and banks, disturbs the natural hydrological regime; and (3) when rocks are excavated with dredges, water is contaminated, and drainage flows contain heavily precipitable mineral particles (Konnov 2008).

The **turbidity** of dredge flows is generally 15–20 g/l, which exceeds the natural turbidity by hundreds of times (Tereshina 2003). Scour of anthropogenic formations in the flood plain and unimpeded carryover of materials of this scour to rivers are also of great importance.

The drag development of **coastal-marine** placers also contaminates the water. For example, in the course of extraction of building materials from the Baltic Sea bottom, the water turbidity increases from 8 to 400 times (Litvin and Tsupikova 1999).

This much water contamination affects **hydrobionts**. The high concentrations of the suspensions reduce illumination and the productivity of phytoplankton. Fine suspensions that are deposited in river channels deprive fish of their spawning grounds, and they prevent small aquatic fauna from seeking refuge between stones (Pain 1987). In the development of a placer located in the higher part of a small

river, the contamination can affect practically the whole downstream part of the watercourse (Potemkin 1995).

In the development of coastal-marine placers, the redeposition of the suspended material constitutes the greatest danger to **fish** spawning on the ground and also to **filtering mollusks**. Some species of fish that are visually searching for food avoid sections with concentrations of suspended substances of more than 10 mg/l. This also influences the nutrition of **sea birds**. When minerals are extracted in the vicinity of **spawning grounds**, the latter are entirely destroyed (Mirzekhanova et al. 2014; Kulikova 2005).

The **condemnation of land** is great in the case of river placer development. In the extraction of alluvial minerals with dredges, quarries caused by ground extraction, dams, and dredge relief elements—numerous dumps of barren rocks and flushing tailings—are formed (Govorushko 2009).

The **atmosphere** is polluted mainly during drilling and blasting operations, as well as due to dust from rock dumps. Some contribution is provided by the construction of hydraulic structures, approach roads, and other structures (Zelinskaya et al. 1999). The effects on **soils** consist of the destruction of the humus layer during construction of structures, blocking with dumps, and contamination of soils with dust.

The effects on **vegetation** occur when the placer and mine site surfaces are cleared of trees, bushes, and grass; difficulties in photosynthesis, growth, and development of plants in adjacent territories result from the pollution of plant leaves with dust.

The environmental effects of dredge development of placers are illustrated by Photos 3.13–3.19.

Photo 3.13 Gold is much heavier than the rocks enclosing it. It has a density of 19.3 g/cm^3, while the density of sands is usually 2–3 g/cm^3. The hydraulic method of gold extraction is based on this difference. The gold-bearing rock is loaded to a jig with flowing water, which carries the sand away while the gold particles remain at the bottom. Sluicing of placer gold in the Ivalojoki Placer Mining District (Lapland, Finland) is shown. Photo credit: J.J. Sederholm, 1898

Photo 3.14 Now this process is mechanized to a large extent. About 90 % of gold, 90 % of zircon and niobium, 80 % of rare-earth elements, 70 % of titanium and tin, 65 % of diamonds, and 60 % of tantalum are extracted with placers. The Blue Ribbon placer gold mine in Alaska is shown. Mining of gold began there in 1906. The total amount recovered is unknown, but at least 20,000 oz have been reported recovered, mostly by small-scale hand or mechanized methods. The placer mine continues operating today. Photo credit: Dennis Garrett, 1999

Photo 3.15 In the case of hydraulic mining, the gold-bearing rock is washed out by pressurized water. This method came into use during the well-known California "gold rush." In 1851–55, the Californian placers yielded about one-half of the world's output of gold; 98 t of gold were panned out in 1853, a record. The photo shows a view of gold miners excavating an eroded bluff with jets of water at a placer mine in Dutch Flat, California, the United States. Photo credit: https://en.wikipedia.org/wiki/Gold_extraction, between 1857 and 1870

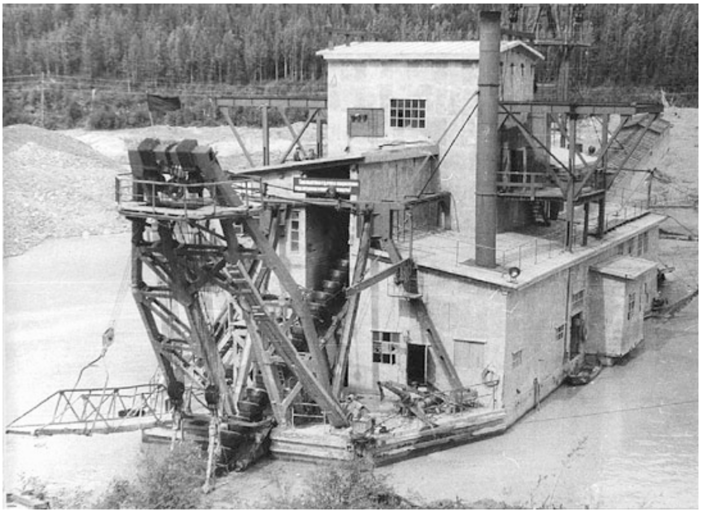

Photo 3.16 A gold dredge is a placer mining machine that extracts gold from sand, gravel, and dirt using water and mechanical methods. In order to excavate material, steel “buckets” move on a circular, continuous “bucket line” at the front end of the dredge. The material is then sorted/sifted by using water. On large gold dredges, the buckets dump the material into a rotating steel cylinder (a specific type of trommel called ‘the screen’) that is sloped downward toward a rubber belt (the stacker) that carries away oversized material (rocks) and dumps the rocks behind the dredge. The photo shows a gold dredge at the Vangash River (Severo-Yeniseyskiy District, Krasnoyarsk Krai, Russia). Photo credit: S.P. Gorshkov (Moscow State University, Russia), June 1966

Photo 3.17 The development of river placers involves cleaning the surface of vegetation, development mining (removal of the upper non-productive stratum), watering, and production (extraction of the commercial component from the productive stratum). The photo shows the finishing stage of flushing on a gold river placer in Amur Oblast, Russia. In the foreground is opened-up placer bedrock (bedding rock). The alluvial sediments are already removed and washed out, and this stage is a last feeding of gold-bearing sands for flushing. Photo credit: I.D. Debelaya (Institute of Water and Ecological Problems, Khabarovsk, Russia), 31 May 2009

Photo 3.18 The dredge development of placers results in considerable contamination of the water, affecting hydrobionts. The high concentrations of the suspensions reduce illumination and the productivity of phytoplankton. Fine suspensions that are deposited in river channels deprive fish of their spawning grounds, and they prevent small aquatic fauna from seeking refuge between stones. The settling ponds for catching the finest fractions of mineral particles in the water after flushing at a p*lacer* deposit of *platinum Conder* (Khabarovsk Krai, Russia) are shown. Productive formation thickness reaches 20 m. Photo credit: A.N. Makhinov (Institute of Water and Ecological Problems, Khabarovsk, Russia), 22 August 2014

Photo 3.19 Using the conventional technologies of flushing, one cannot extract the finest particles of gold (fine, flaky gold that is kept on the surface of the water by surface tension). Mercury, coming into contact with gold washings, dissolves the gold particles. Then the mercury is heated. After the mercury evaporates, the gold precipitate remains. About 20 % of the world's gold is produced by the artisanal and small-scale gold mining sector. This sector is responsible for the largest releases of mercury to the environment of any sector globally. It releases approximately 400 metric tons of airborne elemental mercury each year, threatening the health of 15 million people in 70 countries. The photo shows a gold river placer in Guyana, South America, where heavy mercury pollution takes place. Photo credit: Bill Barclay (Greenpeace), 1 January 1995

3.4 In Situ and Heap Leaching

Mining operations that use **leaching** started not long ago. The **different types** of leaching are based mainly on selective *dissolution of metals* in their oxidized form. As a result of interactions with reagents, the ores are transformed into freely soluble compounds from which one can easily extract the deposited metals (Myazin and Myazina 2006).

In addition to the different kinds of leaching—chemical, bacterial, electrochemical, and radiochemical—there are also different **process flow sheets** for this method of ore concentration. Heap and in situ leaching are the *most widely used methods* (Wippermann et al. 2005).

Heap leaching and, to a lesser extent, **in situ leaching** are widely used in different countries (the United States, Spain, Chile, Czech Republic, Canada, China, Mexico, Peru, Zambia, Australia, Republic of South Africa, and others) to extract uranium, copper, gold, and silver. The production of **uranium** involves these methods, the most. For example, the Beverley uranium mine in Australia, using in situ leaching, produces about 21 % of the world's uranium (www.theoildrum.com/node/3877).

The **technology** of ore processing by **heap leaching** is as follows. The crushed ore is placed on a prepared damp-proof base. Then the stack of ore is irrigated with leaching solutions that filter through the stack and then enter trays or pipelines. Further along, they are collected in specially equipped reservoirs, where they settle. Afterwards, metal is extracted from the solution (Dementyev et al. 2005; Krylova et al. 2005).

The principle of **in situ leaching** is analogous. The leaching solutions are supplied through wells to the underground ore body; then the solutions, saturated with metal, are pumped out to the surface. Further along, the metal is extracted from the solution (Wippermann et al. 2005).

At present, the major method of recovery of metals from ores is **cyanide** leaching. As a reagent, salts of cyanic acid are used—sodium or potassium cyanide with concentrations of 0.02–0.3 %, which are highly toxic. Thus the **major environmental problems** are related to the circulation of production solutions.

In the case of in situ *leaching*, **penetration of the commercial solutions** into underground waters must be prevented. A thorough geological examination of the area, especially from the viewpoint of tectonic disturbances, is required. Where faults or fractured zones are present, artificial watertight barriers must be created (Lbov et al. 2000). In the case of *heap leaching*, environmental problems are caused by things such as spillages, leakages from pipelines, and incomplete flushing or neutralization (Piskunov et al. 2007).

The major **factors** causing adverse ecological influences are (1) contamination of underground waters with toxic substances used to convert the useful mineral into the mobile state; (2) contamination of surface water bodies by emergency discharges of solutions containing toxic substances; (3) contamination of soils by emergency discharges of toxic substances; and (4) contamination of the atmosphere by emissions of gases through sublimation, gasification, and melting (Ovseychuk 2006).

Underground waters are the most vulnerable natural component because existing technologies do not fully prevent losses of cyanide-containing processing media. In the case of in situ *leaching*, they may penetrate into the fresh water-bearing horizons. In the case of *heap leaching*, leakages arise when the watertight diaphragms under the ore stacks and in the clearing pools are damaged (Piskunov et al. 2007).

When in situ *leaching* is used, underground waters are contaminated due to leakage of casing strings. For example, for uranium production in the Czech Republic (Straz deposit), 16,000 wells were drilled in 1967–2000. Through them, 4.1 million tons of sulfuric acid, 315,000 tons of nitric acid, 26,000 tons of hydrofluoric acid, 1400 tons of hydrochloric acid, and 112,000 tons of ammonia were pumped. This resulted in great contamination of the neighboring water-bearing horizon (Kopecky and Slezak 2002; Datel and Ekert 2008).

Impacts of heap leaching units on **surface water bodies** are possible when surface run-off from the industrial site occurs during emergencies, as well as when water from contaminated underground sources reaches surface waters (Robertus et al. 2005).

In the operation of heap leaching units, **soils** and snow cover may be contaminated by ore dust that is released in the course of crushing and transporting of ore and as a result of wind erosion of the ore stake surface (Petrov et al. 2006). In summer, the surface migration of mobile forms of technogeneous substances and their accumulation in soils are possible (Piskunov et al. 2007).

The *major sources* of **air pollution** are crushing-and-sorting plants, ore stakes, and hydrometallurgical shops. Among the *major contaminants* are hydrocyanic acid vapors, nitric oxides, and free chlorine (Petrov 2005).

The environmental effects of in situ and heap leaching operations are illustrated by Photos 3.20 and 3.21.

Photo 3.20 The technology of ore processing by the method of heap leaching is as follows. The crushed ore is placed on a prepared damp-proof base. Then the stack of ore is irrigated with leaching solutions that filter through the stack and then enter trays or pipelines. Farther along, they are collected in specially equipped reservoirs, where they settle. Afterwards, metal is extracted from the solution. The photo shows heap leaching at the Ortiz Gold Mine, New Mexico. The complete processing method includes three-stage crushing, agglomeration, cyanide heap leaching, carbon-in-columns for gold and silver recovery, electrowinning and electroplating from carbon eluate, and gold and silver bullion smelting. Photo credit: http://www.metallurgium.com/projects.html

Photo 3.21 In situ leaching is a mining process used to recover minerals such as copper and uranium. Holes are first drilled into the ore deposit, and explosive or hydraulic fracturing may be used to form open pathways in the deposit to allow leaching solution to penetrate. Leaching solution is pumped into the deposit, where it makes contact with the ore. The solution containing the dissolved mineral is then pumped to the surface and processed. Major environmental problems are related to the circulation of production solutions that are extremely toxic. The photo shows uranium production in the Czech Republic (Straz deposit). Photo credit: http://en.wikipedia.org/wiki/In_situ_leach, 24 March 2007

3.5 Oil and Gas Development

3.5.1 Land Oil and Gas Development

Land oil and gas extraction affects the following environmental components and parameters (Govorushko 2013): (1) surface waters; (2) underground waters; (3) soils; (4) vegetation; (5) animal world; (6) atmospheric air; (7) land withdrawal; (8) geologic environment; and (9) radiation background (Figs. 3.4 and 3.5).

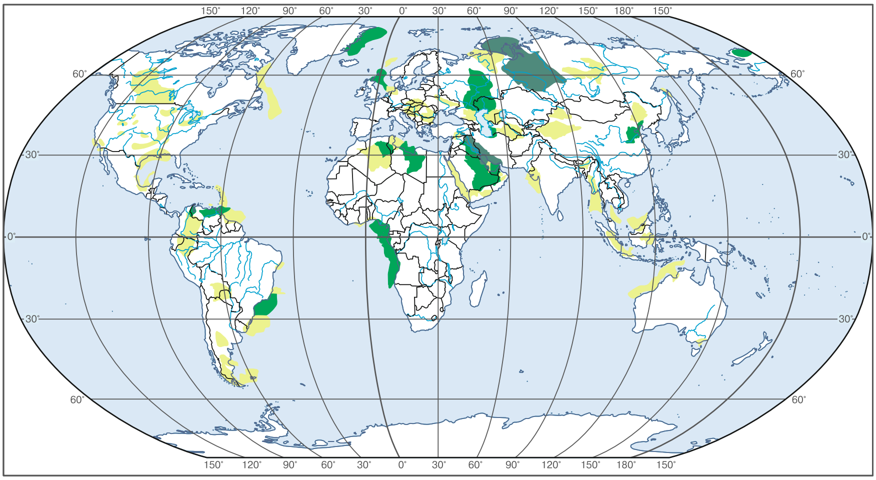

Fig. 3.4 Global distribution of oil resources (USGS 2003; http://www.geo.msu.edu/geogmich/Oil&gas.html; http://en.wikipedia.org/wiki/Oil_reserves_in_the_United_States; http://pubs.usgs.gov/fs/fs-062-03/). Oil endowment (cumulative production plus remaining reserves and undiscovered resources) assessed. Darker green indicates more resources

Oil extraction exerts the greatest effect on **surface waters**. The *major sources* of contamination are spent drilling fluids and grouting mortars, as well as the associated waters. When drilling wastewaters enter a water body, they change the water transparency, color, and odor, while the chemical reagents present in them bind the dissolved oxygen.

The effects on **underground waters** result from the following *processes*: (1) cross-flows between the water-bearing horizons due to the low-quality cementation and leakage of casing strings; (2) filtration of oil and mineralized waters from the ponds (pits); (3) filtration from well embankments; and (4) injection of water, air, or gas into the oil reservoirs (Dorozhukova and Yanin 2002).

The effects, on the whole, include changes in *hydrogeological conditions*, such as intensification of water exchange; formation of new water-bearing horizons;

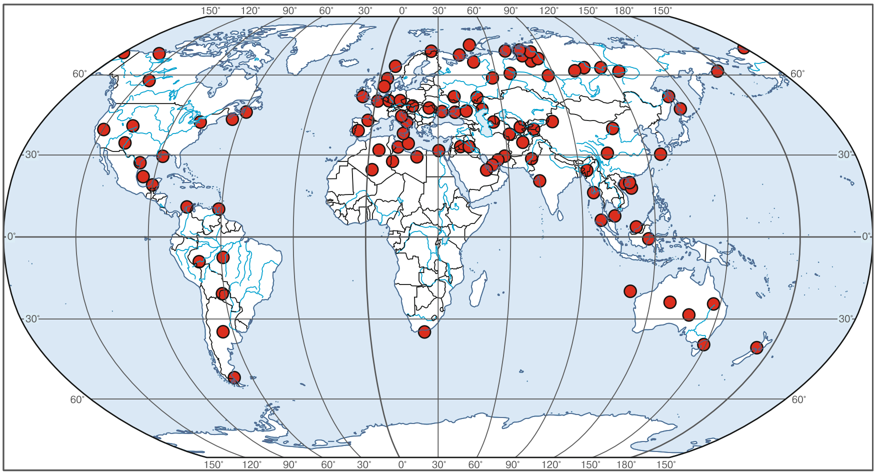

Fig. 3.5 Global gas fields (http://www.eia.gov/oil_gas/rpd/conventional_gas.jpg; http://www.earthscienceworld.org/images/search/lightbox2.html?ID=h5imwy)

mixing of waters; changes in levels, slopes, rates of motion, and the chemical and gas composition of underground waters; changes in temperatures; and drops in intrastratal pressures. On completion of oil production, cross-flows often arise between the fresh and salt horizons or between the water-bearing and oil-bearing horizons (Moskovchenko et al. 2008).

The major *factors* affecting **soils** are (1) drilled-out rocks; (2) drilling sludge; and (3) oil. At a well depth of 2500 m, 350 m^3 of ground are extracted to the surface, while at a depth of 5000 m, 800 m^3 are extracted. These rocks are usually stored in dumps near the wells. Because of strong contamination with drilling mud and oil products, the effects on soils are considerable, including loss of humus, and degradation of the hydrophysical, chemical, and ion-exchange properties of the soils and of their biological activity (Utkina et al. 2005). Arctic, tundra, and marsh peat soils differ in that they have the lowest resistance to contamination with carbohydrates (Gennadiyev 2009).

Direct influences on **vegetation** occur in two ways (Korobov 2004): (1) disturbances of physiological processes due to conformal coating of surfaces of trunks and leaves and (2) poisoning of plants with toxic oil components. Generally, the plants perish and revegetation begins after 2–3 years (Khaustov and Redina 2006).

In the surviving specimens, changes in the rhythm of development, including omission of some phenological stages; their general suppression; and occurrence of necroses and tumors are characteristic (Dorozhukova and Yanin 2002).

Indirect impacts include contamination of soils and atmospheric air. In the case of *intrasoil oil contamination*, effects include destruction of the grass cover, changes in its species composition, and suppression of the growth of trees. *Atmospheric pollution* is expressed through changes in the chemical composition of air and thermal contamination.

The effects on the **animal world** are generally evident in the changes in other natural components: soils, vegetation, and surface waters. Destruction of vegetation during construction affects invertebrates to a greater extent, as the vegetation cover is major habitat. First of all, the numbers of arthropods decrease.

The air is polluted with gases released during well drilling and testing. Associated petroleum gases also play a major role. In west Siberia alone, about 19 billion m^3 of associated gases are burned, which results in air pollution with combustion products such as polyaromatic hydrocarbons, carbon and nitrogen oxides, and some heavy metals. As a rule, the resulting pollution extends for tens and even hundreds of kilometers from the source of the emissions (Polishchuk et al. 2001).

The scales of **land withdrawal** are also great. During prospecting and oil production, a territory is occupied by structures such as wells, processing containers, reservoirs, treatment facilities, oil-gathering stations, oil treatment plants, group pumping stations, and oil transfer pumping stations (Govorushko 2013).

The impacts on the geological environment are significant, including earth surface deformations and increases in seismicity. The intensification of *seismicity* is related to oil recovery, which results in changes in the stressed state of rock (Sharov et al. 2007).

The delivery to the earth surface of matter from large depths is often accompanied by increases in **background radiation**. In some cases, they may be significant. For example, examination of a number of oil fields in the Khanty-Mansi Autonomous Area (Russia) showed that acceptable doses of gamma radiation were exceeded 38 times in the eastern part of the area and 48 times in the western part. In this region, 4 % of fields are characterized by anomalous emissions of radionuclides (Bulatov 2004).

The environmental effects of land oil production are illustrated by Photos 3.22–3.26.

Photo 3.22 A pumpjack is the overground drive for a reciprocating piston pump in an oil well. It is used to mechanically lift liquid out of a well if there is not enough bottom-hole pressure for the liquid to flow all the way to the surface. Depending on the size of the pump, it generally produces 5–40 l of liquid at each stroke. Pump size is also determined by the depth and weight of the oil to remove, with deeper extraction requiring more power to move the increased weight of the discharge column (discharge head). A pumpjack near Surgut (Khanty-Mansiy Autonomous Okrug, Russia) is shown here. Photo credit: Denis Sinyakov (Greenpeace Russia), 31 May 2013

Photo 3.23 Signal Hill is a city (2.2 mi^2, 5.7 km^2) in California located in the greater Los Angeles area. Oil was discovered there in 1921, and this oil field turned out to be one of the most productive oil fields in the world. The gas pressure was so great, the gusher rose 114 ft. (35 m) in the air. Soon Signal Hill was covered with over 100 oil derricks, and because of its prickly appearance at a distance, it became to known as "Porcupine Hill." The photo shows Signal Hill in 1923. Photo credit: http://en.wikipedia.org/wiki/Long_Beach_Oil_Field

Photo 3.24 Contamination of soils with oil causes loss of humus, and degradation of the hydrophysical, chemical, and ion-exchange properties of the soils and their biological activity. A combination picture taken near Usinsk (Komi Republic, Russia) shows an oil spill before and after. Photo credit: Denis Sinyakov (Greenpeace Russia), 10 and 12 August 2014

Photo 3.25 Direct influences of oil production on vegetation occur in two ways: (1) disturbances of physiological processes due to conformal coating of surfaces of trunks and leaves and (2) poisoning of plants with toxic oil components. Generally, the plants perish and revegetation begins after 2–3 years. Destruction of trees due to direct contact with oil near Usinsk (Komi Republic, Russia) is shown here. Photo credit: Denis Sinyakov (Greenpeace Russia), 20 August 2014

Photo 3.26 The sources of atmospheric pollution related to oil production are gases released in the course of well drilling and testing. Associated petroleum gases also play a major role. In west Siberia alone, about 19 billion m^3 of associated gases are burned, which results in air pollution with combustion products such as polyaromatic hydrocarbons, carbon and nitrogen oxides, and some heavy metals. The photo shows burning of associated petroleum gases in Khanty-Mansiy Autonomous Okrug (West Siberia, Russia). Photo credit: Greenpeace Russia, 25 August 2013

3.5.2 Sea Bottom Oil and Gas Development

The **first offshore oil well** was drilled in March 1938, at 2.4 km from the shore in the state of Louisiana (United States) (Mitina and Singh 2005). In 2012, offshore oil extraction accounted for 37 % and gas extraction accounted for 28 % of global production (Oil and gas from the sea 2013).The *adverse environmental consequences* related to this activity are generally related to drilling and emergency oil spills (Fig. 3.6).

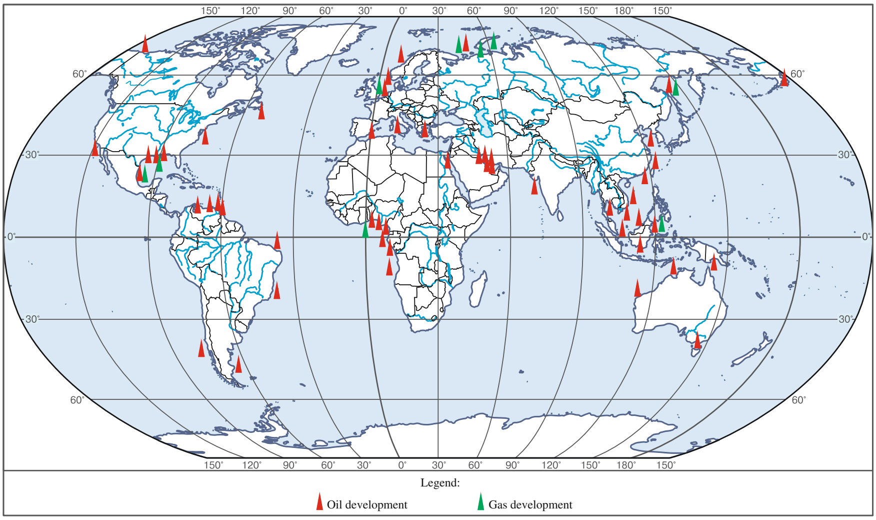

Fig. 3.6 Regions of oil and gas development in the world ocean (Maksakovsky 2006, vol. 1). Reproduced with permission of V.P. Maksakovsky

The impacts of **drilling** on the aquatic environment are associated with (1) drainage to the sea of waste mud and (2) release from the well of drilling deposits. *Used drilling mud* is generally discharged directly to the platform foundation. The depths of most wells vary between 900 and 5000 m. In drilling a well, the drilling mud is changed, on average, 8–10 times, and 160,000–340,000 l are usually changed at a time (Mitina and Singh 2005).

The *solid phase* of the drilling mud forms mud flows or is in the water as a suspension. The turbidity concentration in the flow decreases rapidly with distance from the well. For example, when drilling mud is discharged in a volume of 39,750 l at a rate of 729 l/min, the dilution of the suspended fraction to background levels occurs at 500 m from the platform. The quantity of discharged macroparticles depends on their concentrations in the drilling fluid (Korobov 2004).

The *distance*, the disintegrated particles travel depends on their sizes and the rates of the bottom currents (Patin 1997). For example, the distance fine sand

(0.1–0.25 mm) travels at a current rate of 30 cm/s is only 57.4 m, whereas coarse and medium pelite (particle sizes are 0.001–0.01 mm) travels 37.5 km (Matishov and Denisov 1998).

On completion of drilling, the major source of influence of operating platforms is the **associated waters**. These waters are characterized by high temperatures, low oxygen content, and considerable mineralization (up to 35,000 mg/l, caused by inorganic cations of sodium, magnesium, and potassium, and anions of chloride, sulphate, carbonate, and bicarbonate), as well as carbohydrates and other organic components (in parts-per-million concentrations) (Kochergin et al. 2000).

The *volumes* of the associated water discharges vary depending on time and geological formation. For example, from one platform situated in the Gulf of Mexico (50 km south of Galveston, Texas, United States), the oil field supplies, on average, 160,000–223,000 l of associated water a day, and these waters contain 382 g of alkanes and 17–23 g of light aromatic hydrocarbons—predominantly, benzene, toluene, and ethylbenzene (Mitina and Singh 2005).

Under conditions of drilling and normal operation of oil wells, hydrocarbons contained in the associated waters are of *prime environmental importance*. Although they are released in insignificant volumes from one well on a daily basis, their total quantities over a long period of time are more than sizeable (Patin 2004).

Accidents at oil-producing offshore platforms are the *greatest contributor* to the pollution of sea water. Two that happened in the Gulf of Mexico are well known. First, as a result of the accident on 3 June 1979, at the drilling rig *Ixtoc-1* (Campeche Bay, south-eastern Mexico coast), the daily oil blowout reached 4000 tons at the beginning. Numerous attempts to plug the well only decreased the ingress of oil into the sea. The oil blowout continued until 24 March 1980 (i.e., it lasted for nearly 9 months), when the well head was plugged with 30 tons of concrete block. The **total leakage** of oil reached 475,000 tons (Oil and gas from the sea 2013).

The *second* accident began on 20 April 2010, at a well situated 64 km to the south-east of the Louisiana coast. As a result of an explosion, 11 persons were killed and 17 were wounded. On 15 July 2010, the leak was stopped by capping the gushing well head after it had released about 700,000 tons of crude oil (Gong et al. 2014). The area of the oil patch reached 75,000 km^2 (Puchkov 2013).

The pollution of surface waters adversely affects **hydrobionts** and **sea birds**. For instance, as result of exposure to oil from the *Deepwater Horizon*, an estimated 36,000–670,000 birds died, with the most likely number near 200,000 (Haney et al. 2014). Impacts on **hydrobionts** and **sea birds** are discussed in Sect. 5.5, Water transport.

Accidents at oil-producing platforms result in **loss of life**. During 1970–1995, more than 1200 people were killed in offshore oil fields (Hart 2000). Among the *most damaging accidents* was that on the offshore ***platform*** *Piper Alpha*, which was located in the British sector of the ***North Sea*** oil field in July 1987; 167 lives were lost (Building process safety culture 2005).

The environmental effects of offshore oil and gas production are illustrated by Photos 3.27–3.32.

Photo 3.27 During the first stage of oil-and-gas development, geologo-geophysical exploration is conducted. These activities include seismic exploration works, which interfere with fishing and affect aquatic organisms, and exploration drilling (which disturbs underwater landscapes, leads to condemnation of water areas, pollutes the water due to process water disposal, and pollutes the air with atmospheric emissions). The photo shows the Thunder Horse PDQ semisubmersible platform. It is moored in waters 1840 m (6040 ft.) deep in the Gulf of Mexico. Thunder Horse PDQ is the largest offshore installation of its kind in the world. Photo credit: http://en.wikipedia.org/wiki/Thunder_Horse_PDQ by Andyminicooper (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons, 2005

Photo 3.28 Accidents at oil-producing offshore platforms account for the greatest amount of pollution of seawater. As a result of an accident on 3 June 1979, at the drilling rig Ixtoc-1 (Campeche Bay, south-eastern Mexico coast), the daily oil blowout reached 4000 tons at the beginning. The numerous attempts to plug the well only decreased the discharge of oil into the sea. The oil blowout continued until 24 March 1980 (i.e., it lasted for nearly 9 months), when the wellhead was plugged with 30 tons of concrete block. The total leakage of oil reached 500,000 tons. Photo credit: National Oceanic and Atmospheric Administration, 1979

Photo 3.29 A second famous accident in the Gulf of Mexico began on 20 April 2010, at a well situated 64 km to the south-east of the Louisiana coast. As a result of an explosion, 11 persons were killed and 17 were wounded. Fire then engulfed the platform. After burning for approximately 36 h, the Deepwater Horizon sank on the morning of April 22, 2010. Photo credit: Daniel Beltrá (Greenpeace), 2010

Photo 3.30 Oil spread northeast from the leaking Deepwater Horizon well in the Gulf of Mexico. On 15 July 2010, the leak was stopped by capping the gushing wellhead; it had released about 4.9 million barrels (780,000 m^3) of crude oil. The photo shows dark clouds of smoke and fire that emerged as oil burnt during a controlled burn in the Gulf of Mexico. The U.S. Coast Guard conducted the controlled burn to aid in preventing the spread of the oil. Photo credit: Justin Stumberg, 6 May 2010

Photo 3.31 Hydrocarbon pollution also has severe negative impacts on phytoplankton and zooplankton. The destruction of these organisms causes decreases in the numbers of fish and cetaceans. Marine mammals die because they lose thermal insulation in their pelage when they come into contact with oil. Striped dolphins (*Stenella coeruleoalba*) observed in emulsified oil on April 29, 2010, are shown. Health assessments of dolphins four years later found that the dolphins were 5 times more likely to have moderate to severe lung disease than dolphins at control sites and in previous studies of wild dolphins. Photo credit: National Oceanic and Atmospheric Administration, 11 June 2010

Photo 3.32 Sea birds suffer greatly from oil spills. The oil pastes the feathers together, destroying their thermal insulation properties. The birds maintain body temperature by accelerating their metabolism, which leads to rapid depletion of depot fat and death from exhaustion. When a bird tries to clean itself with its beak, it just moves the oil inside the feather layer. At the same time, oil enters the digestive system. Ducking birds mistake oil patches for food and are poisoned. An oiled bird on a coast is shown. Photo credit: Greenpeace Russia, 14 November 2007

3.5.3 *Extraction of Shale Oil and Shale Gas*

Extraction of **shale oil** and **shale gas** affects the following environmental **components** and parameters: (1) surface waters; (2) underground waters; (3) soils; (4) vegetation; (5) wildlife; (6) atmospheric air; (7) land withdrawal; (8) geologic environment; and (9) radiation background.

The effects on **surface waters** are caused by two factors. *First*, the extraction of these resources requires the use of substantial volumes of water. For example, for one hydraulic fracturing for shale gas extraction, 7500 tons of water are needed (Zelentsova 2011). When extracting shale oil, above-ground retorting typically consumes between one and five barrels of water per barrel of produced shale oil, depending on technology (Bartis et al. 2005) (Fig. 3.7).

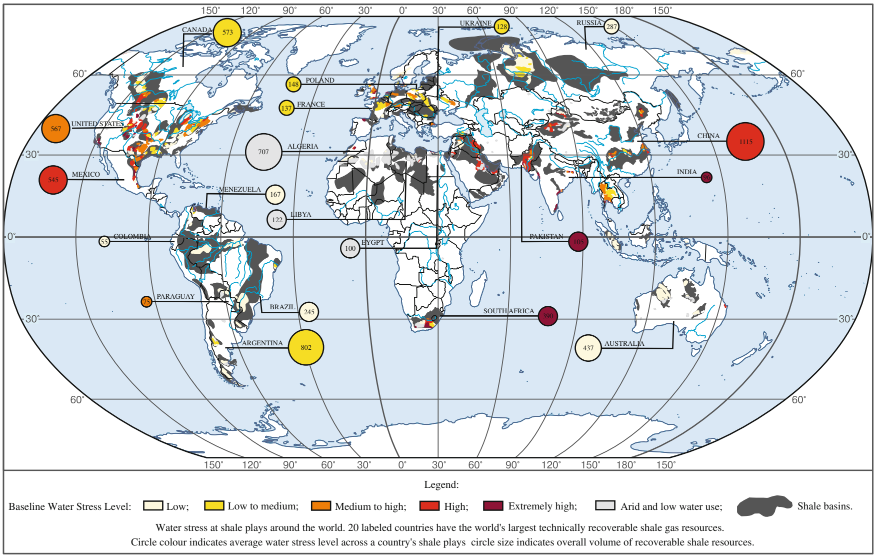

Fig. 3.7 Location of world's shale plays, volume of technically recoverable shale gas (billion cubic meters) in the 20 countries with the largest resources, and the level of baseline water stress (www.wri.org/water-for-shale; Lee 2010; World Shale Gas Resources 2011)

Second, there is significant surface-water contamination. Considerable volumes of waste water contaminated with large quantities of chemicals are often not disposed of by the producer companies in compliance with environmental standards; these chemicals accumulate in surface waters. In addition, run-off from retorting operations also impacts surface waters (http://fossil.energy.gov/programs/reserves/npr/Oil_Shale_Environmental_Fact_Sheet.pdf).

The effects on **underground waters** are related to the use of enormous amounts of chemicals. Chemicals are added to the water to facilitate the underground

fracturing process that releases natural gas. For one underground fracturing operation, 80–300 tons of chemicals are used. The formulas of the chemical cocktail used for underground fracturing are confidential, unavailable from the companies producing the shale gas. It is assumed that shale gas production contaminates ground waters with toluene, benzene, dimethylbenzene, ethylbenzene, arsenic, and other substances (Zelentsova 2011).

Only about 50–70 % of the resulting volume of contaminated water is recovered and stored in above-ground ponds to await removal by tanker. The remaining "produced water" is left in the earth, where it can contaminate ground-water aquifers (http://en.wikipedia.org/wiki/Shale_gas). Fracking has seriously contaminated shallow ground-water supplies in northeastern Pennsylvania with flammable methane (Kerr 2011). In some areas of Pennsylvania, one can ignite the water from the wells (Zelentsova 2011).

Contamination of **soils** occurs from above and from below. When producing shale gas, contamination *from above* takes place from spills of chemical solutions on the soil. Since (depending on the size of the area) millions of liters of water are used, this means that hundreds of thousands of liters of chemicals are often injected into the soil (Cathles III et al. 2012). Contamination *from below* is caused by penetration of chemical materials through cracks formed in the sedimentary mass into the surface soil. When extracting oil from shale, there is soil contamination with heavy metals (mercury, cadmium, lead).

The effects on **vegetation** and **wildlife** are mainly indirect and are expressed through changes in other natural components. For example, chemical-laden water affects livestock, with deaths occurring in major U.S. fracking areas such as Louisiana and Pennsylvania as a direct result of hydraulic fracturing (Fracking in Europe 2012).

The effects on **atmospheric air** are expressed as air pollution. When producing shale gas, fugitive methane emissions from hydraulic fracturing processes can have a large impact on the greenhouse gas balance (Fracking in Europe 2012). The greenhouse gas emissions in the course of shale gas production are larger than those in the production of coal, oil, and conventional gas; when extracting gas, gross leakage of methane is 3.6–7.9 % (Zelentsova 2011).

Methane remains in the atmosphere for around a decade, compared with a residence time of about 100 years for carbon dioxide. Over a 20-year horizon, the GHG footprint of shale gas is primarily influenced by methane and is 22–43 % higher than that for conventional gas, at least 20 % twice as high as the GHG footprint for coal, and at least 50 % to 2.5 times higher than that for oil (Howarth et al. 2011).

Land withdrawal in the course of extraction of shale gas is fairly significant. For example, extraction of oil from oil shale requires large-scale mining operations: nearly 0.5–2 barrels of oil are extracted from one ton of shale; in this case, more than 700 kg of mining waste remain (volume exceeding that of the initial shale).

Impacts on the **geologic environment** are partly expressed as increases in seismicity. Cases are known of earthquakes induced by hydraulic fracturing processes or waste-water injection (Fracking in Europe 2012).

Extraction of shale oil and shale gas results in increases in background **radiation**. The most productive shale fields were formed during the Paleozoic and Mesozoic era and have high levels of gamma radiation, which correlates with the thermal maturity of the shale field. As a result of hydraulic fracturing, radiation enters the upper sedimentary layer and, in areas where shale gas is being extracted, a rise in background radiation is observed (Zelentsova 2011).

The environmental effects of shale oil and shale gas production are illustrated by Photos 3.33–3.34.

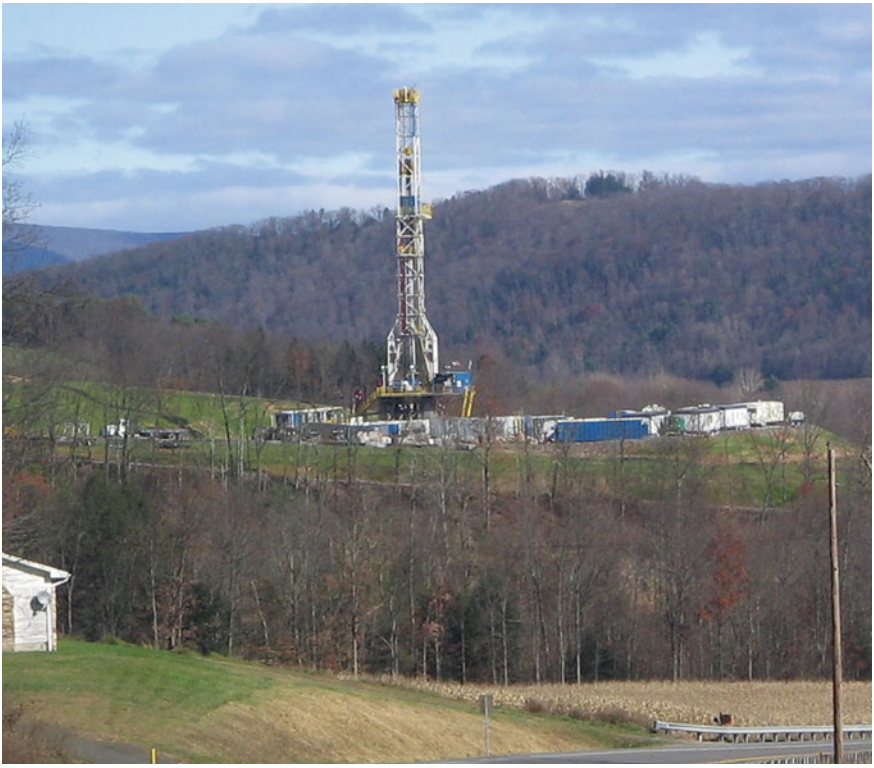

Photo 3.33 Shale gas is a variety of natural gas stored in small gas formations, reservoirs, in the shale layer of Earth. It consists largely of methane. Shale gas is found in shale "plays," which are shale formations containing significant accumulations of natural gas and which share similar geologic and geographic properties. The reserves of separate gas reservoirs are not too large, but they are huge in the aggregate and require special production techniques. A tower for drilling horizontally into the Marcellus Shale Formation in Lycoming County, Pennsylvania, United States, is shown here. Photo credit: http://en.wikipedia.org/wiki/Shale_gas Ruhrfisch [GFDL (http://www.gnu.org/copyleft/fdl.html), CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0), GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 4.0-3.0-2.5-2.0-1.0 (http://creativecommons.org/licenses/by-sa/4.0-3.0-2.5-2.0-1.0)], via Wikimedia Commons, November 2009

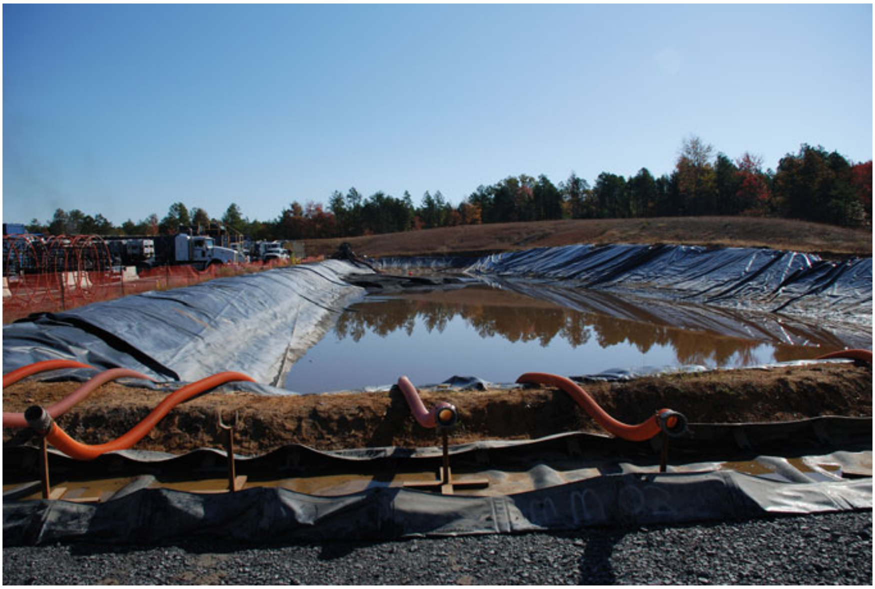

Photo 3.34 The effects of shale gas production on surface water are caused by two factors. First, the extraction of these resources requires the use of substantial volumes of water. Second, there is significant surface-water contamination. Considerable volumes of waste water containing a large quantity of chemicals accumulate near the fields if the waste is not disposed of by the producer companies in compliance with environmental standards. In addition, run-off from retorting operations also impacts surface water. The image shows a water impoundment at a drill pad in the Fayetteville shale gas play in Arkansas, United States. Photo credit: Bill Cunningham, 2012

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http://www.earthscienceworld.org/images/search/lightbox2.html?ID=h5imwy
http://www.eia.gov/oil_gas/rpd/conventional_gas.jpg
http://www.geo.msu.edu/geogmich/Oil&gas.html
http://www.minelinks.com/alluvial/gold_map_5.html
http://www.mining-technology.com/features/feature-top-ten-deepest-mines-world-south-africa
http://www.worstpolluted.org/projects_reports/display/87
www.theoildrum.com/node/3877
www.wri.org/water-for-shale

Chapter 4
Agriculture and Forestry

Agriculture and forest management are two closely related fields. Their similarity can be found both in their aims (to a greater or lesser degree, they are oriented on food provision for the population and raw materials supply for different industries) and in their basic operating principles (based on the growth of living organisms). This similarity can be seen the best when plant growing is compared to forest management. In both cases, practically identical methods of growing, enhancement and increase of productivity, and fertilizers and protection from weeds (herbicides) and pests (pesticides) are used. The differences lay primarily in the duration of the production cycle: half a year for crop farming, 3–5 years for horticulture, but not less than 10 years for forestry. Besides, the object of agriculture greatly depends on human involvement. For many countries and international organizations (e.g., Food and Agriculture Organization of the United Nations), forestry is a part of the agricultural sector.

4.1 Agriculture

Agriculture is the production, processing, marketing, and use of foods, fibers, and by-products from plant crops and animals. The share of agriculture in the gross domestic product (percent) for various countries is shown in Fig 4.1.

4.1.1 Plant Growing

Plant growing is a branch of agriculture that deals with the cultivation of domestic plants. Agricultural land occupies 15.32 million km^2 (FAO 2012). On average, there is 0.32 ha of **agricultural land** per capita (Ivanov et al. 2014). These numbers are the largest in Australia—2.2, Kazakhstan—2.0, and Canada—1.34 ha per capita; and they are the smallest in China—0.09, Egypt—0.05, and Japan—0.04 ha per capita (Karakin et al. 2014). Cultivated land percentage of total land area is illustrated in Fig. 4.2.

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_4

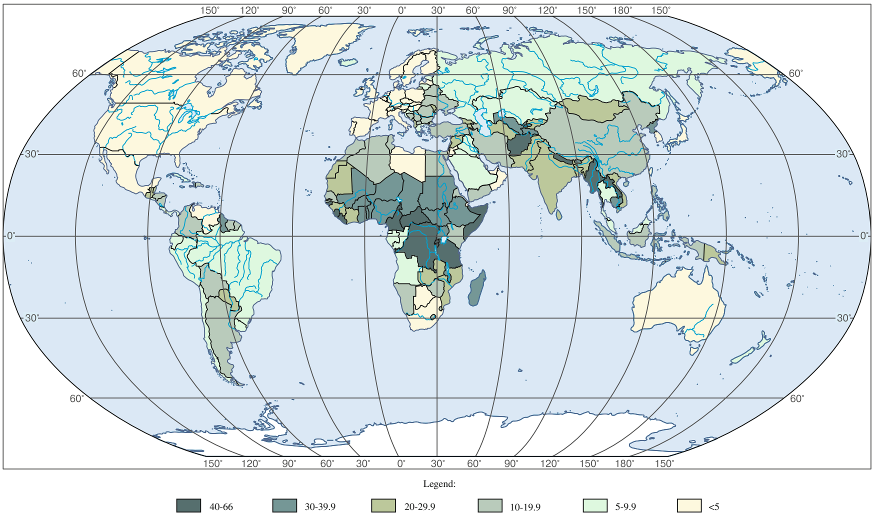

Fig. 4.1 The share of agriculture in GDP (percent) (Kholina et al. 2009). Reproduced with permission of V.N. Kholina

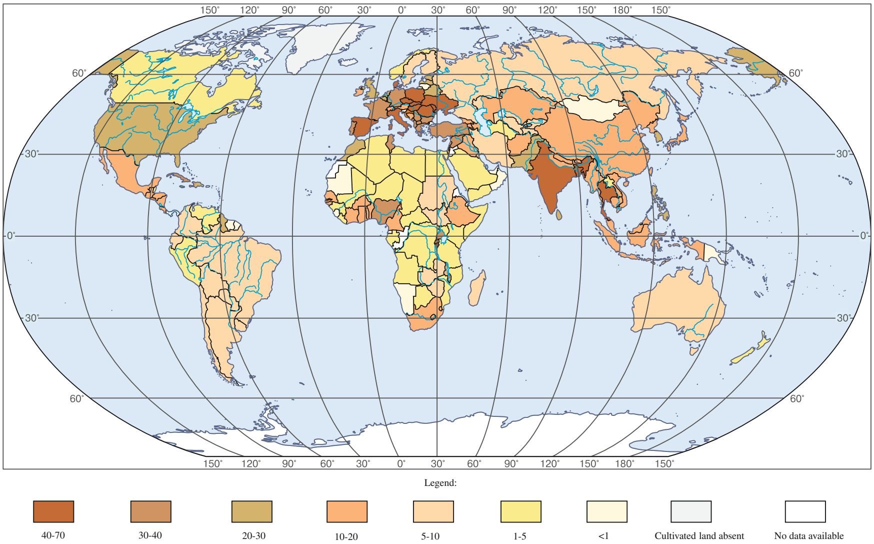

Fig. 4.2 Cultivated land percentage of total land area, 1992 (Resources and Environment 1998). Reproduced with permission of the Institute of Geography of the Russian Academy of Sciences

Plant growing produces 88 % of all food supplies (Modern global changes 2006, vol. 2). The most **important cultivated plants** are (million tons a year, harvest of 2013): corn, 1016; rice, 745; and wheat, 713 (http://en.wikipedia.org/wiki/Cereal)

(Fig. 4.3). Another essential culture is the potato, and in comparison to the first three cultures, its production rate is considerably smaller: 365 million tons in 2012 (http://en.wikipedia.org/wiki/Potatoes).

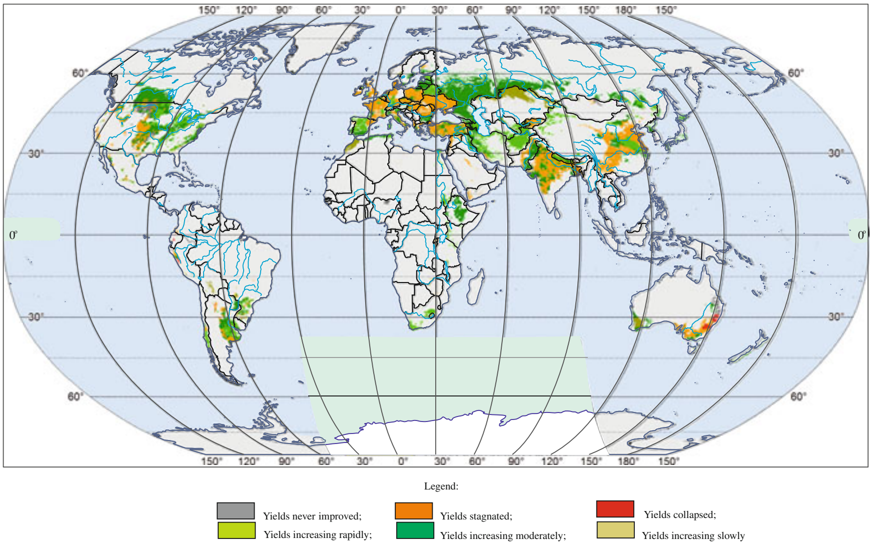

Fig. 4.3 Map of wheat yield growth and stagnation (Ray et al. 2012)

There are three main **factors** of plant growing impact on the environment: (1) agricultural equipment; (2) land reclamation; and (3) agricultural chemicals.

Agricultural equipment is used for cultivating, harvesting, and processing domestic plants. The diversity of the equipment used is huge. It can be self-powered or trail-type. Often it has very heavy gears and powerful combustion engines.

The impacts of agricultural equipment on the natural environment include the **following**: soil *consolidation*; structural *distortion* of soil due to tillage; extermination of soil-forming *microorganisms* and different *invertebrates* (earthworms); *process losses* and *contamination* of soil, water, and air by fuel, lubricant materials, and by-products of running engines; and the *deaths* of animals and birds.

The most environmentally important impact is **soil degradation** due to contact with *machinery*. The ground is affected by the drive systems and operating parts of the agricultural equipment. By the end of fieldwork, only 10–15 % of the agricultural land is not affected. The rest of the territory is exposed to the drive systems at least 3–5 times.

Due to *ruptures* in the sleeves and pipes of agricultural equipment, 500,000 t of fluids get into soil in Russia, which takes 2000 ha of fields out of crop production every year (Afanasyev et al. 2005).

Process losses mean transportation of soil outside the fields. For example, in Turkey, when sugar beets are harvested, permanent soil losses are 1.158 million tons a year (Tugrul et al. 2012).

Land reclamation is divided into *drainage* and *irrigation*. On Earth, 203 million ha of the terrain has been drained, most of it in Asia (68 million ha) and North America and Central America (65 million ha) (International commission on irrigation and drainage 2011). Possible *consequences* of drainage are increases of erosion by wind and water, shallowing of rivers and lakes, risk of floods, a drop in precipitation quantity, declines in animal and fish numbers, vanishing of rare plant species, and depletion of flora. The irrigation aspect of land reclamation is considered in Sect. 6.5, “Water transfers.”

Agricultural **chemicals** used include mineral *fertilizers* and chemical plant *protectors*. Big differences exist in the intensity of fertilization: from an average of 344 kg/ha a year in China, to 7.5 kg in Ghana and just 2.7 kg in Rwanda (A soiled reputation 2013). Globally during the 2006–2007 season, 164 million tons of fertilizer were used, of which 98 million tons were for nitrogen, 27 million tons for potassium, and 39 million tons for phosphates. China is the world’s largest mineral fertilizer consumer, using 49 million tons, followed by India (22 million tons), the United States (21 million tons), Brazil (9 million tons), Indonesia (3.5 million tons), and France (3.4 million tons) (http://www.goodplanet.info/goodplanet/index.php/eng/Food-Agriculture/Fertilizers/Engrais-agricoles/(theme)/263) Fig. 4.4.

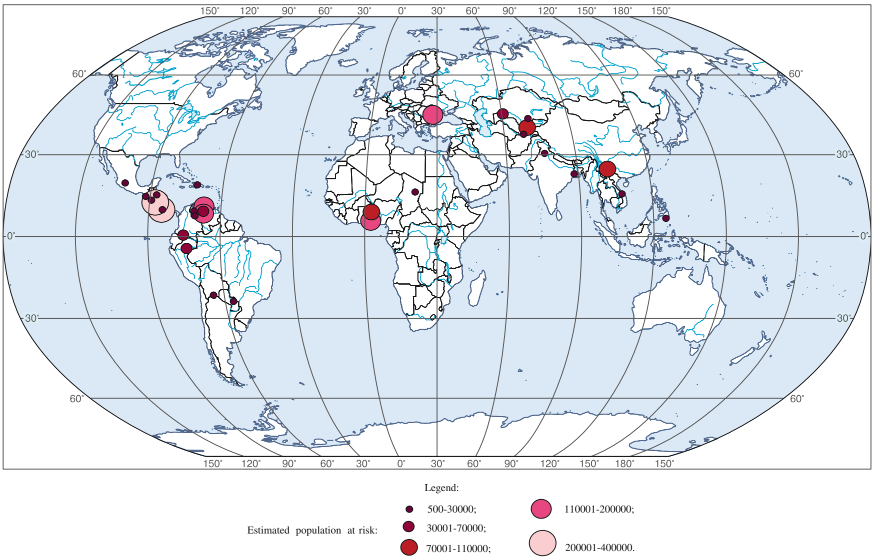

Fig. 4.4 Pesticide pollution from agricultural production (http://www.worstpolluted.org/projects_reports/display/85). Reproduced by permission of Blacksmith Institute for a Pure Earth

The most dangerous of these chemicals are **nitrogen fertilizers**, due to the considerable mobility of the nitrate nitrogen. The most critical impact is the pollution of surface and ground waters by *bound nitrogen*. At least half of

surface-water pollution by bound nitrogen is due to agriculture. Water contamination by biogenic elements results in excessive algal blooms, which die off and decay due to anerobic bacteria. That process leads to **suffocation** of fish and other aquatic animals due to the lack of oxygen.

Phosphate fertilizers are less hazardous. Nevertheless, considerable amounts of phosphates get into water as a result of erosion by water, which also leads to water eutrophication. One kilogram of phosphorus coming from the fields initiates the growth of 100 kg of phytoplankton, which decreases the amount of dissolved oxygen and reduces water quality (Ecological sketches of nature and humans 1988).

The use of phosphate fertilizers in large amounts also leads to undesirable accumulations of other *elements* in soil (stable strontium, fluorine, natural radioactive uranium compounds, radium, and thorium are present in phosphate fertilizers). Thus, 2–3 g of cadmium is introduced into soil with the application of 70 kg of superphosphate (Heinrich and Hergt 2003).

The **third main element** of mineral fertilizers (potassium) does not impact the environment much. However, along with potassium, a lot of *chlorine* is brought in, which might lead to adverse effects.

The total production of **chemical plant protectors** (to prevent diseases and pest invasions) is 5 million tons (Dyakonov and Anoshko 1995), and their global use, on average, is 300 g/ha. In the United States and Western Europe, this number is 2–3 kg/ha. In the form of aerosols, pesticides can be carried over a distance of 500 km (Heinrich and Hergt 2003). Pesticides are dangerous due to their high biological reactivity, long duration in the environment, and accumulation potential.

Depending on the **way** they are used, the following shares of pesticides (of the total amount introduced) get into the atmosphere (Savenko 1991): introduction into furrows, 1–8 %; and plane spraying, 20–35 %. Of the pesticides applied, 99.9 % does not reach the target objects and gets into soil, air, and water (Hart and Pimentel 2002).

Pesticide use is most dangerous for water ecosystems, soils, animals, and also humans. For example, in the former USSR, around 40 % of hares, hogs, and elk, more than 77 % of ducks, geese, and upland fowl, and more than 30 % of freshwater fish that died were **poisoned** by pesticides (Mavrischev 2000).

Pesticide intoxication kills 220,000 people (Palmborg 2002) and damages the health of another 3 million annually (Cornell 2003). The **causes of intoxication** are given in detail in an article by Ferrer and Cabral (1995). Though developing countries in Asia, Africa, and Latin America account for only 25 % of the pesticides used, 99 % of the deaths take place there (Ngowi et al. 2006).

Apart from the three main **factors** of plant growing impact on the environment, there is also the problem of *methane emissions*. Methane is produced on flooded rice fields during partial organic decay under conditions of oxygen shortage (Rudsky and Sturman 2014). These fields are responsible for 5–10 % of global methane emissions (UNEP 2014). Methane release from all the world's rice bays is estimated to be 20–100 million tons a year (Modern global changes 2006, vol. 1). The *factors* that determine the quantity of methane produced are the soil type, rice variety, temperatures, and growing method (Kwun et al. 2003).

Withdrawal of nutrients from fields during harvesting has some importance. For example, a yield of corn of 7 t/ha takes out 104 kg of nitrogen, 19 kg of phosphorus, and 22 kg of potassium per hectare (Agricultural ecosystems 1987). Grain crops and potatoes exhaust the soil the most. For a global gross wheat yield of 1 billion tons, 33 million tons of nitrogen is taken out of the soil (Introduction to ecology 1992).

Plant growing also contributes considerably to **soil erosion**. Annual soil outflow from agricultural fields into water in the United States is estimated to be more than 1 billion tons. The Mississippi River alone carries out 331 million tons of topsoil into the Gulf of Mexico annually (Ruhl 2000).

The environmental impacts of plant growing are illustrated by Photos 4.1–4.10.

Photo 4.1 Since ancient times, increases in arable area have occurred at the expense of decreasing territories occupied by forests. The photo shows the Lacandon Jungle, which was burned for agricultural use, in Chiapas, Mexico. Photo credit: Jami Dwyer, 5 May 2005

Photo 4.2 Sometimes, the effect of crop husbandry on the relief of an area used for agriculture is quite noticeable. Where agricultural lands are lacking, it is necessary at times to use less fertile lands for crop husbandry. The photo shows a terraced slope used for plant growing in the Trisuli area, Nepal. This country has an area of 147,181 km^2, and approximately 77 % of the total area consists of mountains. Photo credit: G. d'Onofrio (FAO)

Photo 4.3 The most environmentally important impacts of agriculture occur due to contact with machinery. The ground is affected by the drive systems and operating parts of the agricultural equipment. By the end of fieldwork, only 10–15 % of the agricultural land is not affected. The rest of the territory is exposed to the drive systems at least 3–5 times. Numerous traces from the passage of agricultural vehicles afield in Upper Normandy, France, are shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 7 August 2014

Photo 4.4 In cultivating plants, mechanical tillage that overturns soil is often used. This process leads to deep interference with the soil life, causing the destruction of its natural structure, and disturbance of water, air, and thermal conditions. A decrease in the number of soil organisms and natural fertility of the soil takes place. Secondary tillage with a heavy disk harrow in Zambia near the city of Chapula is shown. It is a low-impact technology that preserves soil structure and fertility. It is applied under arid and semiarid conditions before seeding of plants with insignificant depth of root bedding (more often used with grain crops). Photo credit: P. Johnson (FAO)

Photo 4.5 Pesticides are used in order to prevent pest invasions. During plane spraying 20–35 % of the total amount applied gets into the atmosphere and then into soil and water. Pesticide use is most dangerous for water ecosystems, soils, animals, and also humans due to the chemicals' high biological reactivity, long duration in the environment, and accumulation potential. Near Sheldon, Illinois, grower Joe Zumwalt applies a low-insecticide bait that is targeted against western corn rootworms feeding on and laying eggs in these soybeans. Photo credit: Ken Hammond

Photo 4.6 The dangers of pesticides are caused by their high biological activity, persistence in the environment, and capacity to accumulate. They are a serious hazard to aquatic ecosystems and soils as well as to humans. Some 110,000 liters of very hazardous endosulfan (a strong contaminant of surface and ground water) have leaked into the ground at the main Rahad Irrigation Scheme warehouse in El Fao, Sudan. Photo credit: United Nations Environment Program from *UNEP Sudan Post-Conflict Environmental Assessment Report*, 21 June 2007

Photo 4.7 The harvesting of crops and removal (export) of crop residues are major mechanisms of nutrient removal from soils. Different crops **withdraw** different amounts of various **nutrients** from soil. The picture shows a harvest of herbage for ensilage in Noviant-aux-Prés (a commune in the Meurthe-et-Moselle department in north-eastern France). Photo credit: G. Guichard, 2011

Photo 4.8 Removal of soil from fields is a serious problem in agriculture. During harvesting and transporting root crops out of fields, especially when the soil is saturated with water, a considerable amount of humus (in some years, up to 30 % of the harvest mass) adheres to the roots (as well as to agricultural machinery) and is withdrawn from agriculture. The photo was taken at a Vladivostok market, showing a marked difference between a carrot that has been cleansed and one that has not been cleansed of soil. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 6 September 2014

Photo 4.9 All plants from time to time have need of irrigation. The three main methods of irrigation are as follows: (1) surface irrigation, when water is distributed under gravity; (2) sprinkling irrigation; and (3) drip irrigation. These ways differ in cost effectiveness (taking into account both prices and water losses). Sprinkling irrigation of maize in Alsace (France) is shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 24 August 2012

Photo 4.10 Methane emissions can have an impact on the environment in agricultural regions. Methane is produced on flooded rice fields during partial organic decay under conditions of oxygen shortage. Methane release from all the world's rice bays is estimated to be 20–100 million tons a year. The photo shows a flooded rice field in Jilin, China. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 12 June 2014

4.1.2 *Animal Husbandry*

There are about 1.43 billion cattle, 1.87 billion sheep and goats, 0.98 billion pigs, and 19.60 billion chickens on the Earth (Robinson et al. 2014) (Figs. 4.5 and 4.6).

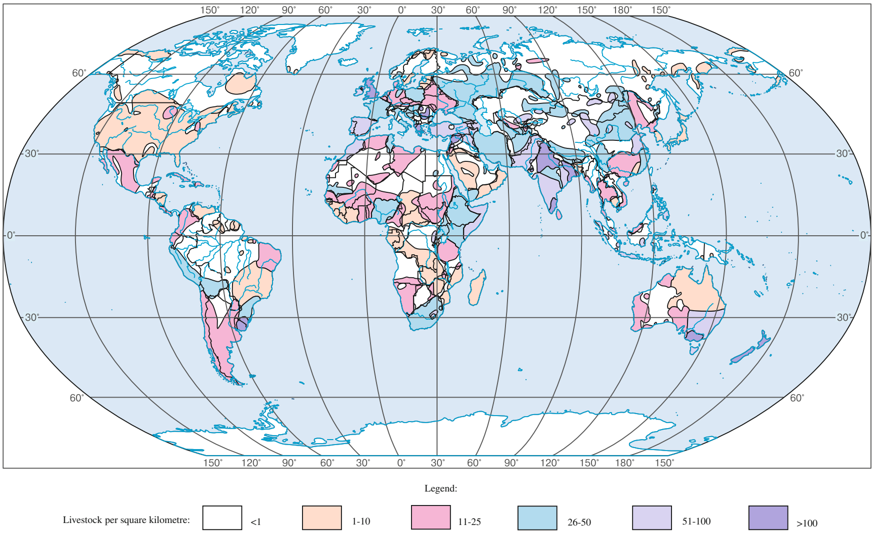

Fig. 4.5 Global livestock density (Lerner and Matthews 1998; Robinson et al. 2014) This map plots density of livestock including cattle, sheep and goats, horses, water buffalo, and camels

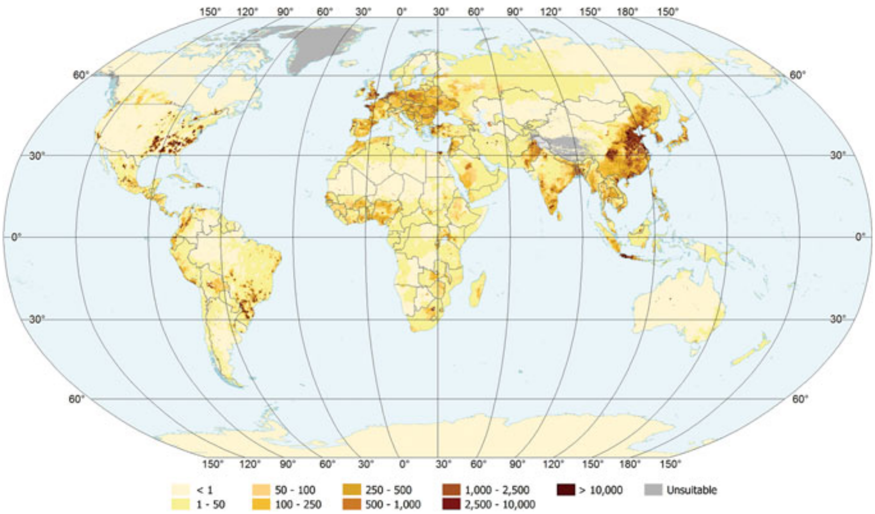

Fig. 4.6 Global density of chickens (Robinson et al. 2014)

4.1.2.1 Stall Feed

The concentrations of animals at stall feeding facilities increase sharply, making a stock breeding complex a point source of environmental impact. The main **factors** in this impact are dumping of raw animal materials (excrement and liquid waste), pressed juice, and haying.

The natural **components** that are most affected include the atmosphere, surface and ground water, soil cover, and vegetation. Fish and other aquatic organisms, as well as animals consuming the food grown on soils that are fertilized with raw animal materials, can be *affected secondarily*.

The main environmental problem is the tremendous amount of **waste** of animal husbandry. For instance, in Russia alone, poultry farms annually produce more than 200 million tons of poultry manure and 2 billion m^3 of waste water (Khazan et al. 2005).

The impacts of animal husbandry waste manifest mainly as **atmospheric pollution**. Cattle yards and manure storage facilities emit 136 different gases and odorous substances (Hartung 1992). Some of them affect air locally (e.g., ammonia), and others (carbon dioxide, methane, ozone, nitrous oxide) are greenhouse gases and contribute to global warming. Livestock worldwide represented approximately 9 % of total greenhouse gas emissions. Beef and dairy cattle account for 74 % of global livestock emissions (Caro et al. 2014).

The manure input into **methane** production is not great; the most important source is intestinal fermentation in ruminants. For example, in South and Southeast Asia in 2000, 29.9 million tons of methane was emitted into the atmosphere; manure accounted for only 4 million tons, while digestive fermentation accounted for the remaining 29.5 million tons. The greatest amount of methane produced from digestive fermentation is in the Ganges delta (Yamaji et al. 2003).

Nitrous oxide is the most reactive greenhouse gas. It is produced mainly by manure and accounts for 7 % of all anthropogenic gases released (UNEP 2013 annual report 2014). Nitrogen oxide contributes to acid precipitation. All domestic animals produce **carbon dioxide** (Tisdell 1998). However, from this point of view, cows are 5 times more dangerous than pigs (Tilman and Clark 2014).

Stall feed is an active polluter of **surface waters**. Manure off-flow contains high levels of biogenic matter, helminths, and pathogenic microorganisms, leading to eutrophication, decreases in dissolved oxygen, and sharp drops in water quality in surface waters (Denisov and Semizhon 2008).

Among all **fauna**, *hydrobionts* are affected the most. They are impacted through surface-water contamination. If an accident occurs, mass mortality can result. For example, in North Carolina (United States), a spill of 96,000 t of manure waste from a pig farming complex in 1995 led to the death of 10 million fish and made mollusk harvesting impossible on almost 147,000 ha of maritime territory (Ruhl 2000).

Impacts on *terrestrial animals* take place during forage procurement. For instance, in Germany, where agricultural equipment is used on fields to make hay, many wild animals are killed or injured, primarily roe deer juveniles. The total number that suffers due to this activity is 420,000 animals (Heiko and Gerold 2002).

Stall feed affects **vegetation** through weed dissemination; 1 ton of manure contains 2 million weed seeds. When manure is applied to fields as fertilizer, many of the seeds sprout (Gruzdev 1988). Some importance must be given to fibrous feed *harvesting* on natural grasslands (haying). It sometimes leads to depauperation of flora due to the full withdrawal of some plant species.

When used correctly, raw animal materials have positive effects on **soils**. Concentrations of biogenic elements (carbon, nitrogen, phosphorus, calcium, potassium) in soil increase, as well as the soil's biological activity, harvests, and quality of plants (carotene, protein). Nevertheless, excessive use of animal waste (manure, watering with waste waters) often leads to increases in nitrate nitrogen concentrations in soil, and that degrades its physicochemical properties.

Excess nitrate nitrogen also leads to the growth of nitrophilous plants, producing huge biomass, mainly weeds (Czerwinski et al. 1987). Further filtration contaminates **groundwater** with water-soluble salts, nitrates, and pathogenic microorganisms, infecting animals and people with brucellosis, encephalitis, gastroenteritis, and other diseases (Nastea and Dumitru 1986).

Impacts on groundwater also happen during *ensilage* harvesting and storage. Some of the products (beet tops, corn, etc.) are kept in concrete pits or bunkers (with special tanks for collecting liquor). Insufficient isolation of these facilities or absence of liquor tanks (which happens often) results in juice leakage. In 1973, in the territory of the modern Czech Republic, 25 % of ensilage liquid was released into the soil (Evaluation of economy effect on nature 1985).

The environmental impacts of stall feed are illustrated by Photos 4.11–4.16.

Photo 4.11 The concentrations of animals at stall feed locations increase sharply, making a stock breeding complex a point source of environmental impact. A commercial turkey meat production house in the United States is shown here. Photo credit: U.S. Department of Agriculture, 4 October 2011

Photo 4.12 Ensilage harvesting and storage have an influence on ground water. Some of the products (beet tops, corn, etc.) are kept in concrete pits or bunkers (with special tanks for collecting liquor). Insufficient isolation of these facilities or absence of liquor tanks (which happens often) results in juice leakage. Loaders compressing wheat silage in Revivim, Israel, are shown here. Photo credit: http://en.wikipedia.org/wiki/Silo by Felagund (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons, 6 March 2007

Photo 4.13 Haying has two major types of environmental impacts: (1) impacts on terrestrial animals that take place during forage procurement (when agricultural equipment is used on fields to make hay, many wild animals are killed or injured); and (2) depauperation of flora due to the full withdrawal of some plant species. The photo shows bales of hay in Upper Normandy, France. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 7 August 2014

Photo 4.14 The impacts of animal husbandry waste manifest mainly as atmospheric pollution. Cattle yards and manure storage facilities emit 136 different gases and odorous substances. Some of them affect air locally (e.g., ammonia), and others (carbon dioxide, methane, ozone, nitrous oxide) are greenhouse gases and contribute to global warming. Confined cattle feeding operations in Yuma, Arizona (United States) are shown here. Photo credit: Jeff Vanuga, USDA Natural Resources Conservation Service, 4 October 2011

Photo 4.15 Where animals are housed in stall barns, one of the key factors affecting natural constituents is disposal of animal waste products (excrements and manure slurry). The amount of such wastes is tremendous. In the production of one kilogram of beef, 25 kg of manure are formed. Correct manure storage is of fundamental importance; when manure is stored incorrectly, concentrations of nitrate nitrogen in soil increase, and the physical and chemical properties of the soil deteriorate. The photos show changes in manure storage in a farm in the United States. Photo credit: Chad Cochrane (U.S. Department of Agriculture)

Photo 4.16 Where animals are housed in stall barns, one of the key factors affecting natural constituents is disposal of animal waste products (excrements and manure slurry). The amount of such wastes is tremendous. In the production of one kilogram of beef, 25 kg of manure are formed. Correct manure storage is of fundamental importance; when manure is stored incorrectly, concentrations of nitrate nitrogen in soil increase, and the physical and chemical properties of the soil deteriorate. The photos show changes in manure storage in a farm in the United States. Photo credit: Chad Cochrane (U.S. Department of Agriculture)

4.1.2.2 Livestock Grazing

Livestock grazing is widespread. In 2009, there were approximately 33 million km^2 of pastures (FAO 2012). Livestock grazing is a form of land use that allows increasing production at minimal costs; it supports ecosystem productivity. Introduction of manure into the soil improves physical properties and conserves **fertility**. Some **seeds sprout** faster or can sprout at all only after being digested. Grazing and the condition of pastures are closely connected; both insufficient grazing and overgrazing degrade the productivity of an area (Taddese et al. 2002).

The main **factor** having environmental impacts is **overgrazing**. This occurs when the livestock density per unit area is very high; in this case the number and the breed of the animals can exceed a pasture's food production capacity. For instance, in the Three-River Headwaters region of China in 2010 total number of sheep was 6.52 million with an average overgrazing number of 27.43 sheep/km^2 (Zhang et al. 2014).

Livestock grazing **impacts** vegetation, soils, fauna, and geomorphology. The impacts of grazing on **vegetation** are diverse and the most serious. The **consequences** of these influences are: (1) vegetation destruction; (2) change in plant species composition; (3) plant community successions; (4) favorable conditions for the spread of plant diseases; (5) decrease of timber quality; and (6) drop in timber growth speed.

The **destruction** of plants occurs in different ways. Animal husbandry often results in the **logging** of forests. In Brazil, for example, 38 % of the forests destroyed by logging between 1966 and 1975 were cleared for animal husbandry operations (Newman 1989).

Overgrazing also results in vegetation loss. There are *many places* where overgrazing by goats has caused forest depletion: Greece, Cyprus, south of Madagascar, and some regions of Venezuela. The fact that animals prefer some plants over others leads to **changes in plant species composition**. The plants they prefer are suppressed, and the plants they neglect thrive (Wu et al. 2013).

Plant community successions happen fairly often. For instance, during intensive grazing, a *meadow* can turn into *bushes*. Natural forest restoration is becoming problematic in forest pastures. Stoll shoots of broadleaf species are more resistant than self-seeding coniferous sprouts. Due to this, coniferous plants are being replaced with deciduous plants (Anuchin 1991).

Morbidity of plants increases as a result of root damage by hooves, which creates favorable conditions for *fungal infections*, and bark gnawing leads to *trunk rot*.

Deterioration of wood **quality** is connected with nibbling of the tops of sprouting trees, which provokes the growth of *curved trunks*, while bark gnawing results in *trunk scars*. The **slowest growth** is observed in forest stands with shallow

roots, such as in spruce forests and coppice oak woods; comparatively high growth rates are found in pine forests and birch wood (Rudsky and Sturman 2014).

Among all domesticated animals, *goats* are the **most** harmful to the environment. Other animals that have adverse effects on the environment include pigs, sheep, and cattle (Spurr and Barnes 1984). Unlike other animals, goats pull out whole plants when they graze. A distinctive trait of goats is that they graze on a very wide range of plant species. They eat even the bark of trees and bushes.

The impacts on **soils** are also diverse. Grazing change the soil water balance through defoliation and soil compaction, causing a shift in vegetation composition toward a drought-tolerant plant community (Veldhuis et al. 2014).

Soil compaction leads to a decline in *water infiltration capacity* and increases in *run-off* (Meules et al. 2001). Breaking of the surface destroys capillaries, which is followed by changes in the evaporation regime. As a result, the land dries out and deflation occurs. Because of vegetation loss, *heating* of the soil increases, which leads to increased evaporation, consolidation of saline liquids, and soil salinization (Modern global changes 2006, V. 2).

At present, the **intensity** of livestock grazing has reached catastrophic proportions. For instance, in India, 250 million feral "sacred" cows have caused huge losses of vegetation in the Himalayan foothills (Rudsky and Sturman 2014).

The **animal world** is influenced through the spread of *epizootic diseases*. Also during cattle grazing in forests, undergrowth thinning leads to a drop in the number of *birds*. The drop is also a result of *anxiety*, destruction of nests, and the killing of chickens by shepherd dogs. Grazing by domestic ungulates has substantial impacts on ecosystem structure and composition. In grasslands of the northern hemisphere, livestock grazing limits populations of small mammals, which are a main food source for a variety of vertebrate predators (Villar et al. 2013).

The main influence on **geomorphology** is the activation of erosion. For instance, each goat could loosen 14 g of soil material per square meter; this material could easily be removed by wind or water (Ries et al. 2014).

The impact of livestock grazing on the environment is demonstrated by the Photos 4.17–4.24.

Photo 4.17 There are two categories of pastures: (1) cultivated (do not differ much from agricultural lands—the same technology of cultivation, chemicals, and sometimes irrigation is used); and (2) natural, usually with unregulated grazing. In 2009, there were approximately 3.3 billion ha of pasture. The picture shows cultivated pasture land in the Netherlands. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 10 August 2014

Photo 4.18 Permanent pastures occupy 20 % of the land area on Earth; in addition, 24.5 % of the land area is deserts and semideserts used as pastures from time to time, and 6.7 % is occupied by tundra deer pastures. The influence of grassland farming is quite uniformly distributed along the horizontal (except for watering points and routes of animal drift). Camels at a watering point in the Dornogovi aimag, Mongolia, are shown. Photo credit: E. Batotsyrenov (The Baikal Institute of Nature Management, Ulan-Ude, Russia), 29 August 2014

Photo 4.19 Grassland farming is a form of land use that allows food production to increase with minimum costs and, at the same time, maintains ecosystem productivity. The addition of manure to the soil helps conserve soil fertility and physical properties. Some seeds sprout faster or can sprout at all only after being digested. The photo shows manure in Schengen, Luxembourg. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 25 August 2012

Photo 4.20 Overgrazing is the main factor having environmental impacts in animal husbandry. This occurs when the livestock density per unit area is very high; in this case the number and the breed of the animals can exceed a pasture's food production capacity. The photo shows the pasturage of sheep in western Tunisia. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 20 August 2008

Photo 4.21 The fact that animals prefer some plants over others leads to changes in plant species composition in pasture land. The plants they prefer are suppressed, and the plants they neglect thrive. Grazing goats near the town of Mandalgovi (Dundgovi aimag of Mongolia) are shown. Photo credit: E. Batotsyrenov (The Baikal Institute of Nature Management, Ulan-Ude, Russia), 27 August 2014

Photo 4.22 Among all domesticated animals, goats are the most harmful to the environment. Other animals that have adverse effects on the environment include pigs, sheep, and cattle. Unlike other animals, goats pull out whole plants when they graze. A distinctive trait of goats is that they graze on a very wide range of plant species. The photo shows a male goat in Primorsky Krai, Russia). Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 11 August 2004

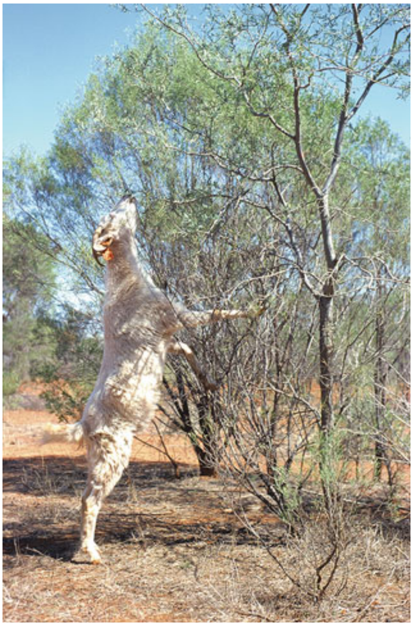

Photo 4.23 Impacts of grazing on vegetation include the following: (1) vegetation destruction; (2) changes in plant species composition; (3) plant community successions; (4) favorable conditions for the spread of plant diseases; (5) decreases in timber quality; and (6) drops in timber growth speeds. A goat browsing native vegetation at Coolabah, New South Wales, Australia, is shown here. Photo credit: Willem van Aken (CSIRO), 1 January 1975

Photo 4.24 Animal husbandry is a major source of atmospheric contamination with greenhouse gases. Methane is a very potent greenhouse gas, some 21 times more potent than carbon dioxide. Methane is produced by sheep and cattle as part of the normal processes of fermentation of feed in the rumen. For instance, in Australia methane produced by sheep and cattle is estimated to contribute 14 % of Australia's total greenhouse gas emissions. This image shows sheep fitted with mechanisms for collecting exhaled methane. Photo credit: Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, 26 November 2001

4.2 Forestry

4.2.1 Timber Processing

Timber processing is the harvesting of wood for economic needs. The annual volume of cuttings is 4.5 billion m^3 (Ivanov et al. 2014). Total employment in logging activities is about 3.5 million people (State of the world's forests 2014).

The world's forest **resources** (standing volume) are equivalent to 340–370 billion m^3, and the area of forest suitable for exploitation is 25–28 million km^2. (Fig. 4.7) The **countries** with the greatest forest area include Russia (8.1 million km^2), Brazil (3.2 million), Canada (2.6 million), and the United States (2.0 million); nevertheless, the **leaders** in timber processing are the United States, Canada, Brazil, and China (Karakin et al. 2014).

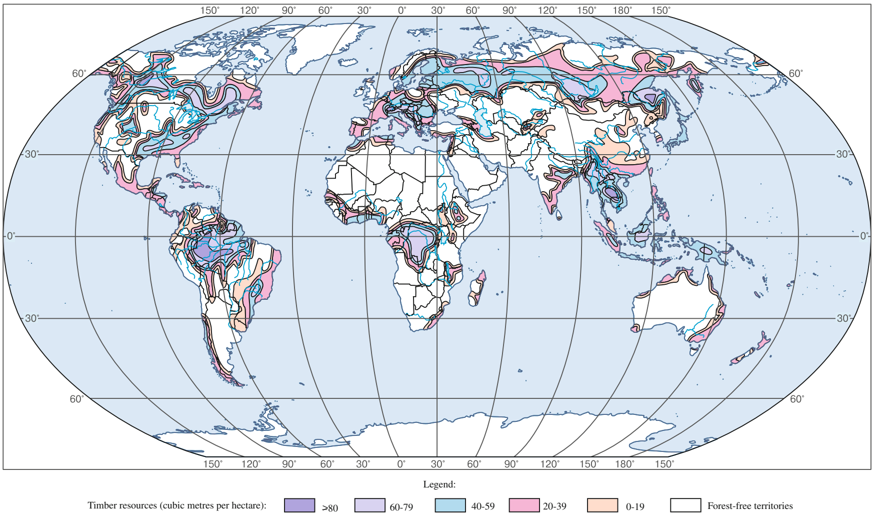

Fig. 4.7 Global distribution of timber resources (Resources and environment 1998). Reproduced with permission of the Institute of Geography of the Russian Academy of Sciences

The environmental impacts of timber processing can be divided into three **categories**: (1) taking matter out of nature (logging and transportation of the wood; sweeping off the soil on some areas, including further washout); (2) introduction of alien substances and energy (such as toxic chemicals for pest control; fuels and combustion products released during timber dragging and transportation); and (3) transformation and redistribution of the matter in nature: changes in forest landscapes due to logging and cleaning out of debris-strewn forest.

Taking matter out of nature (trunks, branches, leaves) leads to soil *impoverishment* and *decreased productivity*. In Russian forests, trunks comprise 65 % of the total timber mass; stumps and roots comprise 13 %; bark, 9 %; branches and lops, 8.5 %; and leaves and needles, 4.5 %. In the low latitudes, the share of trunk timber

is lower. For instance, in the rain forest of the Ivory Coast, trunks and large branches account for only 64 % of the biomass (Gorshkov 2001).

Timber processing influences the following natural **components**: (1) vegetation; (2) soils; (3) animals; (4) surface waters; and (5) atmosphere. In addition, it is not uncommon for this activity to cause human deaths.

Impact on **vegetation** is mainly defined by undergrowth conservation. In tropical forests, selective cutting of the most valuable tree species often takes place. The transportation of one of these trees causes the death or serious damage of another two trees (Golubev 2006). In the developed countries, the damage is much smaller. For instance, during timber processing in south-western France, 30 % of the area remains untouched, 32 % is covered by the remains of cutting, 29 % is changed insignificantly, and only 9 % is seriously damaged (Deconchat 2001).

Harvest cutting is believed to disturb vegetation **diversity** more than gradual felling and selective cutting (Tatarinov 2002). It is also recognized that felling is much safer in winter than during the warm seasons (Bock and Van Rees 2002; Kovalev 2004).

The impacts on **soils** are as follows: (1) fertility decline; (2) soil erosion; and (3) change in physical qualities.

Fertility decline is explained by the fact that most of the biogenic matter is stored in trees and is removed when trees are logged. So intensive logging results in losses in soil nutrient supplies (Sutinen et al. 2010). After logging, the soils are exposed to direct sun-rays and strong rains. Deficits of phosphorus and potassium are observed in soils of the humid tropics, and deficits of nitrogen are found in the dry tropics (Golubev 2006).

Soil erosion is provoked by topsoil disturbance during wood transportation. Intensity of the wash-off during the first couple of years after logging on slopes of 10°–20° reaches hundreds of cubic meters per hectare. Main losses of soils occur within the first 5–6 years (Litvin 2002).

Disturbances of *physical qualities* of soil mainly include changes in density, porosity, and coefficient of filtration (Rosnovsky 1999). Research in Washington state (United States) has shown that soil consolidation as a result of a motor vehicle slipping decreases its filtration characteristics by 92 %; microscopic capillaries shrink by 53 %, and density increases by 35 % (Spurr and Barnes 1984).

Impacts on **animals** are determined by the complexity of ecosystem connections, when a little change can lead to unpredictable results. For example, so-called keystone species play unique, sometimes unclear, roles in ecosystems. Logging of such species sometimes leads to catastrophic consequences for fauna (Golubev 2006). Also, hunting and fishing, including poaching, increase in areas where logging is taking place.

Effects on **surface waters** include increases in seasonal flood levels of rivers and lack of water during other seasons (Geoecological principles of designing of natural-engineering geosystems 1987). The **atmosphere** is polluted by the exhaust of working machinery (Semenov 2001).

Accidents cause **human deaths**, which may be related to defective logging equipment, helicopter crashes, log truck driver fatalities (Enez et al. 2014), and intoxication caused by pesticides. Almost all the cases of poisoning are connected with organophosphate insecticides (Berryman 1990).

The environmental effects of timber processing are illustrated by Photos 4.25–4.30.

Photo 4.25 Felling is the process of downing individual trees, part of the task of logging. For a long time, this process was weakly mechanized. In hand felling, an axe and saw are used to fell a tree. The photo shows two fellers felling a tree on the Atherton Tablelands, Queensland, Australia. Photo credit: State Library of Queensland, between 1890 and 1900

Photo 4.26 Timber processing is the harvesting of wood for economic needs. When a sensible approach is used, the effect on the environment is minimal. However, the use of converted wood is often irrational. Forestry operations near the settlement of Svetlaya (Primorsky Krai, Russia) are shown. Numerous tree stumps are visible. Photo credit: I.S. Seleznev, 1999

Photo 4.27 Timber harvesting operations include three stages: (1) cutting operations; (2) logging; and (3) operations at the log collection point. Cutting operations include logging, branch cutting, cutting area cleaning, timber bucking, dragging, and loading of logs for transport. The photo shows harvesting operations in Karelia (north-western Russia). Photo credit: V. Kantor (Greenpeace Russia), 18 June 2006

Photo 4.28 The second stage of timber processing is timber transportation. Logging roads or logging railways are used, which connect with sawmills, railroads, highways, or floatable rivers. The picture shows a narrow-gage railway in Vologda Oblast (north-western Russia). Photo credit: V. Kantor (Greenpeace Russia), 12 October 2005

Photo 4.29 A plank road in the Vologda region is shown. It is a temporary wood-transport road constructed from bodies of trees. In many cases, for construction of the plank roads, up to 30–35 % of all timber harvested, or about 800 m^3 of timber per kilometer of road, are spent. Depending on the construction technology and region, the operational life of a plank road is from 4–5 to 15–20 years. Photo credit: V. Kantor (Greenpeace Russia), 2003

Photo 4.30 Erosion of soils is provoked by topsoil disturbance during wood transportation. Intensity of the wash-off during the first couple of years after logging on slopes of 10°–20° reaches hundreds of cubic meters per hectare. Main losses of soils occur within the first 5–6 years. Development of erosion on a logging site in the upper reaches of the Maksimovka River (Primorsky Krai, Russia) is shown. Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 15 June 2005

4.2.1.1 Timber Rafting

Timber rafting means transportation of wood by water using timber buoyancy. There are **three types** of timber rafting: (1) drift floating (detached logs float with the current; it is used on unnavigable rivers); (2) rafting (timber is transported in rafts, mainly with the help of towing vessels; the volumes that rafts carry can be from 150 to 40,000 m^3, and transportation distances can reach 2,500 km); and (3) bag boom towing (detached logs are transported by a vessel in special floating booms; it is used on short distances on slow-flowing parts of rivers, lakes, and seas; booms are usually made of logs, and they are connected by ropes, chains, or other means).

Losses are *unavoidable* during all kinds of timber rafting and include (1) losses due to drowning (timber, being porous, absorbs water, which increases its density; sinking logs account for 57 % of all losses); (2) process losses (logs ducking under booms, raft crashes, logs sticking on flood plains; these incidents account for 32 % of all losses); and (3) other losses (logs breaking when they are dumped into water or piled up; some logs are left in storage yards; extra logs are used during indirect works; these losses account for 11 % of all losses) (Manukovsky and Patyakin 2004).

Timber rafting impacts the following natural **components**: (1) surface waters; (2) ichthyofauna; and (3) soils. Impacts on surface waters can be characterized by the following **factors**: (1) increases in solid discharges; (2) pollution with matter emitted by timber; and (3) pollution with waste, branches, and sunken logs.

Solid discharges into water are connected with logs being rolled down from slopes and silt sticking to the logs. During transportation by water, silt is washed off and carried as a suspended or dragged drift (Wohl 2014).

Pollution with matter emitted by timber is the most serious problem. The amount of soluble matter in timber depends on species, age, place of growth, time of logging, length of storage period after logging, and other factors. The main *types of matter* extracted by water include the following: (1) tannins (so-called ‘hardening agents’, which are phenolic compounds); (2) some polysaccharides (so-called ‘gums’ (pectins, starch) or carbohydrates of high molecular weight); (3) some carbohydrates of low molecular weight; and (4) inorganic salts (Fomintsev et al. 1990; Manukovsky and Patyakin 2004).

Washout of water-soluble matter decreases exponentially. The first half is washed out in the first 2–7 days; then the speed of washout drops rapidly. For instance, a drowned pine will contain only 36 % of soluble matter in 5 years, and only 18 % will be present in 18 years (Manukovsky and Patyakin 2004). **Pollution** with waste, branches, and sunken logs (excluding emitted matter) is physical pollution. Its importance is not high.

Impacts on the **ichthyofauna** include (1) impacts on spawning grounds; (2) impacts of extracted matter; (3) timber waste sedimentation on the bottom; and (4) increases in the area of distribution of some animals.

Mechanical damage to **spawning grounds** by drifting logs and branches takes place. This damage has unfavorable effects on the spawning of many fish, decreasing their numbers. To protect spawning grounds, booms consisting of logs or metal pontoons are installed (Novikov 1999).

The impacts of **extracted matter** are controversial: they can be both positive and negative. Increases in the nutritive base for fish is a *positive* effect. Extracts promote phytoplankton growth, providing food for the fish. Nevertheless, those organisms consume oxygen dissolved in water for respiration. After a certain threshold, phytoplankton starts to affect fish adversely.

Negative impacts on hydrobionts are connected with increases in acidity. Many types of extracted matter are toxic for hydrobionts. Plankton is the most vulnerable; benthos is the next to be affected. Timber rafting was the basic cause of drastic reductions in populations of the freshwater pearl mussel (*Margaritifera margaritifera*) in the rivers of the White Sea coast (Bespalaya et al. 2012; Makhrov et al. 2009).

Sedimentation of timber waste on the bottom of water bodies is also useful to a certain extent. It increases the biomass of bottom grounds with low productivity, because colonies of caddis worms, ephemerans, and chironomids form on the timber substrate.

The territories of some animals can increase because insects, snails, lizards, and other organisms can be found on the trunks of rafted trees. It is believed that timber rafting is contributed to the spread of geckos (lizards that lay eggs with a long development period in tree trunks) (Sedlag 1975).

Dumping of logs into water has an **impact on soils** through some increase in erosion and removal of soil that clings to the logs, but, on the whole, it is negligible.

The environmental impacts of timber rafting are illustrated by Photos 4.31–4.38.

Photo 4.31 There are three types of timber rafting: (1) drift floating (detached logs float with the current); (2) rafting (timber is transported in rafts, mainly with the help of towing vessels); and (3) bag boom towing (detached logs are transported by a vessel in special floating booms). The photo shows logs prepared for raft formation next to the Angara River. Below the slipway, one can see a raft section that has already been formed. Photo credit: P. Kurnakov (Ecoline EA Centre, Moscow, Russia), 20 July 2006

Photo 4.32 Drift floating is used on unnavigable rivers. In the former USSR, in 1988, drift floating was practiced on 197 rivers with a total length of 22,900 km, and 40 % of all timber transportation by water was done this way. The photo shows drift floating on the Kostroma River near the town of Buy (Russia). Photo credit: Jacques Dupâquier, July 1976

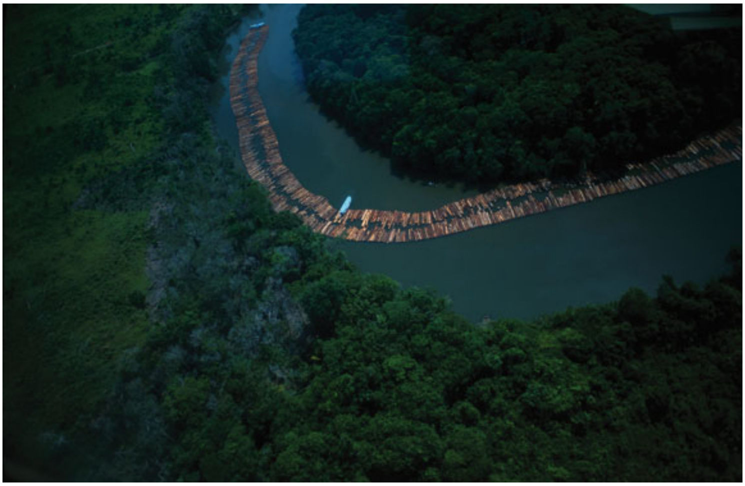

Photo 4.33 Impacts of timber rafting on surface waters can be characterized by the following factors: (1) increases in solid discharge; (2) pollution with matter emitted by timber; and (3) pollution with waste, branches, and sunken logs. The photo shows a long logging raft following the bend of a river in the state of Pará, Brazil. Photo credit: Luciana Napchan (Greenpeace), 1 January 1999

Photo 4.34 In order to speed up the process of timber rafting, tug boats are used to provide safe passage of the raft along the water body and prevent it from colliding with vehicles and the shore. The photo shows the Finnish steam tug Hurma preparing to tow a log boom. Photo credit: Matti Mattila, 13 August 2009

Photo 4.35 Log ponds are entry resistant constructions in water that are protected with floating structures; they are used to retain logs at a fixed position on a watercourse. A traverse (i.e., that blocks the entire width of a water passage) booming ground in the Croix River, Maryland, United States, is shown. Photo credit: Lee Lockwood (National Archives and Records Administration), May 1973

Photo 4.36 Solid discharges into water are associated with logs being rolled down from slopes and silt sticking to the logs. During transportation by water, silt is washed off logs and carried as a suspended or dragged drift. The photo shows logs on a bank slope of the Angara River (Irkutsk Oblast, Russia) that will be transported by timber rafting. Photo credit: P. Kurnakov (Ecoline EA Center, Moscow, Russia)

Photo 4.37 When logs are transported by water (especially in case of floating of loose wood), part of the logs is inevitably lost, being trapped in hurst and covered later on with silt and sand. Logs lost in the process of floating of loose wood on the shoreline overwash of the Karaidel River (Bashkiria, Russia) are shown. The timber of such logs quickly becomes unfit for use due to decay and fungosity. Their use as firewood is also problematic because sand filling hair cracks makes chain saws inoperable. Photo credit: A.A. Lapin, 14 August 2012

Photo 4.38 During floating many logs become waterlogged and sink to the bottom of the bodies of water. After many years of log drives, large quantities of wood have accumulated in certain areas. Because of reduced oxygen and light levels, decomposition is greatly reduced and allows the sunken logs, which may have sunk hundreds of years ago, to be preserved to this day. The Photo shows logs being retrieved in, Canada. Photo credit: Underwater Logging Ltd., Canada

4.2.2 *Reforestation and Plantation Development*

Reforestation is the generation of new forest on sites where logging and fires have taken place; that is, where forests were once. **Plantation development** is cultivation of artificial forest, similar to agriculture. The mean rate of reforestation and plantation development is illustrated in Fig. 4.8.

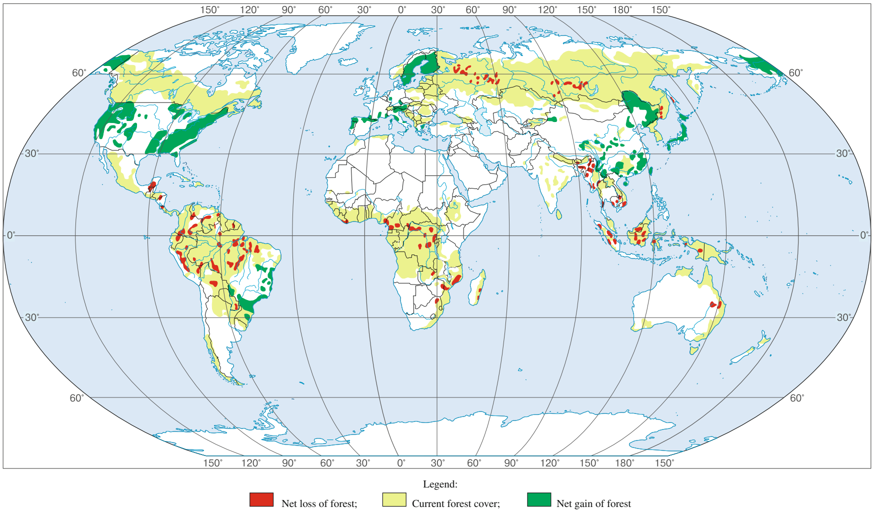

Fig. 4.8 Global forest status (http://www.dtgraham.com/about-reforestation/reforestation-worldwide; Resources and environment 1998)

More than 2 billion ha of land where forests once grew—an area twice the size of China—has the potential to be restored (http://www.wri.org/our-work/topics/forests). Forest restoration can be conducted in two different **ways**: (1) *artificial* (i.e., creation of forest cultures; planting and sowing of trees) and (2) *facilitation of natural forest restoration* (i.e., creation of conditions that ensure fast repopulation by valuable tree species). This facilitation means leaving seed trees and small areas of forest unlogged (Nikonov 2001).

Forest plantations have reached 264 million ha (Global environment outlook 5 2012). More than 60 % of all forest plantations are located in Asia. For the countries with the **largest plantations,** the figures are the following (million hectares): China, 77; India, 33; United States, 25; Russia, 18; and Japan, 10 (Karakin et al. 2014). Plantation development usually means the growing of *monocultures*.

Plantation development, as well as forest restoration, has a number of negative **environmental consequences**. These consequences are mainly connected with aerial chemical treatment and melioration.

Aerial chemical treatment is used to (1) increase soil fertility and (2) regulate juvenile population composition. To accomplish the **first** task, mainly fertilizers are used. The use of fertilizers leads to increased timber growth, but it also results in

considerable water pollution and has an impact on ichthyofauna (Munson et al. 1993).

To **regulate the natural juvenile population composition** formed on logging sites, other chemicals—*arboricides*—are used. They have selective impacts on tree species. For example, in young mixed pine-broadleaf forests, pine, which is the more valuable species, suffers from shading by small-leaved deciduous species (aspen, birch, willow, alder, and linden). Arboricides are disseminated in such forests, killing many of the deciduous trees, while coniferous trees receive much less damage.

Considerable research done on sites where arboricides have been used has shown that they have negative impacts on almost all **animal** species. These impacts include effects such as decreases in the *reproduction* intensity of many groups of animals, *reductions* of some animal population *numbers*, and provocation of *developmental defects* (Sokolov 2008). The impacts of *herbicides* are similar; besides, their use leads to drops in nitrogen and amounts of other nutrients in soils (Maillard et al. 2010).

Forest melioration is applied widely in the taiga zone. In many cases, it is understood as forest draining. Melioration leads to productivity growth in dried forests, due to increases in root layer thickness, accelerated mineralization of organic matter, and improvement of tree root aeration (Handbook of forester 1980).

The **negative impacts** of forest draining are of much more diverse: (1) the importance of drained forest ecosystems in sustaining oxygen and carbon balance in the atmosphere drops radically; (2) waters where drainage waters are dumped are polluted by turf bits and soluble decay products of accumulated organic matter, which results in drops in the oxygen content in water and leads to fish suffocation during winter (see Sect. 6.3); (3) rapid changes in the conditions in marsh ecosystems cause death of many plant and animal populations; and (4) there is also a catastrophic growth of fire hazard in the drained territories.

In addition, plantation development often leads to **soil degradation**. For instance, in cultures of different species of larch in northern China, soil degradation is connected with changes in the nutrient cycle. Larch needles decay for a very long time, and it takes 4.4 years to mineralize forest litter. This process takes 0.9–2.4 years for birch and poplar.

At larch plantations, litter accumulation leads to thermal insulation of soil, decreasing its temperatures and limiting microbial activity. Declines in **fertility** are observed in the first generation and worsen after two rotations. In mixed cultures (with a share of deciduous trees and shrubs), recirculation of nutrients and sustainable soil fertility are more effective (Fu et al. 2015).

Impacts on soils also take place during *timber processing*. Moving equipment causes soil to become denser, which in turn decreases a soil's biological **productivity**. The growth of some cultures in itself can have negative impacts on soils. For instance, **soil erosion** on eucalyptus plantations is very intense (Modern global changes 2006, V. 2).

As a rule, plantation development leads to sharp decreases in **biodiversity** in comparison to less-disturbed forests that grow in similar conditions, but appeared naturally, or even those secondary forests that grew without human interference.

The environmental impacts of plantation development and reforestation are illustrated by Photos 4.39 and 4.40.

Photo 4.39 Plantation development is the cultivation of artificial forest, similar to agriculture. It usually means the growing of monocultures. As a rule, plantation development leads to sharp decreases in biodiversity in comparison to less-disturbed forests that grow in similar conditions. The photo shows a loblolly pine (*Pinus taeda*) plantation in Burke County, Georgia, the United States. Plantations are usually easily distinguished from natural forests because the trees are planted in straight lines. Photo credit: David Stephens (Bugwood.org), 26 August 2006

Photo 4.40 Reforestation is a process in which new forest is generated on sites where logging and fires have taken place; that is, where forests were once. A poplar reforestation project is being carried out in six farm groups in the south of the Paraná state and in the north of the Santa Catarina state (Brazil). Approximately 2500 ha are covered with 800,000 poplar trees, in places where the species has shown good adaptation. Photo credit: Everson Dezgeniski (Swedish Match)

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Chapter 5
Transport

5.1 Automobile Transport

The **impacts** of automobile transport on the environment include the following: (1) air pollution; (2) pollution and breaking of surface and subsurface drainage; (3) soil pollution; (4) loss of lands; (5) fauna impacts; (6) flora impacts; (7) transformation of relief and the geological environment; and (8) noise impacts and vibration (Fig. 5.1).

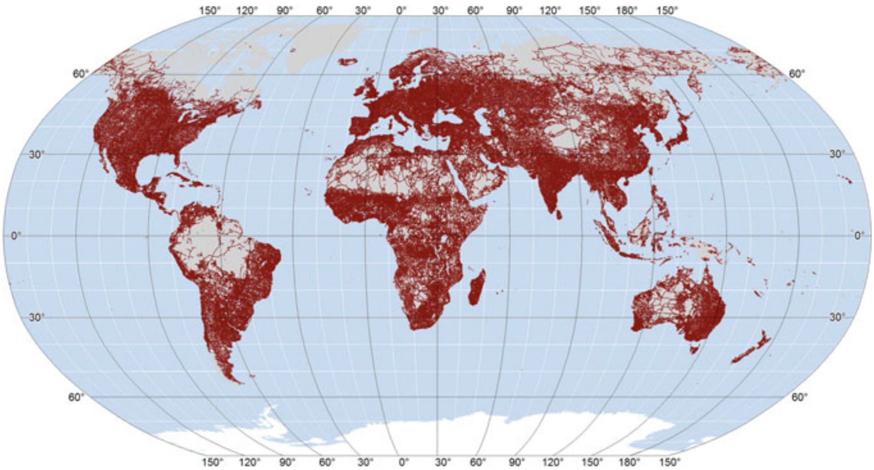

Fig. 5.1 Global road network (http://www.mapability.com/info/vmap0_download.html; http://bioval.jrc.ec.europa.eu/products/gam/sources.htm; http://gis-lab.info/qa/vmap0.html)

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_5

Air pollution is the most significant impact of automobile transport. Its main **components** are (1) burnt engine gases; (2) crankcase fumes; (3) fuel evaporation from tanks, carburettors, or hoses; (4) products of abrasion of tires, brakes, and other parts of vehicles, and (5) products of a roadbed's wear.

The main pollutant is *burnt gases* from engines. The **main emissions component** is carbon dioxide; in consideration of toxicity, however, the **most important pollutants** are carbon monoxide and lead for gasoline engines, and sulfur dioxide for diesel engines.

Road construction often changes **surface flow** and **groundwater conditions** due to the creation of new geomorphologic forms during the construction of a roadbed. In cases when a road embankment interrupts the natural run-off, *upstream* overwetting, rises in the levels of subsoil water, gradual swamping, and the transformation of flora and fauna occur. The *downstream areas* are drained of water and, consequently, biogeocenosis is transformed.

The pollution of **surface waters** happens through, first, transfer into water bodies of mechanical (sediments, suspensions, emulsions) and chemical (dissolved substances in the ionic and molecular forms) pollutants, which are generated during construction and use of the roads. The content of pollution in a flow depends on the area, intensity of traffic, and other factors. In many areas, the main pollutants are chemical substances that are used to counteract ground surface icing (chlorides; nitrates; phosphates and sulfates of sodium, calcium, and magnesium; spirits; and glycols). The *most widely used substances* are chloride compounds, particularly sodium chloride and calcium chloride.

The second way includes sewage disposal by auto transport enterprises. The *main pollutants* are oil products, alkalis, lubricoolants, and others that are generated during car washing, servicing of accumulators, repair of coolant systems, and other maintenance and repair activities.

Soil pollution takes place in a relatively narrow wayside (100–150 m, up to 300 m). It is caused by the settling of *lead compounds* and other metals (copper, zinc, nickel, vanadium, cobalt, molybdenum) from the atmosphere originating from an engine's burnt gas emissions and metal parts wear. A large contribution to soil pollution is made by *de-icing salts*. Chlorides penetrate into the soil the deepest, reaching groundwater.

Regarding **condemnation of land,** automobile roads and other components of the infrastructure occupy a high place among the branches of industry. Total length of roads is 68.937 million km (http://relaxic.net/entertaining-statistics-2/). For instance, in the United States roads and waysides occupy about 1 % of the territory of the country (Elaine 2003). The area under direct ecological influence is much larger; in the United States 19 % of the territory is affected (Forman 2000).

The influences on **fauna** can be both *positive* (the waysides act as ecological niches for synanthropic and semi-synanthropic species of birds and mammals; the roads are migration passages) (Morelli et al. 2014) and *negative* (creation of ecological obstacles, deaths of animals in collisions with cars, the destruction of the animals' habitat, etc.).

Roads are often **barriers** to the migration of animals. Animal **deaths** caused by collisions with motor vehicles occur, *first of all*, with highly mobile animals (birds), with animals having definite peculiarities (slow movement, sluggishness, weakness of hearing or sight), with those showing vulnerable behaviors (stop when being lit by headlights, assume protective poses in case of danger, night activity), and also with those with a larger home range (amphibians, hoofed mammals).

Amphibians seem exceptionally vulnerable to death on the road. In studies on four continents the percentage of vertebrate kills that were amphibians ranged from 6 to >90 % (Beebee 2013). The numbers of **deaths** of animals on roads are extremely high. For example, between 89 and 340 million birds die annually from vehicle collisions on the United States roads (Loss et al. 2014).

Automobile transport contributes to **bioinvasions** of *plants* and *animals*. For example, the **Asian tiger mosquito**, *Aedes albopictus*, was accidentally brought from Japan to the Western Hemisphere in the mid-1980s with used tires (Goddard 2012). Since then, this species has rooted itself in the United States, Argentina, Brazil, Guatemala, the Dominican Republic, Cuba, and Mexico.

The **geomorphologic** and **geological** environments are influenced by the removal of considerable amounts of ground, which leads to transformation of relief (excavation, embankments). The creation and use of roads often intensify geomorphologic processes. The **noises** of road traffic are caused by working engines, wheels, beeps, and so on.

The environmental impacts of automobile transport are illustrated by Photos 5.1–5.10.

Photo 5.1 The worldwide motor vehicle industry now produces more than 220,000 cars a day. When the operating life of a motor vehicle is over, the vehicle must be scrapped. However, vehicles are often put on scrap-heaps. A car dump in the suburbs of Vladivostok is shown. Photo credit: V.A. Solkin (Pacific Geographical Institute, Vladivostok, Russia)

Photo 5.2 During its life cycle, every car produces a large amount of reusable resources (e.g., used engine oil) and waste products, amounting to 10 times more than the weight of the car. The photo shows oil being drained from a GMC sport utility vehicle. Photo credit: Myke Waddy, 8 November 2009

Photo 5.3 Air pollution is the most significant impact of automobile transport. Its main components are (1) burnt engine gases; (2) crankcase fumes; (3) evaporated fuel from tanks, carburettors, or hoses; (4) products of abrasion of tires, brakes, and other parts of a vehicle; and (5) products of a road bed's wear. The photo shows air pollution due to burnt engine gases of cars. Photo credit: http://en.wikipedia.org/wiki/Mobile_source_air_pollution by Ruben de Rijcke (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Photo 5.4 The main component of motor vehicle emissions is carbon dioxide; in consideration of toxicity, however, the most important pollutants are carbon monoxide, and lead in gasoline engines and sulfur dioxide in diesel engines.Traffic jams increase air pollution many times. The photo shows a transport collapse at Istanbul FSM Bridge (look from Etiler), Beşiktaş, Istanbul, Turkey. Photo credit: Adnan Behmen, 13 October 2007

Photo 5.5 Various activities related to construction and functioning of automobile roads also contribute to air pollution. The photo shows an asphalt concrete factory in Primorsky Krai, Russia. The charge of crushed stony material is moved by the front-end loader to the rotating furnace for heating before it is mixed with bitumen to produce an asphalt-concrete mixture. Dust is the smallest mineral particles of broken stone, while smoke (fumes) is products of incomplete combustion of fuel (usually fuel oil) and bitumen vapors. Freshly prepared hot bitumen-concrete mixture is fed from the furnace to the bunker and then to vehicles that transport it to where it will be used. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 27 August 2013

Photo 5.6 The numbers of deaths of animals on roads are extremely high. For example, in the United States, 1 million vertebrate animals die on roads every day. Ungulates, as animals having large home ranges, very often are hit by cars. The photo shows a deer killed on the Okatie Highway along the Chechessee River, South Carolina, United States. The debris surrounding the deer is a mixture of animal body parts and pieces of the car that hit it. A tire apparently passed over the back portion of the animal. Photo credit: John O'Neill, 9 April 2012

Photo 5.7 In order to decrease the number of animals dying on motor roads, warning signs are posted that warn of the presence of animals most likely to be in an area. Depending on the country and particular region, these animals can be most diverse. For example, the risk of collisions of cars with camels is most probable in Tunisia. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 18 August 2008

Photo 5.8 The pollution of surface waters through motor vehicle use happens in two ways. The first one includes transfer into water bodies of mechanical (sediments, suspensions, emulsions) and chemical (dissolved substances in the ionic and molecular forms) pollutants that are generated during construction and use of roads. The products of auto tire wear are one type of contaminant. For example, annual tire abrasion in Germany is estimated at 120,000 tons. The photo shows braking traces on a road on the South Island, New Zealand. Photo credit: I. Kelman (http://www.ilankelman.org/aircraft.html), 26 April 2014

Photo 5.9 In many areas, the main pollutants of surface waters are chemical substances that are used to counteract ground surface icing. The most widely used substances are chloride compounds, particularly sodium chloride and calcium chloride. This photo shows a snowplough and road salt application truck that is used to clear snow and ice from roadways for improving traffic and pedestrian safety. Photo credit: Steven Corsi (U.S. Geological Survey), 1 January 2009

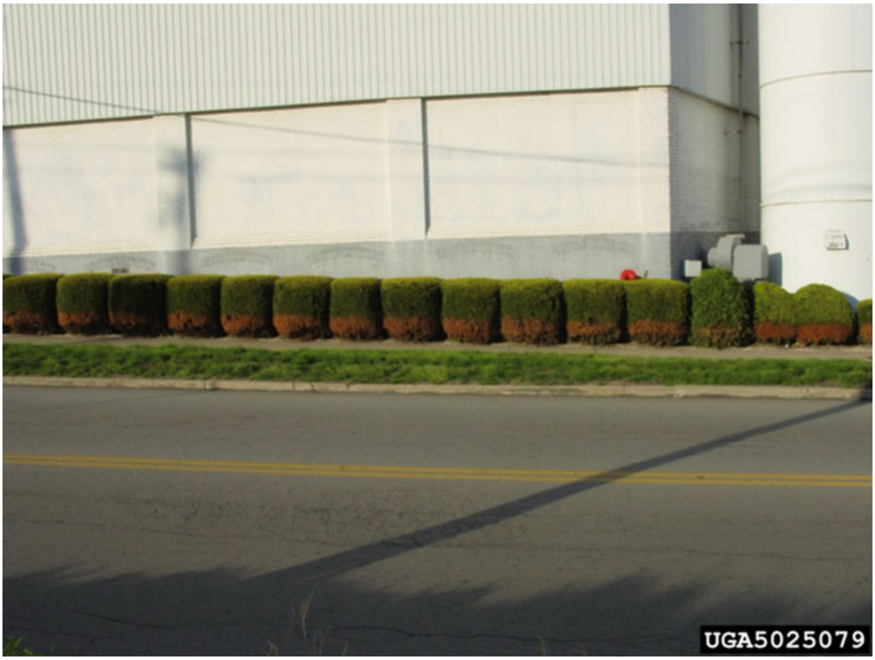

Photo 5.10 De-icing salts include chlorides, nitrates, phosphates, and sulfates of sodium, calcium, and magnesium. These compounds penetrate into the soil the deepest, reaching ground water. Damage to trees and shrubs also occurs. Extensive salt damage of a bush along a sidewalk in Wooster, Ohio, United States, is shown. Photo credit: Joseph LaForest (University of Georgia, United States)

5.2 Railway Transport

Railway transport is the conveyance of cargo and passengers on railroads. The *total length* of railroads over the whole world in 2006 was 1.37 million km. A total of 148 countries have railroads. The **leaders** are (thousands of kilometres) (1) the United States, 224,792 (2011); (2) Russia, 128,000 (2012); and (3) China, 103,144 (2013) (http://en.wikipedia.org/wiki/List_of_countries_by_rail_transport_network_size). Main railways and cities with metrosystems are shown in Figs. 5.2 and 5.3.

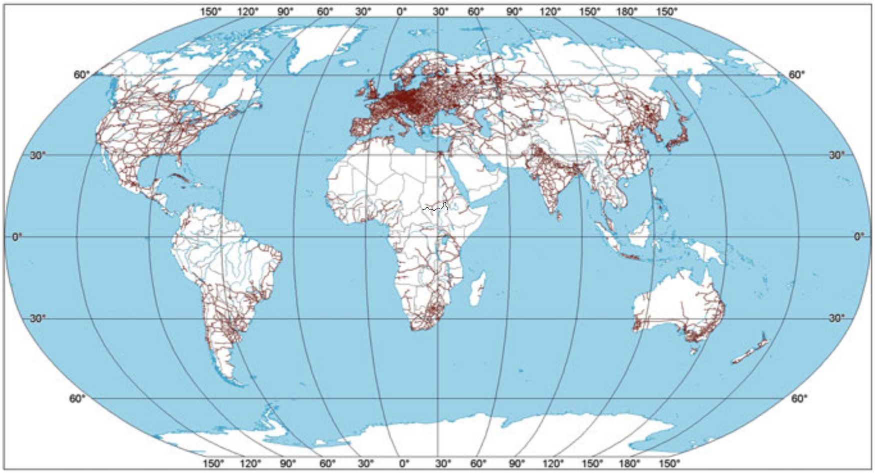

Fig. 5.2 Main railways of the world (http://www.mapsofworld.com/world-maps/major-rail-network-map.html; https://www.reddit.com/r/travel/comments/k0d43/world_map_of_railways/; http://www.theatlantic.com/entertainment/archive/2011/05/the-wonders-of-railway-maps-from-algeria-to-zimbabwe/238575/). *Source* Joint Research Centre, Institute for Environment and Sustainability, © European Communities, 2009

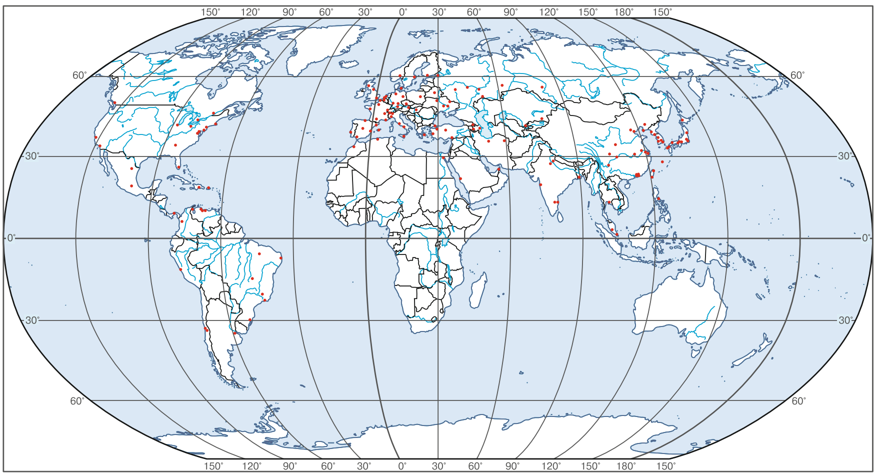

Fig. 5.3 Cities with metrosystems. Prepared by author based on data from numerous Internet sources

Virtually all **components** of the natural environment are impacted by railway transport, including (1) air; (2) surface and ground water; (3) soils; (4) geological and geomorphologic environments; (5) fauna; (6) flora; (7) noise impacts; and (8) land withdrawal.

The main pollutant of the **atmosphere** during railroad **construction** is non-organic *dust* of sand and crushed stone that is created during mining, conveyance, and laying of ballast. The share of *gaseous* pollutants (carbon monoxide, nitrogen oxides, sulfurous anhydride, soot) generated in the burning of fuels and blasting is relatively small.

During the **operation** of railroads, the ratios of volumes of pollutants change. The main factors polluting the atmosphere in railway transport are *burnt gases* from diesel locomotives, which contain benzol, lead, soot, formaldehyde, toluol, and xylol (Bulayev 2006).

Stove heating of carriages also has some impact. The main pollutants emitted by *rolling stock* are carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and soot.

The *goods* being transported themselves are sources of considerable pollution, which is caused by the *leakage* of those goods because of looseness; intensive emissions during loading, unloading, and transportation; and also by blowing-off of dust-like fractions with the wind while a train is moving.

Railway **enterprises** that cause air pollution include sleeper impregnation, rubble, repair factories, disinfection and washing stations, and boiler houses, which emit substances such as particulate matter (dust, soot), carbon monoxide, nitrogen and sulfur oxides, and various varnish and paint substances (Tskhovrebov 1996).

The impacts on **surface waters** include their withdrawal and pollution. The *leakage of oil products* is a main source of pollution in the use of rolling stock. It also occurs when washing a train and changing coolant liquid in diesel locomotives; the **main pollutants** are synthetic surfactants (SS), oil products, phenol, hexavalent chromium, acids, alkalis, and organic and non-organic suspended substances.

Oil oozing from leaks in various locomotive devices and parts of carriages also causes problems. *Fecal drains* and *waste* disposal from passenger cars also have some significance. Stationary sources of waste include considerable volumes of sewage, containing mineral, suspended, and organic substances; phenols; oil products; synthetic surfactants; different metals; and other materials.

Soil impacts basically occur in relatively narrow strips along railways and near enterprises. For instance, investigation of heavy metals pollution in soils along the Delhi-Ulan section of the Qinghai-Tibet railway detected high concentrations of Cr, Ni, Cu, Zn, Pb, and Cd (Zhang et al. 2013). However, the **main pollutants** near tracks are coal and ore dust, oil products, and salt. Metal dust generated as a result of intensive abrasion of cast-iron brake pads is also of some significance.

The **geological** and **geomorphologic** environments are affected by withdrawal and movement of geological materials, and intensification of geomorphologic processes. The impacts on **fauna** consist of blocking by railways of animal migration routes and creation of problems for selected species (Rudsky and Sturman 2014).

Railways are distribution channels of invasive **plant** species. The stripes alongside railways serve as places for naturalization and dissemination (Filippova and Perevoznikova 2006). For instance, warty cabbage (*Bunias orientalis*) has spread in central Europe mainly along railways (Kieltyk 2014).

In many countries, railways are considered as the second source of ambient noise pollution, just after the noise from urban traffic (Monazzam et al. 2014; Grubliauskas et al. 2014). The main source of **noise** is rolling stock. The noise of **locomotives** is caused by motor-ventilators, compressors, generators, traction engines, and so on; for motor carriages of electric trains, they are motor-compressors and traction engines. Noise is also generated by *wheel strokes* over railing junctions, knocks of *automatic couplers*, rattling and knocks of *brake rods* and pads, *braking*, and other factors.

The noise from railway transport **enterprises** is generated during activities such as the operation of different machinery and equipment and ventilation. Some sources of intensive noise at stations are shunting operations, compressors, blow-off of railway points, speakerphones, conveyors, and cranes.

Land withdrawal related to railway transport is not great. For instance, a four-lane highway requires 5.6 ha of land per kilometer, but four railways occupy 2.5 ha/km, and the number of passengers being transported by automobiles is 13 times less (Wrong side of the tracks? 1991).

The environmental impacts of railway transport are illustrated by Photos 5.11–5.20.

Photo 5.11 Railway transport conveys cargo and passengers on railroads. However, some kinds of railway transport hardly meet this definition. A suspension railway in Wuppertal, Germany, is shown here. This unique system is the oldest electric elevated railway with hanging cars in the world. It was built between 1897 and 1903 and is still in use today as a normal means of local public transport, moving 25 million passengers annually. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 10 August 2014

Photo 5.12 Not infrequently, railroad transport modifies the geologic environment. First of all, underground railway systems impact the geologic environment. The first metro system, the London Underground, was opened in 1863. As of 2010, there were approximately 140 metro systems in the world. The photo shows the Santiago Metro in Chile. It opened for service in 1975. It has 5 lines, 108 stations, and 103 km (64 mi) of revenue service. The system serves around 2.4 million passengers per day. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 19 November 2011

Photo 5.13 The use of underground space is sometimes necessary for common railway transport handling long-distance traffic of passengers and goods. More often, it is required to overcome natural obstacles (for example, tunnels under mountains or under water barriers). The Seikan Tunnel travels beneath the Tsugaru Strait, connecting the main Japanese island of Honshu with the northern island of Hokkaido. This tunnel is both the longest and the deepest operational main-line rail tunnel in the world. It has a 53.85 km (33.46 mi) railway tunnel, with a 23.3 km (14.5 mi)—long portion under the seabed. The track is about 100 m (330 ft) below the seabed and 240 m (790 ft) below sea level. Photo credit: https://en.wikipedia.org/wiki/Seikan_Tunnel by Encino (talk/Contributions) at the Chinese Wikipedia [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons, 1 June 2005

Photo 5.14 It is necessary at times to use underground space for railway stations, such as in big cities that lack space for above-ground stations. Grand Central Terminal in New York has the largest such facility in the world. Platforms are on two levels, both below ground, with 41 tracks on the upper level and 26 on the lower, though the total number of tracks along platforms and in rail yards exceeds 100. The terminal covers an area of 48 acres (19 ha). The photo shows one of the tracks of Grand Central Terminal. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 15 April 2014

Photo 5.15 Railway transport is a source of vibrations. Vibration oscillations caused by tramway cars penetrate down to depths of 70 m. The vibration contributes to compaction and structural destruction of grounds, changing their thermal and water conditions. As a result of these changes, reduction of massif resistance to external loads and appearance or activation of unfavorable natural processes (sagging, landslides, solifluction, rock falls, subsidences, etc.) are possible. A tramway in Vienna, Austria, is shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 16 August 2014

Photo 5.16 The main factors polluting the atmosphere in railway transport are burnt gases from diesel locomotives, which contain benzol, lead, soot, formaldehyde, toluol, and xylol. The main pollutants emitted by rolling stock are carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and soot. The stove heating of carriages also has some impact. A passenger train at the station in Vladivostok is shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 31 March 2012

Photo 5.17 Goods being transported on rail cars themselves are sources of considerable pollution. In the case of bulky goods, pollution is caused by intensive emissions during loading, unloading, and transportation; and also by blowing-off of dust-like fractions by the wind while a train is moving. The photo shows a coal train near Old Cambus, Scottish Borders, Scotland, heading past the site of the Penmanshiel Tunnel. Photo credit: Callum Black, 23 May 2007

Photo 5.18 In the transport of oil products, pollution is caused by spills of residues from drain-filling hoses, noncompliance with rules and operation manuals for rolling stock, and spillovers in the course of heating of product and during filling due to unreliable control as well as to pouring by “open jet.” Cars polluted with fuel oil at the station in Vladivostok are shown. The pollution commonly happens when the cistern is charged. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 25 April 2014

Photo 5.19 The scales of contamination increase many times during emergencies. The photo shows the consequences of a train derailment that happened on 30 December 2013 near Casselton, North Dakota, United States. About 400,000 gal (1,283 metric tons) of crude oil spilled from 18 cars of a 106-car train. Workers continue to clean up the area. The train collided with derailed cars of a train carrying soybeans. Photo credit: Ann Arbor Miller (Greenpeace), 2 January 2014

Photo 5.20 Surface-water contamination takes place during railroad train washing and replacement of coolant liquid in diesel locomotives, leakages of oil products, etc. Contamination is also especially great during emergencies. When a freight train derailed on 15 June 2005, near Rzhev (Tver Oblast, Russia), 21 tanks filled with fuel oil overturned. All together, about 300 t (approximately 92,000 gal) of oil products were released, some of it into a nearby river. Floating booms were used in the water to prevent the contamination from spreading. Photo credit: V. Pavlov (Greenpeace Russia), 21 June 2005

5.3 Pipeline Transport

The transportation of **oil** and **gas,** and also the products of processing (e.g., ammonia, ethylene), with pipelines is widespread. The total length of pipelines in 2010 was 1,942,669 km (http://chartsbin.com/view/1322). Besides the pipelines themselves, the **infrastructure** also consists of head and intermediate pump stations, receiving and distribution stations, control stations, approach roads, and so on (Fig. 5.4).

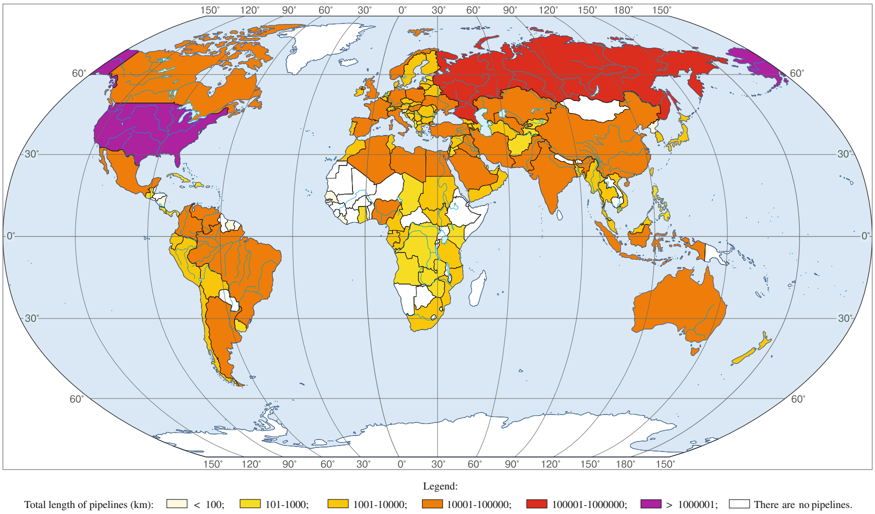

Fig. 5.4 Total length of pipelines in countries of the world. Prepared by the author based on data at https://www.cia.gov/library/publications/the-world-factbook/fields/2117.html

Building a pipeline over land involves the following **stages** of work: (1) geological engineering survey; (2) route clearing; (3) making ditches; (4) laying the pipes along the route of the pipeline; (5) pipe bending; (6) welding; (7) wrapping the pipes with polymeric bands; (8) applying an insulating coating; (9) installing cathodic corrosion protection systems; (10) laying the pipes into ditches; and (11) ditch backfilling.

In the process of building pipelines in the open **sea,** they are placed on the bottom fixed with anchorages (concrete slabs, blocks, etc.). If a pipeline must be laid deeper, ditches are made with underwater digging machines. To lay the pipes, **pipelay ships** are used.

On the whole, **constructing** pipelines has environmental influences similar to those of other industrial projects. The exception is **underwater** laying, which damages water ecosystems considerably. Such cases occur often, as besides building pipelines on the sea bottom, laying numerous underwater crossings through rivers is often required.

Concentrations of suspended soil particles grow rapidly in river sections several kilometers long during the digging of **channel ditches**. This material changes the conditions in the habitats of fish, plankton, and benthos. Feeding water and spawning spots get dirty or are completely destroyed. Wintering pits are often filled during underwater soil storage. Fish are struck with hydrodynamic shock waves during *blasting*. *Ditch backfilling* from floating vehicles causes secondary pollution of water bodies (Telegin et al. 1988).

While a pipeline is being used, the **main sources** of impacts are (1) the pipelines themselves; (2) the products being transported; and (3) the heat of substances being transported.

Basically, the impacts of the pipelines **themselves** involve land withdrawal and obstruction of *migration* routes of a number of animals. For example, in 1969 the spring migration of Taimyr reindeer from winter pastures in the Yenisei River valley was interrupted by the Messoyakha–Norilsk gas pipeline (Russia). The animals moved along it, searching for ravines or parts of the pipeline covered with ice, where they got over it. The reindeer chose a new path to bypass the pipeline in autumn of 1969 and spring of 1970 (Transport and storage of oil and gas 2002).

Additional *slope loading* near pipelines can provoke **landslides**. In the area of *permafrost* soil, pipelines contribute to **swamping** (due to obstruction of surface flow and additional dumping because of snow accumulation) and activation of **erosion processes** (due to destruction of vegetation cover and instability of filled soils).

The most intense *source* of impacts to the environment is **transported products**. During normal pipeline transport, pollution of the atmosphere occurs (emission of oil in reservoirs, loading and unloading operations at transfer stations, gas leakages, etc.).

For example, as a result of **gas leakage** from a linear pipeline portion 1,100 km long in northwestern Siberia, more than 100,000 t of hydrocarbons are emitted to the atmosphere annually. Compressor plants emit 30,700 t of various pollutants, including hydrocarbons, 58 %; nitrogen oxides, 25.7 %; and carbon monoxide, 15.6 % (Rudsky and Sturman 2014).

In Russia, about 7 million tons of oil is **spilt out** at underwater river crossings and near shorelines. In 1988 alone as a result of an oil pipeline breach in the Samotlor field, 110,000 t of oil flowed out into the lake of the same name (Khaustov and Redina 2006). **Accidents** are known to have occurred in the North Sea (where 4,800 km of pipelines are used), on the shelf of Saudi Arabia, in the United States, and in other areas (Patin 1997). Pipeline function leads to deaths of people. For instance, in Nigeria in 1998, 1,000 were killed in a pipeline blast in Warri (Environmental technology in the oil industry 2008).

Accidental spills on land lead to two types of impacts on **plants** (Korobov 2004): (1) malfunction of physiological processes due to covering of the surfaces of the trunks and leaves; and (2) plant intoxication with toxic components of oil. In most cases, vegetation perishes and its regeneration starts after 2–3 years. General oppression, necrosis, and tumors are typical in the surviving specimens (Dorozhukova and Yanin 2002).

Heat impacts of oil transported in pipelines are especially significant in areas of *permafrost*. These impacts include changes in the thermal and humidity conditions of the soils, and the appearance of *thermokarst* and *frost swelling*.

The environmental impacts of pipelines are illustrated by Photos 5.21–5.28.

Photo 5.21 During the construction of pipelines over land, the following primary stages of work are performed: (1) geological engineering survey; (2) route clearing; (3) making ditches; (4) laying the pipes along the route of the pipeline; (5) pipe bending; (6) welding; (7) wrapping the pipes with polymeric bands; (8) applying an insulating coating; (9) installing cathodic corrosion protection systems; (10) laying the pipes into ditches; and (11) ditch back-filling. A pipeline can be an insurmountable obstacle to the movement of animals. Felling of trees on steep slopes also intensifies erosion processes. The photo shows a cut-through for laying a gas pipeline on Sakhalin Island (Russia). Photo credit: V. Kantor (Greenpeace Russia), 27 June 2005

Photo 5.22 While a pipeline is being used, the main sources of environmental impacts are (1) the pipelines themselves; (2) the products being transported; and (3) the heat of the substances being transported. In particular, the impacts of the pipelines themselves involve land withdrawal. The Trans-Alaska Pipeline, in the northern Brooks Range, Alaska, United States, is shown. Rocks in the background produce oil on the North Slope. Photo credit: Dave Houseknecht (U.S. Geological Survey), 20 June 2007

Photo 5.23 Transported products are the source of the most intense impacts to the environment associated with pipelines. During normal pipeline transport, pollution of the atmosphere occurs (emission of oil in reservoirs, loading and unloading operations at transfer stations, gas leakages, etc.). Spatial scales and intensities of impacts increase markedly in case of an incident. A lake of oil that formed after an accident on a pipeline near Surgut (West Siberia, Russia) is shown here. Photo credit: Greenpeace Russia, 29 May 2013

Photo 5.24 The heat of substances being transported impacts the surrounding ground. Thermokarst not infrequently develops along the routes of pipelines. Oil is characterized by high freezing temperatures and viscosity; therefore, oil is preheated so that it will flow through pipelines with the required velocity. There also are compressor stations along natural gas pipelines that compress the gas. This compression increases the temperature of the gas to 30–40 °C. The warmth thaws the top layer of the perennially frozen grounds, which intensifies cryogenic processes. Thermokarst along a gas pipeline is shown. Photo credit: F.M. Rivkin (OJSC Fundamentproekt), 1984

Photo 5.25 The effects of pipelines on wildlife are associated particularly with the fact that they obstruct the migration routes of a number of animals. Frequently, the animals are afraid to get under them and move along them. The photo shows caribou walking alongside the Trans-Alaska Pipeline. Photo credit: Stan Shebs, July 1998

Photo 5.26 Effects on animals also include damage and death due to contamination with pumped products. Fur contaminated with oil loses the ability to retain heat and water. In addition, oil irritates the skin and eyes, and makes it difficult for them to swim. The ingested oil can give rise to digestive hemorrhages, kidney failure, liver intoxication, and disturbances of blood pressure. A dead muskrat is seen in an oil spill in the Pyt-Yakh region of Russia. Photo credit: Denis Sinyakov (Greenpeace Russia), 1 June 2013

Photo 5.27 In the case of accidental oil spills on land, two types of impacts upon plants can be identified: (1) malfunctions of physiological processes due to covering of the surfaces of the trunks and leaves; and (2) plant intoxication with toxic components of oil. In most cases, vegetation perishes and its regeneration starts after 2–3 years. General oppression, necrosis, and tumors are typical in the surviving specimens. Dead trees due to oil spill in the Surgut region in Siberia (Russia) are shown. Photo credit: Denis Sinyakov (Greenpeace Russia), 31 May 2013

Photo 5.28 Pipeline breaks are not infrequent. At times, pipeline fires and explosions result in the deaths of people. The 2010 San Bruno pipeline explosion occurred on 9 September 2010, in San Bruno, California, a suburb of San Francisco, when a 30-inch (76 cm) diameter steel natural gas pipeline exploded in flames. As of 29 September 2010, the death toll was eight people. Eyewitnesses reported the initial blast created a wall of fire more than 1,000 ft high. Photo credit: http://en.wikipedia.org/wiki/2010_San_Bruno_pipeline_explosion by MisterOh (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons, 9 September 2010

5.4 Air Transport

The impacts of air transport include the impacts of **aircraft** themselves and those of **airports**. Numerous planes are in the air at any given time. For instance, 9,864 planes were in flight at 2 p.m. (EST) on 6 July 2014 (http://www.flightradar24.com/data/airplanes/). The **operation** of aircraft and helicopters, first of all, has impacts on the atmosphere (e.g., pollution of air with burnt engine gases, and decreases in ozone concentrations in the lower stratosphere) (Figs. 5.5 and 5.6).

Fig. 5.5 Main air routes and largest airports in the world (Resources and environment 1998). Reproduced with permission of the Institute of Geography of the Russian Academy of Sciences

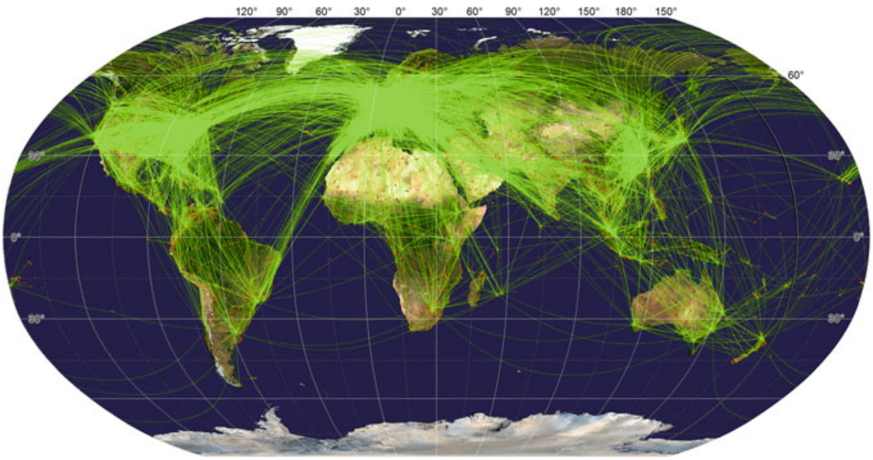

Fig. 5.6 Global air routes map (http://openflights.org/data.html; http://www.gl-co.com/gl_aircargo.html)

The **intensity of pollution** and the composition of the burnt gases are different at the *different stages* of aircraft engine operation. During *idle running* (parking), *taxiing*, and *approach landing*, the quantity of carbon monoxide in burnt gases increases, but the quantity of nitric oxides decreases. During flight, emissions of carbon monoxide decrease, but emissions of nitric oxides increase.

The **greatest pollution** (emission of soot) occurs during take-off and climb (Wood et al. 2008; Masiol and Harrison 2014). The take-off of one big aircraft produces the same amount of pollution as 8,000 cars do; at the same time, as much oxygen is consumed as 50,000 ha of forest produce in 1 day (Rudsky and Sturman 2014).

Soil and **surface waters** are polluted by excess fuel that aircraft discharge in case of emergency to decrease the touchdown weight. The amount of fuel discharged varies from 1,000–2,000 to 50,000 liters. *Mainly*, the fuel is dispersed in the atmosphere. The share of non-evaporating fuel reaching the ground surface in the form of drops depends on the temperature of the air and the height of the discharge. It amounts to up to *several percent* (Naumova 2004).

It also should be noted that **noise impacts** can affect large areas. For example, aircraft acoustic discomfort in the Moscow region affects 5 % of the territory (Geoecological fundamentals of protection 1991). An estimated 2–3 % of the population of Russia currently are exposed to aircraft noise that exceeds exposure standards.

Levels of aircraft noise **depend on** the direction of runways and flight routes, intensity of flights during the day, seasons, types of aircraft that are based at a given airport, and many other factors. *Noise levels* in an airport's 24-hour intensive operation are 80 db in the daytime and 78 db at night; maximum levels are 92–108 db (Govorushko 1999).

The **main source** of pollution from airports is the equipment based there. Impacts include, first of all, pollution of surface waters, noise, and electromagnetic impacts. Main air routes and the largest airports are shown in Fig. 5.4.

Surface waters are polluted by (1) waste water (primarily from buildings and aircraft service facilities); (2) sullage (from buildings and facilities for transportation services—air terminals, hotels, etc.); and (3) airline surface flow (from aircraft technical bases, areas for development works, aircraft washing and de-icing processes, apron and airport land side, etc.) that is formed due to melting snow and rainwater.

The **composition** of waste water is closely related to things such as the kinds of production, feedstock, and various extra products involved in processes, and also to the course of those processes, and the kind and performance characteristics of production equipment.

The **sewage** of airport production departments and other airline facilities **contains** benzol, acetone, oil products, acids, alkalis, dissolved metals, and other polluting substances, and also herbicides and pesticides used in agriculture. Surface flows from airports typically contain mineral suspensions, oil products, dissolved organic admixtures, and nitrogen-containing substances.

The **soil** around airports is polluted with heavy metal salts and organic compounds up to 2–2.5 km away. In autumn and winter, de-icing of aircraft and removal of snow and ice from the surfaces of airports are executed. Active *de-icing* preparations and reagents used during those processes contain urea, ammonia saltpetre, and synthetic surfactants, which also contaminate the soil.

The main **sources** of **noise** at airline facilities are aircraft and auxiliary power houses, starting units, special aerodrome service vehicles, and machining and technological facilities. The *levels* of jet aircraft noise at distances of 5–100 m are 120–140 db.

The **sources** of **electromagnetic fields** are radio and radar equipment comprising air traffic, navigation, and landing management systems. Radio stations, Doppler radars, actual speed and drift angle measuring devices, radio altimeters, radio beacons, and other equipment are included.

On the whole, the environmental impacts of air transport are important enough. At present, it accounts for 3 % of the world's manmade emissions of carbon dioxide (Bofinger and Strand 2013), and it has certain **climatic** consequences (Asaturov 2005). **Aviation** accounts for about 3.5 % of total anthropogenic pollution (Aviation ecology 2004).

The environmental impacts of air transport are illustrated by Photos 5.29–5.34.

Photo 5.29 Large airports occupy vast territories. They include flight strips, bearing tracks, air terminal buildings, buildings and structures for aircraft maintenance, and other structures. The photo shows the Incheon International Airport in Jung-gu, Incheon, South Korea. Photo credit: http://en.wikipedia.org/wiki/Airport, 24 April 2005

Photo 5.30 The intensity of pollution and the composition of burnt gases are different at the different stages of aircraft engine operation. During idle running (parking), taxiing, and landing approaches, the quantities of carbon monoxide in burnt gases increase, but the quantities of nitric oxides decrease. During flight, emissions of carbon monoxide decrease, but emissions of nitric oxides increase. The greatest pollution (emission of soot) occurs during take-off and climb. The photo shows a plane taking off at the Narita International Airport, Tokyo, Japan. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 5 April 2014

Photo 5.31 Air pollution is especially high near airport terminals. Not infrequently, queues form of aircraft waiting to take off or land. London Heathrow Airport is a major international airport in West London, United Kingdom. Heathrow is the busiest airport in Europe based on passenger traffic. Aircrafts flying a holding pattern near Heathrow airdrome are shown. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, 26 April 2014

Photo 5.32 The soil around airports is polluted with heavy metal salts and organic compounds up to 2–2.5 km away. In autumn and winter, de-icing of aircraft and removal of snow and ice from the surfaces of airports take place. Active de-icing preparations and reagents are used during those processes that contain urea, ammonia saltpetre, and synthetic surfactants, which contaminate the soil. The photo shows de-icing operations at an airport in Oslo, Norway. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, 23 May 2010

Photo 5.33 Vapor traces left in the sky behind flying aircraft affect the atmosphere. These traces are known as "contrails" and, under proper atmospheric conditions, they evolve into shallow, high cirrus clouds. They act as an insulator, retaining part of the Earth's heat, and at the same time, they reflect the rays of the Sun back into space. The overall net effect of contrails is positive, i.e., a warming effect. The picture shows how a C-141B Starlifter aircraft leaves four contrails behind it over Antarctica. Photo credit: http://en.wikipedia.org/wiki/Mobile_source_air_pollution

Photo 5.34 The main sources of noise at airline facilities are aircraft and auxiliary power houses, starting units, special aerodrome service vehicles, and machining and technological facilities. The levels of jet aircraft noise at distances of 5–100 m are 120–140 db. Noise impacts can affect large areas, and populations near airports are exposed to aircraft noise that exceeds exposure standards. The photo shows a plane Qantas Boeing 747-400 approaching runway 27L at London Heathrow Airport, England. Photo credit: Adrian Pingstone, July 2004

5.5 Water Transport

The world fleet comprises about 86,000 vessels (without fishing and military ships) (Rodionova 2013). Environmental impacts are associated with (1) ships; (2) transported cargo; and (3) activities aimed at servicing water transport (channel dredging; building of ports, locks, and channels, etc.) (Figs. 5.7 and 5.8).

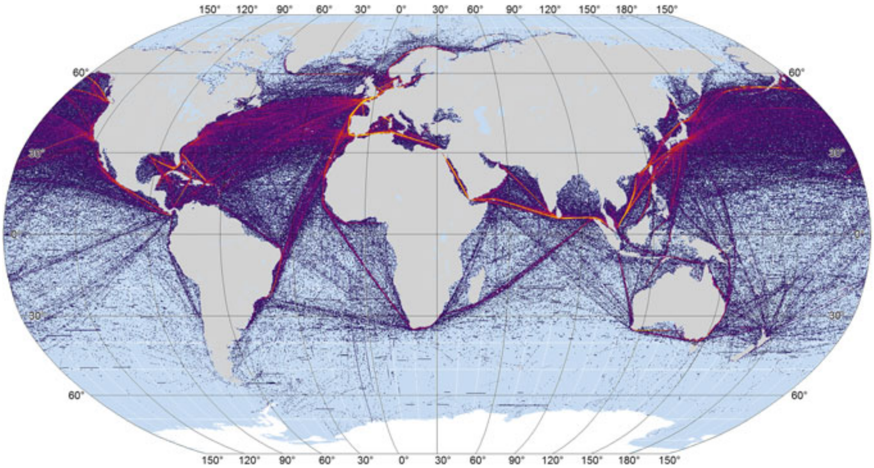

Fig. 5.7 Intensity of navigation in the world (http://www.nceas.ucsb.edu/GlobalMarine/impacts; http://en.wikipedia.org/wiki/Sea; Resources and environment 1998)

Fig. 5.8 Inland water routes in the world (http://www.evl.uic.edu/pape/data/WDB/; http://bioval.jrc.ec.europa.eu/products/gam/sources.htm)

Water transport has negative impacts mainly on **surface waters**, and **aquatic flora and fauna** are affected. **Atmospheric air** is exposed to impacts to a lesser extent.

Pollution in water transport results mainly from the following **operations**: (1) dumping of ballast water; (2) dumping of bilge, sanitary, and waste waters, and garbage; (3) transportation of freight and accidents; (4) transfer operations; and (5) running of ships' engines.

Oil transportation is the most dangerous regarding impacts on the environment. The dumping of tankers' ballast water is the most **powerful** source of impacts, providing more than 50 % of oil pollution.

Ballast water contributes greatly to the **dissemination** of aquatic organisms. Ten billion tons of water are transported in ships' ballast tanks every year, and they contain 7,000 species of hydrocoles (Dynamics of marine ecosystems 2007). It has been established that for the world ocean, successful invasion via ballast waters of 851 species has occurred (Zvyagintsev et al. 2009).

The **second** place goes to bunkering operations and bilge-water dumping, which provide 23 % of oil product pollution. The **third** place goes to ship accidents, which provide 14 % of oil pollution (Khristenko 1983). The **reasons** for accidents include grounding, collisions, navigation equipment malfunctions, damage at moorages, engine breakdowns, fires, and explosions. **Atmospheric** pollution is considerable during **fires** in tankers.

Effects of water pollution on marine organisms are described in a review by A. J. Mearns et al. (2013). **Sea birds** suffer greatly from oil spills. The oil pastes the feathers together, destroying their thermal insulation properties. The birds maintain body temperature by accelerating their metabolism, which leads to rapid depletion of depot fat and death from exhaustion (Petrichenko 2009).

When a bird tries to clean itself with its beak, it just moves the oil inside the feather layer. At the same time, oil enters the **digestive system**. Ducking birds mistake oil patches for food and are poisoned (Blinovskaya, Bocharnikov 2008). In the case of a "medium" oil spill, about 5,000 birds die; the wreck of the tanker *Exxon Valdez* near Alaska's shores killed about half a million birds (Belikov 2003).

The *negative impacts* of oil patches on **plankton** are caused by the following **factors** (Ehrhardt and Seguin 1984): (1) gas exchange between the ocean and the atmosphere is blocked; (2) sunlight is prevented from reaching the water mass; and (3) favorable conditions for bacterial development are created, as hydrocarbons are a growth medium for many species.

Hydrocarbon pollution also has negative impacts on **zooplankton**. Its destruction causes decreases in the numbers of fish and cetaceans (Ehrhardt and Seguin 1984). **Marine mammals** die because they lose thermal insulation in their pelage when they come into contact with oil.

Evaporation of oil products pollutes the air during transportation activities. According to S.I. Khristenko (1983), up to 0.75 % of transported oil products evaporate during transportation and associated activities (0.14 % at the loading stage, 0.48 % during transportation, and 0.13 % at the unloading stage).

Many goods that are transported by dry-cargo ships can emit noxious gases. For example, when mineral **fertilizers** are transported, ammonia and fluorine evaporate. Fertilizers consume **oxygen** in water, leading to the deaths of hydrocoles and contributing to so-called water "bloom" (reproduction of bacteria and plankton).

Transfer operations do not greatly pollute the environment. During loading and unloading of bulked cargo, **atmospheric** pollution occurs because of spills and emissions of dust, and then water becomes polluted.

The running of ships' **engines** contributes to **atmospheric** pollution. It is believed that about 2 % of the fuel is not consumed during engine operation.

As for water transport **infrastructure**, its impacts on environmental components vary. The building of **ports** in river outlets can cause the invasion of seawater, which affects the **freshwater flora** and **fauna**. **Channel** building can cause increases in **groundwater** levels, changes in **plant** species composition, salinization of **soils**, changes in the habitat conditions of various animals, and impacts on **microclimate**.

Channel dredging increases water turbidity and, consequently, decreases light penetration and photosynthetic activity. Redistribution of particles of alluvium leads to increases in the concentrations of toxic components and decreases in **oxygen content** in water. The transformation of bottom relief causes changes in water circulation, destruction of ecotopes of aquatic **fauna,** and reductions in species diversity. Moving dredged material to land leads to **land** withdrawal, and pollution of ground and surface **waters**.

The environmental impacts of water transport are illustrated by Photos 5.35–5.44.

Photo 5.35 Water transport has negative impacts mainly on surface waters. The accident of the tanker *Amoco Cadiz* 5 km (3.1 mi) from the coast of Brittany, France, is shown. The tanker went aground on 16 March 1978. It contained 1,604,500 barrels (219,797 t) of light crude oil. Severe weather resulted in the complete breakup of the ship before any oil could be pumped out of the wreck, so its entire cargo of crude oil and 4,000 tons of fuel oil were spilled into the sea. The total extent of oiling one month after the spill included approximately 200 miles (320 km) of coastline. Beaches of 76 different Breton communities were oiled. Photo credit: National Oceanic and Atmospheric Administration, March 1978

Photo 5.36 Atmospheric pollution is considerable during fires in tankers. The photo shows a fire on the Cypriot tanker *Haven* on 11 April 1991 near the coast of Genoa, Italy. It was unloading a cargo of 230,000 tons of crude oil. There was an awful explosion. As fire engulfed the ship, flames rose 100 m high, and after a series of further explosions occurred, between 30,000 and 40,000 tons of oil poured into the sea. On 14 April, the 250 m-long main body sank a mile and a half from the coast, between Arenzano and Varazze. For the next 12 years the Mediterranean coast of Italy and France was polluted, especially around Genoa and southern France. Photo credit: Paolo Vaccari (Greenpeace), 13 April 1991

Photo 5.37 The world fleet comprises about 86 thousand vessels. Every ship generates waste during its operation and when it is transporting cargo, including sludge, oily tank washings known as slops, rubbish from the crew, and cargo residues. Depending on its size, a ship can generate a few hundred tons of slops during a voyage. With 50,000 ships of more than 500 GT (gross tonnage) in the world fleet, and assuming an average of ten port calls per ship, half a million port calls take place annually. The photo shows water pollution due to water discharge in the Brasfels shipyard facilities in Jacuecanga, Rio de Janeiro, Brazil. Photo credit: http://en.wikipedia.org/wiki/Water_pollution, 15 July 2006

Photo 5.38 Ballast water makes a considerable contribution to the dissemination of aquatic organisms. Ten billion tons of water are transported in ships' ballast tanks every year, and they contain 7,000 species of hydrocoles. It has been established that for the world ocean, successful invasion via ballast waters of 851 species has occurred. The photo shows a ship pumping ballast water. The tanker is designed for carrying sulfuric acid and not oil. Photo credit: Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Photo 5.39 The laying of canals also leads to biological invasions. The Welland Canal is a ship canal connecting Lake Ontario and Lake Erie. The canal forms a key section of the St. Lawrence Seaway, enabling ships to bypass Niagara Falls. Approximately 40 million tons of cargo are carried through the Welland Canal annually by about 3,000 ocean and Great Lakes vessels. Construction of the canal resulted in penetration of a number of alien species into the Great Lakes system. Some of these, such as the sea lamprey and the zebra mussel, have had economic as well as ecological impacts. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 17 November 2011

Photo 5.40 The lamprey came into Lake Ontario in 1825, but it could not go farther because of Niagara Falls. However, after the Welland Canal was built, lamprey entered Lake Erie in 1921, Lake Michigan in 1936, Lake Huron in 1937, and, finally, the eastern part of Lake Superior in 1946. Lampreys cause damage to local ichthyofauna. Victims typically die from excessive blood loss or infection. Only about 10 % of fish survive after attacks by lampreys. A **sea lamprey on a lake trout is shown here.** Photo credit: U.S. Fish & Wildlife Service

Photo 5.41 The environmental pollution that occurs during cargo transfer operations is not great. During loading and unloading of bulked cargo, atmospheric pollution occurs because of spills and emissions of dust, and then water becomes polluted. The photo shows air pollution with aluminum powder being unloaded in the port of Bar, Montenegro. It is used as a pigment for paints, enamels, and rubber adhesives. Aluminum powder has low toxicity, not mixing with water. Photo credit: E.V. Kovalev, 13 May 2012

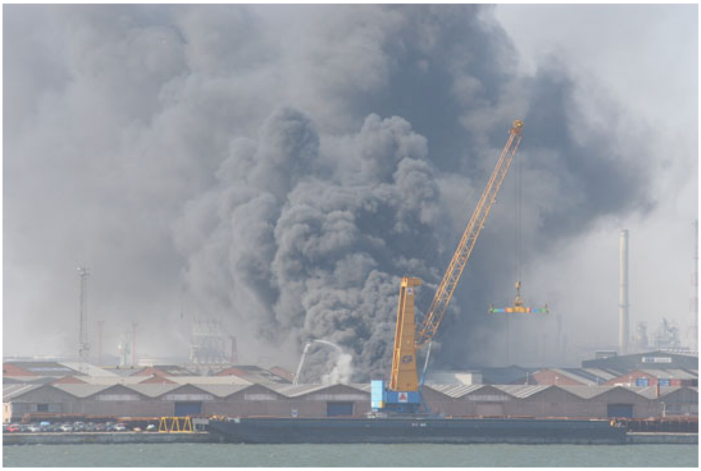

Photo 5.42 Environmental impacts related to the creation and functioning of water transport infrastructure vary. In the course of construction and functioning of ports, the atmosphere and surface waters are contaminated. Atmospheric contamination is especially high during fires. The photo shows a fire at the port of Antwerp, Belgium. This port is the second largest (by tonnage) in Europe (after Rotterdam). Photo credit: E.V. Kovalev, 2 April 2013

Photo 5.43 Channel dredging causes increases in water turbidity and, consequently, decreases in light penetration and photosynthetic activity. The transformation of bottom relief causes changes in water circulation, destruction of ecotopes of aquatic fauna, and reductions in species diversity. Moving dredged material to land leads to land withdrawal, and pollution of ground and surface waters. The photo shows dredging at the Government Cut shipping channel. It was created in 1905, cutting off Fisher Island from the south end of the Miami Beach peninsula. This channel is commonly used by cargo ships and ocean liners. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 14 April 2014

Photo 5.44 Environmental problems also arise during emergencies at ports. The Roberts Bank Superport is one of the busiest import/export ports in North America. It is a twin-terminal port facility located on the mainland coastline of the Strait of Georgia in British Columbia. It typically ships about 29 million tons of export coal a year. On 7 December 2012, the bulk carrier *Cape Apricot* crashed into a causeway at the coal terminal, destroying about 100 m of the structure, including a coal conveyor system. The accident resulted in an estimated 30 tons of coal entering the water from the severed conveyor and the disabling of the largest of the terminal's two coal-loading berths. Photo credit: J. Newcomb, 12 September 2011

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Chapter 6
Other Kinds of Activity

6.1 Fisheries

Despite the name, the targets of **fisheries** include not only fish, but also other sea animals, invertebrates, and algae. There are about 3.5 million fishing vessels (Mamin 2011). In 2012, 79.7 million tons were harvested in seas and 11.6 million tons, in inland waters (The state of world fisheries 2014). Several *species* form the **major part** of the catch: herring, cod, anchovies, tuna, flounder, mullet, squid, shrimp, salmon, crabs, lobsters, oysters, and scallops (http://en.wikipedia.org/wiki/Fishery). Areas of world fisheries are shown in Fig. 6.1.

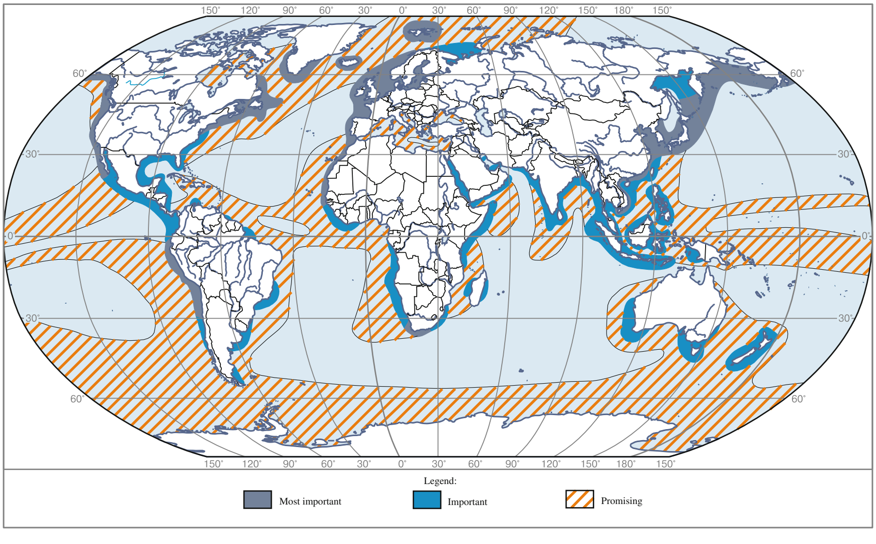

Fig. 6.1 Areas of world fisheries (Maksakovsky 2006, V. 1). Reproduced with permission of V.P. Maksakovsky

S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5_6

The **by-catch** has the strongest influence on the environment. It is the unintentional or incidental capture of non-target species during fishing operations. Unlike target species—animals specifically targeted for capture—by-catch is unwanted and often unused. By-catch that cannot be used must be thrown back. This returned by-catch is called discard.

There are different estimates of global by-catch (%): 8 (Kelleher 2005), 26 (Alverson et al. 1994), 33 (Norinov 2004), and 40.4 (Davies et al. 2009). Recently by-catch and discard have declined. The reasons of this decline have included: (1) greater utilization of by-catch species in Asia; (2) adoption of more selective fishing methods; (3) a decline in the intensity of fishing for some species having high by-catch rates; (4) a variety of management actions; and (5) more progressive attitudes by fishery managers, user groups, and society toward the need to solve discarding problems (Kelleher 2005). The level now is probably between 10 and 20 %.

Tropical shrimp trawl fisheries have the highest discard rate and alone account for over 27 % of total estimated discards (Kelleher 2005). The by-catch can **include** (1) fish; (2) mammals; (3) reptiles; (4) birds; and (5) different seabed biota.

In catching **fish,** the presence of other species in the haul is unavoidable. For instance, European tuna fisheries in the Atlantic alone report that 12 species of skate and ray, 11 species of pelagic shark, and 46 species of coastal shark are taken as by-catch (Fordham 2006). An estimated 97 million sharks were caught and discarded in 2010 (Worm et al. 2013).

Mammals are often found in the by-catch—an estimated 653,365 marine mammals per year, comprising 307,753 cetaceans and 345,611 pinnipeds (Read et al. 2006).

Reptiles in the by-catch are mostly represented by *turtles*. An estimated 90,000–450,000 turtles are caught and discarded every year (Wallace et al. 2010). Considering by-catch intensity by gear categories worldwide, gillnets had the highest by-catch intensity scores followed by long-lines and then trawls (Lewison et al. 2014).

The main reasons for marine **bird** fatalities (albatross, tufted puffin, etc.) are that they get tangled in fishing gear or get hooked when swallowing bait. For instance, during Japanese drift-net fishing of salmon in the northwest Pacific more than 94,000 birds (32,500 slender-billed shearwaters, 23,300 thick-billed guillemots, 15,300 tufted puffins, 12,700 crested auklets, and 5700 northern fulmars, etc.), are killed on average per year (Artukhin et al. 2010). In many cases, the deaths of the adults lead to the deaths of the eggs or chicks. After the death of the breeding partner, a new couple is usually formed after a long delay (Cuthbert et al. 2014).

Seabed biota (**echinoderms**, **polychaetes**, **mollusks**, **sponges**, **crustaceans**, etc.) are in the by-catch of trails, dredges, and traps, which are installed on the bottom or dragged along it. For example, during trawler fishing in the Barents Sea, the amount of sponges and cucumaria caught at one time sometimes reaches several tons. When cucumaria are caught by trails in winter, it is lethal for them. Sponges

often get seriously damaged and do not survive after they have been returned to the water (Dynamics of marine ecosystems 2007).

The second important consequence of fishery is **habitat deterioration**. Much fishing gear is dragged along the sea bottom, damaging algae fields in particular. Removal of seabed biota (sponges, hydroids, bryozoans, amphipod tubes, etc.) can also result in habitat deterioration (Seitz et al. 2014).

Indirect impacts include changes in the numbers of prey organisms available to predators; changes in the numbers of predators, which take out the prey; and influences on interspecies competition intensity. For instance, the diet of many sea-birds and mammals is restricted to a very limited number of fish species, and decreases in ichthyofauna stock (as a result of fishery) will immediately affect their reproduction and abundance.

Fishery therefore has significant environmental implications. Impacts are the **greatest** in equatorial reefs, on solid substrates in temperate waters, and in the depths. The influence on communities of sandy bottoms on shallow shelves is **insignificant** by comparison, because they have already adapted to constant movement and mudding (Jenings and Kaiser 1998).

The environmental impacts of fisheries are shown in Photos 6.1–6.16.

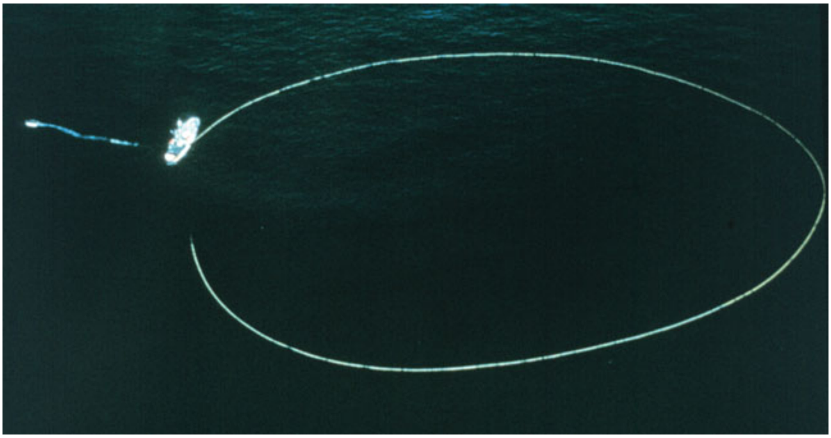

Photo 6.1 Fishing gear is divided into active (moving in water) and passive (stationary). It is categorized based on function as follows: (1) filtering gear (trail net; seine net—shore seine, ring seine, purse seine, dredge, etc.); (2) enmeshing gear (drift net, stationary net, stationary seine); and (3) hook gear (trolling, hook long-lines, etc.). A purse seine is shown here. The net is now closing in a nearly perfect circle, and the purse seiner is starting to pull the net back on board. The work boat is seen to the left and is secured to the ship. It is acting like a tugboat and is pulling the purse seiner away from the net so that it does not become entangled. Photo credit: National Oceanic and Atmospheric Administration

Photo 6.2 A purse seine gets its name because there are a number of rings are placed along the bottom. A line (referred to as a purse line) passes through all the rings, and when pulled, the line draws the rings close to one another, preventing the fish from "sounding," or swimming down to escape the net. A school of about 400 t of Chilean jack mackerel (*Trachurus murphyi*) encircled by a Chilean purse seine is shown here. Photo credit: C. Ortiz Rojas, 1997

Photo 6.3 Another method of catching fish uses pumps. Light, electricity, and chemicals are used to attract aquatic animals to the fishing gear. Individual fishermen also use gigs, chemicals, and explosives. The picture shows fish that have been killed as a result of blast fishing. Photo credit: http://en.wikipedia.org/wiki/Blast_fishing

Photo 6.4 On average, the by-catch comprises 10–20 % of the total catch around the world, but sometimes it exceeds the amount of the target species being harvested by several times. For example, there are 3000 t of by-catch for every 500 t of prawns off the coast of Australia. The photo shows the separation of shrimp from by-catch near the coast of North Carolina (United States). Photo credit: National Oceanic and Atmospheric Administration, June 1969

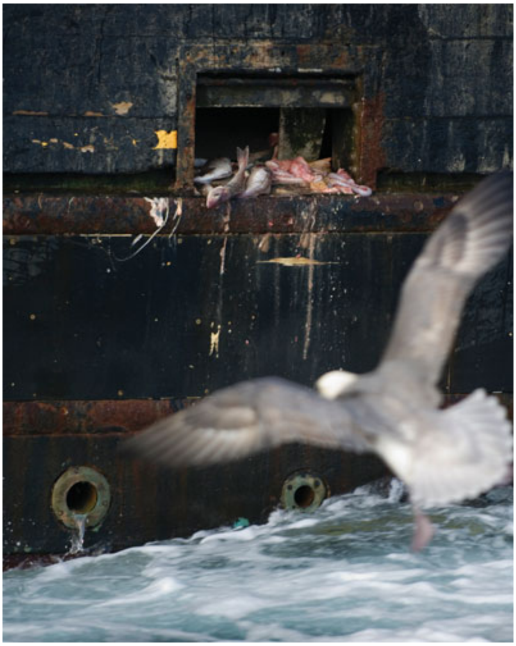

Photo 6.5 In catching fish, the presence of other species in the haul is unavoidable. By-catch comprises unwanted, undersized, and low-value species that are discarded, dead, at sea. The wasted catch is not included in fishing quotas. The picture shows by-catch being discarded through the hatch of the Scottish trawler *Carisanne II* in the North Sea. A gull flys in for a feed. Photo credit: Christian Aslund (Greenpeace), 13 May 2007

Photo 6.6 Sunfish are accidentally but frequently caught in drift gill net fisheries. The by-catch rate of sunfish in the Mediterranean swordfish industry, for instance, is between 71 and 90 % of the total catch. The photo shows a diver freeing a sunfish caught in a Japanese drift net in the Tasman Sea. Photo credit: Roger Grace (Greenpeace)

Photo 6.7 Incidental capture in fishing operations is the major threat to whales, dolphins, and porpoises worldwide. The presence of dolphins in the by-catch during fishing for salmon was a serious problem. It is believed that 6 million dolphins were killed this way. The photo shows two dead dolphins that were caught and drowned in large fishing nets in the English Channel near Plymouth. Photo credit: Kate Davison (Greenpeace), 7 February 2004

Photo 6.8 Fishing nets also catch other marine mammals. The global by-catch during 1990–1994 yielded 653,000 marine mammals per year, including 308,000 cetaceans and 345,000 pinnipeds. A young seal killed by being entangled in a net near the coast of Bering Island (Commander Islands, Russia) is shown here. Photo credit: V.A. Aramilev (Pacific Geographical Institute, Vladivostok, Russia), 2 September 2004

Photo 6.9 Reptiles in the by-catch are mostly represented by sea turtles. Their total global by-catch is estimated to be in the millions. The highest reported by-catch rates for long-line fisheries occurred off Mexico's Baja California peninsula, the highest rates for gill-net fishing took place in the North Adriatic region of the Mediterranean, and the highest rates for trawls occurred off the coast of Uruguay. A sea turtle entangled in a derelict gill net is shown here. Photo credit: National Oceanic and Atmospheric Administration

Photo 6.10 Marine bird fatalities in fisheries occur mainly when they get tangled in fishing gear. The by-catch of sea-birds in the Baltic Sea and the North Sea is estimated at between 100,000 and 200,000 each year. The haul of dead sea-birds shown in the photo is from one fishing trip by a single vessel that was targeting tuna and swordfish off the coast of South Africa. These birds are mostly white-chinned petrels, plus a variety of small albatrosses (Thalassarche) and a few giant petrels (Macronectes). Photo credit: Peter Ryan (Percy Fitz Patrick Institute of African Ornithology), 1998

Photo 6.11 Large numbers of birds are lost in the course of drift-net fishing of salmon in the northwest Pacific. On average for a year, more than 94,000 birds, including 32,500 slender billed shearwaters, 23,300 thick-billed guillemots, 15,300 tufted puffins, 12,700 crested auklets, and 5700 northern fulmars, are killed in the drift nets of the Japanese fishing fleet. The photo shows a tufted puffin running afoul of a drift net. Photo credit: V. Kantor (Greenpeace Russia), 15 June 2000

Photo 6.12 Other marine bird fatalities occur when the animals get hooked when swallowing bait. The photo shows a black-browed albatross (*Thalassarche melanophris*) caught on a long-line near the coast of Santa Catarina, southern Brazil. Photo credit: Fabio Olmos, 30 May 1997

Photo 6.13 As a rule, swallowing bait leads to the death of birds. Twenty-six species of sea-bird, including 17 albatross species, are threatened with extinction because of long-lining, which kills more than 300,000 sea-birds each year. The photo shows a Tristan albatross (*Diomedea dabbenena*) that was killed by drowning. Photo credit: Guy Marcovaldi (Projeto Tamar Brazil Image Bank)

Photo 6.14 Sea-bed biota (echinoderms, polychaetes, mollusks, sponges, crustaceans, etc.) are present in the by-catch of trails, dredges, and traps, which are installed on the sea bottom or dragged along it. The photo shows sponges found in a trawl net after a fish trawl survey in Spirits Bay at the northern tip of New Zealand. Photo credit: New Zealand Ministry of Fisheries, 1989

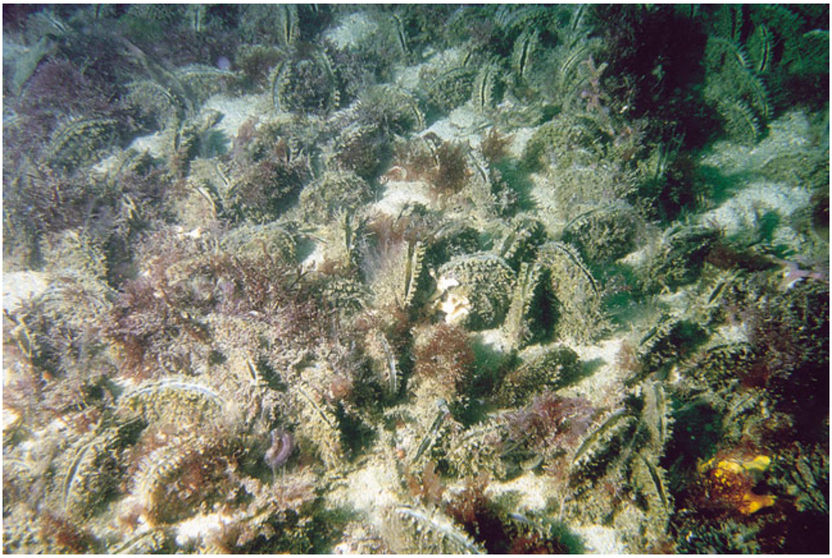

Photo 6.15 Habitat deterioration is another important consequence of fishery. Much fishing gear is dragged along the sea bottom, damaging algae fields, removing sea-bed biota (sponges, hydroids, bryozoans, amphipod tubes), and causing other impacts. The photo shows the bottom near Otama Beach on the Coromandel Peninsula, New Zealand, before dredging. Photo credit: S. Thrush (National Institute of Water and Atmospheric Research, Hamilton, New Zealand), 1997

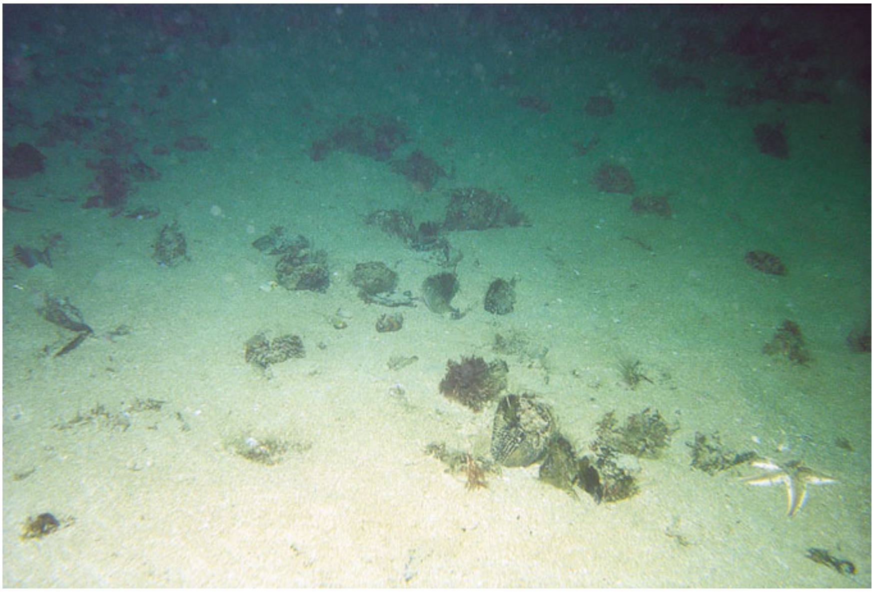

Photo 6.16 This photo illustrates the area of the sea bottom shown in Photo 15 (depth is 16–18 m), but after dredging operations. Photo credit: S. Thrush (National Institute of Water and Atmospheric Research, Hamilton, New Zealand), 1997

6.2 Aquaculture

Aquaculture is the breeding and raising of hydrobionts in conditions controlled by humans. The main **groups** grown in culture are fish, mollusks, crustaceans, echinoderms, and algae. In 2012 a total of 66.6 million tons were grown in aquaculture: 41.9 million tons inland and 24.7 million tons in mariculture (The state of world fisheries 2014).

Aquaculture has the following **environmental impacts**: (1) resources consumption; (2) emission of chemicals from construction materials; and (3) influences on ecosystems.

Resources consumption means that fish flour and fish oil (made of 'free-living' fish) are used to feed hydrobionts; as a result, the amounts of wild fish that are consumed exceed the amounts of fish that are produced.

Chemicals introduced into the water by construction materials include heavy metals, plastic additives (stabilizers, pigments, antioxidants, flame retardants, fungicides, etc.), and antifoulants (e.g., tributyltin, antiseptics). Many of these chemicals are toxic to fish, though their low solubility and low rates of leaching and dilution ensure some protection.

Aquatic culture has **impacts** on the following natural **components**: (1) surface waters; (2) flora; (3) fauna; (4) soils; and (5) the atmosphere. In addition to that, social impacts also take place.

The influences on the **aquatic environment** are more typical, and they occur in the farming of all types of hydrobionts. These effects consist mainly of **water pollution** with different substances. For instance, artificial granulated nutrition is used for feeding many fish species. Food spreads all over the water surface and is eaten by fish during its sedimentation (people can observe this effect in aquariums). Even in a well-balanced feeding process, 30 % of the nutrition is not consumed. It reaches the bottom, where it is utilized by benthos or is degraded by microorganisms (Boyd and Clay 1998).

Dumping from aquaculture facilities leads to **eutrophication** of surface waters. The main materials launching the process are nitrogen and phosphorus. Their global annual release in 2010 was estimated at 1.2 million tons of N and 0.1 million tons of P in freshwater environments and 0.3 million tons of N and 0.05 million tons of P in marine aquatic environments (Bouwman et al. 2013).

Other pollutants resulting from aquaculture include antibiotics, hormones, growth stimulators, and pesticides (Langford et al. 2014). **Antibiotics** are added to the food to prevent diseases. It is believed that 20–30 % of the antibiotics are consumed by the fish; the rest, 70–80 %, pollutes the water.

Hormones and **growth stimulators** are used to change the gender, productive capacity, and growth of the cultivated organisms. Their environmental impacts have

not yet been studied sufficiently to draw any conclusions as to their effects. **Pesticides** are used for pest control.

The impacts on **fauna** have many forms. *First*, a lot of wild fish are used to feed fish in culture. *Second*, the grown fish often escape. Different scenarios are possible if fish escape. Escapees can win the competition with the local species at first, but then their numbers may drop or the offspring resulting from interbreeding may be poorly adapted to the ecosystem (Bailly and Paquotte 1996).

Cases of infections or parasitic **invasions** of wild fish are frequent (Bergqvist and Gunnarsson 2013). *Salmon lice* is a typical example. Overcrowding of fish creates ideal conditions for the breeding of lice. If there are salmon farms on the routes fingerlings take through estuaries or bays, the parasites enter the nearby waters and infect the juveniles. At the Pacific coast of Canada, the infection rate of juveniles in natural conditions does not exceed 5 %. Next to fish farms, it increases dramatically, which leads to **five times the mortality rate** (Naymark 2007).

The transportation of prawns is known to disseminate **pathogens** (Liang et al. 2011). Viral diseases originating at prawn farms have been noted in some countries (Bonami and Widada 2011).

The destruction of mangrove forests for building aquaculture facilities (mostly prawn farms) affects **vegetation**. An estimated 10 % of mangrove forests worldwide have been lost because of this (Boyd and Clay 1998). For instance, shrimp farming converted 17 % of the Peruvian mangrove (Mialhe et al. 2013).

Aquaculture has impacts on the **atmosphere**. For instance, nitrous oxide (N_2O) is an important greenhouse gas that has a global warming potential 310 times that of carbon dioxide (CO_2) over a hundred-year life span. The global N_2O–N emission from aquaculture in 2009 was estimated at 9.30×10^{10} g. Their annual growth rate is about 7.10 % (Hu et al. 2012).

The **social impacts** of aquaculture include the limitation of free access to the seashore and decreases in its recreational value (swimming, sailing, windsurfing, and other activities); the esthetic characteristics of the shoreline are also changed (Pomeroy et al. 2014).

The influences of aquaculture on the environment are illustrated by Photos 6.17–6.24.

Photo 6.17 Mariculture is the breeding and raising of hydrobionts under conditions controlled by humans. Although, it is a quite ancient activity (aboriginal inhabitants reared eels as early as 8000 years ago in the area of the present-day state of Victoria in Australia), development of this industry generally took place in the twentieth century. In 2007, 443 species of hydrobionts were under cultivation; of those, the farming of 430 of them was initiated after 1900. A salmon farm near Puerto Chacabuco, Chile, is shown. Photo credit: Daniel Beltrá (Greenpeace), 3 February 2004

Photo 6.18 Aquaculture is divided into freshwater aquaculture and mariculture—farming of useful algae, mollusks, fishes, and other organisms in seas, lagoons, limans, and estuaries. The major portion (61 %) of the aquaculture production of fish, crustaceans, and mollusks occurs in inland waters. The most commonly encountered fish species in freshwater aquaculture are carp, tilapia, and sheat-fish. The catching of carp in an aquaculture pond (Bangladesh) is shown. Photo credit: M. Hasan (FAO Aquaculture Photo Library), 2011

Photo 6.19 The influences of aquaculture on the aquatic environment consist mainly of water pollution with different substances. For instance, artificial granulated nutrition is used for feeding many fish species. Food spreads all over the water surface and is eaten by fish during its sedimentation (people can observe this effect in aquariums). Even in a well-balanced feeding process, 30 % of the nutrition is not consumed. It reaches the bottom, where it is utilized by benthos or is degraded by microorganisms. The photo shows fish feeding on a farm for breeding tuna in Croatia. Photo credit: Bartolomeo Gorgoglione (University of Veterinary Medicine, Vienna, Austria)

Photo 6.20 Overcrowding of fish creates ideal conditions for the spread of infections or parasitic invasions. Salmon lice are a typical example. The infected fish become sick, and their resistance is low. The photo shows male and female of salmon lice (*Lepeophtheirus salmonis*). Photo credit: http://en.wikipedia.org/wiki/Sea_louse by 7Barrym0re (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html), CC BY-SA 4.0-3.0-2.5-2.0-1.0 (http://creativecommons.org/licenses/by-sa/4.0-3.0-2.5-2.0-1.0) or Public domain], via Wikimedia Commons

Photo 6.21 Pesticides are used in aquaculture for pest control. For example, at fish farms in Norway in 1989, 3488 kg of dichlorvos was used to prevent salmon louse infection. Such agents have clear negative impacts on the environment; thus their use must be strictly limited. Treatment of fish against parasites before transport in Százhalombatta, Hungary, is shown. Photo credit: FAO Aquaculture Photo Library, 1980

Photo 6.22 Other pollutants associated with aquaculture include antibiotics (added to forage for disease prevention), and hormones and growth additives (used for sex transformation, and for changing productive ability and growth of cultivated organisms). A dressing of salmon at a farm in Norway is shown. The red color of the flesh is attained by adding coloring agents to forage. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, 24 September 2010

Photo 6.23 Bulldozers clearing mangroves for the creation of shrimp ponds in the Bay of Guayaquil, Ecuador, are shown. Shrimp farms of all types, from extensive to super-intensive, can cause severe ecological problems wherever they are located. For extensive farms, huge areas of mangroves are cleared, reducing biodiversity. During the 1980s and 1990s, about 35 % of the world's mangrove forests had vanished. Shrimp farming was a major cause of this change, accounting for over a third of the loss. Photo credit: Clive Shirley (Greenpeace), 24 April 1999

Photo 6.24 The picture shows workers harvesting channel catfish (*Ictalurus punctatus*) at a Delta Pride Catfish farm in Mississippi, the United States. Catfish farming leads to pollution of the atmosphere with ammonia. For instance, in the United States, annual emissions of this gas from channel catfish breeding ponds (which have a total area of 66,000 ha) are estimated to be 1548 t. Photo credit: Ken Hammond

6.3 Hunting

Hunting is the practice of killing or trapping any living organism used for food, recreation, or trade. Contemporary tools for hunting wild animals can be divided into two **groups**: (1) tools for **active hunting** (the presence of the hunter and his actions are necessary at the moment of the bird or animal kill) and (2) **self-activating tools** for hunting (the catch usually happens without the presence of the hunter).

The **first** group includes (1) gun hunting; (2) use of hunting animals (predacious birds, greyhounds, ferrets, domesticated cheetahs); and (3) nets. The **second** group includes (1) steel traps (squeezing and jamming); (2) falling traps (jaws, billets, sable traps); (3) snares and nooses; (4) live trapping; and (5) nets (Gusev 2001; Alves et al. 2009).

This activity is most important in five countries of the Congo River basin. The meat of wild animals is a main source of animal protein, and hunting provides income for families living in forests. This situation is most typical for Gabon and Cameroon (Fa et al. 2003).

Hunting is less important in other regions of tropical rain forests. For instance, during one year, the count of killed animals brought to 24 (Amazon) and 14 (Congo) villages showed that the rate of withdrawal of wild mammals with masses more than 10 kg was 177.7 kg/km^2 a year for the Congo basin, whereas for the Amazon basin this number was just 3.69 kg/km^2 (Fa et al. 2002).

Hunting influences mainly **vegetation** and the **animal world** (Fig. 6.2). The impacts became noticeable after man had mastered *fire* in the end of the Palaeolithic

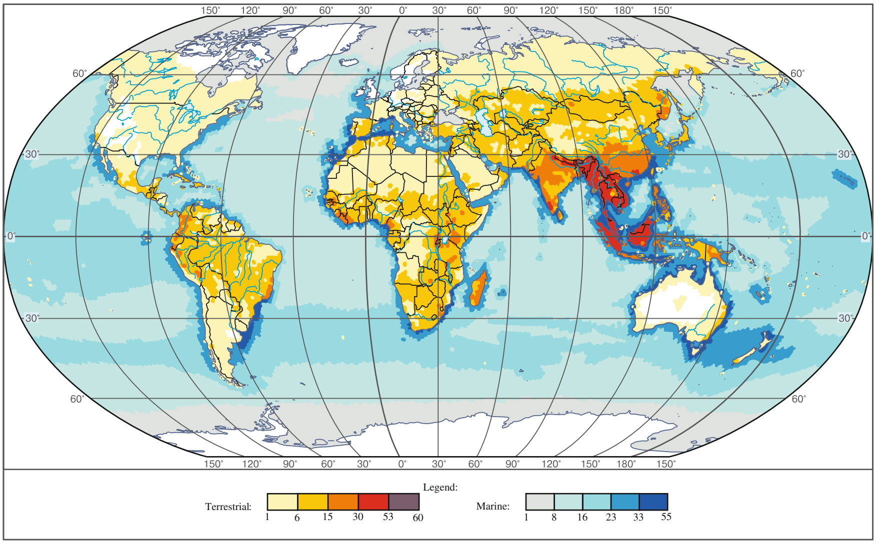

Fig. 6.2 Number of species threatened by hunting, fishing, or trapping. Reproduced with permission of IUCN Red List Unit

Age. At the same time that "fire technology" appeared, forests and other vegetation were burnt down during hunting. In some regions, such practices persist (Bird et al. 2005).

Systematic burning of forests used as a "*universal hunting too'*" led to considerable environmental disturbance, degrading ecosystems, and decreasing the quantity and quality of biological resources (Ramade 1981). It is presumed that habitat degradation contributed to the extinction of some animal species. Plant successions led from forests to savannas, steppe, and shrubs, and the climate was changing.

Sometimes, excessively intense hunting caused population densities to drop to critical levels, when regular (during mating season) meetings of animals of different genders were becoming improbable, thus leading to **species extinction**. Hunting caused the extinction of 21 bird species, 14 mammal species, and 7 reptile species (Ivanov et al. 2014). Illegal ivory trade has tripled since 1998 (UNEP 2014).

Though habitat conversion is largely to blame in this process, since 1600 AD many cases of extinction have been recorded as a result of overhunting (Rowcliffe et al. 2003; Bocharnikov 2014). The scale of hunting can be characterized by the figure 5 million tons, the *amount of meat* obtained by villagers in African and Latin American tropical forests (Fa et al. 2002). Ungulates and rodents make up the highest proportion of biomass extracted (Fa and Brown 2009).

The story of the **American passenger pigeon**, *Ectopistes migratorius*, is well known. It's population was estimated at 3–5 billion individuals in the early and middle 1800s (Hung et al. 2014). Nevertheless, intense hunting for their delicious meat (in the state of Michigan [United States] alone in 1879, 1 billion pigeons were caught) resulted in their extinction. The last passenger pigeon died at the Cincinnati Zoo on September 1, 1914 (Greenberg 2014).

The environmental impacts of animal withdrawal are ambiguous. Limited hunting has **positive influences** on animal populations, because it prevents land degradation and resources, depletion by creating optimal population densities. It also prevents animal migrations, and stops or limits pandemics that appear due to overcrowding (Conover 2001).

Hunting often influences the **sex-age structure** of animal populations (Gosselin et al. 2015). Very often during hunting, preference is given to individuals with certain characteristics (e.g., males with big horns or females with tender meat). Selective killing very often results in negative environmental outcomes (Cullen et al. 2001).

Indirect effects of hunting on animals also take place. Lead poisoning in waterfowl due to ingestion of lead pellets is a long recognized worldwide problem (Ferreyra et al. 2014). Aquatic birds mistake them for gravel and seeds (Hutarova et al. 2013). In North America, 630,000 wild ducks die because of lead poisoning every year (Laptev 1981).

Impacts on **vegetation** take different forms. For example, selective killing can influence the populations of some plant pests (Wright 2003). The hunting of certain animal species can lead to long-term changes in tropical forest dynamics because of the loss of *seed dispersers*, large *granivores*, *frugivores*, and "*habitat landscapers*" such as large forest mammals (Abernethy et al. 2013).

The environmental impacts of hunting are shown in Photos 6.25–6.30.

Photo 6.25 Contemporary tools for hunting wild animals can be divided into two groups: (1) tools for active hunting (the presence of the hunter and his actions are necessary at the moment of the bird or animal kill) and (2) self-activating tools for hunting (the catch usually happens without the presence of the hunter). The first group includes (1) gun hunting; (2) use of hunting animals (predacious birds, greyhounds, ferrets, domesticated cheetahs); and (3) use of nets. A Kyrgyz hunter with his golden eagle, in front of a traditional felt (yurt) in Karakol, Kyrgyzstan, is shown. Photo credit: https://en.wikipedia.org/wiki/Falconry, July 2002

Photo 6.26 Self-activating tools for hunting include (1) steel traps (squeezing and jamming); (2) falling traps (jaws, billets, sable traps); (3) snares and nooses; (4) live trapping; and (5) nets. A sable (*Martes zibellina*) trapped in Khabarovsk Krai, Russia, is shown. On 22 July 2012, a ban on the use of standard steel-jaw leg-hold traps was introduced in the Russian Federation. Photo credit: V.M. Govorushko, 8 February 2012

Photo 6.27 A musk deer (*Moschus moschiferus*) entrapped in Primorsky Krai is shown. Generally, hunters wish to catch the males (but they are caught with wire snares much less frequently) in order to extract the musk gland. This musk gland is highly valued in traditional oriental medicine and in the European cosmetic and perfume industries. The wire snare is convenient and accessible for poachers but the most pitiless method of hunting. An animal restrained in one is subject to a lingering and painful death by hunger and injuries. Hunting with wire snares has been banned in a number of countries, including Russia. At present, there are about 125,000 musk deer in Russia. Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 12 February 2013

Photo 6.28 At the present time, the importance of hunting is not very great overall. However, in some regions of tropical rain forests the meat of wild animals is a main source of animal protein, and hunting provides the greatest share of income for families living in the forests. The photo shows a man carrying a dead cassowary bird on his back in the forest near Lake Murray, Papua New Guinea. Photo credit: Brent Stirton (Greenpeace), 1 January 2009

Photo 6.29 The Asiatic grass frog (*Rana chensinensis*) is a fodder for some animal species, and the frog itself eats a great many invertebrates. The number of this species within Primorsky Krai is about 25 million. This species of frog is in great demand in the countries of Southeast Asia: it is used in cooking and traditional oriental medicine. The harvesting of frogs is basically carried out by Chinese poachers who immobilize the frogs in the hibernating ponds using electric shocks or pour toxic agents into the water. The drying carcasses of frogs outside Vladivostok are shown. Photo credit: L.O. Kudryavtseva, 29 August 2013

Photo 6.30 Indirect effects of hunting on animals also take place. Aquatic birds swallow lead pellets, mistaking them for gravel and seeds. In the state of Oregon (United States), pellets were found in the stomachs of 40.2 % of wild ducks, 40.4 % of pintails, and 13.7 % of widgeons. In North America, 630,000 wild ducks die because of lead poisoning every year. The numbers of pellets per hectare can reach 100,000, in a 9 mm layer of bottom deposits. Hunting with decoy ducks in the United States is depicted. Photo credit: F. Eugene (U.S. Fish and Wildlife Service)

6.4 Introductions

Introduction is a conscious transfer of animal and plant species to other regions. Motives for this are diverse. Animals and plants can be transferred to increase species diversity; birds and mammals, for purposes of hunting; fish, for subsequent catching; animals and insects, for pest control; and agricultural, forest, and ornamental plants, for dissemination of the species (Fig. 6.3).

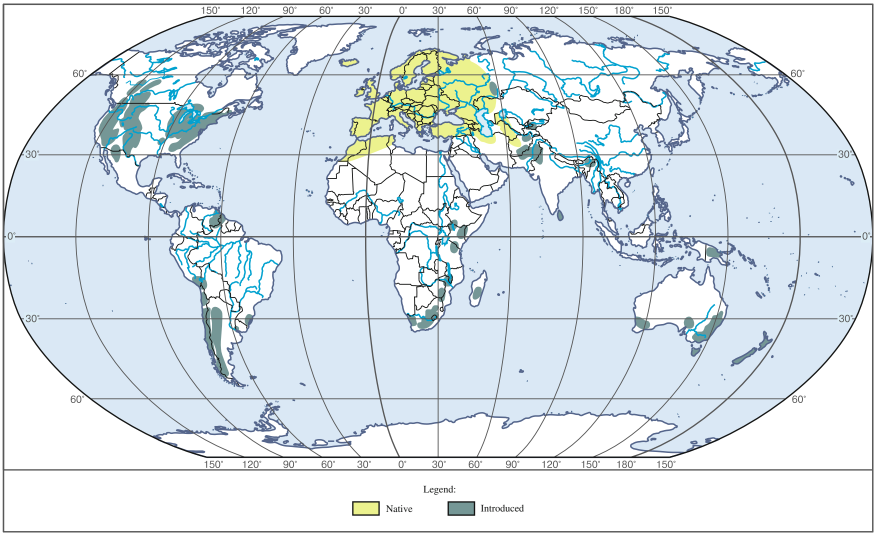

Fig. 6.3 Global distribution of brown trout (*Salmo trutta*). Adapted from Goudie (1997) and Elliott (1994)

Not infrequently, the objectives of the resettlement are not completely met. In the new environment, a species-colonizer does not often encounter enemies that existed in its native environment, and populations expand. In many cases, the transfer of species has resulted in catastrophic environmental consequences and serious economic damage.

Introduction of the common **water hyacinth** (*Eichhornia crassipes*) has had notable negative effects. It is often called the "green plague." South America is the home of this spectacular plant, which has flowers resembling orchids. It was shipped to New Orleans (United States) from Venezuela during an exhibition of cotton in 1884. Visitors bought seedlings and planted them in their ponds and rivers (Farb 1971).

The plants **quickly multiplied** under the new conditions and carpeted the surfaces of water bodies. Later, the water hyacinth was brought into many countries to decorate ponds. Currently, it is found in more than **50 countries** on five continents (www.issg.org/booklet.pdf).

Water hyacinths dramatically impact **water flow**, block sunlight from native aquatic plants, and change the physical and chemical composition of water (Pawari

and Haram 2011). **Oxygen** is less available due to the dense mat, often killing fish (or turtles). Water hyacinths have a significantly negative impact on aquatic invertebrate biodiversity (Coetzee et al. 2014). The plants also create prime habitat for mosquitoes (Pawari and Haram 2011), classic vectors of disease, and a species of snail known to host a parasitic flatworm that causes schistosomiasis (snail fever).

Introduction of **kudzu** (*Pueraria lobata*) in the United States is another example of negative effects. It appeared in Philadelphia in 1896, and American gardeners started to use it as an *ornamental* plant. It was actively planted to combat soil erosion during the Great Depression.

Gradually, it became clear that kudzu **harms other plants**. It overwhelms them with its dense foliage, wraps around stems and the trunks of trees, and breaks branches with its weight. Rooted kudzu grows rapidly, extending to 18 m in length at rates of about 30 cm/day during the vegetative period.

Kudzu impacts the **atmosphere** due to changes in nitrogen cycling and trace nitrogen gas emissions (Hickman and Lerdau 2013). Changes in leaf litter associated with kudzu infestation resulted in changes to decomposition processes and a 28 % reduction in stocks of **soil carbon**, with potential implications for **climate change** (Tamura and Tharayil 2014).

Lake Victoria was one of the **richest lakes** in the world, based on the diversity of fish species, before the introduction of the **Nile perch** (*Lates niloticus*). In particular, there were over 400 haplochromine cichlid species, accounting for 5 % of the world's known freshwater fish. Haplochromine species accounted for 83 % of the fish biomass in the lake (Cophen et al. 1995).

The Nile perch was **transported** there in 1954 from Lake Albert (Ogutu-Ohwayo 2004). At first, the environmental effects were minor. However, the Nile perch population surged dramatically in the 1980s (van de Wolfshaar et al. 2014). Predation by the Nile perch destroyed 200 endemic fish species.

The introduction of Nile perch had **additional ecological effects** onshore. Native cichlids were traditionally sun-dried fish, but Nile perch has a higher fat content than cichlids, so instead, it is needed to be smoked to avoid spoilage. This led to an increased demand for firewood in a region already hard-hit by deforestation, soil erosion, and desertification (http://en.wikipedia.org/wiki/Nile_perch).

The introduction of the **European starling** (*Sturnus vulgaris*) into the **United States** is another example. In 1890, several pairs of these birds were released in Central Park in New York City (http://iimk.ac.in/gsdl/cgi-bin/library). Now its range extends from the western to the eastern coast and from Alaska to southern Mexico.

Starlings compete with **native cavity-nesting birds** such as bluebirds, flickers and other woodpeckers, purple martins, and wood ducks for nest sites. One report showed that, where nest cavities were limited, starlings had severe impacts on local populations of native cavity-nesting species (http://icwdm.org/handbook/birds/EuropeanStarlings.asp).

Starlings may also be responsible for **transferring disease** from one livestock facility to another. Tests show that gastroenteritis virus (TGE) can pass through the digestive tract of a starling and be infectious in the starling feces (http://icwdm.org/handbook/birds/EuropeanStarlings.asp). Also, these birds can be reservoirs and vectors for the human pathogen *Escherichia coli* O157:H7 (Kauffman and LeJeune 2011).

The environmental impacts of introductions are illustrated in Photos 6.31–6.34.

Photo 6.31 The picture shows a ship blocked by water hyacinths in Winam Bay (Kisumu port, Kenya). In the countries adjacent to Lake Victoria, abundant masses of water hyacinths are called "green icebergs" since, driven by seasonal trade winds, they alternately migrate to the shores of Kenya, Tanzania, and Uganda. The port of Kisumu is blocked by water hyacinths from late December till early May every year. Photo credit: N.R. Robertson (Aquarius Systems Inc.) January 1999

Photo 6.32 The introduction of kudzu (*Pueraria lobata*) in the United States is a striking example of negative environmental consequences. It causes significant harm to other plants. It overwhelms them with its dense foliage, wraps around stems and the trunks of trees, and breaks branches with its weight. At the present time, kudzu occupies a territory of 20,000–30,000 km^2, and US$500 million is spent annually to fight it. A kudzu-covered field near Port Gibson, Mississippi, United States, is shown. Photo credit: Galen Parks Smith, 14 August 2006

Photo 6.33 The photo shows an unusually large Nile perch (*Lates niloticus*). Its introduction into Lake Victoria in 1954 had extremely adverse effects on local icthyofauna. Predation by Nile perch led to the destruction of 200 endemic fish species. At present it makes up 80 % of the lake fish mass. Photo credit: http://en.wikipedia.org/wiki/Nile_perch by smudger888 [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons, 26 January 2004

Photo 6.34 The European starling (*Sturnus vulgaris*) was introduced into the United States in 1890. Now it is one of the most numerous birds there. They create flocks reaching up to 1.5 million birds and cause problems with their droppings. These may accumulate up to 30 cm deep, killing trees due to their concentrated chemicals. The photo shows a flock of starlings. Photo credit: Tommy Hansen

6.5 Water Transfers

The term **water transfers** mean the process of water withdrawal from one source (river, reservoir, lake, etc.) and its transportation by riverbed, channel, tunnel, or pipeline to consumers. One can **subdivide** such water transportation into transfers for water supplies, providing navigation, hydropower engineering, irrigated farming, and drainage of overhumid lands.

The **volume** of transported water and the **distance** it is transported are the crucial parameters of river flow transportation systems. The most widespread *index to estimate the scale* of river flow modification is calculated as the product of the annual river flow transported (cubic kilometers per year) times the distance it is transported (kilometers).

The largest channel, judging by this index, is the South–North Water Transfer Project, which transports water from the Yangtze River in southern China to the northern Chinese plain. This channel will transfer 44.8 km^3/year over a distance of 1300 km (Qiu et al. 2013). By 2014, more than US$79 billion had been spent, making it one of the most expensive engineering projects in the world (http://en.wikipedia.org/wiki/South%E2%80%93North_Water_Transfer_Project).

Most river flow transfers, however, are carried out for **irrigation** needs and are classified as small or average (up to 1000 km^3/year). Irrigation is used for 37 % of all cultivated lands in China, 32 % in India, 23 % in Mexico, and 15–17 % in Philippines and Indonesia (Starikov 2013). The global distribution of areas under irrigation is shown in Fig. 6.4.

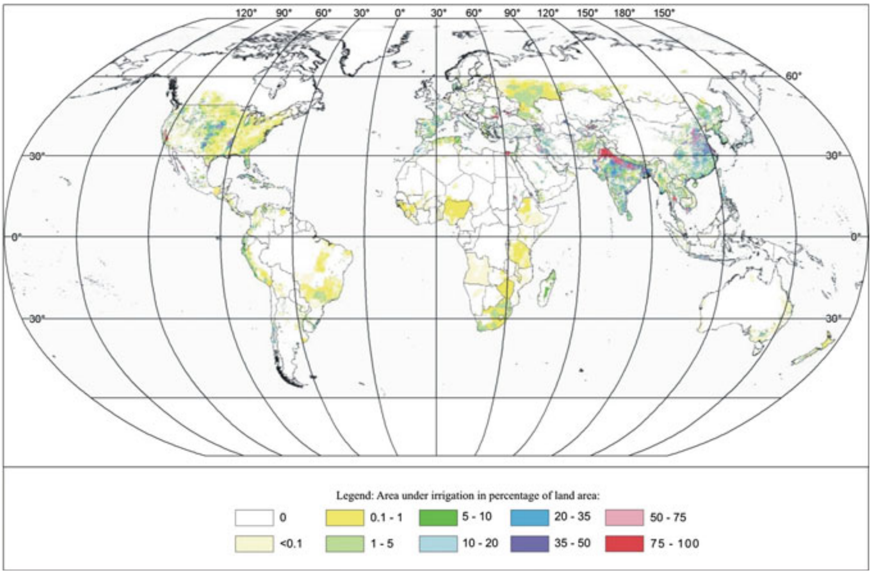

Fig. 6.4 Distribution of areas under irrigation in the world, 2000 (Water: a shared responsibility 2006). Reproduced with permission of Food and Agriculture Organization of the United Nations

Three zones are used to describe water transfers: (1) zone of water withdrawal; (2) zone of water transportation; and (3) zone of water usage. Environmental impacts in these zones are as follows.

The zone of **withdrawal** is characterized by decreases in river flow, drops in water levels, intensification of riverbed processes, diminution of waterlogged sites, greater penetration of salty seawater, and other effects. The zone of **transportation** is characterized by increases in river flow, rises in water levels, underflooding and waterlogging of nearby lands, intensification of erosion and evaporation, and other impacts (Shiklomanov and Markova 1987; Ye et al. 2014). The zone of **water usage** is characterized by intensification of erosion and evaporation, worsening of surface water quality, and other effects (Shiklomanov and Markova 1987; Gu et al. 2012).

River flow has been almost **completely eliminated** in the zone of withdrawal in some cases. One example is the *Colorado River*, which stopped flowing into the Gulf of California, since water was used to irrigate fields in the United States and Mexico (Rosenberg et al. 2000). The *Syr Darya River* and the *Amu Darya River* did not reach the Aral Sea in drier years (e.g., 1980 and 1985) (Sempere-Antuan 2000).

Reducing water loss in the zone of transportation is very important. Sizeable volumes of transported water are often lost because of **ground leakage**. For example, in the first years after the Karakum Channel was created, 3 km^3/year (out of 11) were lost in that manner; nowadays, those losses have been reduced to 1 km^3/year due to silting where the leakage occurred (Govorushko 2009) (Fig. 6.5).

All together, more than 2200 channels with a total length of 170,000 km have been built in the basin of the Aral Sea; but no measures to mitigate filtration have been taken in most cases (Stadnitsky and Rodionov 1996). **Water losses** in irrigation systems in Pakistan amount to 55–65 % (Shiklomanov and Markova 1987).

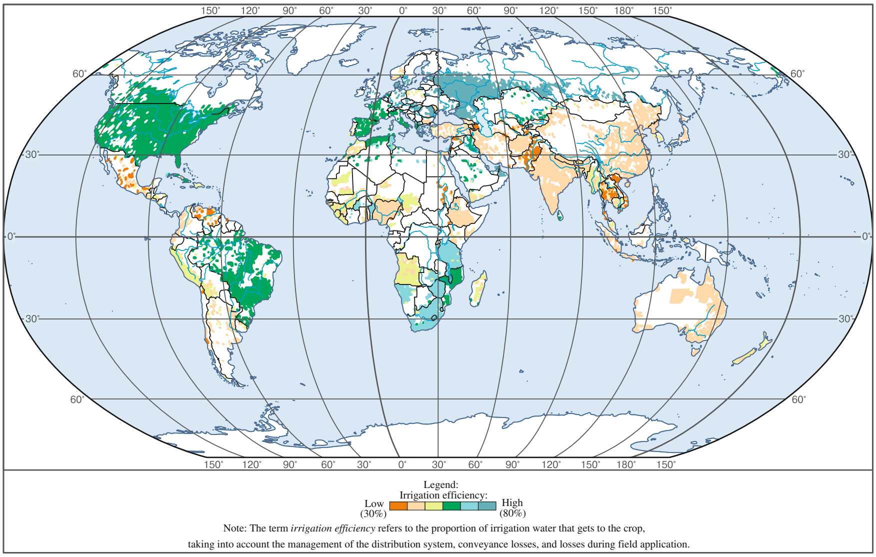

Fig. 6.5 Global irrigation efficiencies, 2000. Reproduced with permission of Dr. D. Gerten (Potsdam Institute of Climate Impact Research, Potsdam)

In the zone of water usage, river flow increases considerably. Thus, the annual river flow of the Burntwood River, which transports water to the Nelson River, increased from 3.3 to 27.3 km^3/year, or by 800 % (Shiklomanov and Markova 1987). Canada, the United States, India, China, and Turkmenistan show the *greatest river inflow transfers*.

Water transfer, apart from changing river flow, also influences **ichthyofauna** composition. Channels act as environmental pathways through which fish can migrate. For example, when the waters from Dnepr went through the North Crimea Channel (402 km long), Dnepr fish became usual for the Crimea—primarily low-value fish such as **perch**, **ruff**, **tench**, and **silver bream** (Kozlov 1979).

Another negative result of water transfer is that **weeds** are spread. Detailed research on weeds spreading through the water of irrigation channels in the Vakhshskaya Valley in Tajikistan have shown how serious the problem is. For example, on one farm during 14 h, irrigation water brought in 955,000 seeds/ha in July, 2 million seeds/ha in August, and 3.9 million seeds/ha in September (10 species were represented). The source of the seeds in irrigation water is the coppices of weeds at the banks of the channels (Nikitin 1983).

The environmental impacts of water transfers re illustrated in Photos 6.35–6.39.

Photo 6.35 Water transfer is the process of water withdrawal from one source (river, reservoir, lake, or other body of water) and its further transportation by river-bed, channel, tunnel, or pipeline to consumers. These transfers can be for water supplies, providing navigation, hydropower engineering, irrigated farming, and other uses. This aerial photo shows the Central Arizona Project. It allows passage of water from the Colorado River to central and southern Arizona. At 336 miles (541 km) long, it is the longest aqueduct ever constructed in the United States. Water is used for municipal, industrial, and agricultural needs. Photo credit: http://en.wikipedia.org/wiki/Aqueduct_(water_supply)

Photo 6.36 The largest volume of transferred water is used for irrigation. Among the most water-retaining cultures is rice, which is usually raised by means of prolonged flooding of its seeds. One of the channels of the Khanka rice irrigation system in Primorsky Krai (Russia) is shown. The water intake from Lake Khanka for flooding rice reaches about 340 million m^3/year. Much of the water in such channels is lost due to infiltration. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), June 2014

Photo 6.37 In order to reduce water losses from the channels, seepage-control linings are applied. These linings can be made of concrete, natural ground, petroleum bitumen, or plastic films. Siphon irrigation in southern Tunisia is shown. The bed was lined with plastic film. The water is fed to the plants growing in the fields under gravity through a hose system. Photo credit: Florita Botts (U.N. Food and Agriculture Organization)

Photo 6.38 In some cases, water transfers are for industrial needs. A water supply canal channeling water from the Yellow River as part of a stage I water supply project of the Ningdong coal-chemical base, Ningxia Hui Autonomous Region, is shown. Ten billion cubic meters of water are expected to be consumed by 16 new coal-fired power plants and mines in China in 2015, triggering severe water crises in the country's arid northwest. The water is needed to minimize the coal-dust explosion risk associated with coal mining, and it is involved in the production of electric power at coal-fired thermal electric power stations. Photo credit: Lu Guang (Greenpeace)

Photo 6.39 In Canada, the water transfer is used mainly for hydropower purposes. For example, 60 % of the Churchill River flow (water flow was 1270 m^3/s) was transferred to the Nelson River in 1977 for the purpose of electric power generation. The photo shows Churchill Falls as it appeared in 2008, four decades after the water was redirected. Photo credit: http://en.wikipedia.org/wiki/Churchill_Falls by infernocow

6.6 Housing and Communal Services

Housing and **communal services**, apart from the built-up area, include the complex of enterprises and organizations of public services. These include sanitary enterprises (public water supplies, sewage facilities, saunas, laundries), services that remove and dispose of household wastes, energy facilities, communal construction (roads, bridges, etc.), hotels, chemical clothes cleaning enterprises, funeral bureaus, and others (Fig. 6.6).

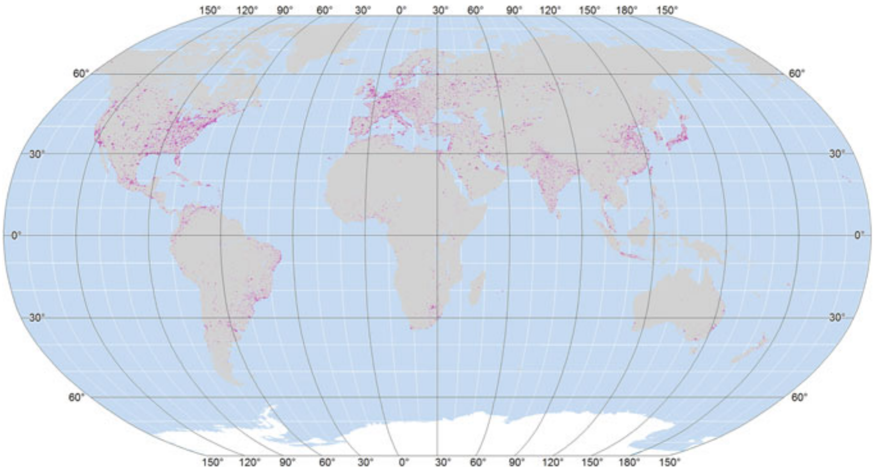

Fig. 6.6 Urban areas in the world (http://sedac.ciesin.columbia.edu/gpw/index.jsp4; http://en.wikipedia.org/wiki/Population_density; http://people.hofstra.edu/geotrans/gotmaps/)

Cities currently occupy 3 % of the land on Earth (Modern global changes 2006, V. 1). The *proportion* of built-up area is the greatest in small and densely populated countries of Western Europe. For instance, a third of Malta is covered with built-up and other artificial areas, followed by Belgium (13 %), and Luxembourg and the Netherlands (both 12 %) (Malta 2013). For the European Union, built-up areas occupy 7 % of the total land area (Prieler 2006).

The problem of **waste** is very complicated. About 1.3 billion tons of solid waste is produced globally every year (Hoornweg and Bhada-Tata 2012). Its volume is proportional to the economic development level of a country. In the developed world, for example, the amounts per capita are as follows (in kilograms in 2010): the United States, 720; Switzerland, 700; Luxembourg, 680; Denmark, 670; and Ireland, 660. In the developing countries the amount of waste produced is much less; for instance, in Indonesia it was 40 kg in 2010 (OECD factbook 2011).

Housing and communal services influence the following natural **components**: (1) atmosphere; (2) surface waters; (3) groundwater; (4) animal world; (5) geomorphologic environment; and (6) geological environment.

One-third of food production gets lost or wasted, totaling 1.3 billion tons. It adds 3.3 billion tons of greenhouse gases to the atmosphere each year (UNEP 2014). Significant **air pollution** also results from burning waste; when 1 ton of domestic waste is burnt, emissions contain 23 g of lead, 4 g of mercury, and 1.3 g of cadmium. Waste decay at landfills releases methane, an estimated 20–70 million tons a year globally (Modern global changes 2006, V. 1).

Every country has its own **sources** of emissions. In India, for example, *cremation fires* contribute considerably to atmospheric pollution, because 10 million dead people are burnt annually. For each cremation, funeral bureaus use 450 kg of wood. Annually, in India 50 million trees are felled for this purpose. As a result, 50,000 t of solid particles and 8000 t of carbon dioxide are emitted (Agarval 2008).

The most serious pollutants of **surface waters** are sewage and storm collection run-off. In the cities of the developing countries, human *feces* are the most dangerous pollutant (Fig. 6.7).

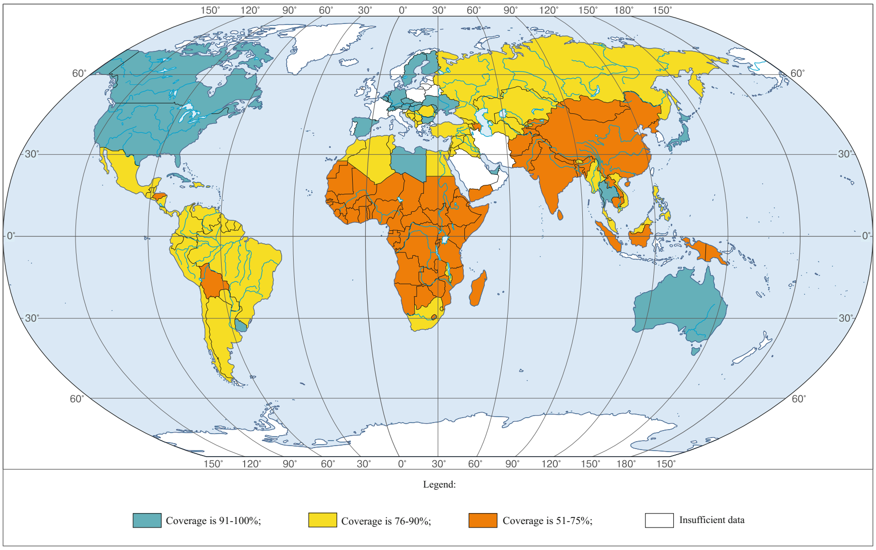

Fig. 6.7 Sanitation coverage in the world, 2004 (Global Water Supply and Sanitation Assessment 2000; Global Environment Outlook 2007)

In the least developed countries, only one-third of the houses have sewage systems, and water treatment plants are also absent (Environmental assessment sourcebook 1994). Only 209 out of 3119 Indian cities have facilities for partial effluent treatment of sewage waters, and only 8 have full processing plants (Avvannavar and Mani 2008).

The impact of *water supplies* is mostly in the withdrawal of great amounts of water. *Water loss* due to leakage, run-off from watering streets and lawns, air conditioning, and other reasons is also serious. In housing and communal services of Canada, water loss amounts to 13.3 % (Renzetti and Dupont 2013).

Groundwater is also affected. For example, chemical clothes cleaning enterprises often emit perchloroethylene, a chlorocarbon solvent (Mitashova 1998). Cemeteries pollute groundwater, especially in warm and humid regions; e.g., Republic of South Africa and Brazil. Ammonia, and nitrogen- and phosphorus-containing ions, as well as bacteria and viruses, are the greatest threats posed by cemeteries (Żychowski 2012, 2014).

Changes in phreatic levels are typical. In some regions, they drop due to declines in water penetration capacity of the ground (soil thickening; waterproof coverings such as asphalt and concrete). In other cases, phreatic levels increase because of sewage waters and leakage from water pipes (Kovalevsky 1994).

One factor that influences the **animal world** is skyscrapers that are lit at night. Migrating birds head toward the light and crash into the glass facades of the buildings. The daily death toll peaks early in the morning, when **birds** see trees and clouds reflected in **glass facades.** For instance, New York is a major stopover for migratory birds on the Atlantic flyway, and an estimated 90,000 birds are killed by flying into buildings each year (Foderaro 2011).

Impacts on the **geomorphologic environment** mainly include relief changes caused by construction, landfills, etc. Buildings and construction directly influence the **geological environment** through their sheer weight and warming of the soil (e.g., thickening, thermal sagging, thermokarst, and thixotropic dilution).

Build-up of an area changes the **climate** considerably; for example, the levels of solar radiation drop; humidity, wind speed, and precipitation regimes change; and temperatures increase.

The environmental impacts of housing and communal services are illustrated by Photos 6.40–6.50.

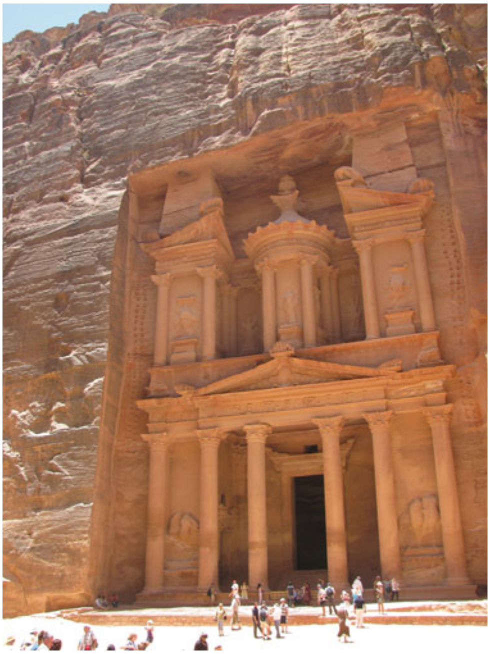

Photo 6.40 Since ancient times, humans have used underground space for living. At the earliest stage, they settled in the natural hollows, caves, and, later, they began to actively transform the geological environment. Petra is a historical and archeological city in southern Jordan that is famous for its rock-cut architecture. The Khazneh, or the Treasury, was originally built as a mausoleum and crypt at the beginning of the first century AD. It is hewn into a sandstone cliff and has a height of about 40 m. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), August 2010

Photo 6.41 Humans also impact the geomorphologic environment during the construction of dwellings. These impacts consist more often in the cutting of relief in connection with grading and leveling for the purposes of construction. In such cases, the impacts on the geomorphologic environment are different. The photo shows troglodyte (indigenous Berber inhabitant) dwellings in southern Tunisia. Their underground dwellings allow the people to escape from the heat. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 20 August 2008

Photo 6.42 The presence of buildings and structures in itself impacts the geologic and geomorphologic environment. The pressure of their mass and heating effects result in changes in the underlying soils (compaction, thermokarst, thixotropic liquefaction, and others). Such impacts are particularly strong in big cities with high-density multi-storied development. The photo shows a view of Paris from the Eiffel Tower. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 5 August 2014

Photo 6.43 Sky-scrapers are a cause of the deaths of birds. At night, they collide with the luminous faces of the buildings; by day, they attempt to rest in the reflections of trees. In particular, a large number of birds are killed in spring and in autumn during migrations. According to various data, from 100 million to 1 billion birds perish yearly in North America. The photo shows a sky-scraper with reflective glass in Tampa, Florida, United States. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 12 April 2014

Photo 6.44 In many developing countries, surface waters are polluted with detergents—synthetic surface-active agents—used for washing. Detergents are severe toxins that are difficult to remove, and they are almost nonbiodegradable. The photo shows laundry in a river in Abidjan, Ivory Coast. Photo credit: Ferdinand Reus (Arnhem, Holland), 27 August 2006

Photo 6.45 About 400–450 million tons of solid domestic waste is produced globally every year. The dumps of domestic garbage are sources of food for synanthropes, particularly rats. Cans, bottles, and other vessels with residues of organic matter can play the part of traps for wild animals and insects. The photo shows a garbage dump in Pskov, Russia. Photo credit: E. Marakanova (Ecoline EA Centre, Moscow, Russia), 17 September 2010

Photo 6.46 Incineration is used more often as a method of waste disposal. This method has the serious disadvantage of formation of highly toxic chemical compounds; for example, dioxins and furans. From the environmental viewpoint, low-temperature combustion is the most dangerous. The photo shows burning of waste in Sudan. Photo credit: U.N. Environment Program, from *UNEP Sudan Post-Conflict Environmental Assessment Report*

Photo 6.47 The most serious pollutants of surface waters are sewage and storm collection run-off. In the cities of the developing countries, human feces are the most dangerous pollutant. In the least developed countries, only one-third of the houses have sewage systems, and water treatment plants are also absent. Raw sewage flowing to the White Nile is shown. Though there is a sewage network in Khartoum, it does not cover the entire city and no longer works properly, as it is stretched well beyond capacity. Photo credit: U.N. Environment Program, from *UNEP Sudan Post-Conflict Environmental Assessment Report*, 22 June 2007

Photo 6.48 Environmental impacts of dry-cleaning include toxic waste and pollution of natural components. Chemical clothes cleaning enterprises often emit perchloroethylene, a chlorocarbon solvent. This compound is considered to be carcinogenic to humans, and it should be handled as a hazardous waste. Dry-cleaners that use perchloroethylene must take steps to ensure that it does not enter drinking water. Perchloroethylene can also contribute to smog when it enters the atmosphere and reacts with other volatile organic compounds. The compound is retained in dry-cleaned clothes, and levels increase with successive cleanings. A Serier 3 P300 dry-cleaning machine in Germany is shown. Photo credit: http://en.wikipedia.org/wiki/Dry_cleaning by Los3 (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons, 9 January 2007

Photo 6.49 The greatest hazard associated with housing and utilities infrastructure is the threat of ruptures of steam and high-pressure gas pipelines. Pipeline breakages can result in explosions due to gas leakage and burns with steam condensate. The photo shows a steam explosion in New York City, United States. The explosion sent a geyser of hot steam and other material up 40 storeys, and mud and flying debris rained down on the crowded streets. The incident was caused by the failure of a 24-in. (0.61 m) underground steam pipe installed in 1924. The towering cloud of billowing steam rose higher than the nearby 1047-ft (319 m)-tall Chrysler Building and persisted for at least 2 h, leaving a crater about 35 ft (10 m) wide and 15 ft (4 m) deep. Photo credit: https://en.wikipedia.org/wiki/2007_New_York_City_steam_explosion by Zazienyc; touched up and cropped by User: BlastOButter42 (Smoke/Steam) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons, 18 July 2007

Photo 6.50 Maintenance of the safe condition of residential buildings requires the use of considerable manual labor; various building materials are used during this work, including organic solvents and resin compounds that can be harmful to the health of the workers. Emphasizing low cost over worker safety leads to high injury rates among workers. The photo shows finishing operations on a building with the use of bamboo staging in Jaipur, India. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 2 November 2007

6.7 Power Transmission and Communication Lines

A **power transmission line** (PTL) is a system of wires (or cables) and auxiliary devices that are designed to transmit electric power from a power station to consumers. A **communication line** is an assembly of engineering devices for transmitting electric signals from the transmitter to the receiver (Fig. 6.8).

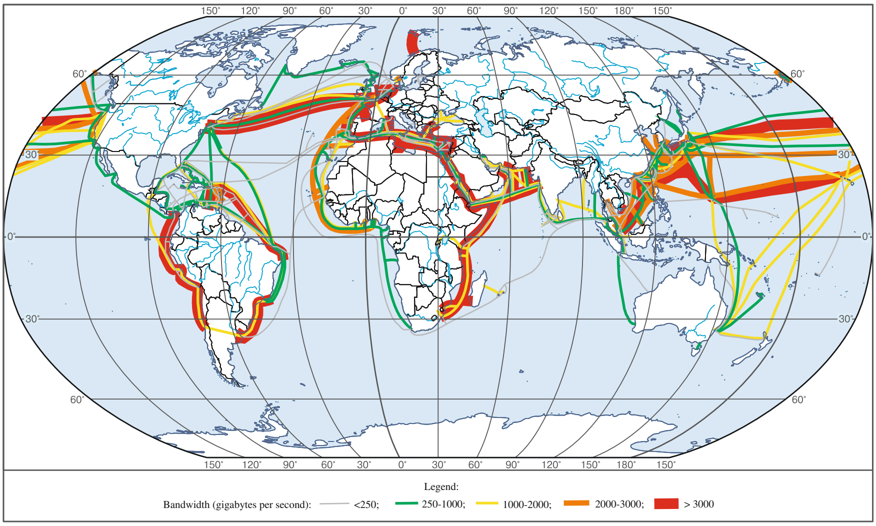

Fig. 6.8 Undersea Internet cables (http://www.cablemap.info; http://www.geezam.com/undersea-internet-cables/; http://ansonalex.com/technology/the-world-map-of-internet-connections/)

The effects of power transmission and communication lines on the environment are observed during construction and operation; these effects generally grow with increases in their lengths and voltages. Influences at the **construction stage** are related to activities such as slashing; laying of access roads; excavation works for setting of poles, towers, and transformer stations; and wiring work (Ecology guidelines 2012). All of these activities are accompanied by noise impacts.

During **operation**, impacts are caused by things such as the presence of the ride itself and the power transmission line (towers, wires, transformer stations, and outdoor switchgears), application of physical or mechanical methods of vegetation destruction within the right of way, and the action of electromagnetic fields.

Power transmission and communication lines affect the following environmental **components**: (1) land resources; (2) vegetation; (3) animal world; (4) atmospheric air; (5) soils; and (6) geomorphology.

The construction of power transmission and communication lines has the strongest effect on **land resources**. An area 2 m in radius around towers is permanently allotted for use by a PTL. This situation affects *agriculture* to the greatest extent. The disordered arrangement of power transmission and telephone lines breaks the integrity of fields and natural meadows. Problems arise in using farming equipment, and towers and poles prevent aerial activities.

Vegetation is affected by its large-scale destruction due to cuttings. Later on, during operation, cuttings are repeatedly carried out and herbicides are applied for maintenance of rides.

An increase in the ride width when small sections of forest are crossed by lines (first of all, under conditions of forest-tundra and forest-steppe), results not infrequently in disappearance of the whole forested area due to *water imbalance* and dying-off of woody vegetation on the edge of the ride as a result of *windfalls* (Popov 1986).

The effects on the **animal world** are ambiguous. For example, the *presence of a ride,* on the one hand, results in the "*forest border effect*," increases in the diversity of the living environment and fast growth of the number of bird and animal species (Ecology guidelines 2012). On the other hand, a ride can be an insurmountable obstacle for movement of animals.

Birds are also affected by the *construction of PTLs, their presence*, and transmission of *electric energy* by wire. For instance, construction of transmission lines likely impacted 2,588,494 nests, and transmission line maintenance can possibly affect 388,274 nests each year (Savard and Rioux 2013). The presence of PTLs leads to collisions; 8–57 million birds are killed each year at the United States power lines due to collisions (Loss et al. 2014).

Birds are killed by **electric shock** more rarely. For instance, in the United States between 0.9 and 11.6 million birds are killed by electrocution per year (Loss et al. 2014). Estimates of avian mortality due to electrocution for Canada ranged from 160,836 to 801,962 birds annually (Savard and Rioux 2013). Generally, when such deaths do occur, they happen with large birds due to wire closure by opened wings, and more often in rain or snowstorms.

In France, the hollow poles of telephone lines are mortal traps for animals living in holes. Such animals (e.g., owls, bats, squirrels, and small birds) penetrate through holes into the interior of the poles, and they cannot escape and therefore starve. In France, there are millions of such poles, and inspection showed that some of them were filled with the bodies of such animals to heights of 2 m (Noblet 2004).

The effects on **ichthyofauna** are mainly related to electric power transmission. For example, if electric and magnetic field strengths exceed permissible values in

functioning submarine cables, a zone where fish are frightened is created (so the cable becomes an obstacle for the migration of fish), or the fish are immobilized with paralysis of muscles and breathing (Kadomskaya et al. 2006).

Air pollution occurs when electric energy is transmitted by wire (gas flows in the course of corona discharges). Ozone formed in the operation of PTLs is believed to contribute to the destruction of forests (Ecology guidelines 2012).

Soil contamination occurs during the laying of underground lead-sheathed communication cables. In Denmark, for example, lead from cable sheaths was found to accumulate in soil and reach concentrations of 85 mg/kg (Jaspers et al. 2001). Power transmission and communication lines impact the **geomorphologic environment** through extraction of ground.

The environmental effects of power transmission and communication lines are illustrated by Photos 6.51–6.56.

Photo 6.51 An area with a radius of 2 m around power transmission towers is permanently allotted for use for PTLs. This situation affects agriculture to the greatest extent. The disordered arrangement of power transmission and telephone lines breaks the integrity of fields and natural meadows. Problems arise in using farming equipment, and towers and poles prevent aerial activities. The photo shows towers of PTLs at an agricultural field in Brandenburg, Germany. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 3 August 2014

Photo 6.52 The effects of electric power transmission on the animal world are ambiguous and are caused by different factors. For example, the presence of a ride, on the one hand, results in the "forest border effect," increases in the diversity of the living environment, and fast growth of a number of bird and animal species. On the other hand, a ride can be an insurmountable obstacle for movement of animals. To a considerable degree, the tendency of the impacts (positive or negative) depends on the ride width. A power transmission line in Primorsky Krai (Russia) is shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 27 August 2013

Photo 6.53 Effects of electric power transmission on birds are caused by the presence of power and communication transmission lines and transmission of electric energy by wire. The major reasons of deaths of birds are traumas caused by collisions with towers and wires and electric shock, which usually happens with large birds when their opened wings touch more than one wire. This photo shows insulated communication lines that resulted in the death of a young redstart (*Phoenicurus phoenicurus*), either because of impact with the wires or because the bird accidentally clutched at the wires with its beak, rather than as a result of electric shock. Photo credit: A.P. Levashkin (Russian Bird Conservation Union, Nizhniy Novgorod Branch, Russia), 4 August 2010

Photo 6.54 The greatest danger of power transmission lines to birds is lines with voltages of 6–10 kV on reinforced concrete poles with pin-type insulators. The hazard of these lines lies in the short distance between the pole or its traverse and wires or other live assemblies. When taking wing and approaching, the birds can simultaneously touch to the grounded traverse and a hot wire, causing a lethal short circuit. These lines are particularly dangerous, where birds are present at high densities, where woody vegetation is absent, and at the intersections of bird migration paths. A dead common buzzard (*Buteo buteo*) in Samarskaya Oblast (Russia) is shown. When taking wing from the pole, the bird short-circuited and hung there (for the most part, birds fall). Photo credit: A.P. Levashkin (Russian Bird Conservation Union, Nizhniy Novgorod Branch, Russia), 4 September 2011

Photo 6.55 Birds commonly construct nests on overhead transmission lines, where the risk of their death as a result of electric shock increases many times. Ornithologists propose to equip electric transmission lines with accessories to protect birds; for example, plastic housings mounted on bare wires where they attach to insulators, which prevents short circuits caused by birds. The photo shows cranes nesting on the metal poles of a 110 kV power transmission line in the Khanka District (Primorsky Krai, Russia). Photo credit: V.V. Paletsky, 3 September 2014

Photo 6.56 Ichthyofauna are also affected by electric power transmission. If a power transmission line crosses a river, it creates an electromagnetic dam that can be obstacle for the migration of fish. The photo shows a PTL crossing the Angara River in Russia. Photo credit: P. Kurnakov (Ecoline EA Centre, Moscow, Russia), 17 July 2006

6.8 Recreational Activity

Recreational activity is usually defined as an activity aimed at rest and recovery of physical and mental resources. Tourism accounts for 3.2 % of the world GDP (Ivanov et al. 2014) (Figs. 6.9 and 6.10).

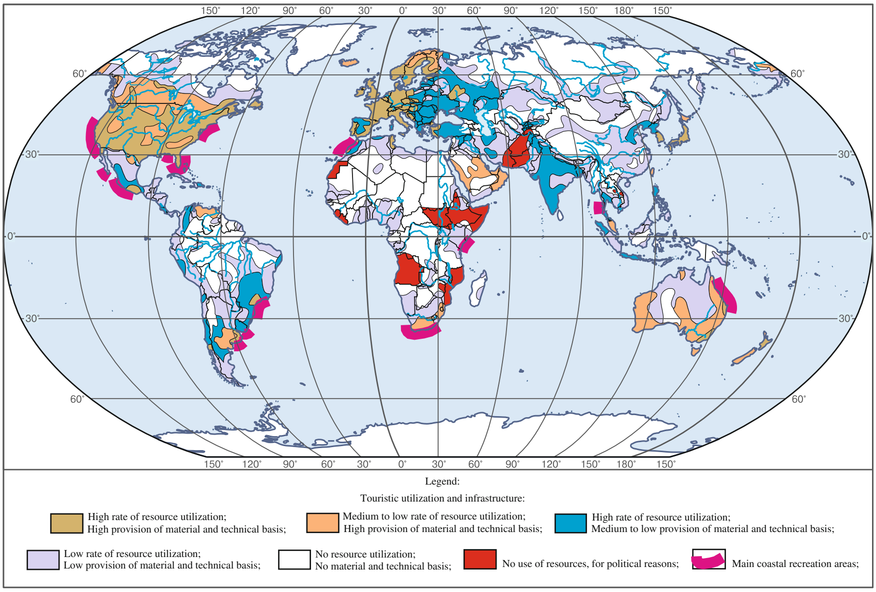

Fig. 6.9 Global recreation and tourism (Resources and environment 1998). Reproduced with permission of the Institute of Geography of the Russian Academy of Sciences

Recreational activities include (1) medical, based at stationary facilities having medicinal purposes (sanatoria, health resorts, etc.); (2) health-improving, engaged in at stationary facilities designed for recreation (preventative clinics, rest homes, campsites, etc.); (3) sports, combined sports activities, hunting, and fishing; (4) tourism; and (5) educational tourism to valuable natural, cultural, and historical objects (Geography of tourism 2009; Mirzekhanova 2011).

To engage in these activities, people need **recreational resources**, categorized as **follows** (Rydsky and Sturman 2014): (1) natural (e.g., hydrological, climatic, forest, landscape, geological, hydrogeological, specially protected natural complexes); (2) balneological (mineral waters, therapeutic muds, etc.); and (3) architectural-historic (e.g., monuments of culture, history, archeology).

Recreational activities affect the following natural **components**: (1) geological environment; (2) soils; (3) vegetation; (4) animal world; and (5) surface and ground waters. They also influence the social environment of a region.

Searching for and collecting minerals, crystal formations, and fossils impact the **geological environment**. One of the most dramatic examples of such activity is the

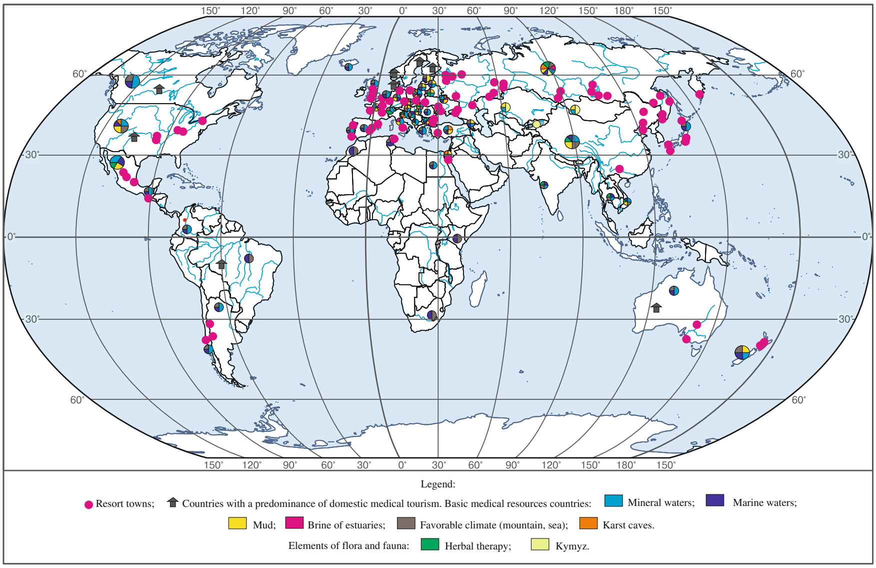

Fig. 6.10 Medical and health tourism in the world (Mirzekhanova 2011)

Petrified Forest National Park in Arizona (United States), where souvenir hunters completely destroyed the cover of some fossil trees. The destruction of *stalactites* and *stalagmites* by speleologists is also typical.

Impacts on the **soil** include its thickening due to pedestrian, horse, or vehicle traffic (e.g., at campsites). *Horse transport* has especially devastating effects on soils (Monz et al. 2013). Thickening of soils results in drainage distortions (provoking erosion) and insufficient aeration of plant roots and soil organisms.

Pedestrian movement also destroys grass, bushes, and undergrowth. The **consequences** of the pressure on **vegetation** include (1) damage to plants; (2) stunting of growth; (3) thinning of leaf cover; and (4) vanishing of species with low productivity (Wolf and Croft 2014). Some species disappear when collected for *herbariums* and *bouquets*.

Recreational activity has especially strong impacts on *forests*. There are **five stages** of recreational effects on **forests**: (1) forest litter is not disturbed, species composition is typical for the studied forest type, and the damage of undergrowth and shrubs is not more than 5 %; (2) tracks have appeared, but they do not occupy more than 8 % of the area; (3) routes cover 17 % of the area, forest stand thinning is up to 10 %, and meadow grass is appearing; (4) 40 % of the forest has been trampled, only 50 % of the tree stand has been saved, and turf cover has formed; and (5) 70 % of the forest area has been trampled and some sick trees are still growing. At stages 4 and 5, the forest is no longer capable of self-restoration (Kuskov et al. 2005).

The influences of recreation on **wild animals** are different (e.g., anxiety factor, elimination of some animals due to hunting and fishing, habitat deterioration). The very presence of people can have very negative impacts on animals, especially at times of feeding, migration, breeding, and nesting. For example, in the Alps, chamois (Schnidrig-Petrig 1998), and partridges (Ingold et al. 1993) experience stress due to paragliding.

When they encounter people, animals *run* away, spending 10 times more energy in comparison to the rest stage. As a result of this excessive tension, animals are often killed by predacious animals and birds (Balandin and Bondarev 1988). Scaring nestlings only two or three times is enough to cause them to **die** (Manush 1990).

Motor vehicles and sailing boats affect *aquatic birds* through noise and petrol spills (Gladstone et al. 2013). Mooring on reefs and anchoring disturbs *seabed fauna* (Hilmi et al. 2012). Tourism often promotes souvenir sales (corals, shells, turtle carapace, etc.). Though many animals suffer from direct impacts of recreational activity, indirect **habitat deterioration** is much more important.

Recreational activity negatively impacts **water** quality. Sewage pollution takes place next to coastal hotels. Many hotels use chemicals (chlorine or hydrate of sodium) to control sewage odours or to make oils and fats soluble.

Recreational activity may have serious **social impacts**. For instance, some activities (e.g., excursions to archaeological sites) can be seen as *blasphemous* by local residents (Buckley 2000).

Visual pollution of landscapes by tourism infrastructure also is created. It is especially noticeable for natural objects, which are appreciated for their *esthetics* (waterfalls, gorges, etc.).

Uncontrolled tourism can damage those natural elements that are the **target** objects of the recreation. It is very important to preserve balance between scale and types of recreational activity, on one hand, and sensitivity and stability of the natural objects, on the other.

The environmental impacts of recreational activity are illustrated by Photos 6.57–6.62.

Photo 6.57 A distinctive feature of places of public amusement is often the gathering of a large number of people in a small area. The photo shows holiday-makers in Dorset, United Kingdom. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, 19 September 2010

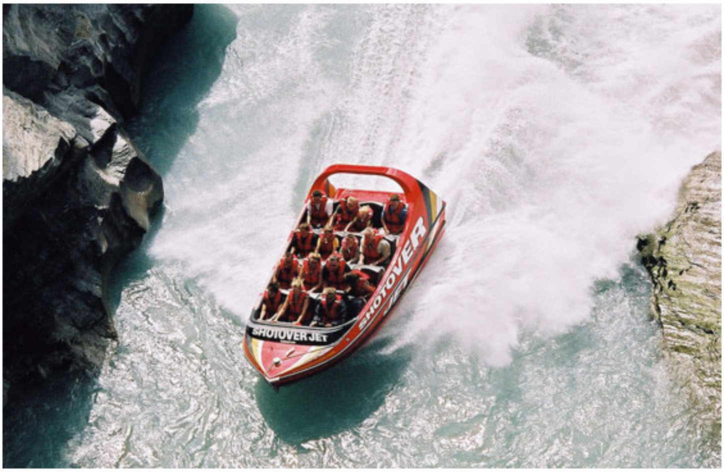

Photo 6.58 The environmental impacts of motor-boats result from the following factors: (1) propeller action (turbulence, disturbance of sediments, increase in nutrients, increase in phytoplankton, cutting of macrophytes); (2) wash (washing out of roots of macrophytes and riparian vegetation); and (3) direct contact (bank erosion, decrease in submerged macrophytes, decrease in emergent and floating macrophytes, dispersal of macrophytes/phytoplankton between different water bodies). The photo shows a power-boat New Zealand. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, 26 April 2014

Photo 6.59 In many developing countries, the withdrawal of hydrobionts for sale to collectors has reached large proportions. The photo shows portable stalls with shells in a gift shop in Dar es Salaam, Tanzania. The shop sells seashells that have been taken from the sea alive, killing the animal inside. Photo credit: Richard Ling, 22 March 2000

Photo 6.60 The influences of recreation on wild animals are different (e.g., cause anxiety, elimination of some animals due to hunting and fishing, habitat deterioration). The very presence of people can have very negative impacts on animals, especially at times of feeding, migration, breeding, and nesting. For example, in the Alps, partridges experience stress during hatching because of hang-gliders and paragliders. The photo shows paragliding in Interlaken, Switzerland. Photo credit: I. Kelman, http://www.ilankelman.org/aircraft.html, April 2014

Photo 6.61 Caves not infrequently are damaged by visitors. The Cave Victory (Kinderlinsky), in the Gafurijsky area of Bashkiria, is 9 km long and is one of the most beautiful caves in the Ural Mountains. Tourists visit the cave continually, and many act as though they own it. The visitors draw on walls, dig out and carry away remains of ancient animals, burn fires, pass the time drinking alcoholic beverages, and even create a public toilet. The photo shows garbage collection in the cave. Photo credit: N.I. Rychagova, 14 July 2013

Photo 6.62 Debris often accumulates in areas where people spend their leisure time. The photo shows garbage at the forest opening before the descent to the Cherny Shaman waterfall in the Amgu River valley (Primorsky Krai, Russia). A group of tourists recently had thrown all their garbage at the site where a bonfire had taken place. Photo credit: A.V. Golik (Pacific Oceanological Institute, Vladivostok, Russia), 20 August 2012

6.9 Sports Activity

Sports complexes and competition areas sometimes occupy **large areas** of land. For example, *golf courses* occupy 0.6 % of the United Kingdom; on average, each course is 50–60 ha in size (Gange et al. 2003). In Switzerland, *pistes* cover 1 % of the country (Rixen et al. 2004) (Fig. 6.11).

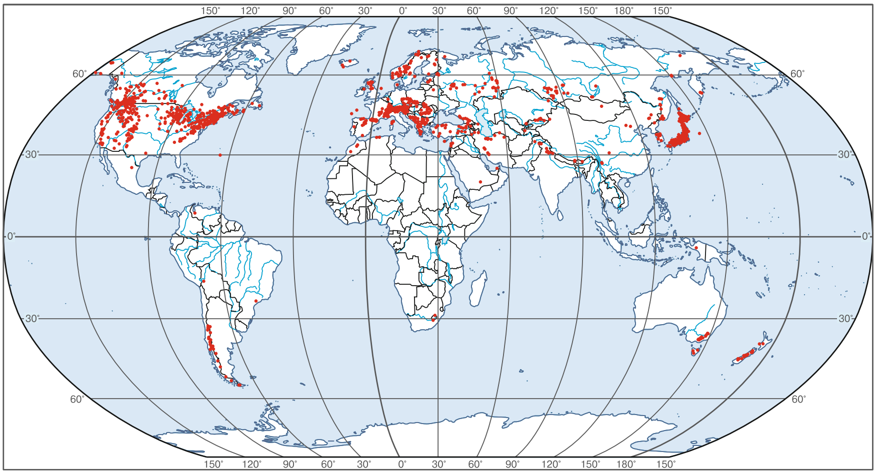

Fig. 6.11 Ski areas and resorts. Prepared by author based on data from numerous Internet sources

The influences of sports activities on the environment occur during *construction* and *exploitation* of sports facilities, during training and competitions. In addition, not only the *participants* have impacts on the environment, but also the *audience*.

At the **construction** stage, the environmental impacts of sports facilities are equivalent to those of many industries (e.g., vegetation destruction as a result of logging and machinery work, relief changes during excavation and shaping work, soil consolidation and erosion, local drainage increases, and noise pollution).

During **exploitation** of sports facilities, their impacts on the environment differ. Many sports events affect **soils** and **vegetation**. For example, to increase how long ski slopes can be used, different chemicals are used (calcium and sodium chlorides, ammonia sulfate and nitrate), which degrade soils and vegetation (Geography of tourism 2009).

Consolidation of snow cover decreases its *heat-insulating properties* and leads to freezing of the deeper layers of the soil (Schlochtern et al. 2014). Snow on skiing pistes melts 2–4 weeks later than normal (Eagleston and Rubin 2013). In turn, that delay leads to shorter periods of plant growth (Bradbury 2006). On the sites of skiing pistes, **productivity** and **biodiversity** are dropping (Zeidler et al. 2014). On extreme spots where the snow cover is thin (tops, hills, steep slopes), ski edges damage nival vegetation and soil (Heinrich and Hergt 2003).

During *sports orienteering* competitions, the use of *sprint shoes* can cause **soil erosion**. During mass starts, trampling of **grass** and damage to **shrubs** are unavoidable. The maximum press is at the *checkpoint* areas (approximately 50–100 m) and especially in areas of 1.75 m radius around them. Near the worst affected control points, 50–75 % of the vegetation within an area of 10 m^2 (equivalent to 1.75 m radius) suffered damage. Similar damage was reported for the start and finish areas (Review of research 2005).

Golf courses affect **soils** and **vegetation**, usually connected with the use of *fertilizers* and *pesticides* (Krcmar et al. 2014). *Shooting sport* leads to *lead poisoning of soils*. Research performed at two shooting ranges in Finland showed extremely high concentrations of lead (reaching 50,000 mg/kg) in the organic soil layer. Elevated lead concentrations were also found in leachate waters and in the biota (Selonen et al. 2012).

Some sports affect **surface waters**. For example, water discharges from *swimming pools* lead to chlorine poisoning of water bodies (Sa'ari et al. 2004). *Water-motor sport* competitions lead to petrol pollution (Heinrich and Hergt 2003).

Some sports activities have negative influences on the **animal world**. During mass *sports orienteering* competitions, for example, large birds and animals experience considerable stress. Research conducted in Sweden showed that when a sportsman approached, **elk** (*Alces alces*) took flight at a "flushing distance" of about 200–300 m and slowed down for another 1300–1500 m before stopping. The animals returned to their habitats over a period of 24 h, and some of them had signs of stress (Cederlund et al. 1981). *Ski pistes* are ecological barriers to **forest small mammals** (Negro et al. 2013).

Effects on **birds** are especially serious during nesting and hatching. For example, during the Scottish Orienteering Championships in June 1987, concern was expressed about the disturbance at a critical period for certain ground-nesting birds. Ornithological research done prior to the date helped to minimize the damage (Brackenridge 1988). The noise impacts on aquatic birds are considered to be strong during *water-motor sports* competitions (Environment 1999, V. 2).

The **atmosphere** is polluted with dust and exhaust during *motor vehicle* competitions, explosive gas emissions during *shooting* competitions, and emissions at other events. Refrigerators needed for some sports (*hockey*, *skating*, *figure skating*, *curling*) contribute to ozone layer depletion.

Sports activity has impacts on **resources depletion**, waste production, and other degradation of the environment. In sports like *mountaineering*, *rock climbing*, and *sports tourism*, competitions often take place in areas untouched by human activities—sportsmen are the first polluters there. For example, in the 1950s, when the first attempts to climb Mt. Everest were undertaken, one or two expeditions were conducted annually. In the 2000s, their number had reached 50 expeditions a year. At present, degradation of the natural environment there (deforestation and waste pollution) is visible (Nyaupane et al. 2014).

In general, sports activities have *insignificant impacts* on the environment. The influences on natural components can be seen in Photos 6.63–6.71.

Photo 6.63 Sports complexes and areas where sports competitions take place sometimes occupy large areas of land. For example, golf courses occupy 0.6 % of the United Kingdom; on average, each course is 50–60 ha in size. The Palmetto Golf Course in Miami, Florida, United States, is shown. The 18-hole course was built on 121 acres (49 ha) in 1959. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 13 April 2014

Photo 6.64 During sports orienteering competitions, the use of sprint shoes sometimes leads to soil erosion. Trampling of grass and damage to shrubs are unavoidable. The maximum stress on soils and vegetation occurs in areas of 1.75 m radius around control points. Around the control points with the greatest effects, 50–75 % of the vegetation within an area of 10 m^2 suffered damage. The photo shows checking on a control point during a sports orienteering championship in Kyshtym (Chelyabinsk Oblast, Russia). Photo credit: V.N. Popov, 27 August 2010

Photo 6.65 Motor sport competitions often intensify soil erosion. Various motor rallies held where there is a lack of proper roads are especially significant in this context. Car racing near the town of Spassk-Dalny (Primorsky Krai, Russia) is shown. Photo credit: A.V. Golik (Pacific Oceanological Institute, Vladivostok, Russia), 10 October 2010

Photo 6.66 Competitions in many sports (e.g., motor-boating, trail orienteering, golf, mountain skiing) have a marked effect on vegetation. This photo shows damage to bodies of trees as a result of the Trophy Raid running competition in Croatia. Photo credit: A.V. Golik (Pacific Oceanological Institute, Vladivostok, Russia), 6 May 2013

Photo 6.67 Skiing has some environmental impact. Compaction of snow cover decreases its heat-insulating properties and leads to freezing of the deeper layers of the soil. Snow on skiing pistes melts 2–4 weeks later than normal. In turn, that delay leads to shorter periods of plant growth. On the sites of skiing pistes, productivity and biodiversity are dropping. On extreme spots where the snow cover is thin (tops, hills, steep slopes), ski edges damage nival vegetation and soil. The photo shows skiing pistes at the Blue Mountain Ski Resort, the largest mountain resort in Ontario, Canada. Photo credit: http://en.wikipedia.org/wiki/Blue_Mountain_(ski_resort), Chensiyuan at the English language Wikipedia [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/), GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

Photo 6.68 Some sports have impacts on surface waters. For example, water discharges from swimming pools lead to chlorine poisoning of water bodies. The photo shows a water polo match between Greece and Hungary (World Junior Championship 2004, Naples, Italy). Photo credit: Massimo Finizio

Photo 6.69 Some sports activities have negative influences on the animal world. During mass sports orienteering competitions, for example, large birds and animals experience considerable stress. On meeting the sportsmen, the deer and elk ran away to distances of up to 1 km. The animals returned to their habitats over a period of 24 h, and some of them had signs of stress. The photo shows the beginning of relay competitions in Finland. Photo credit: A.M. Mikhailov, 2005

Photo 6.70 Impacts of shooting on the environment connected with pollution of atmosphere by explosive gas emissions and poisoning of soils by heavy metals. The biathlon complex in Petropavlovsk-Kamchatsky (Russia) is depicted. The local Children's Sports School expends annually 2.5 million cartridges. At bullet mass of 2.56 g (except lead, the bullet contains also antimony, arsenic and nickel), 6 t of lead, 308 kg of antimony, 134 kg of arsenic, and 33 kg of nickel are found within area of targets. The atmospheric fallouts wash away these heavy metals from the soil and they enter the nearby brook. Photo credit: A. A. Nikolayeva, 21 July 2013

Photo 6.71 Refrigeration systems needed for some sports (hockey, skating, figure skating, curling) make their contribution to ozone-layer depletion. This photo was taken during an ice hockey match between the Tampa Bay Lightning and the Toronto Maple Leafs. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 8 April 2014

6.10 Military Activity

The impacts of military activity on the environment occur during both **wars** and **times of peace** (e.g., play-wars; manoeuvres; routine military services; production or disposal of weapons, ammunition, and other equipment) (Figs. 6.12 and 6.13).

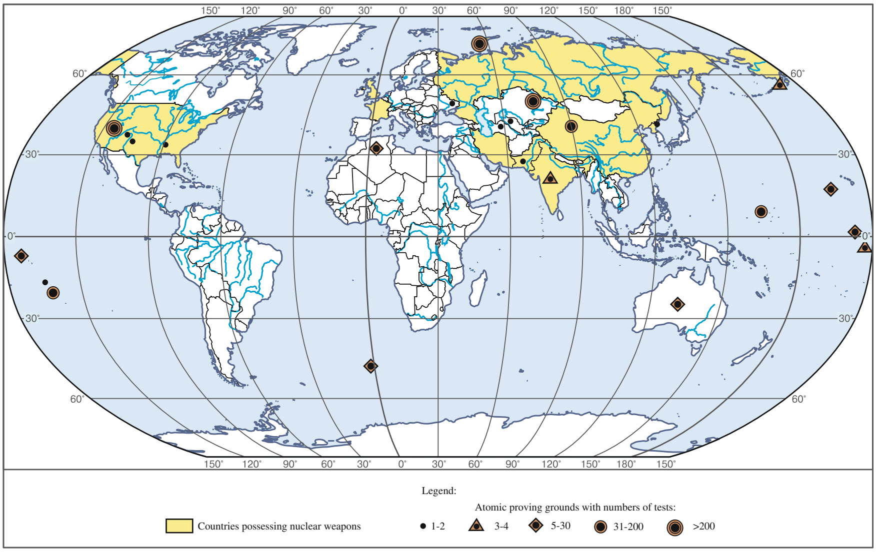

Fig. 6.12 Global distribution of nuclear weapons (adapted from www.nationalsecurity.ru; www.pbs.org)

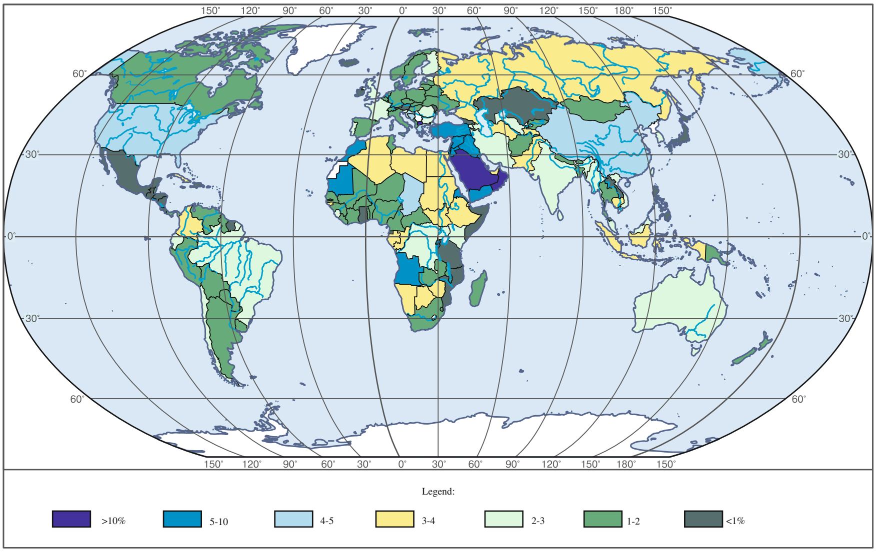

Fig. 6.13 Military expenditures as percent of GDP (http://en.wikipedia.org/wiki/Military)

Many wars had large environmental impacts. For example, the armies of Genghis Khan and Timur-i-lang destroyed irrigation systems in Middle Asia, Mesopotamia, India, and the Caucasus, which led to desertification and salinization of the soils (Mazur and Ivanov 2004). The Romans covered soils in Carthage with salt in order to disrupt its agriculture (Adushkin and Kozlov 2011). Other wars that devastated the environment include the Peloponnesian War (431–404 BC) between Sparta and Athens and the Thirty Years' War (1618–48) in Bohemia (Mamin 2011)).

In the twentieth century, World War II (1939–45), the Vietnam War (1961–75), and the Gulf War (1990–91) had the **most serious effects** on the environment. During peaceful times, military training activity affects at least 50 million ha globally, an area roughly the size of France (Zentelis and Lindenmayer 2015).

Two more aspects of military activity include (1) environmental ways to conduct war and (2) ecocide.

Elements of the environment have been used for energy release and to inflict the maximal damage to the enemy. The energy of forest fires, the water energy released when dams are broken, provocation of avalanches and rockfalls, and inland water contamination has been used.

The **first well-known example** is the war between the Persians and the Scythians in 512 BC. To prevent attack by the Persian king Darius, the Scythians used the tactic of "scorched earth," destroying all vegetation and houses while retreating (Pearson 2012).

During the *Taiping movement* in China (1850–64), the ruling Manchu dynasty used **fires** against the revolutionists. The flow of the lower Yangtze River was devastated (Westing 2000). Other examples include the **bombing** of two big **dams** in the *Ruhr valley* by the English in 1943 (Accidents and catastrophes 1995) and the **demolition of dams** in the Netherlands by the Germans in 1944, when seawater flooded 200,000 ha (Prokhorov 1998).

Ecocide is usually defined as intentional destruction of the natural environment of the enemy. During the *Vietnam War*, Americans disseminated 57,000 t of herbicides—*Agent Orange*—and around 23,000 t of defoliants (13 recipes), destroying 17 million ha of vegetation (Sofronov et al. 2004). About 7.9 million bombs were dropped (Petrenko 2014). To extend the rainy season, planes disseminated iodine compounds of silver and lead (Mironenko 2002).

Some of the results of the **Gulf War**, a second example, included the following: 12 million barrels of oil were spilt into the water (Omar et al. 2009), more than 600 oil well sites were burnt and emitted 125,000 t of oil combustion products over a period of several months (Sidel et al. 2009), and oil spills covered 2500 km^2 of land. Huge numbers of birds died, and the populations of ichthyofauna dropped sharply (Oksengendler 1992).

The impacts on the **geological environment** include disturbances of rock formation *integrity* (fragmentation, disintegration, mixing, dissemination) due to explosions, land use engineering, and other activities. Bombing and underground nuclear tests initiate *earthquakes* (Balassanian 2005; Nikolaeyv and Vereschagina

2006). Military services typically use *underground spaces* due to the need for maintaining secrecy, protecting from bombing, and other reasons.

The impacts on the **geomorphologic environment** include considerable relief transformation, due to *explosions* of weapons such as bombs, grenades, and mines. Trenches, pits, communication trenches, and blindages are dug during military operations. The fortifications of the First World War were 3000 km long, and during trench construction, more than 240 million m^3 of ground were excavated (Mironenko 2007). In 1943, on the Voronezh front (Russia) alone, 244 km in length, 83,912 rifle and machine-gun pits, and 17,505 doovers and dug-outs were excavated. The length of trenches and communication trenches reached 4240 km (Petrenko 2014).

The impacts on **soil** include consolidation during troop movements, pollution after industries are destroyed, and other effects (Certini et al. 2013). **Vegetation** disappears due to fires, blasts, ammunition fragmentation, etc.

Military activity leads to **animal** deaths and habitat deterioration. For example, when a 100 kg marine mine explodes, all aquatic animals die within a 44 m radius (Mironenko 2002). During the Second World War, many whales were killed because they were mistaken for submarines (Mamin 2011).

Atmospheric emissions released as a result of military activity comprise 6–10 % of total air pollution (Twentieth century 1992); these emissions are connected with unavoidable fires, as well as with releases of dust, gases, and poisonous chemicals due to demolition of storage and industrial facilities.

The environmental impacts of military activity are illustrated by Photos 6.72–6.78.

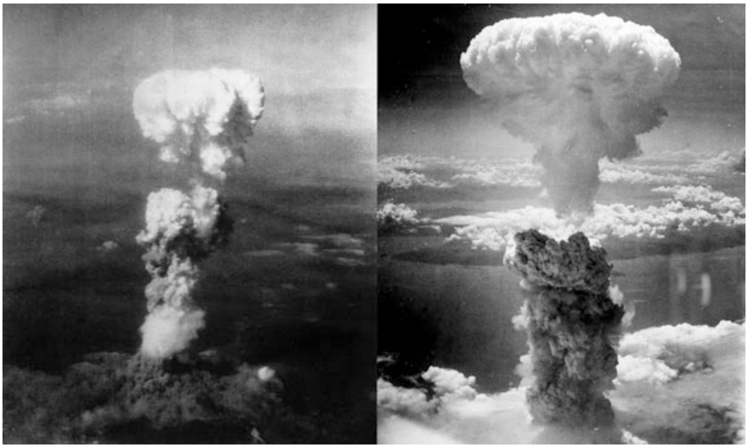

Photo 6.72 The impact of atomic weapons on nature is colossal because all components of natural landscapes collapse or are simply annihilated. Since 1945, 2049 atomic explosions have been carried out. The largest number of them were performed by the United States (1032), the USSR (715), and France (210). The atomic bombings of Hiroshima on 6 August 1945 (left) and Nagasaki on 9 August 1945 (right) are shown here. Photo credit: http://en.wikipedia.org/wiki/Atomic_bombings_of_Hiroshima_and_Nagasaki

Photo 6.73 The use of underground space is typical for the military services, due to the need for maintaining secrecy, protection from bombing, and other purposes. For the construction of fortified structures, huge amounts of rocky materials are extracted. For example, Fort Douaumont (Verdun fortifications in France) has total area of 30,000 m^2 and is approximately 400 m long. One of the forts of the Verdun fortifications is shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 4 August 2014

Photo 6.74 The Great Wall of China (shown in the photo) was constructed of stone, brick, tamped earth, wood, and other materials, extending from east to west across the historical northern borders of China. The wall was built to protect the Chinese Empire against invasions by nomadic groups and military forces. It is 21,196 km (13,171 mi) long. One of the ecological consequences of the wall is that it acts as a barrier to the migration of wild animals. Photo credit: http://en.wikipedia.org/wiki/Great_Wall_of_China, Severin.stalder [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

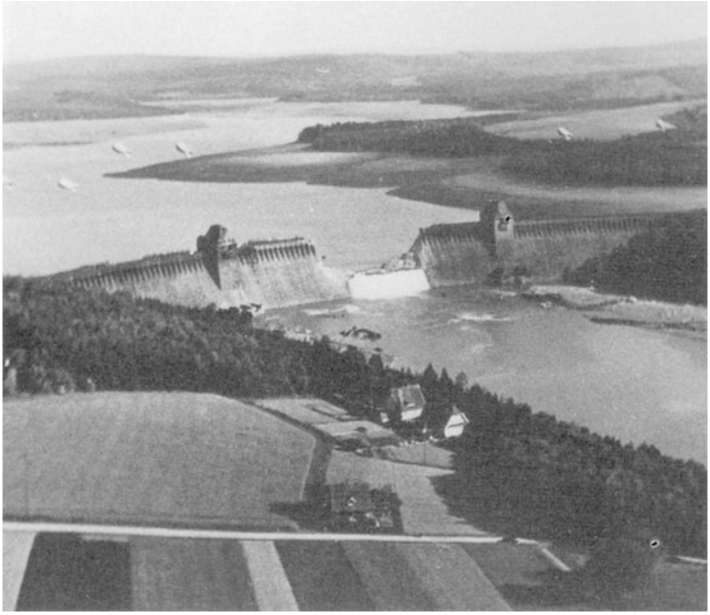

Photo 6.75 During human history, some elements of the environment have been used to inflict maximal damage to the enemy. Elements such as the release of energy through forest fires, the release of water energy when dams are broken, the provocation of avalanches and rock-falls, and inland water contamination have been used. The photo shows consequences of bombing the Möhne Dam (16–17 May 1943). It was breached, and catastrophic flooding resulted. An estimated 1600 people drowned. Photo credit: Jerry Fray, 17 May 1943

Photo 6.76 Use of gas as a weapon began in 1915 during World War I. The first killing agent employed by the German military was chlorine. It is a powerful irritant that can inflict damage to the eyes, nose, throat, and lungs. At high concentrations and prolonged exposure chlorine can cause death by asphyxiation. By 22 April 1915, the German army had 168 tons of chlorine deployed in 5730 cylinders near Ypres (Belgium). At 17:30, in a slight easterly breeze, the gas was released, forming a gray-green cloud that drifted across positions held by French colonial troops from Martinique, who broke ranks, abandoning their trenches and creating an 8000-yard (7 km) gap in the Allied line. The photo shows dispersion of chlorine gas in World War I. Photo credit: http://en.wikipedia.org/wiki/Chemical_warfare

Photo 6.77 *Ecocide* is usually defined as the intentional destruction of the natural environment of the enemy. A primary case of ecocide occurred during the Vietnam War. Americans disseminated 57,000 t of herbicides—Agent Orange—and around 23,000 t of defoliants (13 recipes), destroying 17 million ha of vegetation. Fourteen million bombs were dropped. To extend the rainy season, planes disseminated iodine compounds of silver and lead. The photo shows a defoliant spray run during the Vietnam War by a UC-123B Provider aircraft. Photo credit: U.S. Air Force, 1960s

Photo 6.78 The Gulf War was a second large-scale example of ecocide. In Kuwait, 550 oil well sites were burned and emitted 125,000 t of oil combustion products over a period of several months, and oil spills covered 2500 km^2 of land. Huge numbers of birds died, and the populations of ichthyofauna dropped sharply. The photo shows burning oil wells in Kuwait, 1991 Photo credit: http://en.wikipedia.org/wiki/Gulf_War, 21 March 1991

6.11 Space Exploration

There are currently about 30 spaceports in the world (see Fig. 6.14). Every one of them is a complicated engineering facility. During launch and placement of spacecraft into orbit, the environmental impacts are mainly due to the descent of carrier rocket parts.

First stages detach at altitudes of 60–90 km. When a stage hits the ground, the remaining fuel usually explodes and leaves a crater of 5 m radius; fragments scatter for 100–200 m.

Second stages of carrier rockets separate at altitudes of 140–160 km. Due to heating in the atmosphere, the fuel explodes when the stage is 25–30 km above sea level. Fragments fall to the ground over a large area (Kondratyev et al. 2007).

When the **nose fairing** and **missile tail** (which do not contain fuel) fall, environmental impacts are small: only the upper layer of the soil and vegetation are damaged, and the area is littered with fragments (Kretchetov et al. 2008).

The fragments of the stages fall over a large area. For all active launching sites, millions of square kilometers are affected (Engineering ecology 2003). The total area for Russia and other countries of the former USSR is 200,000 km^2, and the area polluted because of space activity is 1 million km^2 (Vronsky 2009).

The most **dangerous** matter in the carrier rocket is the components of its fuel—*unsymmetrical dimethylhydrazine* (*heptyl*) and *plutonium-238*. Global production of *heptyl* in 1981 was 35,000 t (Roshchin and Frindland 2004).

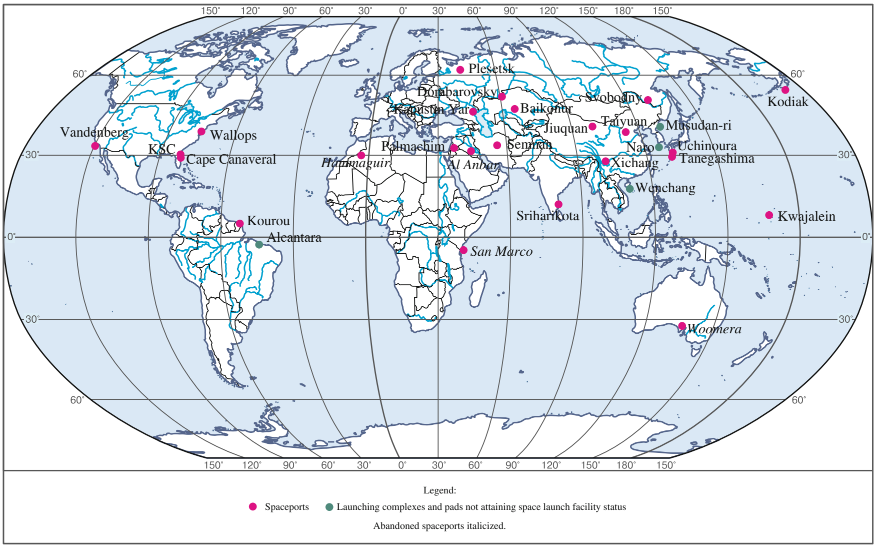

Fig. 6.14 Global distribution of spaceports. Prepared by author based on data from numerous Internet sources

Space activity influences the following environmental **components** and parameters: (1) atmosphere, (2) near-Earth space; (3) soils; (4) vegetation; (5) animal world; (6) surface waters; (7) geological environment; and (8) background radiation.

Pollution and *ozone-layer depletion* occur in the atmosphere. For every launch of a "Proton" missile, about 265 t of nitrogen dioxide is emitted (Piven 2006). *Chlorine* exhaust from the "Shuttle" and "Energia" spacecraft also leads to ozone depletion. One launch of a "Shuttle" results in the loss of 1 million tons of ozone (Prokhorov 1998).

Near-Earth space is affected by heat pollution, pollution with solid fragments, electromagnetic radiation from transmission systems, and radiation from nuclear power sources on satellites (Environmental problems and risks 2000).

The problem of **space waste** becomes more and more serious every year. Ten thousand objects in Earth orbit are tracked. There are hundreds of thousands of objects several centimeters in size and sometimes smaller (Korniyenko 2008). Earth orbit is the most polluted at altitudes of 850–1200 km, where meteorological and remote sensing satellites are placed (Vronsky 2009).

Soils are impacted mainly by fuel. For instance, the first stages of the "Proton" carrier rocket, which detach at altitudes of 35–45 km, still carry 500 kg of heptyl in their tanks. The fuel left in the propulsion packs and conduit of pipes is usually spilled on the Earth surface (Kasimov et al. 2006). Half of this pollutant is removed by run-off within the first 7 years, and after 50 years only 5 % of the heptyl remains (Popov and Yudakhin 2008).

Soil pollution affects **flora** and **fauna**. The smell of liquid fuel attracts birds and other animals. Tests on sheep that are grazed in areas where carrier rocket parts fall have shown the presence of heptyl in their tissues (Social-ecological consequences 2000).

Seawaters are usually affected to a far **greater** degree than **freshwater bodies**. Areas where detached rocket parts fall are located in the sea for most spacefaring nations. Even Russia has 12 sea regions like this, with a total area of 9 million ha. On average, 4200 kg of heptyl, 6820 kg of azotic acid, and 1300 kg of azotic tetroxide fall in the Arctic Ocean every year (Vlasov and Krichevsky 1999).

Impacts on the **geological environment** include increases in *earthquake* activity, noted particularly after launches of heavy rockets carrying the *Apollo* and *Soyuz* spacecraft (Nikolayev and Vereshchagina 2006). In addition, rocket launches at Cape Canaveral (Florida, United States) have been connected with earthquakes in California (United States) and Mexico (Vlasov and Krichevsky 1999).

Radioactive pollution is especially dangerous in *emergency situations*. For example, in 1978, after the accident with the Soviet satellite *Kosmos-954*, 37.1 kg of spent nuclear fuel were disseminated in the atmosphere, and fragments of the reactor fell in northern Canada (Vlasov and Krichevsky 1999).

Falling parts endanger **people**. For instance, in 1969, a fragment lost by a Soviet space vehicle fell on a Japanese trade ship and injured five sailors (Prokhorov 1998). On 5 July 1997, a second stage fell in the Altai region (Russia) and caused a short circuit in a power line and a transformer box to burn (Social-ecological consequences 2000).

The environmental impacts of space activity are illustrated by Photos 6.79–6.82.

Photo 6.79 The impacts of space travel on the atmosphere include pollution and ozone-layer depletion. When 1 t of heptyl is burnt, 1.6 t of nitrogen dioxide is emitted. Every launch of a Proton missile requires 160 t of fuel. Thus, at every launch, about 265 t of nitrogen dioxide is emitted. The photo shows the space shuttle *Atlantis* launch on 14 May 2010, at the Kennedy Space Center, Florida, United States. Photo credit: http://en.wikipedia.org/wiki/STS-132

Photo 6.80 Second stages of carrier rockets separate at altitudes of 140–160 km. Due to heating in the atmosphere, the fuel explodes when the stage is 25–30 km above sea level. Fragments fall to the ground, covering a large area. The fuel tank of the second stage of a Proton rocket that fell in the Altai reserve (Russia) is shown. Photo credit: A.M. Panichev (Pacific Geographical Institute, Vladivostok, Russia), 1994

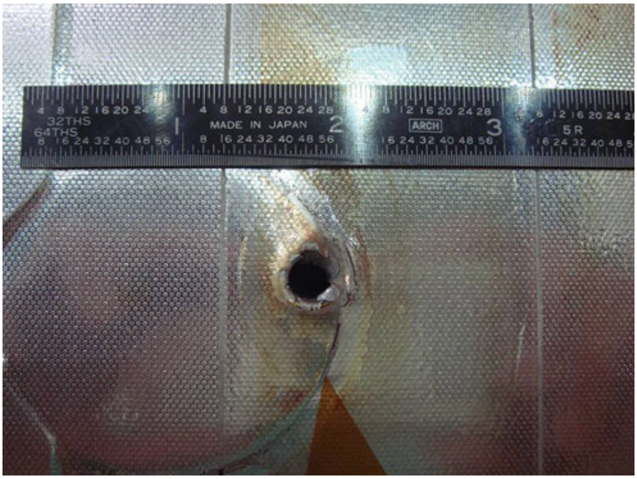

Photo 6.81 With every passing year, the problem of space waste becomes more and more serious. Space waste includes things such as space vehicles that are no longer active, stages of carrier rockets and upper stage rockets, and fragments of demolished missiles. Ten thousand objects in Earth orbit are tracked. There are hundreds of thousands of objects several centimeters in size and sometimes smaller. Earth orbit is the most polluted at altitudes of 850–1200 km, where meteorological and remote sensing satellites are placed. This is an image of the entry hole created on the space shuttle *Endeavor'*s radiator panel by the impact of unknown space debris. Photo credit: National Aeronautics and Space Administration

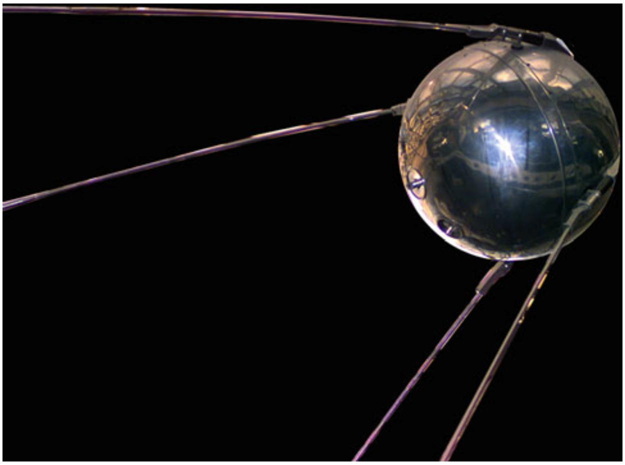

Photo 6.82 Radioactive pollution from space vehicles is especially dangerous in emergency situations. For example, in 1978, after an accident with the Soviet satellite *Kosmos-954*, 37.1 kg of spent nuclear fuel were disseminated in the atmosphere, and fragments of the reactor fell in northern Canada. On 21 April 1964, the navigation satellite *Transit 5BN-3* (United States) did not enter the intended orbit, fell apart, and burnt in the atmosphere north of Madagascar; 950 g of plutonium-238 were dumped. A replica of *Sputnik 1*, the first artificial satellite in the world, is shown here. Photo credit: National Aeronautics and Space Administration

6.12 Health and Veterinary Services

Health and **veterinary services** are activities aimed at preventing and treating diseases of humans and animals, respectively. These activities impact the environment mainly through **wastes**, 20 % of which involve risks of infection, trauma, or chemical or radiation exposure (Medical waste management 2011).

Human and animal amputated limbs, blood and other body fluids (e.g., mucus, lymph), used bandages, disposable syringes, scalpels, gloves, expired drugs, X-ray film, and broken mercury thermometers are among the types of **dangerous** medical waste. There are **two groups** that produce this waste: (1) health and veterinary facilities and (2) the general population.

Health and **veterinary** facilities produce the full spectrum of medical waste; the associated dangers (e.g., toxicity, contamination, concentration) are much higher in comparison to the waste of the general population.

Medical waste of the general **population** comprises mainly *expired drugs* and *broken thermometers*. It is believed that *one-third of drugs* are not used; when it expires, it is reprocessed or thrown away. Nevertheless, drugs are rarely reprocessed; most people just flush them into the sewage system or throw them away with household waste (Jones et al. 2001); in the same way, mercury thermometers are thrown into landfills.

Mercury thermometers represent serious environmental danger. The number of medical thermometers in Russia is about 100 million; each contains 2 g of mercury. In 1998–2000, 9 million thermometers (containing 18 t of mercury) were broken every year (Yanin 2004).

Still, the most serious problem is contamination of the environment with **drugs**. Many are transformed insignificantly in humans or **do not change** at all. Furthermore, they enter the sewage system with urine and can be still found after sewage water treatment. Some substances of pharmaceutical origin even can be found in drinking water (Schaider et al. 2014; Postigo and Barcelo 2015).

Veterinary pharmaceutical drugs used in animal feed get into the environment as a result of manure storage overfilling or leakage, or when dung is put into soils (Kolpin et al. 2002). The yearly consumption to treat human and animal diseases was estimated to be hundreds of thousands of tons per year, leading to high concentrations in surface water of developed countries (Zenker et al. 2014).

Health and veterinary services mostly influence the following environmental **components**: (1) surface waters; (2) groundwater; (3) soils; and (4) the animal world.

In the early 1990s, drugs were first found in the **surface waters** of Germany. Now human pharmaceuticals have been found in the aquatic environment of many countries (Al-Odaini et al. 2013; Jarvis et al. 2014; Carmona et al. 2014). At present, more than 200 drugs are found in the environment (Dong et al. 2013). The most common are popular drugs such as *diclofenac* and *ibuprofen* (Ribas et al. 2014).

Drugs usually enter surface waters through **sewage systems**. Most of these drugs are analgesics, antibiotics, anti-epileptics, β-blockers, β_2-sympathomimetics, and lipid regulators (Jones et al. 2001; Manzetti and Ghisi 2014).

Groundwater becomes polluted through processes such as filtration of contaminated waters at landfills containing household and industrial wastes, and

manure drainage infiltration through soils. For instance, in near-surface groundwater in Germany heightened concentrations of sulfadimidine, sulfadiazine, and sulfamethoxazole were detected (Hannappel et al. 2014). Also, 17 veterinary pharmaceuticals were found in groundwater adjacent to operating swine and beef cattle facilities in the United States (Bartelt-Hunt et al. 2011). Groundwater can also contain *iodinated contrast agents* (Zemann et al. 2014).

Of all representatives of the **animal world,** drugs influence mostly *hydrobionts*. In many rivers in Great Britain, for example, the numbers of hermaphroditic fish have increased considerably. This development is believed to be connected with *estrogen* (including EE2) emissions from water purification facilities (Christensen 1998). A worldwide decline of amphibian populations can be explained by adverse effects on sexual differentiation; evidence for EE2 affecting amphibian mating behavior is lacking (Hoffmann and Kloas 2012). The presence of this drug in Lakes Erie and Ontario resulted in male **perch** having not just male genitalia, but also rudimentary female organs. Their sexual behavior changed, and they became infertile (Kolpin et al. 2002).

Other drugs—for instance, *analgesics* and *sedatives*—are also of interest. *Barbiturates* reportedly influence DDT metabolism in fish. They also may modulate behavior and predator-prey relationships by *lowering swimming velocity* and influencing *reaction* times (Kummerer 2001).

Thus, the influences of health and veterinary services on the environment are cause for **deep concern**. Many problems still *need to be investigated*. It is obvious that the presence of some drugs in drinking water can lead to genetic mutations in people.

The environmental impacts of health and veterinary services are illustrated by Photos 6.83–6.85.

Photo 6.83 Estrogen emissions from water purification facilities considerably increase numbers of hermaphroditic fish. The photo shows milt and hard-roe of hermaphroditic Siberian salmon in Khabarovsk Krai, Russia. Photo credit: I.I. Bubovich (Department of Fish Conservation, Okhotsk District, Khabarovsk Krai, Russia)

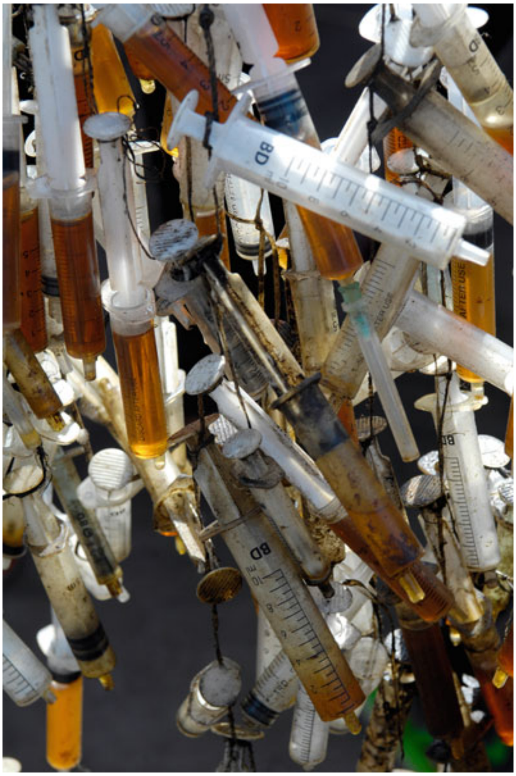

Photo 6.84 Health and veterinary services impact the environment mainly through waste. Human and animal amputated limbs, blood and other body fluids (e.g., mucus, lymph), used bandages, disposable syringes, scalpels, gloves, expired drugs, X-ray film, and broken mercury thermometers are among the types of dangerous medical waste. The photo shows used syringes for sale in a market in Bumba, Democratic Republic of the Congo. Photo credit: Thomas Einberger (Greenpeace), 16 March 2008

Photo 6.85 Medical diagnostic methods provide the major contribution to the radiation dose sustained by the majority of men from artificial sources. The digital photofluorographic unit in one of the policlinics of Vladivostok is illustrated. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 9 June 2007

6.13 Ritual Activity

A **rite** is a complex of ritualistic, traditional actions, without apparent practical value, but serving to express certain social relations. In most cases, rites have a *religious background*.

The following are some **types** of rites that influence the environment: (1) sacrifice; (2) fire; (3) ritual construction; (4) making and destruction of puppets; and (5) pilgrimages to holy sites (Figs. 6.15 and 6.16).

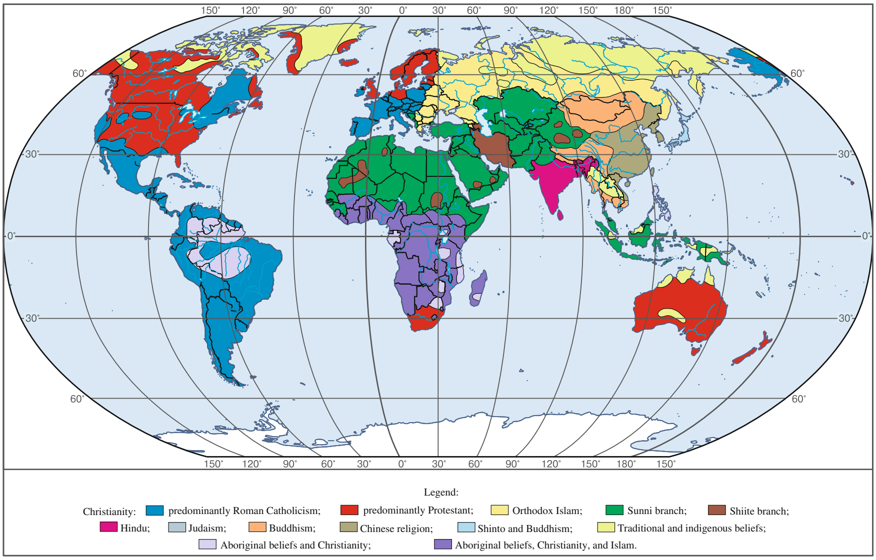

Fig. 6.15 Distribution of world religions (http://www.worldreligions.psu.edu/maps-introduction.htm; http://mapcollection.wordpress.com/2012/06/28/modern-distribution-of-world-religions/)

Sacrifice is a widespread rite, typical for the majority of religions. History has preserved many descriptions of such rites. For example, ancient Germans traditionally sacrificed captives and their horses to the war god. Some tribes that lived in the first century AD on the territory of modern Denmark used to sacrifice people to the goddess Nerthus; Roman authors associated her with Earth Mother (Todd 2005).

At the dawn of recorded history, people practiced ritual killing during *burial rituals*. Those traditions were practiced for a long time in the nations of tropical latitudes. In some areas, ritual killings are still performed.

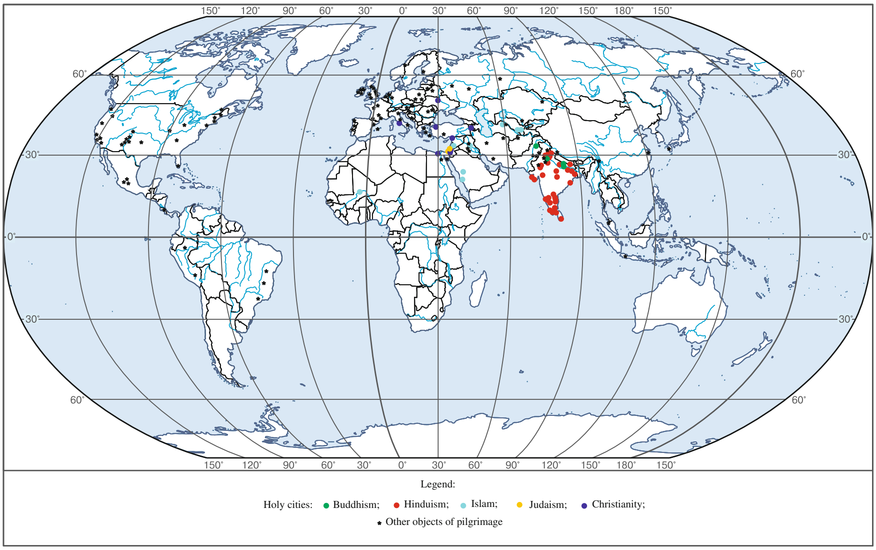

Fig. 6.16 The most important objects of religious pilgrimages. Prepared by author based on data from the following websites: http://kagyu-sfla.org/lamas-on-pilgrimage/; http://en.wikipedia.org/wiki/Christian_pilgrimage; www.alunajoy.com/pilgrimages.html; and http://www.mapsofindia.com/tourism/buddhist-pilgrimage-locations.html

Rites of sacrifice, blood, and death were typical of the **Aztecs**. They were practiced less by the **Maya** (Scherer et al. 2011). Every year, 20,000 people were sacrificed on the flat roofs of pyramids. In 1486, when a new temple was hallowed in the Aztec capital city of Tenochtitlan, 70,000 people were murdered in just one day. During their invasion into Mexico, Hernán Cortés and his companions counted 136,000 skulls of sacrificed people in one of the biggest temples there (Golubchikov 2005; Johnson et al. 2012; Pennock 2012).

After a time, most nations began to sacrifice different **animals** (O'Connor 2013; Alves et al. 2012). In the Harz Mountains (Germany), *squirrels* were burned on Easter; in the department of Ardennes (France), *cats* were burned on the first Sunday of fasting. In some regions of Greece, *oxen* were sacrificed; in south India, *goats*; and in the southern part of Celebes (Sulawesi) island, *swine*.

Sacrifice often has certain *objectives*. For example, to *invoke rain* in Bohemia (Czechia), *frogs* were noosed; in the mountains of Japan, a *black dog* was sacrificed; in India, a *black goat*; and on Timor island, *black swine* (Frazer 2006).

Burial rituals often involved the erection of special **structures**. Ancient Egyptian monumental tombs (*pyramids*), the Scythians' *tumuli* (round mound on top of a burial chamber), and *dolmens* (vertical slabs with another slab laid on top) are widely known (Lozano et al. 2014).

Many countries customarily have **fires** during certain times of the year to dance around or jump over. The numbers of fires can be great. For instance, during the Easter fire celebration in central and northern Germany, fires were burned simultaneously on the tops of hills, and sometimes 40 could be seen at once (Frazer 2006).

Rituals using different **trees** have been widespread. The classic example is *Christmas trees*; nevertheless, they are not only cut for the New Year. In many parts of Europe (England, Germany, France, Switzerland), *pines* were installed in May. The Gypsies of Transylvania and Romania at the eve of St. George's Day (23 April) used young *willows*; in ***Boeotia*** (Greece), the biggest *oak* was taken (Frazer 2006).

Puppets are traditionally thrown into water in many countries. For instance, in Bohemia, on the fourth Sunday of Lent, a doll called Death was thrown into the water (Frazer 2006); the Eastern Slavs, during the celebration of St. John the Baptist Day, drowned a puppet (Levkiyevskaya 2004).

In **India,** the rite of drowning puppets is very common; there it is called the "**immersion of idols**." In Bhopal (center of the Madhya Pradesh state) in September through October, for example, the rite of the idols *Lord Ganesha* and the *goddess Durga* is conducted. Sixteen hundred idols were immersed in the suburban lakes of Bhopal alone (Avvannavar et al. 2009).

This custom introduces **pollution into water bodies**. Though the idols themselves are made of inert materials, their paint contains considerable amounts of **toxic metals** such as lead, arsenic, chrome, and mercury (Bajpaiz et al. 2008; Sharma 2014). Also, during every rite, large amounts of oil and fat, flower garlands, and food waste get into the water (Vyas et al. 2008). Serious damage is caused to the workers' health. **Noise pollution** also is important. During such festivals the noise levels reach 104 db (Vyas et al. 2006).

Pilgrimages play an important role in many religions, with millions of people participating annually. During pilgrimages serious damage to the environment is unavoidable, caused by the presence of *considerable numbers of people* concentrated in small areas.

Thus rites make significant contributions to **environmental degradation**, and many **natural components** (e.g., vegetation, the animal world, soils, surface waters, the geomorphologic environment) are affected.

The environmental impacts of rites are illustrated by Photos 6.86–6.93.

Photo 6.86 The following are some of the types of rites that influence the environment: (1) sacrifice; (2) fire; (3) ritual construction; (4) making and destruction of puppets; and (5) pilgrimages to holy sites. Sacrifice is a very widespread rite, typical for the majority of religions. At the dawn of recorded history, people practiced ritual killing during burial rituals. The photo shows a pig being killed as a sacrifice during a burial ceremony in the town of Gasa, Xinping County, Yunnan Province, China. Photo credit: Bai Yunxian (Greenpeace), 1 January 2005

Photo 6.87 Burial rituals very often involved the erection of special structures. Ancient Egyptian monumental tombs (pyramids), the Scythians' tumuli (round mound on top of a burial chamber), and dolmens (vertical slabs with another slab laid on top) are widely known. A Poulnabrone dolmen in Burren, County Clare, Ireland, is shown. It is a portal tomb, dating probably between 4200 and 2900 BC. The dolmen consists of a 12-foot, thin, slab-like, tabular capstone supported by two slender portal stones, which support the capstone 1.8 m (6 ft) from the ground, creating a chamber in a 9 m (30 ft) low cairn. Photo credit: http://en.wikipedia.org/wiki/Poulnabrone_dolmen

Photo 6.88 Pyramids have been built by civilizations in many parts of the world. For thousands of years, the largest structures on Earth were pyramids. The Great Pyramid of Khufu in Giza is the only one of the Seven Wonders of the Ancient World still remaining. Khufu's Pyramid is built mainly of limestone (with large red granite blocks used in some interior chambers), and is considered an architectural masterpiece. It contains around 1.3 million blocks ranging in weight from 2.5 tons (5500 lb) to 15 tons (33,000 lb) and is built on a square base with sides measuring about 230 m (755 ft), covering 13 acres. Pyramids in Giza, Egypt, are shown. Photo credit: Ricardo Liberato, 19 June 2006

Photo 6.89 There is a tradition of throwing puppets into water in many countries. In India this rite is very common; there it is called the "immersion of idols." This custom introduces a lot of pollution into water bodies. Though the idols themselves are made of inert materials, their paint contains considerable amounts of toxic metals such as lead, arsenic, chromium, and mercury. Devotees immerse an idol of Lord Ganesh at Girgaum *Chowpatty*, Mumbai, India. Photo credit: http://en.wikipedia.org/wiki/Anant_Chaturdashi by Chris (Flickr: Ganesh) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons, 25 September 2007

Photo 6.90 A typical ceremonial burial requires 600–880 pounds of wood. However, wood in India is not cheap, and there are thousands more who cannot afford cremation and whose bodies are simply placed into the Ganges. A dead body in Manikarnika Ghat, Ganges River, Varanasi, India, is shown. Photo credit: http://commons.wikimedia.org/wiki/File:20110825_dead_body_Ganges_river_Manikarnika_Ghat_Varanasi_India.JPG by User:Ggia (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Photo 6.91 A cremation in Varanasi on a bank of the Ganges River is shown. About 40,000 cremations are performed each year here, most on wood pyres that do not completely consume the body. Wherever, a fire is burning (smoke), someone is being cremated; this happen day and night. Cremation takes place shortly after death; the body is dipped into the Ganges after it dries. Consequently, this rite results in contamination of the atmosphere and surface waters as well as having an impact on forests. Photo credit: http://commons.wikimedia.org/wiki/File:Cremation_in_Varanasi.jpg

Photo 6.92 Rituals associated with the use of different trees have been widespread. A classic example is Christmas trees. The photo shows a lorry with firs for sale in Vladivostok (Russia). Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 26 December 2010

Photo 6.93 Pilgrimages play an important role in many religions. Millions of people participate in pilgrimages annually. When pilgrims visit holy places, serious damage to the environment caused by high concentrations of people within limited areas is inevitable. Mount Fuji in Japan is a functioning Shinto holy place, and cultic structures of the Japanese traditional religion of Shinto are situated on its slopes. The mount has attracted pilgrims for many centuries. Pilgrims ascending Mount Fuji are shown. Photo credit: S.M. Govorushko (Pacific Geographical Institute, Vladivostok, Russia), 13 August 2013

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Appendix 1
List of Maps

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S. Govorushko, *Human Impact on the Environment*,
DOI 10.1007/978-3-319-24957-5