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Impact Assessment of Energy Facilities on Geoecology

V.S. Davtyan [a]

[a] *Russian-Armenian University, 0051, Armenia, vahe.davtian@gmail.com*

Abstract: The article is devoted to the problems of the impact of energy facilities on geoecology. The main criteria for the impact of the operation of energy facilities on the environment are identified. Separate sectors of the energy sector (nuclear, thermal, hydro- and alternative energy) are singled out for a separate determination of the level of influence of different energy facilities on the geoecological situation. The main geoecological problems of energy development of Armenia are considered. A geoecological assessment of the key energy facilities in Armenia is given.

Keywords: geoecology, energy, facilities, assessment, pollution, ecosystem.

1. Introduction

In the modern world, energy is the basis for the development of basic industries that determine the progress of social production. In all industrialized countries, the pace of development of the energy industry outpaced the development dynamic of other industries.

At the same time, energy is one of the sources of adverse effects on the environment and humans. It affects the atmosphere (oxygen consumption, emissions of gases, moisture and particulate matter), the hydrosphere (water consumption, creation of artificial reservoirs, discharges of polluted and heated waters, liquid waste) and the lithosphere (consumption of fossil fuels, landscape change, emissions of toxic substances).

The main forms of energy impact on the environment are:

- air pollution: thermal effect, emission of gases and dust into the atmosphere;
- pollution of the hydrosphere: thermal pollution of water bodies, emissions of pollutants;
- pollution of the lithosphere during the transportation of energy carriers and waste disposal, in the production of energy;
- pollution of the environment by radioactive and toxic wastes;
- changes in the hydrological regime of rivers by hydroelectric power plants (HPPs) and, as a result, pollution in the territory of the watercourse;
- creation of electromagnetic fields around power lines [1].

Figure 1 shows a diagram of greenhouse gas emissions from various sectors of the world economy. As you can see, generating facilities operating on traditional energy sources contribute about 70% of the global anthropogenic greenhouse gas emissions to the atmosphere, pollute land and water with combustion products and wastewater.

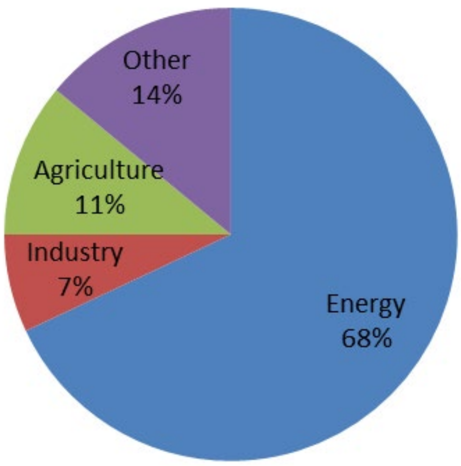

Fig. 1. Greenhouse gas emissions from various sectors of the world economy

2. Methods

The research methodology is based on an integrated approach, including the study of international practice of impact assessment of energy on geoecology. The study uses a structural-functional method, as well as a comparative analysis method in order to identify the features of the geoecological influence of energy facilities. By comparing the different kind og electeicity production, the study reveals the basic problems of geoecology security. Methods of statistical and systemic analysis are also used in the research.

3. Results

From the point of view of the impact of energy facilities on the geosphere, several groups of the most important interactions can be distinguished:

- water consumption and water use, causing a change in the natural material balance of the aquatic environment (transfer of salts, nutrients, etc.);
- deposition on the surface of solid emissions of products of combustion of organic fuels from the atmosphere, causing a change in the properties of water, its color, albedo, etc.;
- fallout on the surface in the form of solid particles and liquid solutions of atmospheric emissions products, including: acids and acid residues, metals and their compounds, carcinogens;
- emissions directly onto the surface of land and water of the products of burning solid fuels (ash, slag), as well as products of blowdown, cleaning of heating surfaces (soot, ash, etc.);
- emissions of liquid and solid fuels onto the surface of water and land during transportation, processing, reloading;
- releases of solid and liquid radioactive waste, characterized by the conditions of their distribution in the hydro- and lithosphere;
- heat emissions, the consequences of which may be: a constant local increase in temperature in the reservoir; temporary rise in temperature; changes in freezing conditions, winter hydrological regime; change in the distribution of precipitation, evaporation, fog;
- creation of reservoirs in river valleys or using the natural relief of the surface, as well as the creation of artificial cooling ponds, which causes: changes in the qualitative and quantitative composition of river flows, changes in the hydrology of the water basin; increased pressure on the bottom, penetration of moisture into crustal faults and changes in seismicity; changes in fishing conditions, development of plankton and aquatic vegetation; microclimate change; changing the conditions of recreation, sports activities, balneological and other environmental factors;
- landscape changes during the construction of heterogeneous energy facilities, consumption of lithosphere resources, including: deforestation; withdrawal from agricultural circulation of arable land, meadows; interaction of coasts with reservoirs;
- the impact of emissions, removals and changes in the nature of the interaction of water basins with land on the structure and properties of the continental shelves. Impurity pollution can collectively affect the natural circulation and material balances of certain substances between the hydro-, litho- and atmosphere. Common to all energy sources (both traditional and non-traditional) is the problem of thermal emissions [2].

All of these interactions are interconnected, and each of them cannot be considered separately. In addition, the mechanism of interaction in each of the groups is based on heterogeneous physical and physico-chemical processes and phenomena.

On a spatial basis, the sources of technogenesis are divided into point (wells, barns), linear (pipelines, water conduits) and areal (deposits). Most of the geo-ecological risks in the field of oil and gas production are generated by emergency situations: the flowing of wells, the formation of griffins, leakage of pollutants from tanks, pipeline ruptures, etc. should be highlighted. As noted by I.A. Karlovich, geochemical changes in soils begin at the stage of drilling a well, and pollutants (e.g., nitrates, lead, and zinc) are found in the soil within a radius of 2 km from the drilling site. In the process of drilling, the main risks are caused by cuttings and settling pits for flushing fluid, which include such chemical components as thinners, heat stabilizers, emulsifiers, weighting agents, etc. [3]. In all cycles and production and technological stages of drilling for oil, gas and condensate, land is allocated for wells, waste storage, for the construction of oil and gas pipelines, which inevitably leads to soil and vegetation pollution [4].

Now, let's briefly consider the features of the impact of main energy facilities on geoecology.

4. Discussion

4.1. Thermal power plants (TPP)

TPPs are characterized by high radiation and toxic pollution of the environment. Traditionally, thermal power plants operate on fossil fuels - coal and fuel oil. When fuel is burned at TPPs, combustion products are formed, which contain many substances that pollute the atmosphere. These include, for example, fly ash, sulfuric and sulfurous anhydride, nitrogen oxide, vanadium compounds, coke, sodium salts, soot particles, etc. When switching from solid to gas fuel, the cost of electricity generated increases significantly, but there is no ash when using liquefied gas.

Also polluting the environment is the waste water from TPPs, which contain petroleum products. At the same time, at stations where liquid fuel is used, the volumes of industrial water discharges are somewhat higher. The negative impact of thermal power plants is exacerbated by the fact that their operation must be ensured by the constant production of fuel, which is accompanied by additional negative impacts on the environment. Such impacts include, for example, pollution of the air basin, water and land, consumption of land and water resources, etc. [5].

Depending on the initial composition of the fuel, combustion products emitted into the atmosphere contain nitrogen oxides (NOx), carbon oxides (COx), sulfur oxides (SOx), hydrocarbons, water vapor and other substances in solid, liquid and gaseous states, which are the main environmental pollutants. Pollution of the atmosphere with fine solid particles of ash is mainly associated with the use of coal as a fuel, which is pre-ground in special mills. However, with the proper organization of the combustion process and the use of modern filters with an efficiency factor (COP) of 95...99%, their number can be reduced to the required minimum. When burning liquid fuel (fuel oil), sulfur and nitrogen oxides, gaseous and solid products of incomplete combustion of fuel, and vanadium compounds enter the atmosphere with emissions. When natural gas is burned, nitrogen oxides also enter the atmosphere, but they are formed significantly less than when fuel oil is burned. This is due not only to the properties of the fuel itself, but also to the peculiarities of the combustion processes.

Obviously, today natural gas is the cleanest type of energy fuel. Improving the design of TPP equipment, as well as compliance with its operation standards, can significantly reduce the amount of oil products entering wastewater, and the use of traps and settling tanks practically eliminates their entry into the external environment [1].

4.2. Nuclear power plants (NPP)

The impact of NPPs on the environment, taking into account the technology of construction and operation, is much less than other technological facilities. However, radiation in the event of an accident is one of the dangerous factors for the environment, human life and health. In this case, emissions are equated to those arising from the testing of nuclear weapons. For the operation of nuclear facilities, uranium ore is mined, from which radioactive uranium is obtained by enrichment. Reactors produce plutonium, which is the most toxic man-made substance in existence. Processing, transportation and disposal of waste from NPPs require careful precautions and safety measures.

The impact of an NPP on the environment begins from the moment of construction, continues during operation and even after its completion. On the territory of the location of the station for the generation of electricity and beyond, various negative influences may occur. These include, for example, the withdrawal of a land plot for the construction and arrangement of sanitary zones, the destruction of vegetation due to construction, air pollution if blasting is necessary, the resettlement of local residents to other territories, harm to populations of local animals, the chemical impact of NPPs, etc.

One of the most significant polluting factors is the thermal impact of NPPs which occurs during the operation of cooling towers, cooling systems and spray pools. They affect the microclimate, the state of waters, the life of flora and fauna within a radius of several kilometers from the object. The efficiency of NPPs is about 33...35%, the rest of the heat (65...67%) is released into the atmosphere. Under normal operating conditions, radiation contamination and the effect of ionizing radiation are minimized and do not exceed the permissible natural background. The catastrophic impact of NPPs on the environment and people can occur in case of accidents and leaks [6].

In accordance with the IAEA "Nuclear Safety Rules for Nuclear Power Plants", the designs of all systems and components of NPPs that affect nuclear safety must contain a detailed analysis of all possible failures of constituent elements, highlighting dangerous failures and assessing their consequences. Taking into account the distribution of emissions during accidents, sanitary protection zones are established at NPPs. All other types of NPP effects on the hydro- and lithosphere that are not related to radioactivity (the effect of the water supply system, inlet and outlet channels, filters), do not qualitatively differ from similar effects of TPP.

The main heat release from NPPs to the environment, as well as at TPPs, occurs in the condensers of steam turbine plants. However, the specific heat release into the cooling water at NPPs is greater than at TPPs, due to the higher specific steam consumption. This determines significant specific costs of cooling water. In connection with the foregoing, most new NPPs provide for the installation of cooling towers in which heat is removed directly to the atmosphere. The cooling water then enters the pre-cooler. This reservoir of separate use is designed to provide a closed water supply system for nuclear power plants.

The most difficult environmental problem in the operation of NPPs is the disposal of large-tonnage radioactive waste generated during the dismantling of equipment elements that are radioactive at the end of their service life or for other reasons, as well as spent nuclear fuel. Several disposal options are envisaged: placement of all radioactively contaminated elements in mine workings; burial of only the most contaminated by induced radioactivity with the reuse of the rest for their intended purpose; periodic decontamination of equipment on site with the disposal of concentrated waste and washouts. A nuclear power plant differs from any industrial facility at which an accident may occur with the release of harmful substances into the environment; in the case of an accident at a nuclear power plant, radioactive elements can enter the environment, which are the result of the life of a NPP and pose a serious danger to the environment and the population. The sufficiency of protecting the environment and the population is achieved when dose loads and concentrations of harmful substances in the media do not exceed the limiting, critical values defined in the rules and regulations for nuclear energy [7].

The impact of an NPP must be controlled at every stage of plant design and operation. Special comprehensive measures are designed to predict and prevent accidental emissions and their development, and to minimize the consequences. One of the factors of environmental protection from the impact of NPPs is the rationing of indicators, i.e. establishing acceptable values for a particular risk, and following them. Modern NPPs are built with high levels of security and safety [1].

4.3. Hydropower plants (HPP)

The main advantages of HPPs are the low cost of generated electricity, quick payback (the cost is about 4 times lower, and the payback is 3-4 times faster than at TPPs), high maneuverability, which is very important during periods of peak loads, the possibility of energy accumulation. However, the construction and operation of HPPs lead to many geoecological problems.

A huge geoecological problem of HPPs is the construction of reservoirs, which affect climate change in nearby areas and are natural accumulators of pollution. Reservoirs, necessary to ensure the uniform operation of HPPs, cause climate change in adjacent areas at distances of up to hundreds of kilometers, and are natural accumulators of pollution. Also, the construction of dams leads to flooding of nearby areas. Dams impede fish migration upstream, resulting in the impoverishment of river ecosystems [8].

To solve this problem, some countries create artificial reservoirs for fish. The most significant factors influencing local conditions are: changes in the landscape, groundwater levels, reshaping of banks, as well as changes in other natural conditions (soil, flora and fauna) in the areas of both the reservoir and the lower basin of the HPP.

The change in the hydrogeological regime of rivers during the construction of HPP is characterized by a change in the redistribution of runoff; level regime and its dependence on winds; current regimes, wave, thermal, and ice regimes. The flow rates can decrease by dozens of times, and completely stagnant zones appear in some zones of the reservoir. In shallow parts, sharp fluctuations in water temperature are observed depending on changes in air temperature.

More promising is the construction of HPPs on mountain rivers. This is due to the higher hydropower potential of mountain rivers compared to lowland rivers. During the construction of reservoirs in mountainous areas, large areas of fertile land are not withdrawn from land use [1].

4.5. Alternative energy

Solar modules cause dimming over the area, which leads to a change in the soil cover. Also, solar stations cause heating of the surrounding air, which leads to a change in the heat balance. The very production of solar modules with the manufacture of monocrystalline or semi-crystalline silicon cells is a rather dirty production.

The most significant aspect of the impact of wind energy on the environment is noise pollution. The removal of these stations from settlements and recreation areas solves the problem of the noise effect for people [8]. However, noise affects the surrounding fauna, including marine life, since wind farms are often installed in marine areas. Wind farms can influence the migration of birds and fish.

Geothermal power plants have the main impact on the natural environment during the development of the field, the construction of steam pipelines and station buildings. The potential impact of such stations may be soil subsidence. Thus, the underlying layers cease to support the upper layers of the soil, and there is a decrease in the flow rates of thermal springs and geysers. Another aspect of the influence of these stations is the pollution of surface and ground waters in case of release of concentrates during well drilling. In this case, waterlogging of the soil or salinization may occur, depending on the climate.

Hydrocarbon fuels are not burned at such stations, so emissions from such sources have a different chemical composition. Gas impurities consist mainly of carbon dioxide and contain small amounts of methane, hydrogen, nitrogen, ammonia and hydrogen sulfide. The most harmful is hydrogen sulfide [9].

Bioenergy plants are fairly clean technologies, but direct combustion of wood produces large amounts of particulate matter, organic compounds, carbon monoxide and other gases. Compared to wood, biogas is a cleaner fuel, producing no harmful gases or particles. At the same time, precautions are necessary in the production and consumption of both biogas and synthesis gas, since methane is explosive. Therefore, during its storage, transportation, use, monitoring should be carried out to detect and eliminate leaks [1].

4.6. The impact of energy on the geoecology of Armenia

The energy system of the Republic of Armenia has a significant impact on geoecology - the environment and population, social and ecological subsystems. Such an impact occurs as a result of the construction and operation of elements of the economic subsystem, namely, from NPPs, TPPs, HPPs.

As a result of the construction of the Sevan-Hrazdan HPP cascade, water intake from Lake Sevan turned out to be excessive. The ecosystem of Lake Sevan, the only major source of fresh water in the country, was disturbed [10]. The fall in the lake level, together with an increase in wastewater emissions, adversely affected the biochemical turnover of substances, led to a disruption in the normal functioning of ecosystems, which ultimately led to the process of eutrophication - an increase in the accumulation of organic substances in water. The biota of the ecosystem has qualitatively changed - from salmon to cyprinids.

This problem also affected the social subsystem - many rural residents who were engaged in fishing lost their source of income. Recently, the repair of the Arpa-Sevan hydrotechnical tunnel was completed, through which water is transferred from the Arpa River to Sevan. As a result, the water level in the lake began to rise again. This caused great harm to the environment. Now it is necessary to rationally use this resource and maximize energy production from these power plants by investing in their modernization. Recently, there has been an increase in the construction of HPPs and, in particular, small HPPs. Such stations have a much smaller impact on the environment compared to others.

The largest emissions from the energy system of Armenia are observed at TPPs. The operation of TPPs has a negative impact on both the environmental and social subsystems. Reducing the negative impact from these sources can be addressed by modernizing TPPs, while at the same time increasing their energy efficiency. The recent modernization and construction of new power units at the Yerevan and Hrazdan TPPs have made it possible to significantly reduce emissions into the environment. In addition, the new power plant will consume 2-2.3 times less fuel (natural gas) to generate 1 kWh of electricity than other power plants in the country.

In addition to electricity, NPPs produce highly radioactive, medium radioactive and slightly radioactive waste, which is also very toxic. They need to be buried in a safe place for a very long time. For many countries this problem is still not solved, but for Armenia with such a small territory it is especially relevant [1].

Now radioactive waste is stored in special canisters in a dry storage facility on the territory of the NPP. The amount of waste is 30 tons per year. Radioactive waste should be sent to Russia for disposal, but for this it is necessary to ensure their removal by rail. As we know, the road is closed due to the blockade, and it is forbidden to transport such waste by air. Building a burial ground in the country is also very difficult due to the resistance of the local population and the difficulty of finding a suitable area.

5. Conclusion

Thus, the impact of energy facilities on the geo-ecological situation is quite high, which dictates the need to develop new environmentally-centric methods and approaches to the energy development of both individual countries and regions as well as the world. The negative impact of energy on the environment significantly affects the pace of sustainable development, creating various risks and threats to security of society and ecological system.

Armenia with its main sources of electricity generation (TPP, NPP, HPP, alternative), is also exposed to these risks and threats due to the low level of environmental responsibility in the basis of the national energy policy. Therefore, consistent diversification of the energy system of Armenia, aimed at its convergent development (harmonization of conventional and alternative energy) is a strategic challenge.

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