Ecological monitoring in the impact zone of an industrial enterprise producing alumina

I I Shepelev¹,², ⁴, E N Eskova¹, E V Kiryushin¹ and O V Pilaeva³

¹ Krasnoyarsk state agrarian university, Mira Ave., 90, Krasnoyarsk, 660049, Russia
² SRO, JSC “ECO-Engineering”, South industrial Zone, quater XII, building 1, Achinsk, 662150, Russia
³ Achinsk branches of Krasnoyarsk state agricultural university, Kommunisticheskaya St., 49, Achinsk, 662150, Russia
⁴ E-mail: Ekoing@mail.ru

Abstract. Ecological monitoring in the impact zone of an industrial enterprise that produces alumina will ensure effective management of production processes. In the course of monitoring in the area of sludge farm near Achinsk alumina plant in Russia, systematic observations and timely detection of underground water contamination, determining the size of the contamination area, as well as studying the development of the underground water contamination area in time and space is carried out. In wells located in the immediate proximity of the sludge storage, maximum values of alkalinity, potassium and bicarbonate are observed and away from the sludge storage, the values of these indicators decrease. It is established that the zone of negative impact is located within 300-500 m from the contour of the sludge storage, outside of which the chemical composition of underground water almost corresponds to the background. Monitoring studies of the soil in the area adjacent to the sludge storage showed their recovery after reclamation and phytosanation. The analysis has shown that the ecological monitoring system at JSC “RUSAL Achinsk” combines all the necessary components: instrument and hardware maintenance, a measurement organization system, and a set of methods for analyzing the results of observations, providing all the necessary conditions for its implementation in practice.

Information about the state of the natural environment and changes in this state in the course of production activities has long been used in world practice [1-3]. In the civilized world, for more than 100 years, observations of changes in weather and climate have been conducted regularly. The range of observations, the number of measured parameters, and the network of observation wells around hazardous industrial facilities are becoming ever wider. Problems related to ecological monitoring are becoming increasingly complex. When solving these problems, there is an urgent need for routine monitoring of the environment, and each large industrial enterprise must create its own local monitoring system. In this case, both natural and anthropogenic ecosystems can be monitored. At the enterprises of the aluminum industry, much attention is paid to the organization of ecological monitoring systems [4-5]. One of the largest industrial enterprises of alumina and soda production in Russia is Achinsk alumina plant (JSC “RUSAL Achinsk”), which for the first time in the world mastered the method of obtaining alumina from nephelins by sintering [6]. The plant has created an ecological monitoring system, new technologies for cleaning gas emissions into the atmosphere are
being introduced, and water protection facilities are being reconstructed to eliminate the discharge of pollutants into open reservoirs, while using closed water circulation systems. Since 2003 the ISO 14001 ecological management system has been implemented and is successfully functioning.

The purpose of this work was to classify and analyze the functioning of ecological monitoring systems by sources, factors and scale of ecological impact in the impact zone of an industrial enterprise producing alumina.

Ecological management at an industrial enterprise involves the management of technological processes and the management was quite effective, it is necessary to have data on the dynamic properties of these objects, their modification by anthropogenic impacts, to foresee the consequences of production interference in the natural processes of the ecosystem. The main task of ecological monitoring is to maximize the provision of reliable information for ecological safety and ecological management systems, on the basis of which: assessment of the state indicators and functional integrity of the environment can be made, identification of reasons for deviations in ecological indicators and assessment of the consequences of such changes of indicators.

JSC "RUSAL Achinsk" is the 1st category enterprise in terms of gross air emissions. In this regard, the main direction in the production of works should be compliance with the rules and standards of ecological safety to prevent excess emissions of pollutants into the air, pollution of the environment with waste, pollution of surface and underground waters. For this purpose, this industrial enterprise has developed and is implementing in practice a comprehensive program for ecological production monitoring of ecological indicators. When implementing the integrated ecological monitoring program, JSC “RUSAL Achinsk” continuously assesses the ecological conditions of the human environment and biological objects, as well as assesses the state and functional integrity of ecosystems, while creating conditions for determining corrective actions in cases when the target indicators of ecological conditions are not achieved. The system of integrated ecological monitoring provides for: selection of the observation object; survey of the selected object of observation; preparation of an information model for the object of observation; measurement planning; evaluating the object state of observation and identification of its information model; forecasting changes in the object state of observation; providing information in a convenient form and communicating it to the personnel of the enterprise and controlling organizations.

One of the most complex objects of local monitoring is the sludge storage facility of JSC “RUSAL Achinsk”. The sludge storage area of 451 ha consists of three maps: map № 1 (190 ha), map № 2 (115 ha) and map № 3 (146 ha). Operation of the sludge storage facility (map № 1) started in 1970. Map № 1 was designed and executed without an anti-filtration screen, which is due to the lack of relevant regulatory requirements during the project development period. Map № 1 receives nepheline sludge from the main production, ash and slag from the heat and power plant in the form of pulp. Sludge map № 2 was constructed with an anti-filtration screen made of tape, 1.0 mm thick, and was put into operation in 2003. Currently, maps № 1 and № 2 are almost full and are being decommissioned. In order to prevent filtration water from entering natural reservoirs, protective channels have been constructed along the perimeter of map № 1 and map № 2, from which filtered water is constantly pumped to circulating systems. All the generated nepheline sludge is sent to the sludge map № 3, and the recycled alkaline water is returned back to the alumina production process. The sludge storage facility is a high-pressure hydraulic structure, which causes unavoidable filtration losses and an unconditional impact on the underground hydrosphere and surface water. The dynamics of industrial effluent filtration in the process of filling the sludge storage maps is constantly changing due to the increase and redistribution of pressure, as well as compaction of soil due to increasing static pressure. Monitoring of underground water quality is an integral part of general safety monitoring, which is a system of observations and control conducted regularly according to a specific program to assess the condition of structures, analyze processes occurring in them and timely identify trends in their changes.

The tasks of ecological monitoring of underground water in the area of the sludge farm near JSC “RUSAL Achinsk” are:
systematic observations and timely detection of underground water contamination,
determining the size of the contamination area;
assessment of the scale and direction of modern underground water pollution;
studying the development of the underground water pollution area over time and space.

The network of observation wells is located taking into account the existing geomorphological
position of the sludge storage and the direction of the natural flow of underground water. Underground
water is fed by infiltration of atmospheric precipitation in places where it reaches the surface and
flows from neighboring water horizon, and discharge into rivers and adjacent horizons. The presence
of water-resistant layers makes it difficult to communicate hydraulically with surface water, which in
the case of contamination ensures the transit of substandard water over sufficiently long distances. The
natural drainage is the Chulym River. The terrigenous water horizon complex is composed of weakly
cemented sandstones, siltstones, interlayers and layers of mudstones and brown coals. Water horizon
is separated from alluvial deposits by a weathering crust with a thickness of the first meters,
represented by loam with rubble and sandstone dredging. Eluvium is considered as a water barrier,
albeit there is no sufficient evidence for this. Water-accommodating rocks are sandstones and
layers of brown coals. Water supply coefficients vary from 24 to 190 m²/day. According to
monitoring studies on the chemical composition, at a distance from the sludge storage, the water of the
alluvial horizon is bicarbonate magnesium-sodium with a mineralization of 510-520 mg/dm³, pH 7.3-
7.5. The hardness does not exceed 6 mg-eq/l. The water temperature is 4-6°C. The total flow of
underground water is directed in the north and north-east directions to the regional discharge area - the
Chulym riverbed. The regional feeding area extends in the south to the outcrops of the fractured rocks
of the Arga range.

The evaluating the chemical contamination degree of underground water was carried out by
comparing quality indicators in relation to the maximum permissible concentration (MPC) for
drinking water. In the area of sludge management, hygiene standards for drinking water exceed the
hydrogen index, permanganate oxidation, aluminum, petroleum products, iron, sodium, and sulfates.
The maximum exceeding of hygienic standards for the majority of underground water quality
indicators observed in wells located in the proximity of sludge pits, as the removal of sludge from the
content of contaminants is reduced to values lower than the MPC for drinking water in extreme
observation wells on the sites. At the same time, the content of nitrates, nitrites, magnesium, chlorides,
phenols and the hardness index is significantly lower than the MPC. There are no hygienic standards
for drinking water for indicators of alkalinity and content of calcium, potassium and bicarbonates.
Maximum values of alkalinity and grade of potassium and bicarbonate are observed in wells located in
the proximity of sludge pits, as the removal of sludge from the values of these parameters is much
lower.

The penetration of drainage sludge into the alluvial water horizon causes an increase in the
hydrogen index, aluminum and sodium oxides in underground waters to values exceeding hygienic
standards. The negative impact of sludge storage on underground horizons has a limited area of
distribution. The zone of negative impact is located within 300-500 m from the contour of the sludge
storage, outside of which the chemical composition of underground water almost corresponds to the
background.

The results of water analysis in the Chulym River in recent years indicate a significant
improvement. Thus, the value of the pH of river water 500 m below the discharge of water from the
thermal power plant of JSC “RUSAL Achinsk” in 2015 along the river was 9.0. In 2019 the water was
almost neutral (pH = 7.0-7.2) This is due to the fact that with the commissioning of two modern
cooling towers necessary for cooling the water of the CHPP, the outlet № 1 to the Chulym River was
eliminated with the organization of a closed water circulation system [7].

The soils are not saline and have relatively high fertility and high resistance to anthropogenic
influences on the impact territory of the enterprise. Everywhere, except for wetlands, chernozems are
used in agricultural land for the production of mainly forage crops, as well as in the form of pastures
and hay meadows. However, in some areas near the sludge storage, soil degradation was noted due to
the filling of sludge water from the bypass channel of the sludge map. To restore disturbed land, the enterprise jointly with the Krasnoyarsk state agrarian university has developed a technology using non-toxic technogenic materials for this purpose. Monitoring studies of the soil in the area adjacent to the sludge storages showed their recovery after reclamation and phytosanation [8].

Soil monitoring showed that the change in soil temperature during the year is similar to the change in air temperature. Negative values of temperature on the soil surface are observed from November to March, positive values from April to October. The average annual soil temperature is 2°C, which is 1.5°C higher than the air temperature. In winter, the average monthly temperature of the soil surface differs little from the average air temperature (the difference is less than 1°C). The lowest temperatures on the soil surface are observed in January at depths of 20-40 cm and 80 cm in February. At depths of 160 and 320 cm, the minimum is in March-May.

The lowest relative humidity (53-62 %) is observed in April-June, due to the rapid warming of the surface layers of air and a small amount of precipitation. By August, its value increases, reaching 76%.

The annual precipitation within the city of Achinsk is 520 mm. Maximum precipitation (up to 72 %) falls during the warm period. During the year, the fifth of precipitation (about 20 %) falls in solid form. During the transition months (March, April, October, November), mixed precipitation falls in the form of snow with rain, sleet, and freezing rain, all together accounting for 9 % of the annual precipitation. The lowest monthly precipitation (20-21 mm) is observed in February-March. Since April, the amount of precipitation gradually increases, reaching a maximum in July (71 mm).

Snow cover appears in mid-October. The earliest date of its appearance is September 4, and the latest is November 9. Usually, the first snow cover is short-lived and disappears when warming. The average multi-year date for the formation of a stable snow cover is November 4. Snow density is not constant. At the beginning of winter, it is 0.15 g / cm³. At the end of December, the density is constantly increasing and reaches the highest values (0.24 g / cm³) in the first decade of February. The water supply in the snow is 50-55 mm. The presence of dust particles (silicon and calcium oxides) in the snow cover caused by anthropogenic impact of gas emissions from sintering furnaces was noted.

Plans of enterprises ecological activities are planned in the near future, design and industrial implementation of the following technical solutions; improve the ecological situation in the zone of its influence on the environment:

- the liquidation of № 2 sewage Mazul limestone quarry in the Matulka River and guide them to pools for use in preparation of a raw batch of aluminous;
- creation of an additional third stage of "wet" emissions cleaning from sintering furnaces into the atmospheric air, which reduces the content of fine dust in emissions;
- restoration of lands contaminated sludge water, sludge in close proximity cards with the use of non-toxic technogenic materials;
- performing reclamation of the sludge maps № 1 and № 2 surface after their decommissioning.

The set of ecological monitoring measures carried out by JSC “RUSAL Achinsk” is based on a sequence of monitoring stages: measurement - analysis - description - modeling – design - optimization. At the same time, monitoring studies will determine the levels of pollutants in various environments, their distribution in space and time, the magnitude and speed of the pollutants flow, and possible ways of their transformation. An equally important problem in ecological monitoring is the problem of analyses results comparability performed by different laboratories. For this purpose, the company has its own two accredited laboratories. According to its structural and functional composition, the ecological monitoring system at JSC “RUSAL Achinsk” combines all the necessary components: instrument and hardware maintenance, a measurement organization system, and a set of methods for analyzing observation results that are necessary for its implementation in practice. Financial and technological support of the ecological monitoring system is also an important issue in organizing the full functioning of the ecological monitoring system. JSC “RUSAL Achinsk” pays great attention to this issue and annually re-equip the hardware of measuring equipment used for monitoring. The negative consequences of economic activity and the technogenic impact of industrial production on the environment for the biosphere today are already an objective reality, but the
negative results of anthropogenic impact in modern conditions of human civilization development are not inevitable. In many ways, ecological degradation is associated with the irrational use of natural resources, the low level of development and further implementation of modern waste-free technologies, errors in ecological and technical policies, and the lack of knowledge about the possible consequences of anthropogenic impact on the ecosystem.

Thus, continuous ecological monitoring, proper use of its results and determination of trends in ecological indicators are extremely important for long-term forecasting of the quality of the ecological system and practical actions to improve it in the impact zone of an industrial enterprise.

References
[1] Krasnogorsk N N, Fashchevskaya T B and Rogozin T A 2006 Assessment of quality of water objects in the conditions of anthropogenic influence (Ufa. UGATU Publishing house) 278 p
[2] Vetrov V A, Kuzovkin V V and Manzon D A 2015 Kislotnost of an atmospheric precipitation and loss of sulfur and nitrogen in the territory of the Russian Federation according to monitoring of the chemical composition of snow cover Meteorology and Hydrology 10 44-53
[3] Barinova S and Krupa E 2017 Bioindication of Ecological State and Water Quality by Phytoplankton in the Shardara Reservoir Kazakhstan. Environment and Ecology Research 5 73-92
[4] Sizyakov V M, Vlasov A A and Bazhin V Yu 2016 Strategic problems of a metallurgical complex of Russia Non-ferrous metals 1 32-8
[5] Gaponyuk E I 1983 Degree and environmental impacts of fluoride pollution Hydrometeorology, series: control of pollution of the environment, survey information p 55
[6] Arlyuk B I, Layner YuA and Pivnev AI 1994 Complex processing of alkaline aluminum-bearing raw materials (Moscow: Metallurgy) 384 p
[7] Shepelev I I, Nemerov A M, Eskova E N, Zhukov E I, Sakhachev A Yu, Pilyaeva O V, Kiryushin E V and Potapova S O 2020 Reduction of anthropogenic impact of alumina sludge storage on the environment Ecology and industry of Russia 24 2 4-9
[8] Nemerov A M, Shepelev I I, Eskova E N, Kniga Y A and Orlegova N V 2019 The use of nontoxic technogenic and natural materials to ensure the stability of disturbed ecosystems Collection of materials of the interun. scientific and practical conference "Science and education : experience, problems, development prospects 315 5