Use of waste water formed on the Absheron Peninsula to irrigate the green areas

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Abstract. *This article examines methods for treating wastewater generated in the city of Baku and its surrounding residential areas, as well as ways to utilize this water resource for the establishment of forest plantations on vacant lands located on the Absheron Peninsula . Against the backdrop of a potential water shortage resulting from the depletion of water reserves in the streams feeding the Samur-Absheron Canal system due to global climate change, the paper emphasizes the need for more efficient use of the wastewater reserves generated in the region. It is considered appropriate to collect this water reserve and use it for the irrigation of oak forestry to be planted around industrial zones.*

Keywords: *wastewater, water supply, rivers, water treatment plant, forestry.*

Introduction. The Absheron Peninsula is considered one of the Republic's most water-scarce regions. The annual precipitation on the peninsula is less than the norm, at 200–250 mm; there are no surface water reserves, and the majority of groundwater is saline. For this reason, the water supply for the city of Baku and the Absheron Peninsula is entirely dependent on water brought in from outside the region. Currently, the water supply for residential areas, industrial zones, and agricultural lands on the peninsula is primarily provided by water reserves collected in the Takhtakorpu and Geyranbatan reservoirs via the Samur-Absheron Canal. Global climate change, which is occurring worldwide, has begun to be felt in Azerbaijan as well. According to the latest findings of global scientists studying climate change, it is projected that by 2050, water reserves in the South Caucasus region will decrease by 25–30%/1/. Significant decreases have also occurred in the water reserves of the Samur River, the main source of the Samur-Absheron Canal system. Hydrological studies indicate that, due to the effects of global climate change, a decrease of 20–25% in the water reserves of the Samur River has been observed. It appears that the average annual flow has been declining since the 1970s and that this process continues with a downward trend.

Against this backdrop, the use of treated wastewater for irrigating green spaces on the Absheron Peninsula and for meeting the growing water demand of certain industrial sectors has become a pressing issue. Since approximately 40% of the country's population and 70% of its industrial potential are concentrated on the Absheron Peninsula, the majority of the environmental problems that need to be addressed are found in this region. One of the main environmental problems on the

Absheron Peninsula is related to soil and air pollution. The total area of the Absheron Peninsula is 222,000 hectares; the total area of its contaminated soils is 33,300 hectares, of which oil-contaminated soils account for approximately 10,000 hectares. In recent years, the expansion of the areas occupied by limestone quarries located in the Garadag district has created serious environmental problems. The full industrialization of the peninsula and the existing semi-arid natural conditions have reduced the soil's ability to regenerate to zero. The main causes of these environmental problems are the contamination of the soil with oil and sludge during oil and gas production and drilling operations over many years, and the accumulation of waste generated during oil extraction on the land. One of the main environmental problems in the city of Baku is air pollution. In recent years, the increase in the number of vehicles and the burning of waste in landfills have led to a rise in the amount of harmful substances released into the atmosphere, posing a serious threat to the environment and human health.

In 2023, the total volume of pollutants emitted into the atmosphere from stationary sources and vehicles in the country amounted to 965.1 thousand tons, of which 85.0 percent, or 820.8 thousand tons, came from vehicle emissions. In the city of Baku, 475,000 tons of emissions released into the atmosphere were attributable to motor vehicles, while 215,000 tons were attributable to stationary sources. In connection with the rapid development of the construction sector, the use of natural stone deposits located on the Absheron Peninsula has expanded significantly, which has led to a sharp increase in dust levels in the surrounding areas. The villages of Sahil, Sangachal, Gobustan, Guzdak, Korgoz, Gızıldash, and Buta, Gobu, and Lokbatan, where higher dust levels are observed, and during windy weather, the amount of dust in the air increases sharply, far exceeding permissible limits. In particular, when northern winds blow, the dust released into the air from these areas causes the background dust level in the villages of Sahil, Sangachal, and Gobustan to be 2–3 times higher than normal. The dust cloud formed in this area due to the influence of winds blowing from the southeast is also significantly felt in the central parts of Baku (Figure 1).

Figure 1. Dust-laden air conditions in Baku.

There is no green zone between the seashore and the areas where these industrial facilities are located. These areas are currently unused. Our preliminary research indicates that **a Green Zone** could be created on these currently unused areas, which extend up to 30 square kilometers from the factories to the sea. To supply the proposed Green Zone with irrigation water, it is appropriate to utilize the groundwater resources formed in the southwestern part of the Absheron Peninsula (in the direction of Lokbatan-Gobustan). The complete industrialization of the peninsula and the existing semi-arid natural conditions have reduced the soil's ability to regenerate to zero. The main causes of environmental problems here are the contamination of soils with oil and sludge during oil and gas production and drilling operations over many years, the formation of oil-contaminated artificial lakes and ponds due to the lack of proper management of wastewater, and the accumulation of sludge generated during oil extraction on the land.

Environmental conditions on the Absheron Peninsula. In recent years, the exploitation of existing stone reserves on the Absheron Peninsula has expanded significantly. Compared to the 1980s, the areas used for stone extraction have expanded by 10 to 15 times. Currently, stone quarries are operating on up to 1,500 hectares of land in the southwestern part of the peninsula, in the areas west of the villages of Gobu and Gobustan. Although some quarries in these areas have ceased operations, the accumulated waste piles act as a significant source of dust in windy conditions. When strong northern winds blow, dust levels in the atmosphere in the southwestern part of the peninsula are observed to be 2–3 times higher than normal, which poses serious health risks to the local population. In windy weather, air quality indicators in the Garadakh district—specifically around the villages of Lokbatan, Gobu, Guzdek, Gızıldash, Gobustan, Sangachal, and Sahil villages in the Garadağ district, air quality indicators deteriorate sharply, posing a serious threat to population health.

Currently, there are up to 150 quarries in this area, and the total area of these quarries is approximately 1500 hectares. Waste discharged from the quarries into the surrounding area is a major source of dust pollution. Observations indicate that the environmental situation is particularly severe in the villages of Guzduk and Gızıldash, which are located within the quarries' impact zone. Even during light winds, the dust levels in these villages are several times higher than the norm. During strong winds, the dust level in the village is 100 times higher than the norm, and as a result of the impact of these quarries, the dust level in the western part of the peninsula is also higher than the norm. In general, since vegetation cover is sparse on the Absheron Peninsula and adjacent areas, wind erosion is rapid, which contributes to high dust levels in the city.

Use of wastewater for irrigation.

Wastewater from populated areas is valuable for agriculture; while addressing the issue of fertilization, it also solves the problem of irrigation—supplying plants with the moisture they need. The use of wastewater in agriculture has been known since ancient times (Rome, Athens, Babylon, etc.). In Germany, irrigation fields have existed since 1559; in the United Kingdom (Edinburgh) since 1709; in France (Paris) since 1868; and in Russia since 1887 in Odessa, since 1895 in Kyiv, and since 1898 in the Moscow Region. In the former USSR, wastewater irrigation in agriculture has been used since 1922. Wastewater undergoes preliminary treatment before being used for irrigation. Municipal wastewater is widely used for irrigating agricultural land in India, the United States, Israel, Mexico, and a number of other countries. In some cases, significant volumes of domestic wastewater are directed toward agricultural needs. For example, most of Mexico City's wastewater is used to irrigate 80,000 hectares of land, primarily planted with alfalfa, corn, barley, and oats [8,9]. In a number of countries (Cyprus, Israel, Jordan, Peru, Saudi Arabia), the use of wastewater for irrigation is a matter of state policy. For example, in Cyprus, the entire volume of treated wastewater is used for crop irrigation, and in Israel, several hundred basins and reservoirs have been installed to collect and reuse treated wastewater, the volume of which in 2000 amounted to approximately 300 million m^3/year. In this country, more than 70% of all urban wastewater is reused **/6, 8, 9/.** Irrigation of green spaces with treated wastewater is widespread in the United States, Latin America, Australia, Mediterranean and Arab countries, and North Africa **/9/.** Wastewater is widely used, particularly for irrigating parks, street lawns, golf courses, roadside green belts, and other areas. In Uzbekistan, wastewater was used for growing cotton, corn, alfalfa, and other crops.

To improve the ecological situation on the Absheron Peninsula, green belts should be established around existing factories on the peninsula and on the sites of decommissioned factories. Studies show that planting a forest of coniferous trees, which capture more dust, is more appropriate for this purpose. In this region, which faces a serious water scarcity problem, it is possible to make extensive use of the surface water reserves formed on the peninsula for the planting and irrigation of oak forests **/1,2,3/.** The Azerbaijan State Water Resources Agency (ASWRA) has prepared a Master Plan for the collection and treatment of wastewater generated on the Absheron Peninsula, taking into account development up to the year 2035.

Within the framework of the Master Plan, it is envisaged that wastewater generated in all residential areas on the Absheron Peninsula will be collected, treated through purification facilities, and discharged into the sea. Taking into account development projections through 2040, it is estimated that up to 1.7 million cubic meters of wastewater will be generated daily across all residential areas on the Absheron Peninsula. By collecting and managing this volume of wastewater, it will be possible to supply irrigation water to up to 120,000 hectares of green spaces. Within the framework of the Master Plan, several large-scale wastewater treatment plants are planned for the western part of the peninsula (Table 1).

Wastewater treatment plants planned for the western part of the peninsula (Table 1).

No.	Wastewater Treatment Plants (WWTP)	Capacity M^3/day
1.	Coastal WWTP	10,000
2.	Lokbatan WWTP	300,000
	TOTAL	310,000

As shown, this area will generate up to 310 million cubic meters of domestic wastewater per day. This amounts to a total annual water supply of 110 million cubic meters. By utilizing this treated wastewater, it is possible to supply water for irrigation (using drip irrigation) to a forest area of up to 25,000 hectares in the Lokbatan-Gobustan region. By creating such a forest area in the vacant land between the Baku-Salyan highway and the stone quarries, it is possible to significantly improve the existing ecological situation. The new forest area to be created will also be of great importance to the local population as a recreational park.

To irrigate the crops to be planted in these areas (during the spring and summer months), approximately 0.55–0.6 million cubic meters of water are required per day. As can be seen, during the growing season—when the demand for irrigation water is highest—the volume of treated wastewater discharged from WWTP s amounts to 0.31 million cubic meters per day and does not meet the demand. To ensure a reliable supply of irrigation water for the forest area to be planted, it is necessary to collect the water discharged from the WWTP s in reservoirs during the 6 month period (winter months) when irrigation is not carried out. As shown in the calculations, during the autumn and winter months that is, over a 6 month period, it is necessary to collect and store 55.80 million cubic meters of treated wastewater (V = 310,000 × 30 × 6).

Hydrological studies conducted in the area indicate that there is a suitable reservoir site in the low-lying mountainous region of Gobustan, near the Shongar villagy, for the collection and storage of this volume of water. During the winter months, water collected in the WWTP can be pumped into a reservoir to be constructed in the area before it flows into the sea. During the spring months, irrigation water from this reservoir can be directed toward irrigating the forest massif under a gravity-fed system. The “Shongar” water reservoir, with a useful capacity of 65.0 million cubic meters, is planned to be located 20.0 km west along the Lokbatan valley at an elevation of 100.0 meters. Wastewater to be treated at the Lokbatan and Sahil WWTPs will be discharged into this reservoir. A 20.0 km long water pipeline with a diameter of DN1800 mm must be constructed to convey water from the Lokbatan and WWTPs to this reservoir. Treated water will be pumped to the “Shongar” reservoir via a pumping station (capacity N = 6,500 kW, head H = 170 m) to be constructed at the outlet of the Lokbatan WWTP.

Additionally, a 21 km long, DN500 mm diameter pressurized water pipeline must be constructed to collect water generated at the Sahil WWTP and transfer it to the “Şonqar” reservoir during the winter months. By constructing a pumping station with a capacity of N = 335 kW and a head of H = 170.0 m at the outlet of the “Sahil” WWTP, it will be possible to transfer the treated wastewater to the “Shongar” reservoir. The layout plan for the reservoirs that will collect the wastewater is shown in Figure 2.

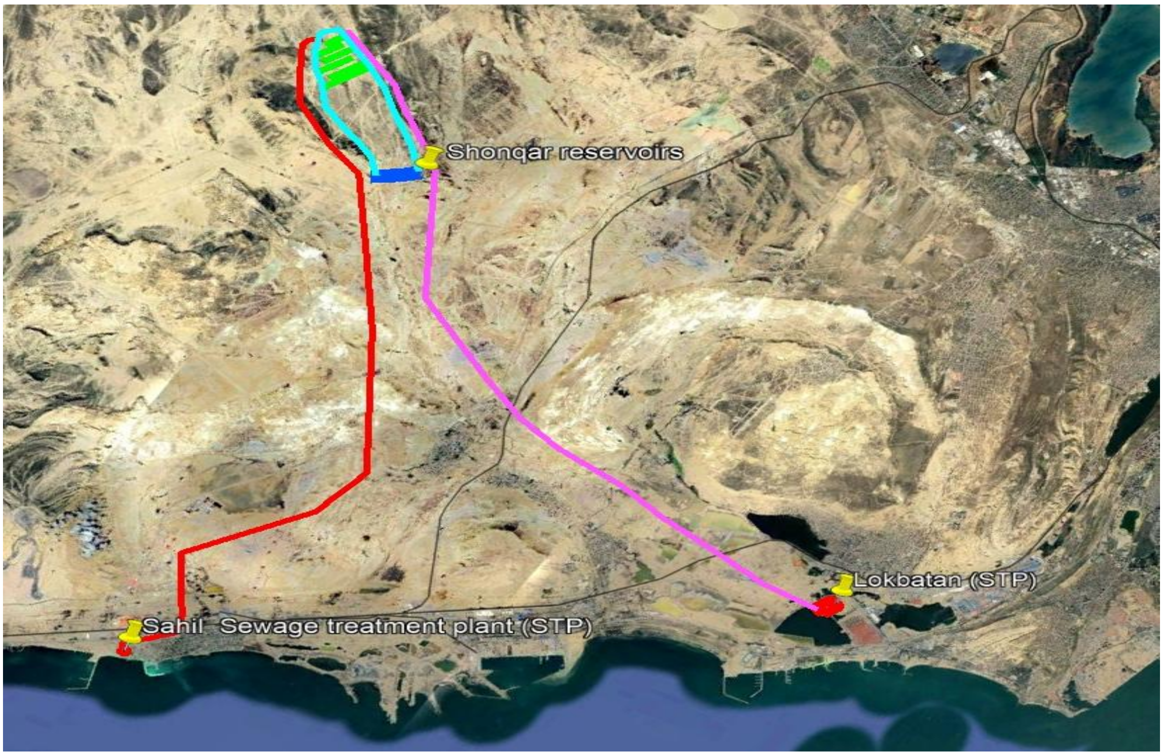

***Figure 2. Layout plan for the reservoirs that will collect wastewater*.**

Proposals regarding the re-deep treatment of treated wastewater.

In accordance with the requirements of the technical specifications of the Azerbaijan State Water Resources Agency (“ASWRA”), wastewater is treated through a biological treatment process and discharged into the deep part of the sea at a depth of 10 meter using special diffuser structures. The treatment process consists sequentially of a lattise, a sand trap, a primary clarifier, a biological aeration tank, a secondary clarifier, and a disinfection unit, and is treated to meet discharge standards before being released into the sea (Figure 3).

In accordance with the requirements of the technical specifications, the Wastewater Treatment Plant (WWTP) must be designed to treat wastewater to meet the water quality standards shown below (Table 2).

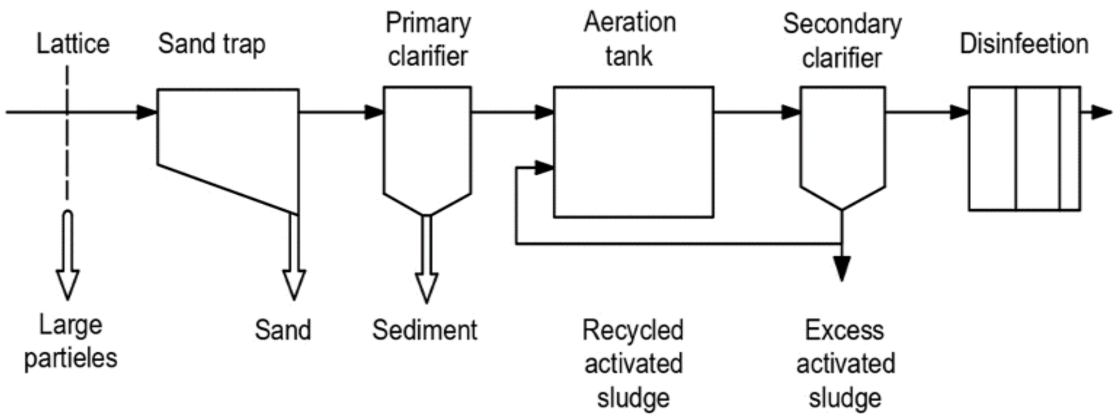

Figure 3. Diagram of the biological wastewater treatment process.

Standards for water discharged from the treatment plant (Table 2)

Chemical parameter	Unit of measurement	Amount
Biochemical oxygen demand (BOD_5)	mg/L	25
Chemical oxygen demand (COD)	mg/liter	125
Suspended solids (SS)	mg/L	35 (N > 10,000) 60 (N = 2,000–10,000)
Phosphorus (P)	mg/liter	2 (N = 10,000–100,000) 1 (N > 100,000)
Nitrogen (N)	mg/liter	15 (N = 10,000 – 100,000) 10 (N > 100,000)

The design of the treatment plants and coastal WWTP s has been developed in accordance with the requirements set forth in Table 2. Biological ponds are widely used in global practice to thoroughly treat the treated wastewater collected in the storage tank. The aquatic plants cultivated in these ponds enable the retention of petroleum products, phenols, and heavy metals present in the wastewater, thereby significantly improving water quality. Currently, several types of biohydrobotanical methods are proposed for the advanced treatment of wastewater. The biohydrobotanical method of wastewater treatment is based on biochemical processes of oxidation, filtration, absorption, accumulation of organic and inorganic substances, mineralization, detoxification, adsorption, chemisorption, and others. A high purification effect is achieved where water flows through a community of semi-submerged, floating, and submerged plants. The slime (periphyton) present on the surface of plants, as well as the reduction in fluid flow velocity in overgrown areas, promotes the precipitation of suspended organic and mineral substances, which increases water clarity. Higher aquatic vegetation is capable of detoxifying various harmful substances discharged into the water body. They absorb pesticides—such as sevin and atrazine. As they are absorbed by plants, toxic substances are inactivated through various chemical transformations. Moreover, the depth of submersion and the concentration of absorbed elements significantly influence the intensity of absorption of organic and mineral substances. The root system of higher aquatic vegetation releases bactericidal substances—phytoncides—resulting in the disinfection of the water body **/7/.**

Thus, the trace element composition of plants is closely linked to the composition of the substrate on which they grow. Plant roots penetrate the filter media (usually gravel), through which the water being treated flows in a continuous stream. During wastewater treatment in a bio-plateau, most organic substances—both in solution and in particulate form—decompose into carbon dioxide and water. This process demonstrates high efficiency in removing biogenic elements, toxic metals, and pathogenic microorganisms. Plants assimilate biogenic substances into their biomass, and conditions are created in the rhizosphere that enhance the activity of biochemical reactions; that is, macrophytes serve as catalysts for the treatment processes. According to the results of industrial-scale experimental studies on the treatment of domestic wastewater using water hyacinth in the United States, the BOD5 removal rate reaches 97–98%. The following types of higher aquatic plants are most commonly used in wastewater treatment: common reed, lake reed, narrow-leaved and broad-leaved cattail (Fig. 4), crested and curly pondweed, elodea, water hyacinth (Eichhornia), sedge, water milfoil, stone-wort, iris, and others **/6.7/.**

Fig. 4. Cattail (Latin: Týpha) — the only genus of plants in the monotypic family Typhaceae

Studies have shown that the root system of cattail has a high capacity to accumulate heavy metals. The concentration of metals in the root system of cattail growing on the banks of power plant sludge ponds reached (mg/kg): iron—199.1, manganese—159.5, copper—3.4, zinc—16.6. Riparian and aquatic vegetation, by releasing oxygen during photosynthesis, has a beneficial effect on the oxygen regime of the riparian zone of the water body. Bacteria and algae (periphyton) inhabiting the surface of plants play an active role in water purification. Under the influence of all these processes, the dissolved oxygen content in the water increases, its transparency and the content of biogenic substances rise, while water mineralization and the amount of intermediate organic decomposition products decrease **/7,8,9/.**

We propose the use of biohydrobotanical methods to further purify the water waste from Lokbatan and Sahil WWTP and collect it in a water reservoir. At the inlet of the water reservoir, it is necessary to create a biological filter using reeds, common reed, narrow-leaved and broad-leaved cattails, crested and curly pondweed, elodea, water hyacinth, sedge, and other plants to create a biological filter and ensure that the wastewater flows through it at a very slow rate.To prevent stagnant zones within the biological filter, walls that direct the flow have been installed inside the filter. A concrete weir has been installed at the end of the biological filter to ensure that the flow enters the water tank evenly. Depending on the flow rate, it is recommended that the water velocity in the biological reactor be maintained within the range of (0.07–0.08) m/s. During calculations, the retention time of the influent in the biological reactor should be estimated at approximately (1.5–2) days. The layout plan of the proposed advanced treatment system is shown in Figure 5.

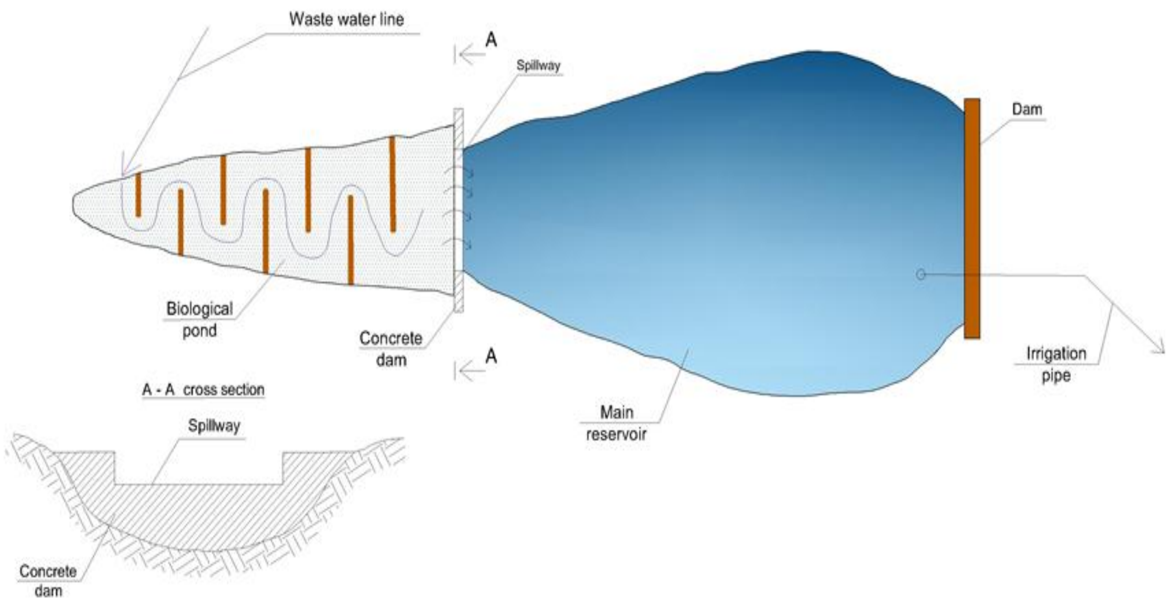

Figure 5. Schematic diagram of the system for the thorough treatment of wastewater in the biological treatment tank located at the inlet of the reservoir.

By utilizing the treated wastewater collected in the reservoir to be constructed, around the Baku-Alat highway,around the Garadagh cement plant, and in the Gobustan Reserve area. The plan for the forest to be planted on the site is shown in Figure 6.

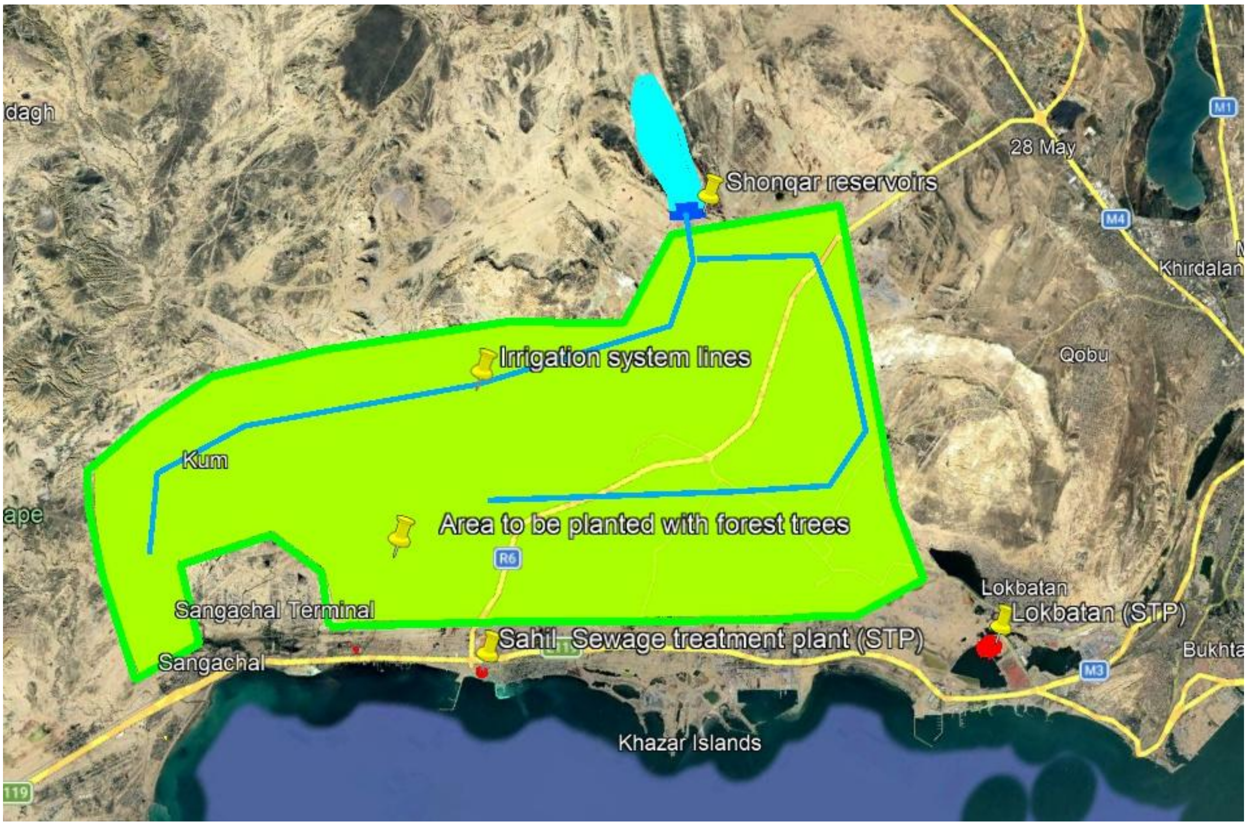

Figure 6. Plan of the forest area to be created

In this planned forest area, specific tree species should be planted primarily to partially capture dust generated by industrial facilities. The best trees for dust capture are those with coarse, hairy, or sticky leaves, as well as coniferous trees. Coniferous trees such as spruce, black pine, larch, fir, cypress, juniper, and thuja are considered the best. These trees effectively capture fine dust particles due to their large leaf surface area and resin secretion. Among these trees, the poplar traps the most dust. The tree's broad, slightly sticky leaves trap dust perfectly, and a single tree releases a lot of oxygen. Black poplar and aspen trees also collect up to 50% more dust. Coniferous trees (pine, spruce, fir) trap dust throughout the year thanks to their needles and sticky resin. To achieve a greater effect, it is recommended to plant a mixed forest of trees and shrubs in a dense manner.

Water to be purified in water purification facilities will be pumped directly into water reservoirs located at the highest points of the area. To ensure that the new forest to be planted in the area is supplied with irrigation water, an irrigation network must be established that draws water from these reservoirs. Planting the forest in this manner will help partially mitigate the dust pollution currently frequently observed in this area. The creation of these green zones will be an important step toward providing recreation for the population and protecting and improving the environment. Perhaps, with the creation of the forest massif, it will be possible to counteract the discharge of wastewater into the sea and make maximum use of water reserves. Reusing wastewater will allow for more efficient use of the freshwater reserves entering the peninsula.

Conclusion

1. A green belt of dust-trapping coniferous trees should be created on an area of up to 30 hectares located between the quarries currently operating along the Baku-Salyan highway in the Garadagh district.

2. In the Lokbatan – Sangachal district of Baku, the water collected from the 310,000 cubic meters of runoff generated daily and treated in the purification facilities to be constructed should be used to irrigate the newly planted forestis considered appropriate.

3. It is appropriate to collect and store the water reserves generated during the winter months in the wastewater treatment facilities of Lokbatan and Sahil and to use them for irrigating the forest in the summer months.

4. In the Lokbatan – Sangachal zone, there is a need to construct a water reservoir in the Gobustan Desert with a useful capacity of 65.0 million cubic meters to collect and store the 55.0 million cubic meters of wastewater generated during the winter months and use it for irrigation during the summer months. with a useful capacity of 65.0 million cubic meters.

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