Chapter 24

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Smart Cities and Environmental Water Pollution

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ABSTRACT

In this period, when the processes of industrialization and urbanization are accelerating, a number of environmental problems are manifested. Many sources used as energy in industry eventually have a negative impact on the environment, pollution occurs, and living organisms are also affected by them. Environmental pollution causes many different diseases in humans. Cancer is the most dangerous of them. The substances that cause this disease react with the environment inside various things and eventually spread to wider areas. One of them is organic pollutants, which are Polycyclic Aromatic Hydrocarbons. In the article, the urbanization process that causes ecological pollution, the factors affecting it, PAHs, which are organic pollutants, their discharge into the waters through oil, polluting the sea and ocean waters, and this process in general, over the Caspian Sea, were reviewed. Various analyzes were performed and the results were recorded. In addition, simple steps to prevent pollution are also mentioned at the end.

Keywords: Urbanization; Smart Cities; Industrialization; PAH; Environmental Pollution; Oil; Caspian Sea.

INTRODUCTION

The processes of ruralization and urbanization have recently been developing at an equal speed. In the very recent past, the acceleration of the urbanization process and the migration of people to cities have had many negative effects on agriculture. Countries probably took this into account and began to pay attention to the development of agriculture.

Many important factors were manifested in the desire of people to move to cities. Many of them went to the cities out of necessity rather than desire. This, in turn, led to the increase and acceleration of the urbanization process.

We can mention some of the factors influencing the acceleration of this process.

It is known that the birthplace of industrialization is cities, or in other words, the places where industry has set foot become urbanized later. Employment—most likely in the recent past—before agricultural innovations—was greater in cities, and that was the factor that most attracted people. Socialization was another key factor in accelerating urbanization. And also, other factors.

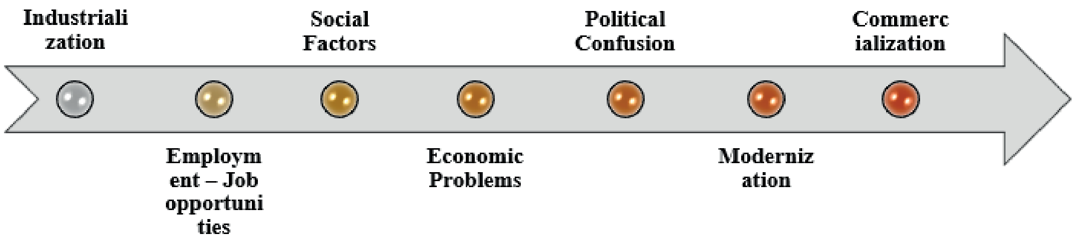

Figure 1. Some factors affecting the urbanization process

According to forecasts, at least 70 % of the world's population will live in cities in the near future - around 2050.

But the introduction of innovations – the introduction of smart village projects along with the application of smart technologies – in agriculture still makes people hopeful about the villages. However, there is still a stronger project than the smart village project. This is the Smart City concept.

The era of industrialization, the increase in human influence, and the further acceleration of urbanization cause many problems. So, along with industrialization, there has been a huge increase in the percentage of environmental pollution. Such pollution eventually leads to a decline in the quality of life of humans and other living beings, and unfortunately continues to this day.

However, continuous technological advances help to prevent pollution and improve the quality of life.

The Smart City project is a concept that combines the capabilities of ICT, that is, using its capabilities, aims to increase both public services and the quality of life of people. From this point of view, various innovations are constantly presented in order to reduce environmental pollution within Smart Cities.

Given that environmental pollution also causes cancer, one of the greatest scourges of our time, it is now the most global problem. With the help of technological possibilities applied in the Smart City, it is estimated that in the near future it will be possible to prevent environmental pollution - to a large extent.

In the article, the following directions are considered:

Environmental Pollution: Impact Of PAH on Human Health

Polycyclic Aromatic Hydrocarbons (PAHs) are persistent organic pollutants (POPs) with two or more benzene rings in their chemical structure.[(1)]

Organic compounds such as polycyclic aromatic hydrocarbons (PAHs) are a global environmental concern as they cause inflammation and skin cancer. As you know there are two types of anthropogenic sources of hydrocarbons: petrogenic and pyrogenic sources. Petrogenic sources include crude oil and petroleum-derived hydrocarbon compounds. Pyrogenic sources of hydrocarbon compounds are formed as a result of incomplete combustion of organic substances such as oil, wood, coal. About 6,1 million tons of oil products are thrown into the ocean annually most of which are of anthropogenic origin. It is known from the literature that according to the latest indicators every year 6 mln tons of oil and oil products are discharged to the world ocean. Pyrogen and petrogen pollution of sea water contamination with ballast water and so on causes pollution of common water basins. These hydrosphere segments are a dynamic system which leads to a decrease and depletion of fresh water supplies over time.[2,3]

More than 100 Polycyclic Aromatic Hydrocarbons can be found in nature. However, 16 of these are designated as specific pollutants by the United States Environmental Protection Agency. These are the following:

Table 1. 16 EPA PAHs

№	PAHs' names
	acenaphthene,
	acenaphthylene,
	anthracene,
	fluoranthene,
	fluorene,
	naphthalene,
	phenanthrene,
	pyrene,
	benz(a)anthracene,
	benzo(b)fluoranthene,
	benzo(k)fluoranthene,
	benzo(ghi)perylene,
	benzo(a)pyrene,
	chrysene,
	dibenz(a,h)anthracene,
	indeno(1,2,3-cd)pyrene.

These 16 EPA PAHs were identified in the 1970s.[4]

These compounds are among the priority pollutants as reasons.[5]

1. Having more information about these compounds than others.
2. More harmful PAHs are suspected to be harmful and demonstrate effects.
3. The risk of exposure to these PAHs is higher than others.
4. In America, these PAHs have the highest indicators on the list of national priorities (National Priorities List, NPL) can be considered.

Human exposure to PAHs can occur through inhalation, skin contact, or ingestion of food contaminated with PAHs. PAHs in air pollution are primarily associated with particulate matter; When PAHs are in the gas phase, their lifetime is less than a day. Overall, current scientific evidence suggests that PAHs in ambient air are associated with increased cancer incidence in exposed populations. A positive association between environmental PAHs and breast cancer, uterine cancer and lung cancer has been reported. Epidemiological studies have shown that PAHs are associated with decreased lung function, exacerbation of asthma, obstructive pulmonary disease, and increased cardiovascular disease. Limited epidemiological evidence also suggests adverse effects on cognitive or behavioral function in children.(6)

Here we will take a look at PAHs in water pollution - more precisely in the waters of the Caspian Sea.

There are many ways to treat wastewater. Since these treatment methods are not completely effective therefore, they become a serious threat to the flora and fauna of the Caspian Sea. We know that after treatment wastewater from the oil refining industry is discharged into the Caspian Sea. Wastewater from the oil industry negatively affects the biota of the sea. The Caspian Sea is a very sensitive ecosystem. Over the past decades under the influence of anthropogenic and biochemical factors the state of ecosystems in general has deteriorated sharply and especially in the northeastern part of the sea.(7)

Industrialization and urbanization in the Caspian region have developed rapidly over the past several decades and the associated increase in hydrocarbons is a concern in the region. Offshore production and accidental oil spills, industrial waste, wastewater, discharges flowing down from river water are considered the main source of anthropogenic hydrocarbons in the marine environment.(8) Industry is believed to be the main source of oil pollution in the Caspian Sea.(9) The total amount of industrial waste discharged into the Caspian Sea averages 2342,0 million m3 per year. Such waters contain 122,5 thousand tons of oil, 1,1 thousand tons of phenols, 9,9 thousand tons of organic chemistry products. The total content of hydrocarbons in the North-Western part of the South Caspian was small - 32-54,2 μg/g. In this area in the vicinity of oil fields the concentration of phenol was 0,002-0,003 μg /g.(10,11)

The main volume of pollution (90 % of the total) enters the Caspian Sea with river runoff. After purification these waste waters are discharged into the Caspian Sea and even in small quantities these harmful substances are dangerous for the flora and fauna of the sea and the environment. As is already known PAHs are very dangerous for the environment for living organisms in aquatic ecosystems and therefore the identification of hazardous substances and the application of methods for their destruction is very important.(12,13)

METHOD

The quantitative analysis of polycyclic aromatic hydrocarbons (PAHs) also of phenol and its derivatives were carried out in a system including an Agilent 6890N gas chromatograph which has an interface with an Agilent 5975 high-performance mass-selective detector manufactured by Agilent Technologies (USA).The chromatograph was equipped with a splitless injector and a ZB-5 capillary column (Phenomenex, USA).Column ZB-5 has the following specifications: 5 %-biphenyl 95 %-dimethylpolysiloxane copolymer length-60 m inner diameter 0,25 mm film thickness 0,25 μm. Helium (99,999 % purity) with a flow rate of 1,5 ml/min was used as a carrier gas. The temperature rise was programmed from 40°C to 310°C. The extracts were introduced using an automatic sampler in a volume of 1 μl (Dettmer-Wilde, 2014). Quantitative analysis was performed against a seven-point calibration against standard reference solutions. A mixture of deuterated polycyclic aromatic hydrocarbons: naphthalene-d8, phenanthrene-d10(Cambridge Isotope Laboratories, Inc., Andover USA) was used as an internal standard for calculating the obtained results of chromatographic analysis.(14)

At first PAHs were analyzed in water samples discharged from the oil industry into the Caspian Sea. The results of the analyses and chromatograms for each sample are given below.

Table 2. Determination of Polycyclic Aromatic Hydrocarbons in Water Samples Taken from the Oil Refinery

№	PAH, mg/l	Standard indicator	Sample 1	Sample 2	Sample 3
	Naphthalene	≥0,01	0,08	0,23	20
	Achenthylene	≥0,01	0,02	0,51	15
	Acenaften	≥0,01	0,04	0,33	43
	Fluorene	≥0,01	0,24	0,81	80
	Phenanthrene	≥0,01	0,29	4,32	298
	Anthracene	≥0,01	0,04	0,33	26
	Fluoranthene	≥0,01	0,03	3,01	15
	Piren	≥0,01	0,05	13	66
	Benz (a) anthracene	≥0,01	0,01	3,5	17
	Chrezen	≥0,01	0,02	15	41
	Benz (b + j + k) fluoranthene	≥0,01	<0,01	2,2	5,0
	Benz (a) pyrene	≥0,01	<0,01	1,3	5,0
	Inden (1,2,3-cd) pyrene	≥0,01	<0,01	0,37	1,5
	Benz (ghi) perilen	≥0,01	<0,01	0,63	1,7
	Dibenz (ah) antracen	≥0,01	<0,01	0,57	1,8

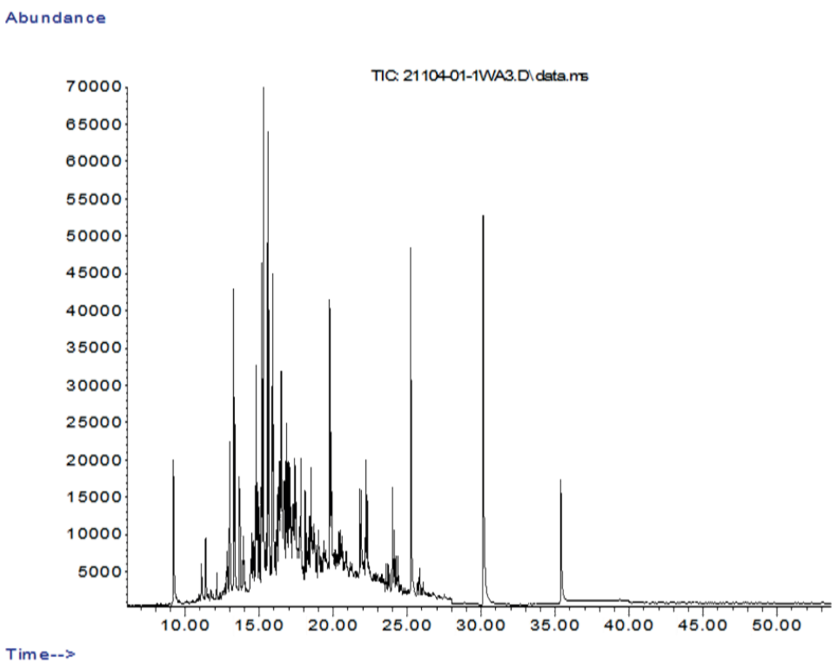

Figure 2. GC-MSD spectroscopy of sample 1

It should be noted that excess PAHs are expected to be present in refinery wastewater. Wastewater of this type is biologically treated and then discharged into the Caspian Sea. Below are the chromatograms taken for 3 water samples of the oil industry.

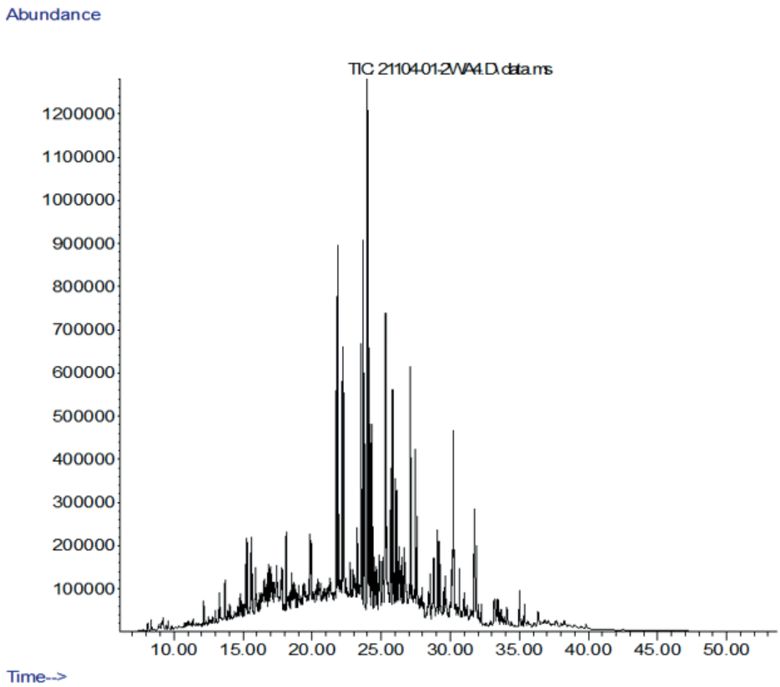

Figure 3. GC-MSD spectroscopy of sample 2

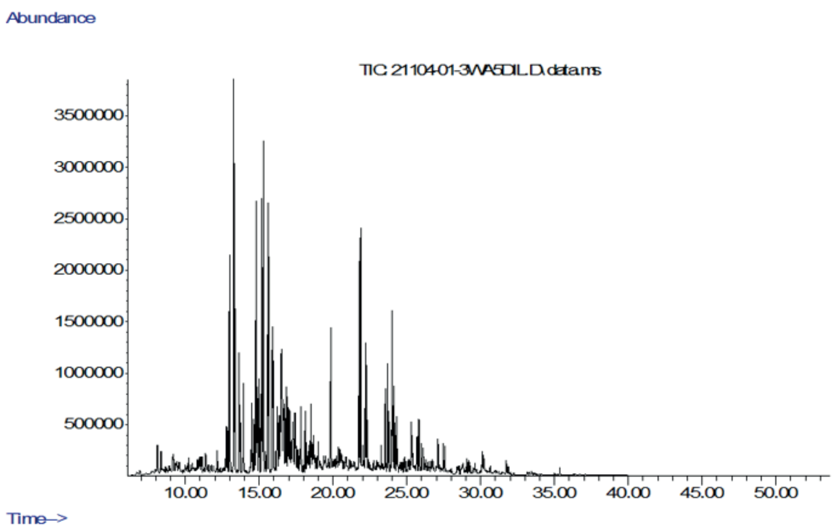

Figure 4. GC-MSD spectroscopy of sample 3

Phenol and its derivatives were also determined in the water samples of the oil industry and the results are given in table 3.

Table 3. Determination of phenol and its derivatives in water samples taken from the Oil Refinery

№	Compounds (mg/l)	Standard indicator	Sample 1	Sample 2	Sample 3
	phenol	≥0,04	5,34	5,65	1,44
	o-cresol	≥0,04	0,76	0,26	0,16
	2-nitrophenol	≥0,04	0,59	0,48	0,08
	2,4-dimethylphenol	≥0,04	31,99	8,71	0,20
	m,p-cresol	≥0,04	20,59	3,81	0,85
	2,6-dichlorphenol	≥0,04	1,14	0,67	1,80
	4-chloro-3-methylphenol	≥0,04	0,63	0,43	0,69
	2,4,5-TCP	≥0,04	0,48	0,28	0,18
	2,4,6-TCP	≥0,04	0,14	0,04	0,25
	2,3,4,6-tetrachlorophenol	≥0,04	0,27	0,18	0,002
	2-methyl-4,6-dinitrophenol	≥0,04	<0,04	<0,04	<0,04
	pentachlorophenol	≥0,04	0,27	0,25	0,06
	2-sec-Butyl-4,6-dinitrophenol	≥0,04	<0,08	<0,08	<0,08
	Compounds (mg/l)	Standard indicator	Sample 1	Sample 2	Sample 3
	phenol	≥0,04	5,34	5,65	1,44

The high amount of phenol in the 2-water sample is due to sampling from a water tank located closer to the production site. At the same time heavy metal ions were identified in the water samples examined. Heavy metals enter aquatic living organisms and enter the human body through the food chain. Determination of heavy metals was performed by ICP-OES, Optima 2100DV emission analysis method. The results are shown in the table 4.

Table 4. Number of heavy metals in wastewater samples of the Oil Refinery

Heavy metals, mg/l	Sample 1	Sample 2	Sample 3
Fe	0,048	0,047	0,042
Zn	0,143	0,078	0,023
Cu	0,023	0,028	0,020
Mn	0,021	0,105	0,038
Pb	0,022	0,017	0,009
Cd	0,007	0,006	0,008
Cr	0,004	0,003	0,004
Co	0,009	0,014	0,012
Ag	0,009	0,010	0,008

All these metals are dangerous if they exceed the MPC norm, but Cd is more dangerous. Norm for Cd is 0,001 mg/l (mg /dm3). As can be seen from the table the amount of Cd in the studied samples is higher than the norm.

Combating Water Pollution in Smart Cities

We gave an analysis of PAHs in waters polluted by oil spills in the previous chapter.

Oil has become one of the main sources of energy since the 1950s, on the eve of the industrialization period. And it still remains so. Although the concept of Smart Cities is an "Environmentally friendly" project, there is still a need for oil-derived energy. However, the use of oil inevitably causes major environmental pollution. Most importantly, it causes ocean and sea water pollution.

We first analyzed PAHs and their effects on water pollution due to oil, as well as subsequent PAH levels in these waters.

Such environmental problems should be minimized through the Smart City concept. Harmful sources of energy such as oil should be replaced with more efficient ones. However, although we cannot completely prevent water pollution in general, we can control it nowadays with a number of smart technologies.

We can look at this chapter in two directions:

1. Prevent water pollution with simple efforts.
2. Steps to combat water pollution and depletion of freshwater resources through smart technologies.

Prevent pollution with simple efforts

The entire responsibility for preventing pollution cannot be placed on smart technologies. People can prevent pollution by simple efforts. By first protecting our own little world from pollution, we can significantly minimize environmental pollution as a whole.

Before the technological approach, people can implement a number of methods to prevent pollution:

Disposal of toxic chemicals

We use many chemical products for daily processes like cleaning etc. Various bleaches and dyes cause serious problems. When such products are subsequently disposed of in the sewers, their harmful effects increase.

The best way to avoid this is to apply recycling.

Proper disposal of medical waste

Medicines should not be thrown into the sewer or into any water such as a lake or the sea. Because it affects the animals living there, it causes various diseases, and in the end, the water that people and cattle drink becomes polluted. This again poses a threat to a person's own health.

Do not pour oil down the drain

Many experts repeat this many times. Products such as oil should not be thrown down the drain. This again has a very heavy impact on water pollution.

Try to avoid using plastic containers

Plastic is one of the things that have a negative impact on nature. It continues to exist in nature for a long time. Similarly, thousands of plastics thrown into the seas have a negative effect on the creatures there. The main effort that can be made here is either not to use plastic items at all or to send plastic items to recycling.

Help clean up beaches and rivers

Unfortunately, 75 out of 100 people make efforts to protect nature, while the other 25 do the opposite. In this regard, whenever possible, people should help to regularly clean the banks of rivers and seas from garbage thrown by other people. In fact, that garbage should not be thrown there. On the other hand, it is the duty of every person to fight against the perpetrators, as well as to clean up. Because this nature is the abode of every living being.

Control your cars: people who use cars should regularly have their cars checked (monitored). Thus, the oils and various liquids leaking from the car flow into the sewers, from where they can eventually go to other water sources.

These are just some of the steps that need to be taken. And they are the simplest ones. People can use hundreds of different methods to prevent pollution.

On the other hand, it is possible to prevent pollution through smart technologies:

Steps to combat water pollution and depletion of freshwater resources through smart technologies

In fact, in a simple case, the main step here is: the proper use of smart technologies.

Due to water pollution, fresh water resources are in danger of diminishing. This eventually leads to drought. In order to prevent this, fresh water resources should be constantly monitored. This is a relatively difficult process without the help of technology. Internet of Things-based devices, especially applied in smart cities, are the ideal smart tools that can help people in such processes.

In general, the following smart technology projects have been proposed:

Data collection systems or Monitoring systems

First, data collection systems are created for any system. Thus, changes in the amount and composition of water are constantly monitored, data is collected and analyzed. At the same time, various data analysis technologies are used for this. Big Data Analytics is also applicable.

IoT-based water distribution systems to monitor water flow, quantity and leakage

Smart Water, Shayp technological innovations are among the main helpers in this direction. For irrigation systems, HydroPoint's Weather TRAK irrigation system applies.

ED technology

Electrodialysis (ED) is notable for removing chromium and arsenic from water contaminated by sources such as textile dyeing, leather tanning, dye and pigment industries.[15,16] ED technology can recover wastewater and reclaim water through concentration, dilution, desalination, regeneration and valorization.

Efficient water management systems

Water management is important in terms of developing water-energy interconnection. For example, SCUBIC is an IoT smart energy management solution that uses data to improve the functionality of water utilities. By deploying sensors and collecting data, pumping schedules can be simplified to reduce costs and improve water safety.[17]

Different countries adopt different acts to prevent water pollution. Accordingly, they use both the above-mentioned and a number of other technologies and build factories.

In Belin, for instance, a phosphorus elimination plant was built to treat the effluent of the pharmaceutical industry in order to limit the quantity of phosphorus discharged into the rivers.[15,18]

CONCLUSIONS

It is known that the waste water of the oil industry is very dangerous for the aquatic ecosystem. Thus, it causes serious damage to flora and fauna of water ecosystem. For this purpose, 3 waste water samples were taken from the oil industry and analyzed. The goal was to determine their composition. For this purpose, PAHs, phenolic organic compounds and heavy metals were determined in water samples. Chemical analysis of water samples was carried out on a GC-MSD gas chromatograph 6890N with a highly efficient mass-selective detecto-Agilent 5975.In water samples heavy metals were analyzed on a PerkinElmer ICP/OES-2100DV.A total of 15 PAHs,13 phenolic and heavy metals compounds were analyzed in water samples. As in the analysis of PAHs the most dangerous naphthalene were observed in the water samples 2 and 3. As can be seen from the Table 2,2, the MPC limit for PAHs is 0,01 mg/l. Naphthalene belongs to a class of high-risk substances and is considered the most hazardous among PAHs. Therefore, the main focus was on which areas of the water samples had the highest levels of naphthalene. The amount of phenol was higher in water samples 1 and 2. In general, the permissible concentration of phenol for industrial water in the maximum case should be 0,1 mg/l. As can be seen from the Table 2, in this 3, 1, 2 samples the amount of phenol gradually increases:1,44–5,34–5,65 mg/l. As for heavy metals most of them (mainly Cd)have exceeded the limit.

In general, we can briefly note the following results:

1. Environmental pollution is one of the most global problems of the time. One of the main reasons for this is the acceleration of the urbanization process. As people came to cities, industry became more developed, and of course, one of the reasons for pollution is the era of industrialization.
2. Environmental pollution is mainly in 3 forms: air, soil and water pollution. In the article, we looked at water pollution and its contamination with PAHs. Various methods were applied and analysis was carried out here.
3. In order to prevent pollution, at least to reduce it to a minimum level, people need to apply various methods. A few of them were mentioned. On the other hand, several technological innovations applied in smart cities have been mentioned.

BIBLIOGRAPHIC REFERENCES

1. Deelaman, Woranuch, Chomsri Choochuay, Siwatt Pongpiachan, Yongming Han. 2023. “Ecological and health risks of polycyclic aromatic hydrocarbons in the sediment core of Phayao Lake, Thailand” Journal of Environmental Exposure Assessment. 2, no.1: 3.

2. Hajiyeva S.R., Gadirova E.M.Methods for cleaning water contaminated with oil. Azerbaijan Chemistry Journal, Baku, 2014, No.1, p.35-38. https://doi.org/10.32737/0005-2531

3. Hajiyeva S.R., Gadirova E.M.Monitoring of the petro-genically polluted territories E3S Web

of Conferences ICBTE, 2020, 01006, p.212. https://doi.org/10.1051/e3sconf/202021201006

4. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4673601/#:~:text=EPA%20selected%2016%20PAHs%2C%20which,%2C%20dibenz%5Ba%2Ch%5D

5. Erol Alver, Ayla Demirci, Mustafa Özcimder, “Polisiklik Aromatik Hidrokarbonlar ve Sağlığa Etkileri”, Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi 3 (1), 2012, pp. 45-52

6. Human health effects of polycyclic aromatic hydrocarbons as ambient air pollutants - Report of the Working Group on Polycyclic Aromatic Hydrocarbons of the Joint Task Force on the Health Aspects of Air Pollution, 30 November 2021 | Report

7. Caspian Sea.State of the Environment // Report of the Interim Secretariat of the Framework Convention for the Protection of the Marine Environment of the Caspian Sea and the Bureau for Management and Coordination of the CASPECO Project, 2011, p.28

8. Novikov Yu.V. Ecology of the environment and man: Moscow, 2005, p.347

9. Ostroumov S.A. Problems of ecological safety of water supply sources, 2006, No.5, p.17-20

10. Neff J.M. Bioaccumulation in marine organisms. Amsterdam, Elsevier, 2002, 460 p

11. Yunker M. B., Macdonald R.W.,Vingarzan R., et al. PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition//Organic Geochemistry. 2002, vol. 33, p.489-515

12. Opekunov A. Yu., Kholmyanskiy M. A., Kurylenko V. V. Introduction to the ecogeology of the shelf://Textbook: Publishing house of St. Petersburg. University, 2000, 176 p

13. Kostianoy Ed. A., Kosarev A., Korshenko A., Gul A.G. The Caspian Sea Environment vol. 5 Water Pollution Pollution of the Caspian Sea. Hdb. Env. Chem.,2005, vol. 5, Part P, Springer-Verlag, p.109-142

14. Dettmer, W., Engewald, K., Werner Practical Gas Chromatography. Comprehensive Reference. ISBN 2014, 978-3-642-54640- 2. http://doi.org/10.1007/978-3- 642-54640-2

15. Clement Kamil Abdallah and Samuel Jerry Cobbina and Khaldoon A. Mourad and Abu Iddrisu and Justice Agyei Ampofo, “Advances in Sustainable Strategies for Water Pollution Control: A Systematic Review”, IntechOpen. 2022

16. Deghles A, Kurt U. Treatment of tannery wastewater by a hybrid electrocoagulation/electrodialysis process. Chemical Engineering and Processing - Process Intensification. 2016;104:43-50. doi:10.1016/J.CEP.2016.02.009

17. https://www.beesmart.city/en/solutions/the-need-of-smart-cities-to-get-smart-about-water

18. Schimmelpfennig S, Kirillin G, Engelhardt C, Nützmann G, Dünnbier U. Seeking a compromise between pharmaceutical pollution and phosphorus load: Management strategies for

Lake Tegel, Berlin. Water Research. 2012;46(13):4153-4163. DOI: 10.1016/j.watres.2012.05.024

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Drafting - original draft: Elmina Gadirova, Tarek Ganat, Swapan Banerjee, Fatma Bassyouni.
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