The issue of lithium exploration and exploitation in Serbia is causing increasing concern, but also confusion among citizens. The series *"Lithium: Experts Speak"* will attempt to provide answers to numerous questions through discussions with experts. The first expert to speak on the topic of lithium was Dr. Vera Dondur, a retired professor of physical chemistry.

At the beginning, I will ask you to answer 5 quick questions with brief answers of one or two sentences, and later we will discuss questions related to your area of expertise. Do you know if there are any plans for lithium extraction on fertile land anywhere in the world?

No. That is not happening anywhere. Why? Because, in fact, mining, especially lithium mining, started in South America in salt flats and is far from populated and rural areas. In Australia, they are also isolated or in mountainous, desert, or dry areas, and they have never been on fertile land. Europe has very few attempts to mine lithium in green areas. So, in fact, this attempt to exploit jadarite in a very populated area on fertile land would, by its capacity and requirements, create an enormous mining-industrial complex that would ruin the entire sector, the entire area, with its presence.

Is it even possible to mine lithium in the Jadar Valley in an environmentally friendly way?

No.

Nowhere in the world is lithium mined in an environmentally friendly way.

There are many studies and papers already published about the environmental impact of lithium mining. Why? Not only because of the mining waste, which is large, but also because a lot of energy is consumed, many chemicals are used, and a large amount of carbon dioxide is emitted into the atmosphere. And the whole process is essentially about extracting lithium to reduce carbon emissions. It is still not proven that lithium mining achieves this goal.

Do you think it is rational and long-term responsible to leave healthy natural resources, with an emphasis on clean water and nature, for future generations?

Certainly, it is. Leaving healthy resources for future generations is absolutely justified. Why? Because Serbia is not a country that has only mineral resources. Countries that do not have other resources resort to using their mineral resources now because they have nothing else. Serbia has many other resources that should be improved and used, not to rush into using mineral resources. At this moment, this is certainly something that should not be undertaken. Technology is advancing, and the lithium in the earth will not disappear. It can wait for 100 years and become a great resource for future generations. I believe that well-educated generations will be able to assess when to use this resource, rather than exploiting it recklessly right now.

Are you against mining as an industry?

Mining, as an industry, I mentioned earlier, only makes sense in countries that do not have other resources. Serbia has other resources, and there is no reason to focus so much on mining. Besides, we have experience in Eastern Serbia where intensive mining completely destroyed nature, people's lives, and health, for minimal gain.

Can any company that would mine in the Jadar Valley guarantee that there will be no leakage of toxic substances and environmental contamination?

No, it cannot for several reasons. The primary reason is that mining in Jadar would create two new components that could potentially have environmental consequences. One is lithium, and the other is boron. Unlike lithium, which has only been mass-produced in the last decade, boron has been produced for a long time. A lot is known about it, and its negative effects on the environment are well-documented. For example, as early as 1935, boron's toxic effects on plants were noted. There is data on this. Introducing these new pollutants into the environment in huge quantities is something for which no technology or company can guarantee that there will be no emission of these two elements into nature.

Thank you for this introductory part. Now, we will move to the area you have dedicated your scientific career to, physical chemistry, although you have nicely introduced the discussion into the direction of the topic, and to begin with, could you explain whether the Jadar project can be reduced to just mining?

No, for the simple reason that when ore is extracted, it must be processed to obtain a concentrate with a sufficiently high amount of jadarite. When this is done, that concentrate has no value. Lithium is produced in the world from other minerals, and the most famous mineral from which the majority of lithium is produced is spodumene, a lithium silicate zeolite material, whose concentrates are traded on the market. It is mostly produced in Australia and exported worldwide for processing. Jadarite is not such a mineral, nor can it become one. So, if only the ore and the concentrate were mined, there would be no market for them to transfer to, to produce lithium, lithium carbonate, lithium hydroxide, and of course boron compounds.

Can you explain what jadarite is, what we know about it, and how unique it is in terms of its structure? What are its key characteristics?

Jadarite is truly a unique mineral. Why? It wouldn't even be called jadarite if it didn't have a specific structure and chemical composition. It is a lithium, sodium borosilicate—meaning it contains sodium, lithium, boron, and silicon, as well as oxygen like other minerals—and that's what makes it unique. However, very little is known about it. From the moment it was first detected until now, only a few scientific papers have been dedicated to it, two of which were focused on its structure to recognize it as a mineral. There are no other scientific papers about it. There are about sixty papers in which it is mentioned as a new mineral, but nothing more. So, in essence, it is a completely under-researched, scientifically unexplored material.

Is the processing of jadarite a complex process?

Yes.

Can it be compared to any currently known processing methods?

No. Why? Because at the site where jadarite is found, it is actually a fine-grained mineral surrounded by dozens of other minerals. In the ore, there are up to 40 to 50 different elements. So, the mining system to be exploited is very complex. When jadarite is mined, it must be practically purified, with that part of the ore enriched by removing the minerals in which jadarite is not present, as much as possible. However, the ore has many carbonates and other minerals that are not so easy to remove. So far, the company has reached a level where the concentrate can contain 40% jadarite, with 55 to 60% being other minerals,

including carbonates. The company plans to break down this concentrate with sulfuric acid, which will require a large amount of sulfuric acid and will emit a large amount of carbon dioxide during the process.

The company has not yet solved the problem of carbon dioxide emissions from this process. Once that happens, a solution is created after treatment with sulfuric acid, which is then further processed. This solution is complicated to further process because both lithium and boron need to be extracted from it.

How much waste would there actually be during the extraction process, that separation, and what would we do with it?

Well, of course, as in any chemical production, there would be solid waste, waste emitted into the atmosphere, and waste that would be involved with wastewater. There's nothing unknown about this—everything that enters the production process and doesn't come out as products will remain in the waste. Practically, lithium and boron will always linger somewhere. For example, the amount of lithium is around 10,000 tons per year, and boron around 2,000 tons. Actually, it's about 10,000 tons of boron, and around 2,500 tons of lithium annually. If you look at this over 30-40 years, these are enormously large quantities. Of course, not all of it will go into the water, air, or soil right away, but it will continuously be involved in all these processes. First and foremost, this is an energy-intensive complex. It will get its energy from electricity, natural gas, and diesel for transportation, with the mildest estimates, which have not been detailed by either Rio Tinto or independent experts, suggesting that CO2 emissions will certainly increase by over 0.5%, which is very large—a significant contribution to CO2 emissions. Everywhere in the world, CO2 emissions are decreasing, while here they would be increasing.

Another important issue is that lithium and boron will also be present in the waters, in the wastewater. This has not yet been precisely determined by Rio Tinto, and why? Because, over all these years, Rio Tinto has not created the basic legal document called the conceptual project for the exploitation and processing of jadarite minerals, from which exact quantitative data would emerge, regarding capacity, production processes, emissions, waste quantities, water, groundwater purification, etc. This doesn't exist so far. Based on the materials available from Rio Tinto, solid waste will be large because the concentration of lithium in the ore is low. And it must be large. The tailings to be disposed of will be approximately 2 million tons per year, and in 30-40 years they will accumulate, of course, reaching about 90,000 tons. The tailings dumps, where they want to dispose of the solid waste, one would be very large, covering 20 hectares. In the Jadar valley, right in front of the windows of people who are currently protesting against the construction of the entire Rio Tinto project in Jadar, the tailings pile would be 60 meters high. 60 meters is roughly the size of the Church of Saint Sava or a 15-story building, on 20 hectares. That's a huge pyramid. A huge stepped pyramid that they say they'll reforest later. In land where there are boron deposits, there will be nothing to reforest.

That's the first tailings dump. The second one would be placed in the valley of the Štavica River, which is a torrential river with many small tributaries. This is a valley where, on 168 or maybe 170 hectares, forests would be cut down, and the large tailings would be placed, which, of course, contain lithium and boron and would, by world standards, be classified as hazardous waste. No country in Europe plans such large-scale tailings for lithium production; only Serbia does. Why does Rio Tinto even want a processing plant right next to the mine? Because it's the cheapest option. It's very simple. It's the cheapest. They found that we, in fact, don't have strict regulations, and we don't have the capacity to oppose this in a sufficiently documented and expert manner. Of course, they found cooperation with our authorities, who aren't sufficiently informed about what's going on. I'll illustrate this with an example. Rio Tinto plans to partially use water from the Drina River, to recycle process water in the plants, which is a normal process in any

chemical plant worldwide, which is done. But then they say the following: they will use the groundwater, which is rich in salts, in a very large percentage, and they will purify it, but they still don't know how they'll purify it, and then they'll add rainwater to it for the processes, though they don't know how much rainwater there will be, they can't estimate it. The only reliable water source for processes, in terms of quality and quantity, could be the alluvial plain of the Drina River. The other two sources are not viable. When it comes to water recycling, they state in some documents that they will recycle 48% of the water, while in others they say 70%. A big difference. Everyone would ask how it can be both 48 and 70. This means the company doesn't have precise data in these areas or is hiding them, which is also not good. And most people, who suspect that Rio Tinto has bad intentions, are even more suspicious as a result.

Are there other mineral processing capacities in our country, and what would be the difference, for example, between processing jadarite and processing lead and zinc?

It's simple. Very simple. In our country, excluding the processing of lead and zinc that we used to have in Kosovo, which we no longer have, there were two mines, one at Rudnik near Gornji Milanovac. One is Majdan, and both were bought by a foreign company, which now transports the ore for processing abroad. The only big producer is Bor, and the experience with Bor is more than evident. Bor is a very old mine, exploited for a very long time. When it was set up, it wasn't expected to be so intensively exploited. It has expanded, and its size now threatens the entire eastern part of Serbia. I think there's no need to say more.

But did you, as a scientist, have sufficient access to all the documents of Rio Tinto, which would be necessary for a scientific worker to make their own assessments?

No. The company is closed to everyone. I'll say that just about two or three weeks ago, I was able to get a sample of jadarite, although I had been trying to get a sample since they practically found it, purely out of scientific interest, because at that time I was researching lithium minerals very intensively. The company has its materials, worked in collaboration with our colleagues and institutes—like the Černi Institute and others—and has done quite a bit of research. That's not disputed. However, those studies are not available to the public. The company has several materials, such as a report on the deposit. They also completed one study that is still unfinished, related to the exploitation of ore, and only sporadically mentions processing. These are the basic materials. On the company's website, there were other materials that were available in fragments. I personally gathered all the materials I could. I dealt with them extensively, and when these environmental impact studies appeared last summer, I was very surprised that the company once again, instead of making a comprehensive environmental impact study on the exploitation and processing of jadarite, presented it fragmentarily in three separate materials, created by different teams who evidently didn't communicate much with each other and which contained many incomplete, contradictory, and partial data. So, when a larger number of people wanted to get involved to investigate what's really behind the project, Jadar was unable to do that. They couldn't do it.

One more very important thing I'll mention. The spatial plan was created based on incomplete data, exclusively from the materials that our institutions received from Rio Tinto. They even stated in the spatial plan that they had documentation from Rio Tinto with conceptual solutions. What are conceptual solutions? No one can say what that is if they are technically educated. There is a conceptual project, not conceptual solutions. So, when I look at this, I'm very surprised that the broader scientific public hasn't been more involved in this issue, but I'm not because people don't know where to start, what to look at.

How would you generally assess the availability of documents and the transparency of Rio Tinto's work at this moment?

Rio Tinto considers itself transparent just because it issues statements, only when someone says something unfavorable, they are very loud in the media, issuing press releases denying it. That's a wrong approach. There are already many such statements, media responses, and attacks that people are hesitant to make their own comments, which is damaging. The company doesn't even realize that it's damaging itself, not just trying to disqualify people who say something. I would actually strongly recommend to the company that the team it hired to work on this project first review the materials it released to the public, especially the so-called environmental impact studies, and remove all the data that is not backed up. Why? People ask why we didn't give objections. What objections could we make on something the company itself says it doesn't guarantee the data in those studies? What should I comment on? I'll take you back to the issue of water, which we briefly touched on. What would the effects of the excavation in Jadar really be, especially on water sources and potential contamination? This is very complex. As I mentioned earlier, the only reliable water source that would supply the entire mining-industrial complex is the alluvial plain of the Drina River. However, what's confusing is that the company states in the same document, even in the spatial plan, that they would use between 1,000 and 5,000 cubic meters of water per day. How much? I don't know. I believe they don't know either.

When water purification is mentioned, a new problem arises. The issue is that wastewater, by the nature of the process that occurs, must contain lithium and boron in amounts that are not insignificant. And what the company says next is this: they will use a combined system for wastewater treatment that involves something called ultrafiltration or reverse osmosis, which are well-known methods widely used around the world for desalinating water—water used for drinking or irrigation. These methods are widely used in Israel, Cyprus, Malaysia, the United Arab Emirates, and many other places. However, in these waters, the concentration of boron is low. Boron is a very specific element, very similar to water, and in the reverse osmosis membranes, it cannot be treated effectively if the concentration is high, significantly higher than that in seawater. Such a concentration is expected in these processing plants. It's not clear how the company intends to handle this; there's no scientific data showing that reverse osmosis is effective for such high concentrations. There is no data anywhere in the world that shows these high concentrations of wastewater can even be purified. Why? Because this method is extremely expensive and requires a large amount of energy to operate. Between three and ten kilowatt-hours per cubic meter of water are consumed in this process. In Saudi Arabia, for example, they install solar cells and can afford to do this. But where would they even discharge this water? That's another problem, a new problem. All chemical processing companies try to separate mines from processing plants. The processing plants are located in so-called industrial zones, which are positioned along the shores of large rivers, seas, and oceans. Australia has placed its two new plants—one is already operational, and the other will be next year—on the coast of the ocean in Perth. The discharge pipe goes several kilometers into the ocean under strict conditions regarding how much lithium must be discharged. There's no boron there.

On the other hand, Turkey is the world's largest producer of boron compounds, with four mines. The largest plant is in Bandirma, also on the coast of the Sea of Marmara, a processing plant that discharges boron waste into seawater where boron is present. Jadar doesn't have the sea. There's no Jadar Sea, there's none. The Jadar River is a small river with a small capacity, and the company is trying to convince us that it will discharge a small amount of wastewater and will recycle a lot. As I said earlier, the data on recycling is all over the place. Again, different sources state different amounts of wastewater that will be discharged. We've heard from colleagues involved in the study that they will carry out remineralization, and that the water will be completely purified. But purified water cannot be completely purified. Water

must contain everything that was in it, it's just a question of concentration. If they were purifying water that has a maximum of 800 milligrams of material, and if they purify it to only 1 milligram—our standard—they would purify the water to 99.9% purity. Absolutely unbelievable. This means that all the statements made by the company must be precise, accurate, and not make promises about things they cannot fulfill. Just as they didn't tell the population that boron is dangerous for plants, they haven't told us how much wastewater will actually be involved. And they can't say until they have a conceptual project. And does anyone even oversee them at this moment, especially with respect to the exploratory boreholes? And who would oversee that in case the mine opens? Well, the exploratory boreholes that leak, which they can't seal, show that. Even though they've been drilling for decades. The exploratory borehole that is leaking and has been the subject of media reports in recent weeks was checked by eminent institutions in 2021. There are photographs showing that the water contains both lithium and boron. The exact amount of boron is known.

That photograph, of those boreholes, shows a barren area where soybeans couldn't grow. Soybeans are very sensitive to boron. Rio Tinto can get angry or make strange statements about our colleagues who studied this, but their data is accurate. And even if it weren't, Rio Tinto knows exactly why the soybeans didn't grow. We always talk about Jadar, the most well-known issue of its type. Is there any other lithium deposit in our country, for example, in Valjevo or some other area? What do your data show? Eurolithium explored Valjevo and Mionica. Balkan Limited explored Rekovac. Before that, the Piskanje deposit, near Baljevac on the Ibar, was explored. There isn't much lithium in those exploration boreholes, but lithium was detected. I'd say that in the 1990s, small concentrations of lithium were detected in surface layers in many parts of Serbia by our colleagues from the Faculty of Geology, led by Professor Jelena Obradović. Would expanding those exploration works lead to the discovery of something that would produce commercially promising results? It's hard to say. These deposits, especially in Valjevo and Mionica, actually contain more boron than lithium. They contain more boron than lithium, but when it comes to boron, the search for it worldwide isn't significant. Why not? Because Turkey's ore reserves are still large enough for the entire world, and Rio Tinto, which is also a producer of boron compounds, knows this. These millions of reserves in Russia, Kazakhstan, and other more acceptable locations are much more cost-effective. Boron compounds aren't expensive products. Right now, I don't know the current price of lithium carbonate, maybe around $12,000 per ton, but boric acid, the other substance that would be produced, is around $720 per ton. For years, the public in Serbia has been hearing about mining plants throughout Serbia, with the Homolje Mountains at the center of attention—Bor, Majdanpek—and this one piece of data that says 40 new mines will be opened in our country by 2035.

Do you know anything about that, are there permits for exploration or mining?

What is certain is that people in Serbia need to be aware. Serbia is too small to have one more mine, and one more mine than Bor is already too much. And of these few mines we have, including the coal mines, opening 40 more would mean that we're gone. That we've disappeared from the land we've managed to preserve for centuries. We have no reason for that. We have no reason for that. This rush that has led mining companies to explore so much is essentially a consequence of many subsidiaries of large foreign companies, and it's one of their outlets that doesn't represent much of a cost to these companies. Most of the advocates for opening mines in Serbia are actually representatives of "trinket" companies that we need to expel from here.

Would anything change if the state, for example, had a 20% stake in a future mine in Jadar?

What I know is that this would just be a cover, because the state wouldn't manage anything with such a small stake. Economists have told me that the state would only be able to manage if it has more than 51%. This would just be a cover for the company to continue doing whatever it wants here, just as it has been doing.

There's something you mentioned at the beginning, and I'd love for you to clarify it a little. If lithium is called the oil of the 21st century and if it's a resource we can leave for future generations, why are we rushing at this moment when it might be worth much more to future generations?

First of all, that's a journalistic cliché—the oil of the 21st century. It can't be. Lithium batteries aren't an energy source; they just store the energy we give them, and when they're depleted, we have to provide that energy again. So, anyone who has ever picked up this mobile phone knows that when the battery runs out, you need to recharge it. Where does it get recharged? From the outlet. Where does the power come from? From electricity. We can produce electricity from hydropower and solar, from wind, and, of course, from coal. We don't have much sunlight, we don't have much wind. What we still have is coal. And we need to be aware that we should use our coal more efficiently, without emitting carbon dioxide into the air. But will this save the global industry and energy sector? That's not true. So, as a university professor who has spent a good 43 years at the University of Belgrade and a few years at the University of Kragujevac, I think we need to educate young people to look at the world's problems and technological development with open eyes and be much more prepared than we were. We wouldn't be in this situation if my generation and the one behind me were more prepared to think about the future. I think we weren't ready. That's why we've fallen into all these difficulties. We need to teach those who come after us to carefully manage resources so that they have something to leave to future generations. As generations, what will we do now? Economists say this is an unprofitable job. We say, fine, it's unprofitable, but we'll do it anyway. What will people who are 20 years old now say to their grandchildren in 40 years? We had lithium, now we don't. We had clean air, now we don't. We had clean water, now we don't. What do we have? We have land, and it's polluted. We need to leave something for future generations. That could be the generational message.

Finally, what would your message be to your colleagues?

My message to my colleagues is that this is not a personal problem for any of us. This is a fundamental problem. And relying on politicians' thinking shouldn't be the way forward. Scientists should rely on what science has always served, which is understanding the future. What is the future? So, I appeal to my colleagues from all universities in Serbia to get involved in this discussion. They don't have to follow the steps of what someone has already said. We should think, does Serbia need these mines? I don't think it does, and I think anyone who has ever been involved in real science in Serbia would say the same.

Thank you, Professor Dondur. I hope we've helped our listeners and viewers understand and clarify this topic a little better.

Thank you.