**Electrochemical Technology in Pollution Control**

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**Lecture - 01**
**Introduction to Electrochemical technology in Pollution Control**

Welcome to the MOOC course on Electrochemical Technology for Pollution Monitoring. This is a beautiful topic for discussion; especially, with respect to modern technology that is available for monitoring the pollution because, nowadays the world is nothing, but sensors. So, sensors are all work on electrochemical technology 99 percent ok.

So, this course; I have designed especially for you, because it has got ramifications in chemistry, in engineering, in pollution control and in several other fields where we need sensors in the electrochemical technology, without electrochemical technology I do not think world will run at all. 99 percent of the metal objects what we use they have all undergone electrochemical treatment either plating, polishing and metallurgical operations something like that.

And, the surface technology is essentially an offshoot of electrochemical technology. Earlier electrochemistry was one of the important subject for all electrochemical for all chemists. And, nowadays they can electro chemical content has become very less and many people cannot connect the electrochemical principles with day to day life as well as in the modern technology.

I can only say that modern technology is not there without electrochemical technology. So, you are all welcome to a new course on electrochemical technology for pollution monitoring. Earlier I have given a couple of courses one on spectrophotometry, one on inductive coupled plasma atomic emission spectroscopy, one on atomic absorption spectroscopy. And, then one on infrared spectroscopy that course has run a repeat course, you can refer to them for the basic understanding of the atomic structure and other things.

But, I also understand that for this course many of you might be might not be chemists; you may be an engineer, you may be a some practicing scientists, you may be just requiring a little bit of knowledge for something else etcetera. So, what I am going to do is I am going to talk to you about the basic principles of the chemistry; fundamental principle a little bit of introduction in case you have forgotten.

For example lot of engineers would have forgotten what is a chemical, what is the atomic structure? What is a periodic table? And how do we correlate the chemistry with electro chemical technology etcetera. So, there is a course on atomic structure there is a module and then there is a course on a little bit of periodic table. And, then fundamental principles of chemistry that is they are all related to the electrochemical technology, because we are going to talk quite a lot about the chemical solutions, the representation, electrical properties, chemical properties etcetera.

So, I would like to welcome you all to a new exciting course initially I thought, I would do this program only for about 8 hours or something like that, but now I think it has the scope has broadened as in when I went on designing this course. So, welcome to an exciting new course and then I would suggest the some of the courses or some of the material, what I have reading material etcetera they are all in the website and you can go through them. And, let us start from the beginning that is an introduction to chemistry.

So, look at the slide and my name is Dr. Mudakavi I am from the Department of Chemical Engineering in Indian Institute of Science, Bangalore. Actually I retired from there and the currently I am I have a chemical laboratory, where I practice my chemistry and we never retire you know. So, there is always this thing. So, you are most welcome to contact me anytime up to 10 o' clock or 12 o' clock at night, but slightly late in the morning, but around 7 am or something after 7 am and I will be available.

You may note down my address and phone number and other things etcetera from the website from the NPTEL office and we will also have some sort of interactive session once we get on with the course you, once you register etcetera; all those things are automatically done. So let

us begin with the introduction part. So, I would like you to understand what I am going to teach, this is something regarding the course itself.

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So, here are the, here is the plan of teaching what I am going to teach you. So, first thing is introduction to into this electrochemical technology as well as sensor technology and this course of course, and then comes atomic structure. If you remember the title I had given that it is the electrochemical technology for pollution control. So, I am going to talk a little bit about the pollution control also. How electro chemical technology can be useful for the monitoring of pollution and pollutants; basically there is lot of instrumentation and other things involved in this in addition to chemistry.

We will go through all that and I wish you a very beautiful sessions of learning. So, first part module 1 is introduction and then comes atomic structure. This is a sort of repetitive course

for those of you who have taken my course earlier, but for others it will be a welcome introduction to the course. Then we are going to talk about the properties of solutions; that is a different ideal gas laws and Henry's laws, Raoult's law etcetera.

And, then we have will discuss about the electrochemical basis of titrations that is also another part, then we are going to talk about voltametry polorography and other electrochemical techniques. Then we are going to talk about electro, basically it will be something like electro analytical techniques that is module number 5. We will be talking about electro analytical techniques which will enable us to determine the pollutants and chemicals etcetera, metal ions in solution at parts per billion and parts per trillion level; nothing you know we are not going to talk much about wet chemistry or bucket chemistry.

We are all moved away from that kind of learning since about last 20-25 years. So, we are going to talk only about microlitres and millilitres etcetera. It will be exciting to discuss those things with you. And I am going to talk about electro chemical sensors. So, what are the sensors made of? How do they work? And in what context they are useful to us? Etcetera.

And, then I am going to talk about battery technology. Today's world is nothing, but batteries you know right from our mobiles to watches and so many devices will not run without battery. Battery can be stored battery energy or it may be on energy something like solar energy, you know solar batteries are available in the market. We will discuss and learn about them and then we are going to talk about the process waste handling. That is also very important concept in pollution control.

So, the modules are not important, but different types of modules what we are going to talk are important. The numbers may change a little bit here and there depending upon our convenience and available time ok.

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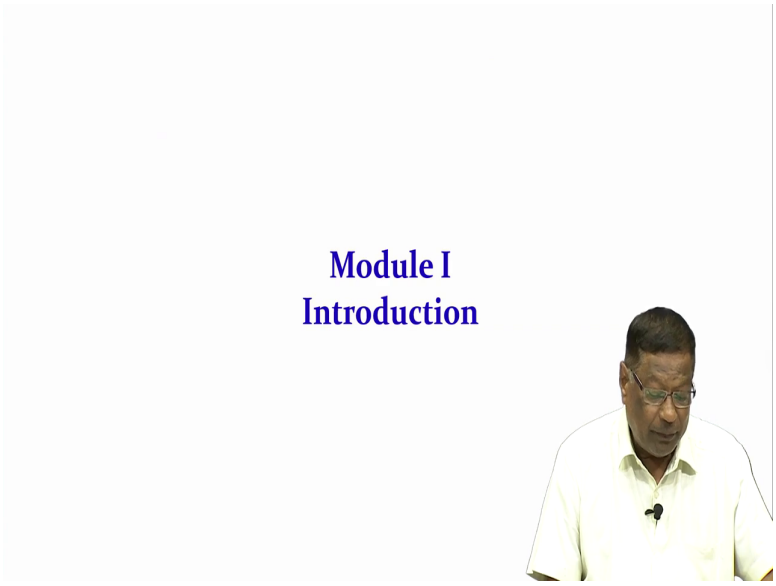


So, we are going to talk about the introduction first.

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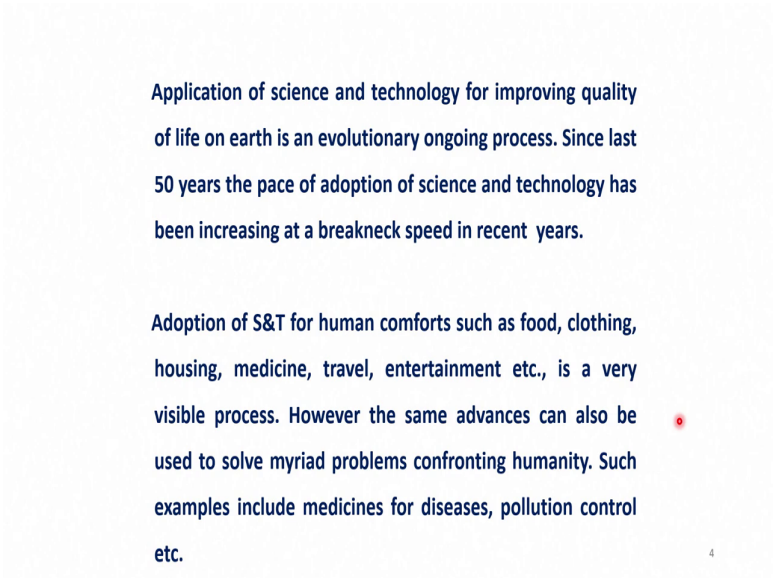


So, this here goes the introduction what I want to tell you is application of science and technology for improving quality of life on earth is an ever going evolutionary process. Since last 50 years the pace of adoption of science and technology has been increasing at breakneck speed. In recent years you may be surprised to know, that there may be the I can give you a small example of how fast things are changing ok.

Here goes one example, man wanted to run faster, move faster. So, initially the only thing a man knew was to run, you know that is several million years before, when man himself was new to this earth. The first homo sapiens and they knew only how to run to save themselves or to catch some food, prey right. So, about 2000 years before man tamed horses. So, with the horse a man was able to travel about 20, 30 kilometers speed per hour.

And then came the industrial revolution, along with that came bicycles and the trains and motorcars all those things increase the traveling speed of a man to about 80 to 100 kilometers per hour maybe 200. Nowadays trains run at 300, 400 kilometers per hour that is also there, but that is the average speed, but then man wanted to more speed then what happened? We all, the world invented aeroplanes 600 kilometers speed achievable yes.

So, again the time gap between an industrial revolution 1700 within 200 years man has been able to fly catch up to 600, then came rockets now we are able to break the sound speed of sound. And our rockets and other things travel several 1000 kilometers per second. So, the same thing happens in our day to day scientific life also. The computers when we were students used to be huge and which we would do primitive calculations.

I remember in IIT Mumbai there were computers who which were occupying about half a room size and nobody would be allowed to go there. Nowadays we have mobile mobiles which can do the job of a computer correct. So, the same mobile what can do what it can do as a computer can also take photographs, it can also take send messages, collect messages, new, receive news, entertainment and thousands of applications. If you just go to applications of mobiles you will be surprised to know these.

What I am trying to tell you is the pace of the speed; the pace of the innovations is fantastic that is number 1, number 2 things have become miniaturized ok. So, adoption of science and technology for human comforts you know this is also sort of technology. So, we employ science and technology for human comforts, we use food, clothing, housing, medicine, travel, entertainment, agriculture everything, everything is a very very very visible process.

However, the same advances have also given us atom bombs, hydrogen bombs, neutron bombs and several things of destruction which can wipe out the earth within minutes. So, I am trying to convey to you that science and technology is playing a huge part in our day to day life, housing, medicines we solve the problems. And, then we have atom bombs, we can destroy everything within no time.

So, the same advances that can be used for the welfare of the society, can also be used for destroying the society. So, we can have milk revolution, we can have green revolution, we can have several other kinds of revolutions, miniaturization revolution, electronic revolution, metal revelation, chemical revolution thousand of things. But, at the same time science can also be used for controlling diseases, pollution control, remedial actions for people.

So, many other things it can be used. So, what is important is fundamental sciences such as electrochemical technology; they have made rapid strides in the last century. And, currently we are able to understand the electro chemical nature of the elements just like internet of things. We are able to understand the electro chemical nature of the elements, ions, compounds, metals, neurons in our body, in our brains.

Now, everything is electrochemical action, even the simple action of moving my hand I need an electrical impulse from the brain and it is just an a basically believe me it is just time electrochemical reaction. So, the electrochemical technology has advanced so much nowadays that the electronic and nuclear structure is very important for us to learn, then only we can do many things. For example: in the miniaturization revolution you all of you must have heard of a nano carbons, fullerenes.

They reduce the size of these instruments to so small level molecular level, but again it is an electrochemical technology basically. So, electrochemical technology is a science which is an offshoot of the structural changes occurring during electronic transitions. Over the years electrochemical technology has grown into a very powerful tool for the identification and quantification of the chemical compounds; the same can also be used to follow the progress of chemical reactions.

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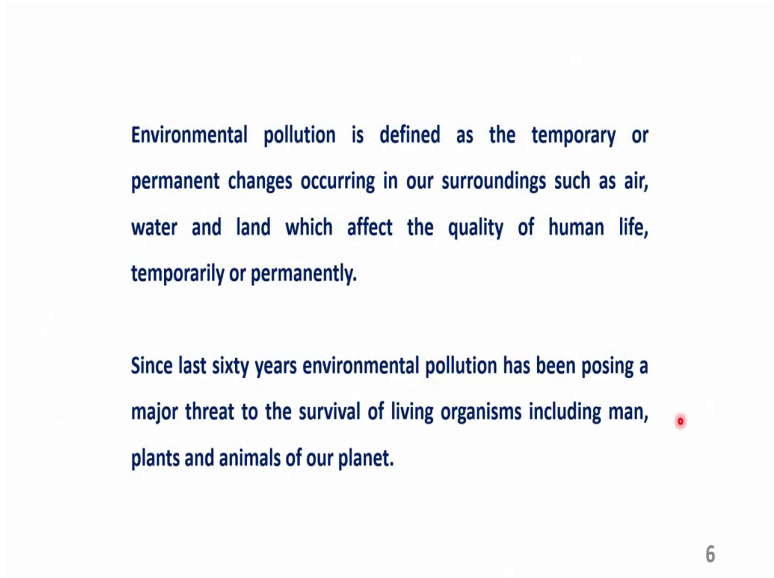


So, you can imagine that electrochemistry is required in every day to day life. Now how do I connect the electrochemical technology to pollution control? Very simple, environmental pollution first of all we define it as the temporary or permanent changes occurring in our surroundings. Our surroundings include air, water, land, troposphere, stratosphere, ionosphere, thermosphere, several other earth connected spaces. And, that affect the normally environmental pollution is what affects the quality of our human life.

It may be temporary or permanent that is different ok. So, since last sixty years environmental pollution has been posing a major threat to our survival, of the living organisms including man, plants, animals, bacterial populations, insects everything. So, environmentally has touched every person's life.

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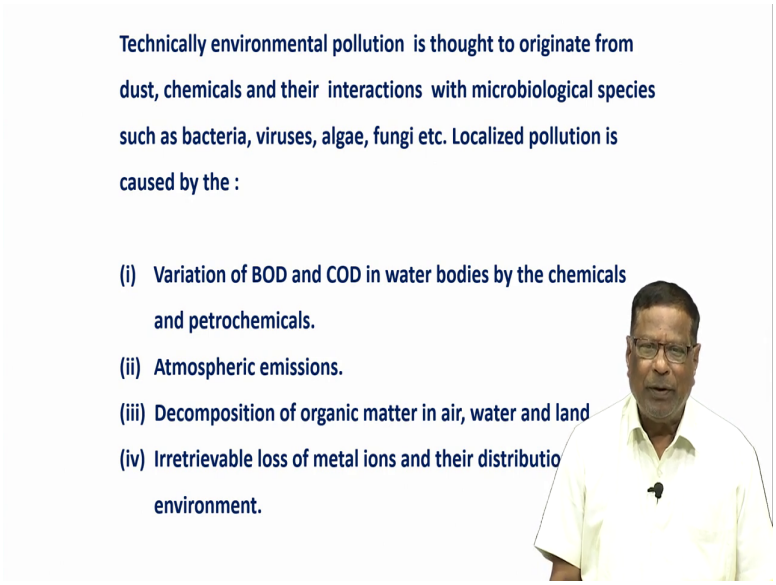


So, what do we have here now? Can we marry both? Environment and electrochemical technology? Answer is yes and technically environmental pollution is thought to originate from dust, chemicals, their interactions with microbiological species, such as bacteria, virus, algae, fungi, animals etcetera. And, a localized pollution is one, it is already written in this slide for you I am just expanding a little bit for your benefit.

So, a localized pollution is caused by variation of biochemical oxygen demand and chemical oxygen demand in our water bodies by the chemicals we let out into the our water bodies. We take bath, we put soap in the solution that will create BOD COD. We use cosmetics, that goes into the water creating BOD COD. We create chemicals, chemicals are let out onto the soil they leach, the leached chemicals will enter into water bodies causing BOD COD.

So, we will talk about BOD and COD: Biochemical Oxygen Demand and Chemical Oxygen Demand for later in greater detail, but for the time being I want to tell you that it is a measure of the pollution, that is occurring in water bodies ok. And, then we have pollution localized pollution from atmospheric emissions, very simple to understand now. Basically what happens? If you have a factory around and it has a stack, it keeps on emitting smoke. Our vehicles emit smoke, diesel vehicles exhaust, diesel exhaust all those things.

So, localized emissions such as tax and automobile exhaust caused atmospheric emissions and the decomposing materials caused atmospheric emissions. Our cows give out methane and other chemicals that is also localized pollution and then decomposition of organic matter in air, water, land etcetera that also causes a localized pollution. And, irretrievable loss of metal ions and their distribution in the environment; that is another biggest problem I will talk to you about it sometime later whenever the time permits.

But, for the time being let us assume that whenever I want a metal to be made because metals are forever we want gold, we want silver, we want copper, we want cobalt, we want lithium, we want many other elements. How do I get them? They are all available only in the form of ores, in the bowels of the earth. We take them out, make the metal so long as the conversion of ore into metal is economically beneficial. The moment its concentration goes down, we throw them out.

We do not use them anymore, we just let them lie on the land and the metal ions will get corroded, will get leached and along with rain it will move into the water bodies, it will move onto the soil, it will move into the our food chain, several other things. So, basically what I am trying to convey in the slide is that the localized pollution is always there all around us touching everyone's life ok.

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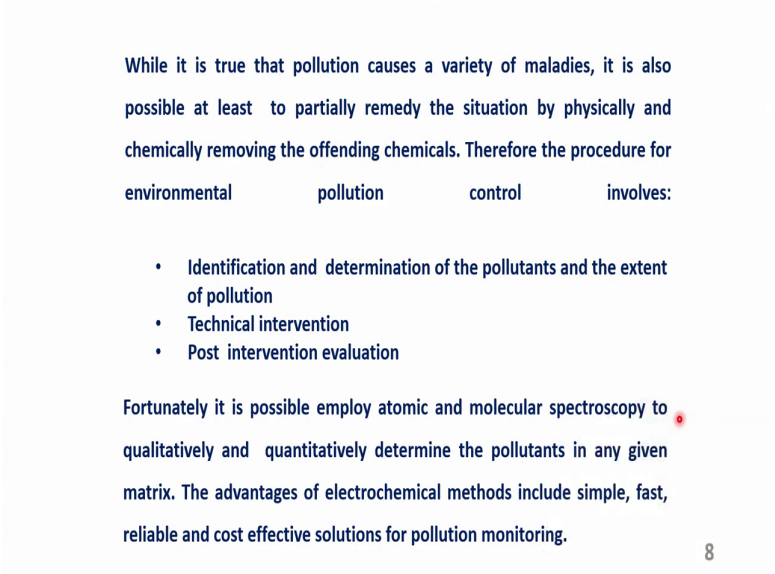


Well it is true that the pollution causes a variety of maladies, it is also possible at least to remedy the situation by physically and chemically removing the offending, you remove the chemicals, offending chemicals can be removed then we have no pollution. So, the procedure for environmental pollution control; what does, what do we do? It is a very simple procedure, first is identifying, identify and determine the pollutants and the extent of pollution.

How much of pollution is there? If you are determining smoke, fog etcetera find out what is the visibility that will tell you what is the extent of pollution right. And, then once you identify suppose the one factory is letting out sulphur dioxide or nitric oxide you identify what is the compound and how much is coming out. Then you can find out how to get rid of the pollutants ok. So, once the identification and determination is accomplished then comes the next step that is engineering evaluation.

So, that is known as technical in intervention, this is man made. So, we all use our technology to reduce, remove the or reduce or remove the pollutants, maybe dilution. There are several methods of reducing the pollution and after we do that job; one more job remains to be done that is post intervention evaluation. After we apply, a particular technique to reduce the pollution how much effective it is, that we have to suppose to understand them; so, that is post intervention evaluation.

Fortunately it is possible to employ atomic and molecular spectroscopy to qualitatively and quantitatively determine the pollutants in any given matrix. So, what is the matrix? Matrix is a body of a material along with the pollutant in which we want to determines. It may be water, it may be soil, it may be air packet all are called matrix. So, the sample in which a material is to be analyzed is called as matrix ok; so, the advantages of electrochemical techniques.

Why do we employ electrochemical techniques at all? Because, there are advantages associated with that right, otherwise who would suffer; if there are advantages we use the use it to our advantage. What are the advantages of electrochemical technology? It is simple, it is fast, it is reliable and it is cost effective, it offers us a cost effective solution for pollution monitoring ok.

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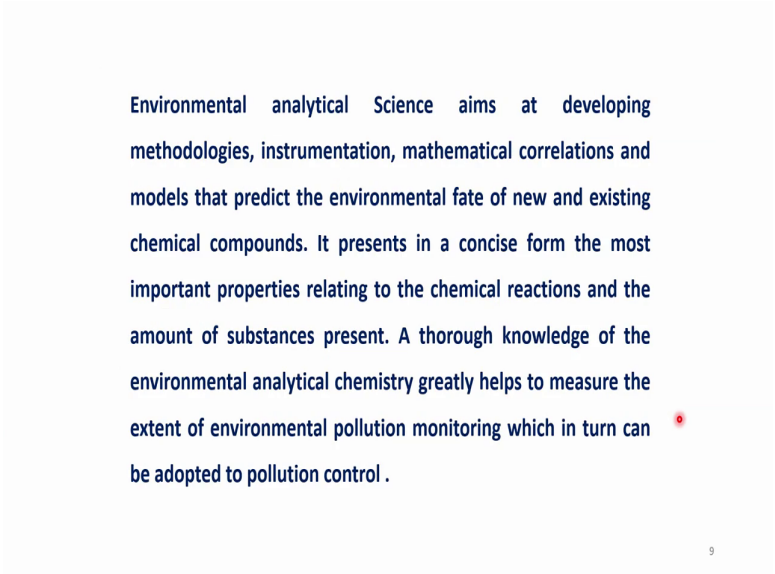


So, and the discussion now moves on to environmental analytical science. So, what does it do? Environmental analytical science aims at developing methodologies instrumentation, mathematical correlations and models that predict the environmental faith of new and existing chemical compounds. So, it presents a concise form, the most important property is related to the chemical reactions and the amount of substance is present, how it can be handled.

So, a thorough knowledge of environmental analytical chemistry greatly helps to measure the extent of environmental pollution monitoring which in turn can be adopted for pollution control. Remember always, a how I attack a problem is first is analyze, determine, quantify and then technical intervention followed by post technical evaluation.

So, among all these things what is required basically is an electro environmental analytical science. We need analytical science. What is analytical science? An analytical science is that

science which teaches us how to estimate, how to determine qualitatively, whether it is there or not pass or fail test or it may it is how much of it is there; so, quantitative analysis. So, an analytical chemistry is that branch of chemistry which is very important in day to day life.

Whether you take medicine, whether you take food, whether you take any other activity; analytical chemistry is part and parcel of the whole life, everybody's life.

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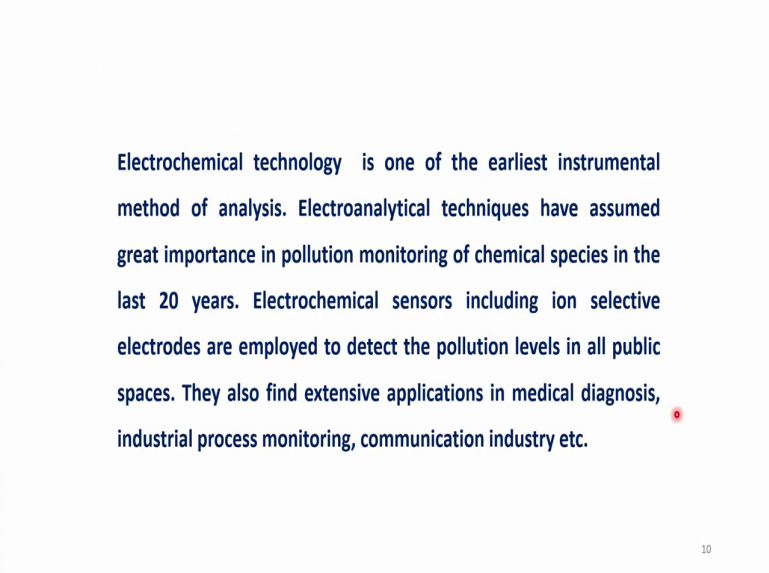


So, electrochemical technology is part of analytical science ok. So, what do we when we talk of electrochemical technology we study apart from spectroscopy electrochemical technology. Earlier there used to be different sections of electrochemical science, analytical science etcetera, spectroscopic science, (Refer Time: 29:31) chromatographic science etcetera.

Nowadays the difference between the disciplines of instrumentation, electronics, analytical science and electrochemical science everything has become merged and electrochemical society, electrochemical not society, electrochemical technology has become one smooth mosaic of several disciplines involving analytical chemistry, electronics and then computerization, data handling and many other things that are rolled into one. So, the distinction between different sciences of analytical science have become merged and electrochemistry is no exception.

So, we are going to learn lot of things about the instruments when we learn we will learn the instrumental parts also how they function, what are the electronic requirements etcetera; electrical and electronic requirements etcetera. So, electro analytical techniques have assumed great importance in pollution monitoring of chemical species since last 20 years that is all. Earlier to very few people use to study electro chemistry asset for day to day problems solving. Nowadays, it is there everywhere. So, electrochemical sensors including ion sensitive electrodes are employed to detection pollution levels in all public spaces.

They also find application in portable instruments. Suppose you want to know how much of fluoride is there in the local pond, you cannot take everything to the laboratory, you just carry an electrochemical sensor in your pocket, take it out, go to the spot, measure the pollution, fluoride level come back. So, miniaturization, pocket transitions, pocket instruments they are all there to handle electrochemical analysis and the accuracy is as much as you wish.

Ion selective electrodes is one of the techniques that can be used to determine many many many parameters which are required in our day to day life. They are ion selective electrodes are employed to detect in to detect the pollution levels in all public spaces. They also find extensive applications in medical diagnosis, industrial process monitoring, communication industry etcetera ok. So, now, look at the next slide.

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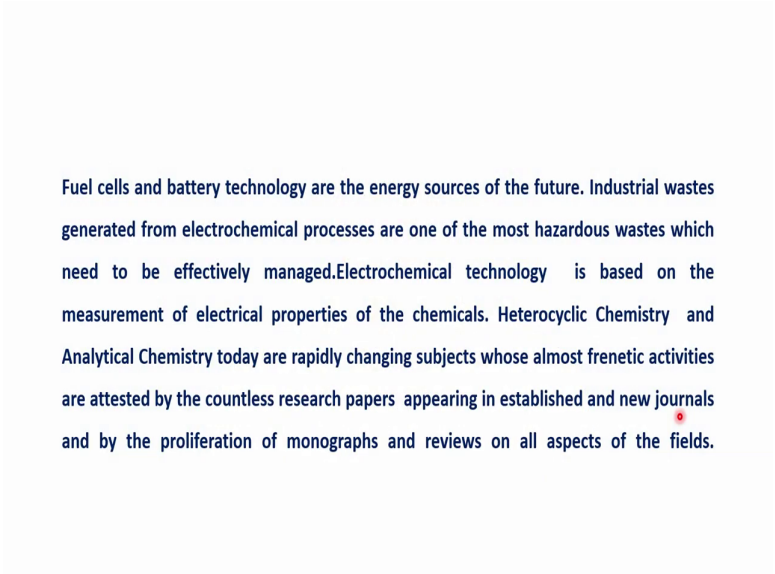


There are other things I wanted you to understand that is fuel cells. How I am trying to explain to you, how electrochemical technology is touching our day to day life nowadays. So, fuel cells and battery technology again are the energy sources of the future. So, industrial waste generated from electrochemical processes are one of the most hazardous wastes and we need specialized knowledge of how to handle such waste. They need to be effectively managed. And, then electrochemical technology is again based on the electrochemical properties of the chemicals.

We have to understand there is heterocyclic chemistry and analytical chemistry are again marrying each other for rapidly changing subjects who is almost frenetic activities are affected by the countless research papers appearing in established and new journals, so many papers and research papers are appearing and by the proliferate. Then there are monographs,

books, reviews and several other technical material is available in our Google and other databases.

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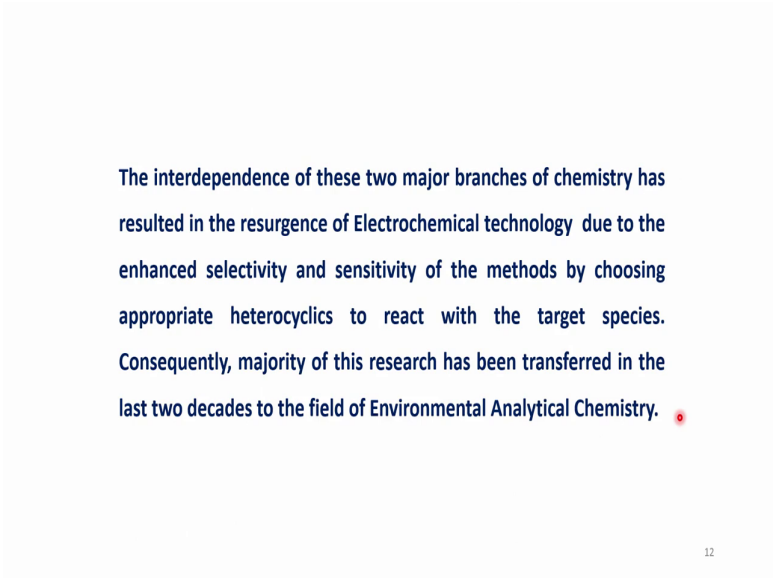


So, the interdependence of these two branches of chemistry has resulted in the resurgence of electrochemical technology due to the enhanced selectivity and sensitivity of the electrochemical methods by choosing appropriate heterocyclics to react with the target species. What are heterocyclics? They are organic compounds basically and they react with specific metal ions or other reacting species to generate the electrochemical systems.

These fuel cells and other things what we have talked about earlier, they are all involving these heterocyclics and then with a organic compounds and inorganic compounds, targets, tin shears etcetera. And, consequently majority of this research has been transferred in the last two decades to the field of environmental analytical chemistry.

So, without pollution control there is no analytical chemistry and without analytical chemistry there is no pollution control. So, this course is designed not only for the chemistry people, but also for engineers. And it is also designed for people with other backgrounds such as botany, zoology and other material research etcetera, but there are things to learn, basic things which we are going to study now.

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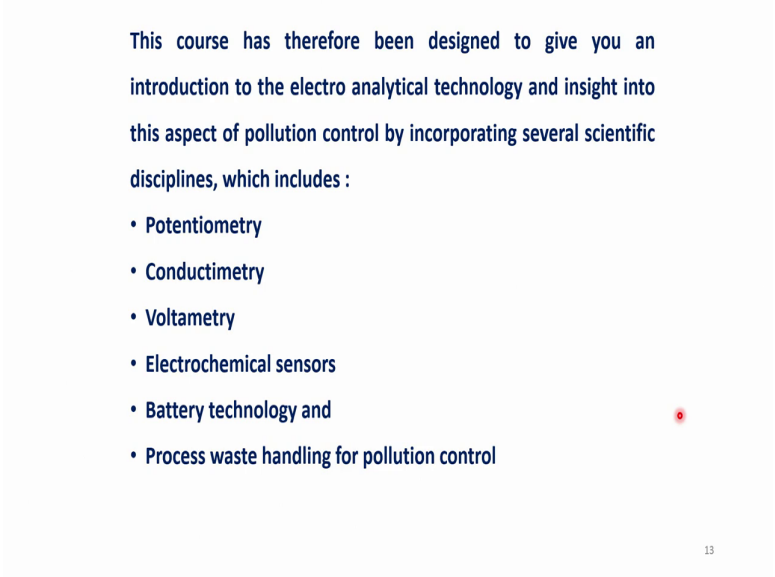


So, here we have the course design basically regarding electroanalytical chemistry. What you have here? So, we have potentiometry, conductometry, voltammetry we are going to talk about electro chemical sensors, battery technology and process waste handling for pollution control.

So, there is another technique in regarding the pollution control that is known as Zero Liquid Discharge: ZLD. So, we do not want any of the industries letting out any water, used or

unused; unused if they want to let out they can as well not take it. But, if somebody is using water for their process no water should come out of the industry which is untreated.

So, zero liquid discharge is a concept that has been popularized since last 10 years in India and abroad and we are going to talk about it in our course.

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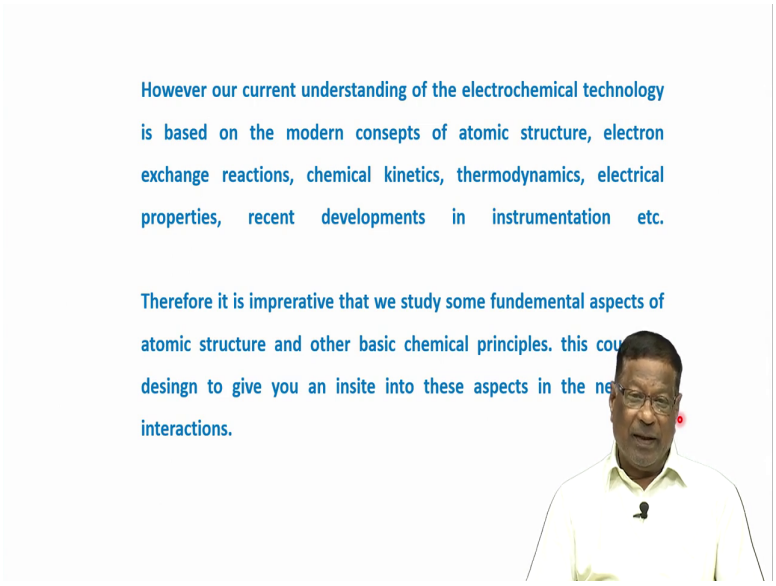


And our current understanding of the electrochemical technology is based on modern concepts of atomic structure, electronic exchange reactions, chemical kinetics thermodynamics, and then electrical properties etcetera, including the recent developments electric instrumentation, electronics and then electrical engineering all those things included.

Therefore, it is imperative that we study some fundamental aspects of atomic structure and other basic chemical principles. Because when I am going to explain to you about the

voltammetry, I do not want you to understand you know get bogged down trying to understand the fundamental basic terms what we are going to discuss. So, this course is designed to give you an insight into these aspects in the next few interactions ok.

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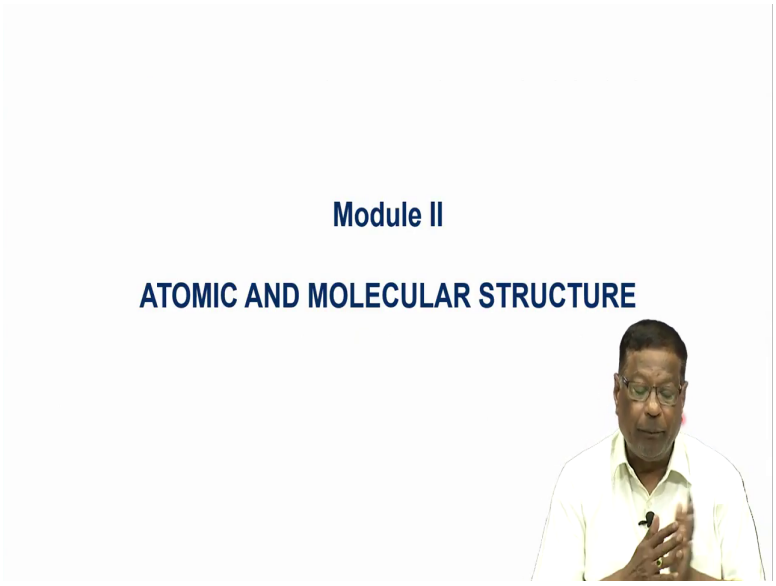


So, this is where I stopped for today and in the next class we will start studying about the atomic and molecular structure. This will be a sort of short introduction regarding the structure of the atom.

So thank you very much. We will discuss again after in the next class