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**Wan Zuhairi Wan Yaacob**

Okay, good morning everybody. Today, I am going to discuss about the concept of what we call risk assessment, and then I will try to concentrate more on human health risk assessment. Before I begin, actually the most important point that we need to understand is what is risk, okay, so what is risk? So, risk is anything or that possibility of something bad happen to us, all right, so that's the risk, all right. So you have the components of probability and then you have the component of consequence in terms of the quantitative risk assessment and its product.

So, in the picture that I show you here is you can see this is a cat, this is a bird, so you can see there is a hazard whereby the cat will eat the bird, and then the bird will die, so that's the consequence. How about probability, the chances? So, probably the bird will fly away, then there is no – no risk. So you need to have two components in the risk, the first one is the chances of this bird get eating by this cat and then the chances of this bird to run away, all right, so it will give you the component of risk assessment.

Okay, this is an example of risk assessment in our daily life, all right. This is a very good cartoon by Malaysian cartoonist C. W. Kee in his edition of Kee's World. So this is a concept of risk assessment how you have to make assessment in all your daily life, all right. So this guy want to park his car, all right, and then he get - he got a very nice place under the tree and then he see a branch of tree here that could probably broken and then hit his car, so that is how he make risk assessment, okay. So, the consequence is the car will get damaged and then the probability is that how much or how many probability that this branch will go and hit this car, yeah. So that's the assessment, all right. And then he tried to manage the risk. He managed the risk by moving his car into the another place, all right, but this time he forgot to make a risk assessment, all right. He forgot to make the risk assessment that the car is very close to the slope which is - you see the sign of landslide here so he missed that the chances of occurrence, of landslide occurrence is very high because that's why they put a pole, a sign of landslide here. So at the end, this car – this car is hit by the - a big block of rock and then this is the consequence, so the car got damaged, then he has to pay some money in order to repair the car, something like that. So this is kind of risk assessment that we make in our daily life.

Okay, so in terms of risk assessment, if we want to classify risk assessment as a risk assessment, there are two types of risk assessments, okay. There are two major types of risk assessment. The first one is called quantitative risk assessment or QRA, okay. The second groups of – the second group of risk assessment is called environmental risk assessment or ERA, okay, and then ERA can be divided into two, 2(a) is human health risk assessment or HRA and 2(b) is called ecological risk assessment, okay. And then if you look at the quantitative risk assessment, there are two components of qualitative risk assessment. So normally in engineering field or possibly you want to check or you want to calculate the risk for the accidents occur on this rig, this oil-gas rig where they drill and get the gas and oil out. So, they want to quantify what is the risk of the rig gets fire, okay.

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So that's the risk, the risk is fire, okay. The consequence, this will get damaged and then probably some people get die, so that's the consequence. So there are two components. The first one is likelihood, the chances, probable - the probability of this accident occur, all right. So you must have a very good database, for 1 year, how many accidents, this type of things happen in this kind of country like Singapore or like Malaysia, okay. So that's the probability. You look at the previous accidents, how many accidents of this kind in year, so that will give you the likelihood, okay. And then consequence, how many people die, in terms of human life, or in terms of money, what is the cost of this accidents, that is in terms of money, okay. So there are two components of risk in quantitative risk assessment, likelihood multiplied by the consequence.

For the second risk is called environmental risk assessment. There are two components of environmental risk assessment; the first one is human health or HRA and then there are two components of risk in HRA, the first one is hazard, the second component is exposure. So if you multiply hazard by exposure, you can get risk. So, for example, this is a kid, a human, and then it is exposed to these contaminants that come out from the – from the – from the factory here, okay. So there is exposure of this children or this kid to this contaminants, so that's exposure, because she inhale the toxic gas, inhale. So the chemical will – will goes – will go into the body of this kid and then there is exposure. And then hazard is - what is the hazardous properties of this gas, for example, okay. So you have two components, hazard multiplied by exposure, and then this hazard can cause you cancer or probably will not cause you cancer, because in environment, we are concerned about cancer. Everybody is – is afraid of cancer, getting cancer, because all the exposure to the chemicals, alright, so in human health risk assessment, the hazardous component of toxic is divided into two components, the first one is whether it is carcinogenic or can bring you cancer and non-carcinogenic chemicals, all right. So that’s the most important part of – of our risk assessment today is to assess the risk of chemicals into the health of human because we are consider – we are concerned about human, not as much as ecology, for example, right.

So ecology risk assessment is when we want to do some risk assessment on the biological components of our environments. For example, we want to check the risk of this bird on to the polluted soil or polluted water. So you have polluted water or river is contaminated probably with sewage all right, with high BOD/COD and etcetera, so you want to check the risk of this bird when it drinks the water from this river, so that’s the ecological risk assessment. So we have quantitative risk assessment in engineering if you have got accidents or burning or something like that and then you are concerned about the human health and then you are concerned about our ecosystem, our ecology and etcetera. So, in terms of risk assessment, there are two groups of risks, quantitative risk and also environmental risk. Environmental risk has been divided into two; human health and also ecologic – ecological risk.

Okay, this is another example of quantitative risk – of quantitative risk where you have - where you have two major components of quantitative risk; the first one is hazard and the second one is probability, the chances of that accident to occur, okay. So this is what we call hazard, accidents.

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This is also hazard, the oil spill, this is a ship, probably there is a leak somewhere and then we spill oil onto the rig – into the sea, so this is also hazard, this is also hazards, another part of hazard, burning, that explosion also is hazard. And then you need to get the probability by looking at the previous accidents that occur in that particular area. So you need to get a big database from the company saying that how many or how often this type of accident occur in the past, all right, probably four accidents per year or probably 10 accidents per year, so that will give you the value of probability. And then consequence or hazard will be 10 people die, three people die and etcetera. You get that components, then you can calculate the risk assessment.

Another form of doing the quantitative risk is by doing this what we call semi-quantitative risk assessment. This is semi-quantitative or they call it qualitative risk matrix. This is another way of presenting the value of hazard and then the value of probability by plotting your risk on this risk matrix, all right. So you have the, what we call it, chances of probability, failure of pro – failure probability increase from very low, very low, low, medium, high and very high and then you have consequence of severity, the hazardous, the consequence, is it very low, low, medium, high, and also very high and then the increase or the risk will increase when you move from this point towards this point. So it means that at this point you have a very high chances of that accident occur and then you also - you also very - you also have a very high consequence. There you have very high risk, contact to this point, this is very low risk, that means very low chances and that very low consequence.

Okay, this is possibly another risk, but the chances is very, very small. You have a whale that jumps on to the rig, all right. This is also another type of risk assessment, but the probability of this thing happen is zero, all right, because there is no – no – no – there is no reported cases before - before - before this saying that the – the whale can jump on to the rig or something like that. So this is another cartoon of risk assessment.

So risk of particular events is probability of that event to occur multiplied by the consequence of the event, and consequence can be how many people died because of the accidents in terms of property damage and then the money involved, so this is also risk, all right. So how much money that is lost because of the accidents, so we need to calculate the risk of money loses from that kind of accident as well. For example, you have a – a large earthquake, for example, large earthquake, the chances is very low, but the consequence is very high. So probably you have a medium to high risk because of the large earthquake in - anywhere in this – in this – in this - on this earth.

And then we – we can also have another risk that we always accept in our daily life, example, driving a car. Professor or president come and told me the accident rate in Kagawa is very high, all right, because of people drive very crazy on the street, for example, so that means the risk of getting accident in Kagawa will be very high compared to accident in Kyoto because the number of accidents per year in Kagawa is high so probability is higher, all right. So if you multiply probability times consequence, then you have a very high risk when you drive a car in Kagawa compared to the risk if you drive the car in another places with very low chances of accidents. So we look at the previous accidents that happened in the past in order to be finding probability of that things to happen.

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So this is another things, two components of risk, probability you multiply by consequence, then you have the landslide risk, for example. Okay, this is to give you the idea of terms, okay. We have risk perception, we have risk assessment, and then we need to do something about the risk, okay. So, perception means what is your perception with that type of risk, so these two persons discuss that this must be the risk so that is the risk perception. You look at something and then you say, oh, risk very dangerous, so that’s your perception. So probably this say – this – this guy said this is very dangerous and then she said, oh, not so critical, so that's perception. And then you make assessment of this things to – to – to – to – to go down and then hit you or something like that so you make a risk assessment. You assess this type of risk, all right.

Management, then you have to some – you have to do something about this risk, then you run away. When you run away from this risk, so that is management, all right. So this is the - the terms of risk perception, risk assessment, and also risk management, how do you manage the risk. Same thing here, in risk assessment, you can do what we call a risk matrix by plotting your events on this matrix plot or matrix table. You have chances of these accidents will happen, likelihood, you have rare, unlikely, possible, likely, and almost certain and then consequence, insignificant, minor, moderate, major, severe, all right. So, and then you have different types of risks - low risk and then extremely high risk or extreme risk. For example, if you say risk of travelling by car in Malaysia, okay, so you have to look at the likelihood of you to getting accident in Malaysia and then also the consequence of people died in Malaysia because of the accident, so you need all data about car accident in Malaysia, then you can get the risk of traveling by car in Malaysia. Then I have been told that the risk of getting accident in Malaysia is very, very high and then I think many foreigners are afraid to – to – to drive a car in Malaysia because we have a very high chances of accident and also very high consequence of accidents.

Risk of traveling with an aeroplane nowadays, all right, so you have probably very low risk and then also very high consequence. Risk of volcanic eruptions in Malaysia, we don’t have any volcanic activity in Malaysia. Therefore, the likelihood is very rare and then if this occur, it is probably very major or severe, then you probably have very low risk in this example. Risk of earthquake in Japan, this is very, very critical, probably you say the chances is very, very high or probably almost certain or likely and then the major, the consequence is very, very high, probably a major consequence, severe consequence, probably the risk is somewhere here, higher, high risk or probably extremely or extreme risk, for example.

Okay, in terms of human health risk assessment. This is the most component or the most – the most important parts of our lecture today, so there are two components of human health risk assessment. The first one is the component of hazard, toxicity; the second component is called exposure. Okay, what is hazard? What is exposure? Okay, so this example of risk of you getting bitten by this dangerous snake, all right. We know that snake is very dangerous, all right, because if it bites you, then you got a problem with it, so that's hazard. Exposure means how is it, is you exposed to that snake, that is exposure, all right. So in this two case, you have risk here because there is exposure of you to the snake, and then in this case, we know that the snake is very, very dangerous, but there is no exposure because the snake is in – is in the cage, all right. So if the exposure is not exist, then the risk is no - I mean there is no risk of you get bite of this kind of snake because there is no exposure.

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This is also another cartoon of chemicals and then there is a fish in the tank. And then this guy says, what's the exposure, and then the lady said what is the hazard of this chemical, and then the fish said, what is the risk. It means that if this chemical is outside of this tank, then there is no risk, but if she puts this chemicals into this bowl of water with fish inside, then there is a risk, all right. So if you have exposure, if you have hazard of this chemical, then you have risk, okay. So that's the concept of human health risk assessment.

Another important things about human health risk assessment is the concept of source, pathways, and also receptors, okay. So the source means is there any chemical or hazard substances in that particular area. So you have a source, probably you have a factory that produce chemicals and then it start to leak and then enter the environment, so that's the source, chemicals. The pathways is how these chemicals can migrate or move and then go to the receptors so that is the pathway, whether through the water, whether through the soil, or whether through the air, all right, that's the pathways, how the source can migrate and then make the receptor expose to the chemicals. Another components - important components is receptors, people, all right. So if you have this three components link with each other then the risk will be exist, okay. So you need source, you need pathways, and you need receptors. I think this is not on your - in your handouts.

So we have the concept of source, we have the concept of pathways, we have the concept of receptors, then we have the concept of risk, all right. If you have source, you have pathways, you have receptors, then the risk will exist, okay, but if there is no source, then there is no risk if there is no pathways, so that means the chemicals will not be exposed to the receptors, then there is no risk, but if you have source, you have pathways, but no people live in that particular area, then there is no risk. So very, very important for you to study about the source, the pathways, and also the receptors and then to study about the exposure of the toxic chemicals to humans and then what is the characteristic of the – of the toxic chemicals, then you can measure the risk.

Okay, this is another concepts of what I mentioned in my previous slide just now. So we have exposure and then we have toxicity, all right. So this guy is exposed to this chemical, that's exposure, and then the chemicals has the properties of toxicity that probably can cause you cancer, then you try to calculate the risk and then normally risk is given in terms of probability of you of getting that kind of cancer or anything related to the – to your health problem or something like that. So there are two components of risk. Same thing here, the concepts of source and then the concept of pathways and also exposure to people, then you can have risk. This is what we call a conceptual site model, okay. So before you start doing risk, you have to do this kind of conceptual site model or conceptual model in order to - in order to give you the idea of source, the idea of pathways, and then the idea of exposure, okay. And then when you have exposure of chemicals to people who probably works on that site or people who probably stay in that particular site, then you have intake, okay.

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How – how – how much chemicals that this guy expose per year, that's the intake, okay. So quantity of contaminant quanti - quantify the contaminant intake at the point of exposure. So this is your point of exposure and then the intake will give you the idea of how many chemicals that gets into the body of this worker or probably into the bodies of this family who probably stay near to the contaminated sites or the polluted site. Okay, this is all the ways of this how you calculate the intake, okay, because risk is equivalent to exposure times toxicity. Exposure means intake, all right. Exposure means intake, so intake will be given to you by this formula, I intake equals C is the chemical concentration at that point times the contact rate multiplied by EFD, two components of exposure frequency and then ED is the exposure durations divided by your body weight. If you are adult, you have to use 70 kilograms, if they are infant, probably 5 kilograms, and then children will be 10 kilograms. This is the standard. You cannot change it, all right. So normally you have to adopt all adults must be – must have 70 kilograms for example, and then multiplied by AT which is the averaging time, or the total exposure time of that chemicals into your body. So that's the way how you calculate intake where C is the chemical concentrations, what is the concentration of chemicals that exist at the point of exposure, okay. It could be given by milligrams per liter if you drink contaminated soil or if you drink contaminated water, milligrams per liter, or if you eat contaminated soil, the unit will be milligram per kilogram, for example.

The contact rates, how much water that you drink per day, how much water or how much contaminated water that you drink per day, 2 liters day you drink contaminated water that contain toxic chemicals, so that's the contact rate, okay. Exposure – exposure frequency and duration, exposure frequency, days per year, how many - how many - how many days you are exposed to that toxic chemicals, okay, so that's the days per day and then exposure durations, how many years you work in that particular place in your – in your – in your whole life, for example, so that's the exposure durations, your body weight, and then you divide it by averaging time which is the time that you are exposed to that kind of contaminants, so period over which exposure is average, particularly - particularly in days, and then there are two ways of evaluating the parameter of AT, whether the chemicals are carcinogenic or whether the chemicals are non-carcinogenic.

If the – if the chemicals are carcinogenic, that can bring you – that can give you cancer, then you have to multiply 70 years multiplied by 365 days, divided by year, 70 years mean this is the maximum human life in US, for example. So average human life in America, in US, is about 70 years, so you multiply 70 years by 365 days per year, then you get the life expectancy for population of concern in US, for example. And then for noncarcinogenic, you have to multiply your exposure duration multiplied by 365 days, so that means the tried the components or these two components will give you the days that you are exposed to that kind of contaminants. So this is the intake, how much chemicals that enter into your body by eating contaminated water or by drinking contaminated water, by eating contaminated soil or contaminated food or by inhale contaminated air.

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So you can calculate how many chemicals, how much chemicals that enter into your body by using this formula, that means what we call exposure, the component of exposure. Now you have the component of exposure, how about the toxicity. The chemicals – the toxicity of chemicals normally determined by using rats for example. This is how toxicologists - toxicologists is the scientist that study the toxicity of the chemicals. So normally you don't inject chemicals to people, right, so you need - we need some – some – some something or some animals, probably rats, and then you inject with chemicals and then you can see the behavior of these animals, you get the data, and then the data that you get from these animals, you extrapolate into human beings, okay. So never inject chemicals to human being in order to get the toxicity values, okay. So this is how the toxicologists study about the behavior of these animals by the toxicity of the chemicals. You get the data of the toxicity and then you multiply by safety factor, probably there are two or three safety factors that you need to consider, and then you get the effects of that chemicals into the human body, whether it is cancer chemical or non-cancer chemicals.

Okay, for carcinogens, all right, so I will go straight to this graphs. So for carcinogens, if you look at the occurrence of cancer and also the dose, the dose means how much chemicals that you give to the animal or how much chemicals that you are exposed to, that's the dose, all right, or probably, you know Panadol, you know Panadol, aspirin tablet, Panadol, you feel dizzy and then you eat Panadol, right, aspirin, medicine, and then you have one tablet, two tablets, three tablets, so that's the dose. One tablet is a dose, two tablets probably middle dose, three tablets probably higher dose, so that's the dose. In – in – in cancer, there is no safety dose. It means that once you expose to the chemicals that bring cancer, then you have potential to have cancer.

So if the dose is small, although the dose is small, there is the chances of cancer here. If the dose is high, then the occurrence of cancer will be high. So that's why the toxicologists come out with this slope factor and then the toxicity is given by the slope factor which is risk or the occurrence of cancer divided by dose and then the unit is one over milligram per kilogram per day. So slope factor means - derivation of slope factor is based on the assumption that every dose poses a risk. So that means that there is no safe dose. Once you are exposed to the chemicals that can bring cancer, then the chances of you to get cancer will be there, so that's why they use slope factor for carcinogenic chemicals. And there is no threshold value for the toxicity values of carcinogens. So remember that with carcinogenic chemicals or chemicals that can bring you cancer, you have to use slope factor. Although the dose is small, the chances of you getting the cancer will be present in that particular case.

Okay, this is for non – this is for carcinogens, this is non-carcinogens, all right. In non-carcinogens case, you have this type of curves, okay, where the curve is produced by plotting the effects and also the dose, all right. For example, I give you what is the chances of you getting drunk by drinking or by drink alcohol, all right.

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Because I never drink alcohol, probably my NOAEL very, very low, for example. So if you drink one glass of alcohol, you probably here, nontoxic, all right. For me, for example, or for you, for example, if you drink two glass, so that means you increase the dose, all right, so after the two glass, you feel dizzy, you feel not comfortable so that's the toxic part of the chemicals. Then your minimum point or the minimum dose that you are stable after one glass of alcohol is called no-observed-adverse-effect-level or NOAEL. Below this point, before or below this point, you had - you don’t have any problem with that chemicals, but after this point, the toxic characteristic of the chemicals can be seen on your behavior.

Probably, you are – are going to - going to vomit, you will feel dizzy or something like that, so that's under this point and then when you increase the dose, that is very toxic. For example, you drink 10 glasses of alcohol, probably the dose is here, then you got very problem with your health for example. So this is what we call no-observed-adverse-effect-level and then this value will give you the value of – of calculating the non-carcinogenic risk of that of the chemicals. Now you have exposure and then you have two values of toxicity, carcinogenic, non-carcinogenic, then we can do risk calculation, you can calculate the risk, all right. So for non-carcinogenic, so for risk in human health, you can have, you do it two ways. The first one is for chemicals which is not – which are not - not –which are not carcinogenic. The second way is for carcinogenic chemicals. For non-carcinogenic chemicals, you use this equations, HQ is hazard quotient equivalent to intake that you – that you calculate divided by the reference – reference dose. Your reference dose is here, equivalent to NOAEL, okay. So that's your reference dose and then so HQ is hazard index or hazard quotient, I is the intake that you calculated, reference dose is normally given, all right.

We have a database of chemicals in this world and then you can measure or you can identify what is the reference dose of that kind of chemicals in the website. We have a big database of reference dose in the – in the website or in the book, for example. So once you get the reference dose, you put it in the formula. If your hazard quotient is less than one, then there is no risk. If the hazard quotient is more than one, then the receptors are exposed to the contaminant and there are risks in that particular example. So this is the standard, this is the standard normally used in different countries. For example, in US, they say that HQ must be one. DOE Malaysia, we say HQ must be one. If you got HQ less than – if equivalent to one, it's okay, less than one, it should be okay, more than one, you got a problem with it. And then US Clean Air Act also say that HQ must be one in order to get you a very safe risk for that particular chemicals.

Okay, for – for carcinogenic, in United States, for example, they use this formula. Risk is equivalent to your intake, CDI or intake multiplied by the slope factor. So remember the slope factor is now, the slope factor, and then the intake you multiply, you will get risk, so that's the risk, okay. And then if you check the standards, you can have, for example, in US, they say risk is in between 10-5 to 10-4. US Clean Air Act says the risk is 10-4 - 10-4. In Malaysia, we put two values, 10-4 to 10-6.

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This is the chances of you getting the – the risk. For example, if you have - the risk is 10-3, is it risk or not risk, 10-3. So, 10-3 means the value of you getting the risk is one over 1000, all right, but if 10-6, 10-7, 10-8, that means the probability of you to getting the risk is very, very small, so that's the meaning of this value. So in US, they put 10-5 to 10-4; in Malaysia, we use 10-4 to 10-6 as the chances for you to get the one over 10,000 and then one over one million. So that means in 10,000 people, there is one who will get the – the cancer, so the chances is very, very – its’ quite high compared to one in one million. In one million people, there is only one will get cancer with that particular chemicals.

Okay, this is the summary. This is not in your slides – in your handouts. This is the summary of what I am measuring in – in – in this lecture. So you have the risk of chemicals of concerns, okay, and then you need to measure or you need to get two values, the first one is called exposure to human by calculating the intake, by inhalation, how much air you – you- you – you – you inhale, and then ingestion, how much food that you eat, ingest, by your stomach, the contact, all right. Is there any contact between the source, the contaminated source, with your skin, for example, so that's exposure. And then you have another component which is called toxicity of chemicals.

There are two components, carcinogenic, you have to use slope factor. For non-carcinogenic - for non-carcinogenic, you have to use NOAEL parameters that I explained in our discussion just now. And then for risk, you have to do two things, you have to calculate risk – you have to calculate risk for carcinogenic and then also you have to calculate risk for non-carcinogenic. You multiply your intake with this value, you get this risk. You multiply intake with this non-carcinogenic values, then you can have non-carcinogenic risk, all right.

This is another summary of what we discussed today. For example, you have toxicity, you have exposure, then you have risk. In analogy, you have a big hole which is your hazard, hole, you can probably jump between and then you can get killed or injured, that's the hazard. The bridge is the exposure, so if you – if you stand on this exposure with the hazard below it, there is expression of risk for how much you can get risk. For example, if the value of risk is 10-2, so this is very high chance of getting cancer. This is what we call unacceptable risk. If you get the value in between 10-4 to 10-5, this is case specific.

In our country, Malaysia, we use 10-4 to 10-6, so if you have your risk in between 10-4 to 10-6, we consider safe, all right, consider it safe, but you have to be careful with it, but if the value is below 10-4, probably 10-3, then the risk is unacceptable. You have to do something with the risk. If the risk is over 10-6, then you are okay, acceptable, means the chances of you getting the risk, of cancer, is very, very low, one in one million, for exam – for example. So that's the expression of – of risk.

As a conclusion, risk is always present in our daily. Before we do something, we have to measure the risk, is it safe or not. Risk can be assessed, we can calculate the risk, whether it is quantitative risk or whether it is human health risk, and then we have to manage the risk properly. If we said that the chemical is there and then the risk is very, very high, then we have to do something with the chemicals, probably we have to rebuild the site, we have to shift the people out from the area and then we have to do remediation on that particular site.

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Then that's the management of risk in order to avoid any health effect and also accidents. So I mentioned to you just now is the manual way of calculating the risk, all right, but nowadays, with technology, we can use a software in order to help us with these calculations. This is the computer software that can be used to calculate the risk that I mentioned to you just now. You can purchase this software through the website. The name of the software is Chemical Releases by GSI which is an environmental company in Texas, US, and then we already purchased this software under my name and then it’s my university, Universiti Kebangsaan Malaysia. It is called risk-based corrective actions. So that means by purchasing this software, you don’t have to do any calculations, and then you have to – you don’t have to – to go and find what is the slope factor, you don’t have to calculate what is NOAEL, all you will get in this database of this software, okay.

This is the first page of the software, all right. You can see the terms of exposure, for example, exposure and the pathway. So how can the chemicals enter receptors or go to receptors? You see by ground water exposure, you see by surface soil exposure, you see by air exposure, and also you can do different type of things using this kind of software, and then at the end, you can have the value of risk by using this kind of software, okay. So you can do it manually if you have got simple data, but if you have many data, then you can do it by using a specific software or commercial software that you can purchase from the – the people who make software regarding to the risk assessment of your contaminated land or contaminated sites. So I think that's all of my presentation today. The latest version of the – of this handouts I already e-mailed to professor Kotake, so probably you can get it from – from Professor Kotake after this class.

So with that, I will say thank you and then I end up my presentation or my discussion today with thank you.

**END**