Technical Textiles

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Lecture No- 27
Ultraviolet Protective Textiles

Hello everyone, so our new topic is UV protective textiles. So UV radiation protective textiles, in this section will discuss different aspects of UV radiation. Initially we will try to understand the UV radiation then we will see the different factors in textile material which can affect the UV transmission performance or how to protect UV radiation and last segment we will discuss about the fabric engineering.

How to engineer fabric to control the UV transmission, ultraviolet ray transmission? So first let us try to understand what is ultraviolet radiation? These are basically electromagnetic wave.

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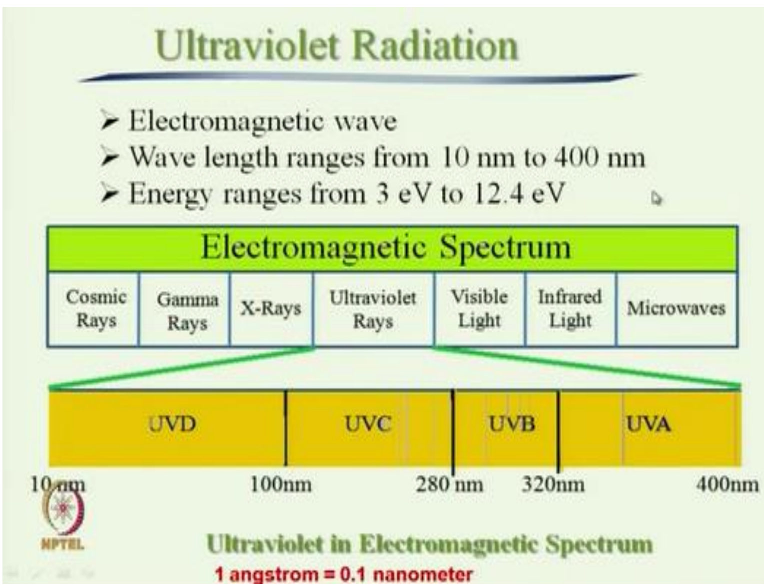

And electromagnetic wave if we classify if we arrange in terms of wavelength, the wavelength from 10 nanometer to 400 nanometers they are coming under the UV radiation UV rays. So first there will be cosmic rays then gamma rays, X-rays, UV rays and above that it is a visible light, infrared and microwave. So UV ray can be divided into four categories again depending on the wavelengths from 10 nanometer to 100 nanometer it is called UVD.

Then 100 to 200 nanometer UVC, 280 to 320 UVB, and 320 to 400 it is UVA ray, and depending on the wavelength they are penetration through the ozone layer take place and their severity that is the effect on human life that also affect on the that depends on the wavelength, these aspects first we will discuss.

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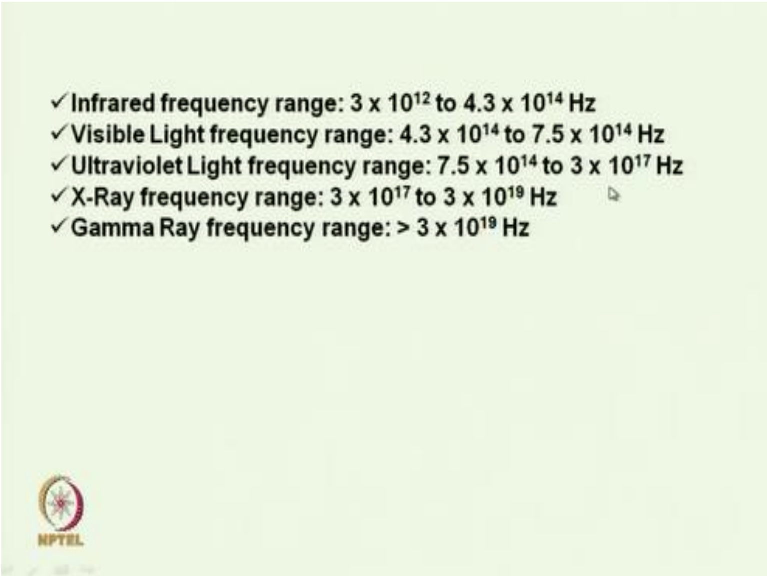

So the energy that wavelength if we see that infrared frequency range from 3 multiplied by 10 to the power 12 to 4.3 multiplied by 10 to the power 14 Hertz and UV light frequency range is in this range 7.5 multiplied by 10 to the power 14 to 3 multiplied by 10 to the power 17 Hertz, this is the frequency range.

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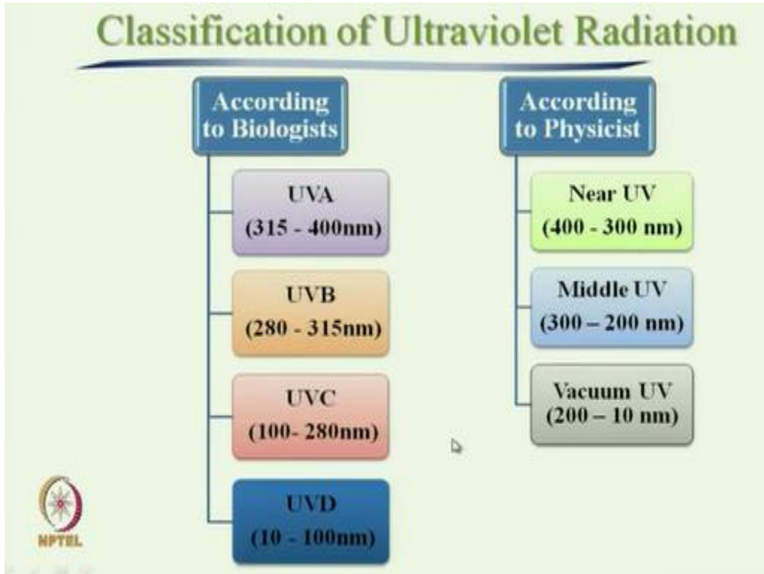

So as I have already mentioned so that ultraviolet radiation is classified into 4 categories depending on the wavelength as per biologist UVA, UVB, UVC, UVD, and as per physicist they are classified into near UV, near Ultraviolet, middle Ultraviolet and vacuum Ultraviolet. So if you talk about the effect on humans or any living organism this classification is based on UVA, UVB, UVC and UVD.

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Name	Abbreviation	Wavelength range (in nanometres)	Energy per photon (in electronvolts)	Notes / alternative names
Ultraviolet A	UVA	400 – 315 nm	3.10 – 3.94 eV	long wave, not absorbed by the ozone layer
Ultraviolet B	UVB	315 – 280 nm	3.94 – 4.43 eV	medium wave, mostly absorbed by the ozone layer
Ultraviolet C	UVC	280 – 100 nm	4.43 – 12.4 eV	short wave, completely absorbed by the ozone layer and atmosphere
Near Ultraviolet	NUV	400 – 300 nm	3.10 – 4.13 eV	
Middle Ultraviolet	MUV	300 – 200 nm	4.13 – 6.20 eV	
Far Ultraviolet	FUV	200 – 122 nm	6.20 – 10.16 eV	

So if you see UVA, so ultraviolet ray A coaches within the range of 315 to 400 nanometer it is energy is 3.1 to 3.94 electron volt so energy here it is lowest energy but wavelength is high as the wavelength reduces the energy increases. So it is a long wavelength it is not absorbed by the ozone layer. So majority around 90%, 95% it penetrates through the ozone layer but here the energy is least, UVB it is from 200 nanometer to 315 nanometer it is a medium wave mostly absorbed by the ozone layer.

Here they absorbed by the ozone layer and it is energy is little bit higher than UVA 3.94 to 4.43 and shortwave that is UVC, 280 to 100 nanometer it is 4.43 to 12.4 electron volt and it is completely absorbed by the ozone layer. So short wave length UV rays it is there absorbed and UVD much shorter wavelengths they are completely observe they do not come to the earth.

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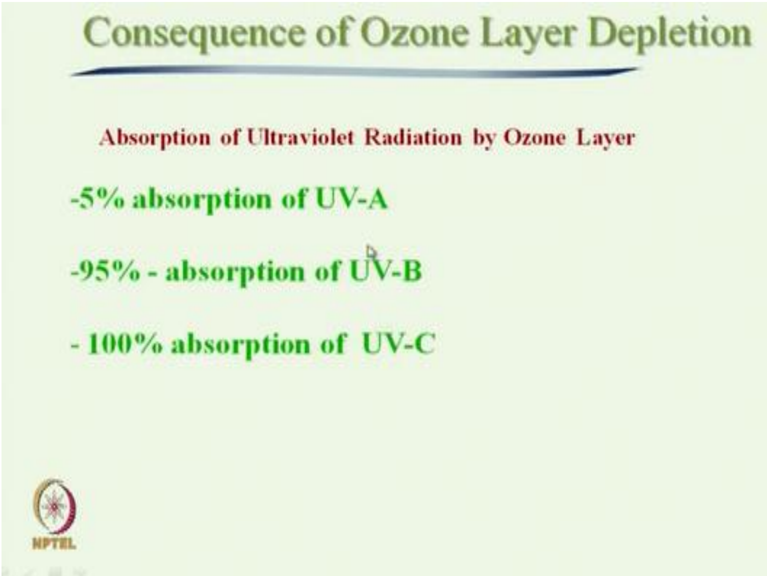

So if we see here the 5% is absorbed in UVA by the ozone layer. So 5% of the energy is being absorbed in the ozone layer for UVA but 95% reaches to the Earth surface. So we should be careful about UVA because majority of the rays are coming to the Earth surface, UVB is 95 % is absorbed very little comes to the earth but here energy is high, higher than UVA and that is why it is more dangerous than UVA and UVC it is almost 100% absorbed. So why do you need UV protection? It is basically effects the human and aquatic ecosystem.

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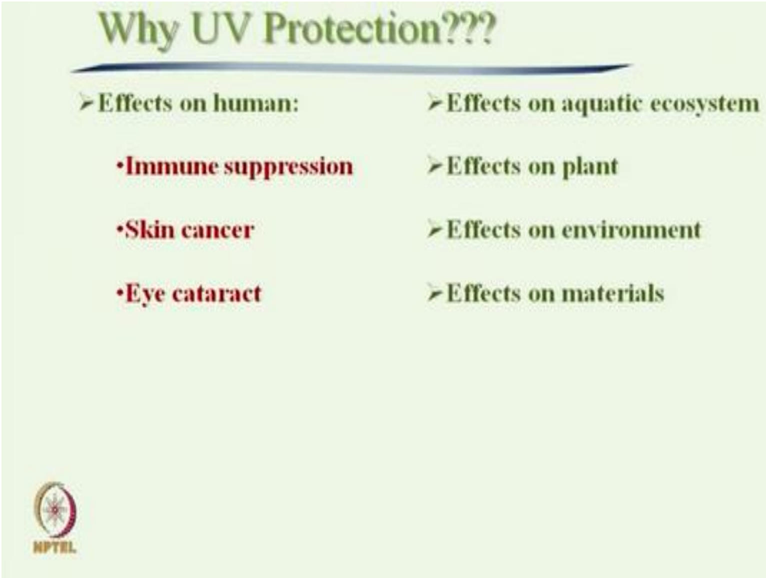

Even plants, so on humans it is skin cancer, eye cataract, immune suppression these are the effects. So effect its effects on plant, environmental effect is there effects on material. So UV rays it affects the synthetic fiber particularly nylon and even polypropylene they get affected easily and reduce the mechanical characteristics and or other characteristics.

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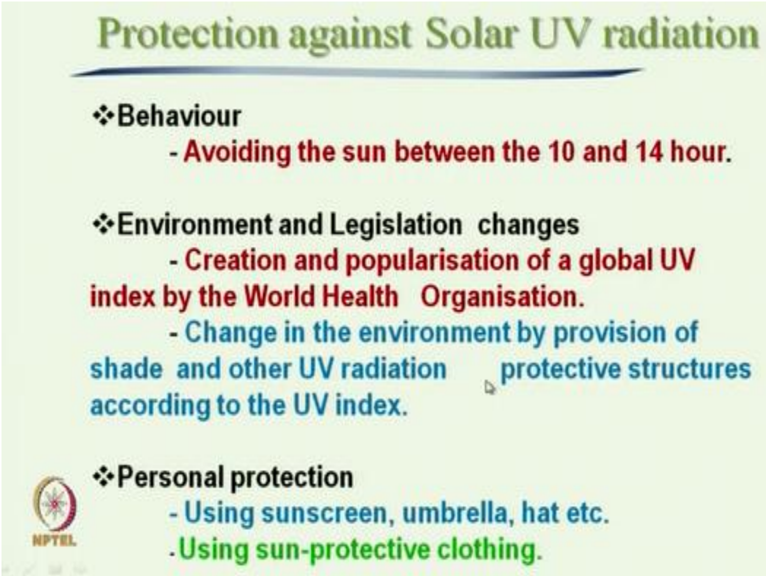

So protection against solar UV radiation it is maximum between 10 to 14 hours. So one should avoid direct sun from 10 to 14 hours, other ways of protection like environment and legislation change creation and popularization of global UV index by WHO. So global UV index people must know and depending on the UV index one should use UV protection maybe UV protective clothing or different shades one can use.

Change in environment by provision of shade or other UV radiation protective structure depending on the UV index. Personal protection also is required using sunscreen, umbrella, hat or sun protective clothing when people are going out. So in our discussion we will try to see how to develop UV rays protective clothing, the most commonly used terms are;

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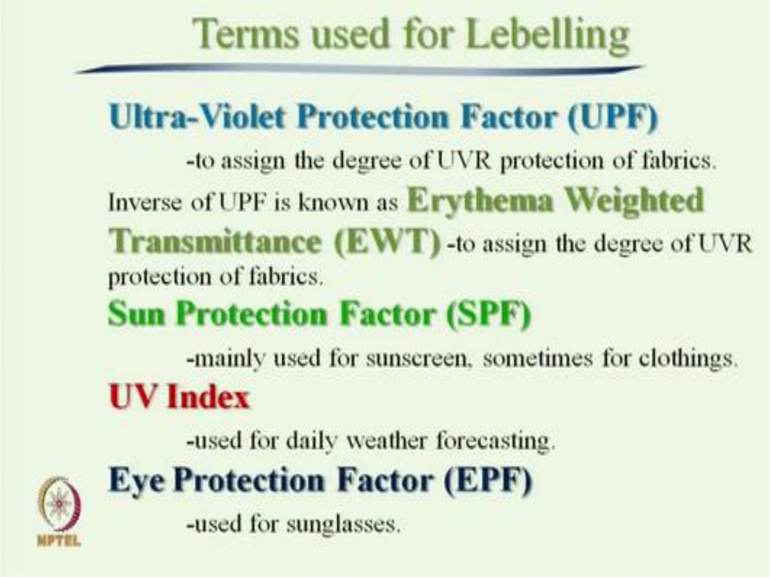

Ultraviolet protection factor UPF is the most commonly used term to, show the level of protection by a fabric or any material. So this is assigning a degree of UV radiation protection of a fabric it is inverse of UPF is that erythema weighted transmittance EWT. So it is the UPF equal to 1 by EWT and sun protection factor SPF it is mainly used for sunglasses as sometimes for clothing SPF also we can use. UV index is another term which used for daily weather forecasting.

UV index is basically it is environmental term it shows how much UV radiation is coming to the earth surface in that particular area, UV index depends on the altitude of the particular place and clouds in that zone. So if it is cloudy this will the UV index of that particular zone will reduce and vice versa, EPF Eye protection factor it is mainly used for sunglasses. So there are different terms we must know UPF, EWT, SPF, UV index and EPF.

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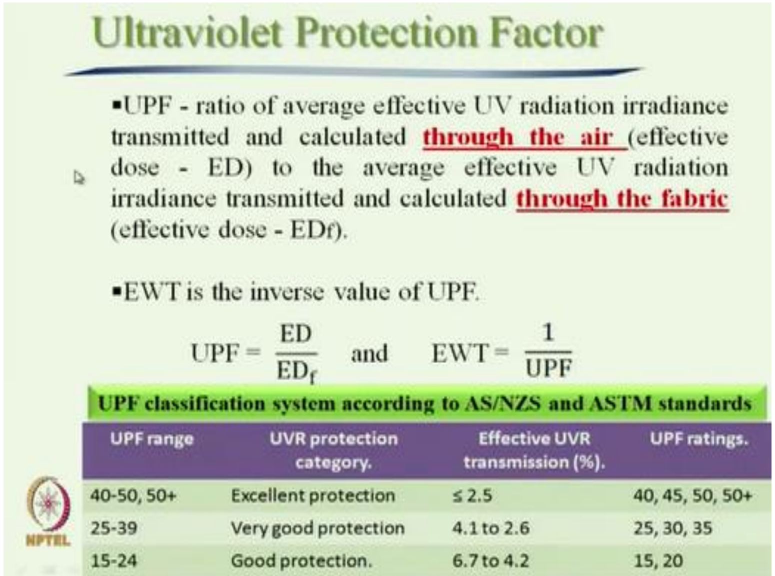

First let us try to understand the UPF ultraviolet protection factor. This is the ratio of average effective UV radiation irradiance transmitted and calculated through air and that radiation to the average effective UV radiation calculated through the fabric.

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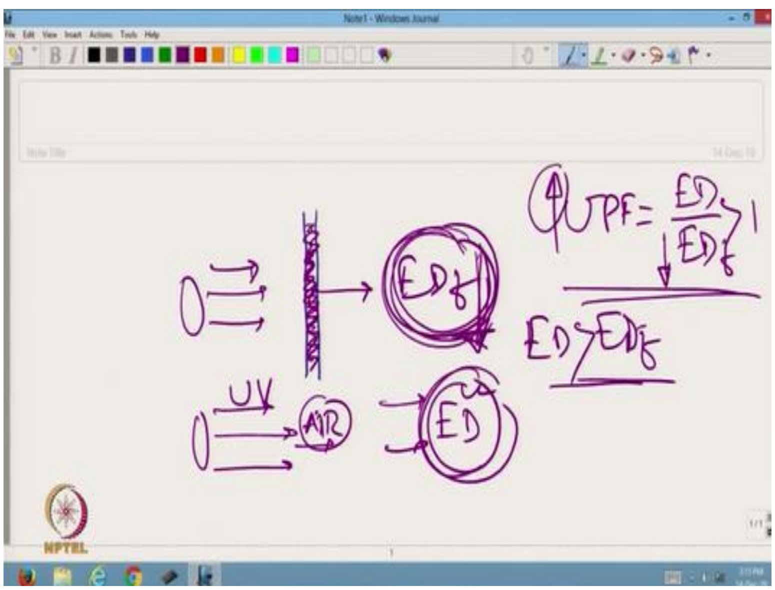

Now let us see this is fabric and here there is no fabric through the air. Now suppose UV radiation is coming UV radiation here also UV radiation now here with the fabric without fabric with through air it is coming ED and through fabric, fabric will absorb little bit UV rays and it will say ED fabric. So ED is more than ED fabric that is energy coming through the fabric here the energy UV radiation energy it is more.

So this will be more so UPf will be ED by EDf which is more than 1, that means higher protection higher absorption by the fabric means if the absorption is high that means the amount of energy transmitted through fabric will be low. So where that is why so if it is low produced then UPF will increase so fabric production will increase, so higher protection of fabric means higher UPF.

So effective dose of the UV radiation it is ED through air are effective dose which is coming out from fabric after absorption by the fabric it is EDf. So, UPF is equal to ED by Edf I have already explained and EWT which is reciprocal of UPF so that we can also derive. Now the ranges are UPF range if it is 40 to 50 it is excellent protection where only less than 2.5% transmission will the UV ray will get transmitted through the fabric rest 97.5% or more will be absorbed.

So these are excellent anything more than 40 UPF is excellent, so if we have rating 40, 45, 50, 50+ like that, 50+ is very good you ultraviolet protection rate, 25 to 39 it is a very good protection where 4.1 to 2.6% of radiation is getting transmitted. So 25, 30, 35 in this way we express the UPF and 15 to 24 is good protection and below that it is a poor protection, so 15 to 24 means typically 6.7 to 4.2% are getting transmitted.

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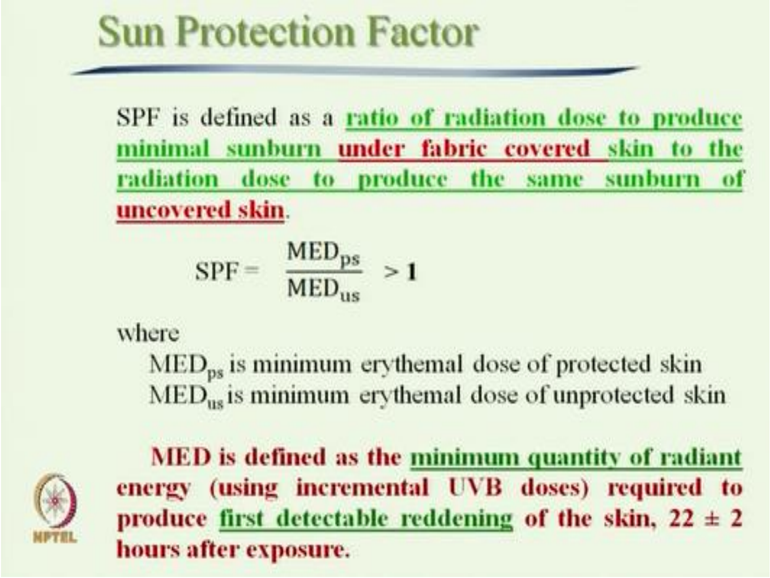

Next is the sun protection factor these are basically used for any Sun protective lotion and some time for fabrics. Sun protection factor is actually it is a ratio of those to produce minimal sunburn under fabric cover or maybe Sun lotion cover to the skin to the radiation dose to produce the same sunburn of uncovered skin.

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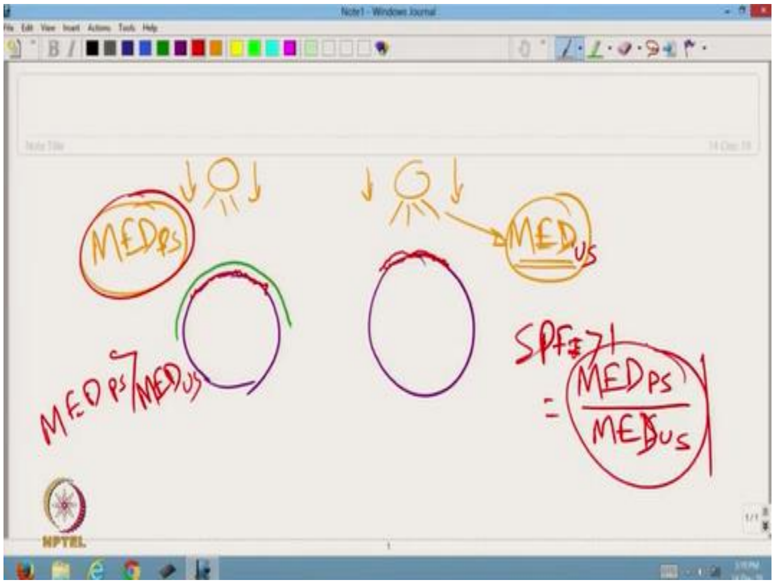

Now so this is one skin suppose human skin here we are protecting through one cloth another human it is without any protection. Now we will keep on increasing the radiation rate, here after certain time mean dose, mean effective dose without any cloth is MED and mean effective dose with protective surface is this one. Now here with mean effective dose certain mean effective dose there will be sunburn after certain time.

But here if we want to have similar sunburn after protection we need to increase the mean effective dose, so mean effective dose here is more than dose without surface unprotected surface. So this is so that is why sun protection factor SPF which is more than 1 is equal to this one is more, so MED protective surface by unprotected skin. So this is a protected skin and unprotected skin the ratio here shows the sun protection factor.

The main difference from the earlier one UPF we do not need any human object but to measure sun protection factor we need human object and this SPF is very important for Sun protective lotion where we have to use our body part and apply the lotion on the body part and after that we try to see any sunburn. So MEDps is minimum erythemal dose of protected skin ps that is maybe by fabric protection or by any lotion protection and minimum erythemal dose of unprotected skin MEDus that is without any protection.

So MED is defined as minimum quantity of radiant energy that it is UVB dose here we normally use UVB dose required to produce first detectable reddening of the skin and it is time is 22+ - 2 hours exposure so that exposure will be in continuous manner and then we will measure the skin redness. So skin will get red, so when as soon as skin reddening will happen then we will stop the experiment and you will keep on change if the skin reddening is not happening then we will go to the next level of dose.

In this way we will do experiment and ultimately we will calculate the SPF. SPF measurement is basically time consuming measurement whereas UPF we can get immediate result.

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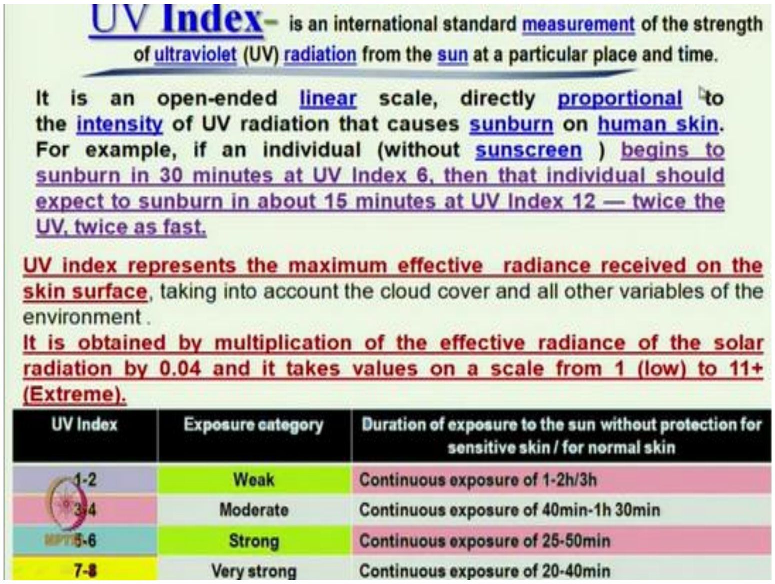

Now try to understand UV index for all this study of UV protection we must know the UV index of that particular environment. So without UV index only developing UV protective clothing will not help we need UV protective clothing where UV index is very high in case of low UV index we have to produce fabric accordingly. UV index is an international standard which measure the strength of UV radiation from the Sun at a particular place at a particular time.

So that is important. UV index changes with the place, altitude, many other factors are there so this index is actually open-ended linear scale that means it is directly proportional to the intensity of UV radiation that cause sunburn to human skin which means that we can extrapolate, for example if an individual without sunscreen begins to sunburn in 30 minutes with UV index of 6 then we can predict that same person will have the same effect of sunburn in 15 minutes with a double intensity, of UV index of 12.

If the UV index becomes say 3 then he may take 1 hour time to have similar sunburn so that is why it is called it works on linear fashion. So UV index represent the maximum effective radiance received on the skin surface taking into account cloud cover and all other variables of the environment so we must know the UV index and that is the maximum radiance which is reaching on our skin.

And this radiance, UV index is it is a combination of UVA, UVB, UVC everything if you should take care. Whichever it is coming accordingly and giving the weightage of different rays that I will explain just now and then we calculate the UV index and it is obtained by multiplication of the effective radius of the solar radiation by 0.04 but typically if you see if we multiply by 0.04 that means we have to divide by 25 basically.

Whatever the UV radiation comes and if we multiply with the weightage and then we if we divide and why do we divide by 25 just to have 1 stand on value within a scale of 1 to 11, 11 or 1 to 15. That particular value if we want to get that is why we divide by 25 otherwise it will the value will be very high that is the standard we can also use total radiation coming into the body but to have the scale from 1 to 11 or 1 to 15 in that scale we have to divide by 25.

Now if we see the UV index 1 to 2 UV index it is week UV index, so it will not be that much harmful so continuous exposure of 1 to 2 hours 2 to 3 hours is we can have that continuous exposure without any effect. UV index 3 to 4 means moderate where exposure of 40 minutes to one and half power, so 1 hour 30 minutes that is possible 5 to 6 it is a strong so if exposure of 25 to 50 minutes and 7 to 8 it is very strong continuous exposure of 20 to 40 minutes duration where sunburn can occur.

So this time during this time if it exceeds then sunburn will occur otherwise without any protection we can have this so before we go into the Sun if we know the UV index then we can use our protection accordingly. So anything above says 8 these are dangerous.

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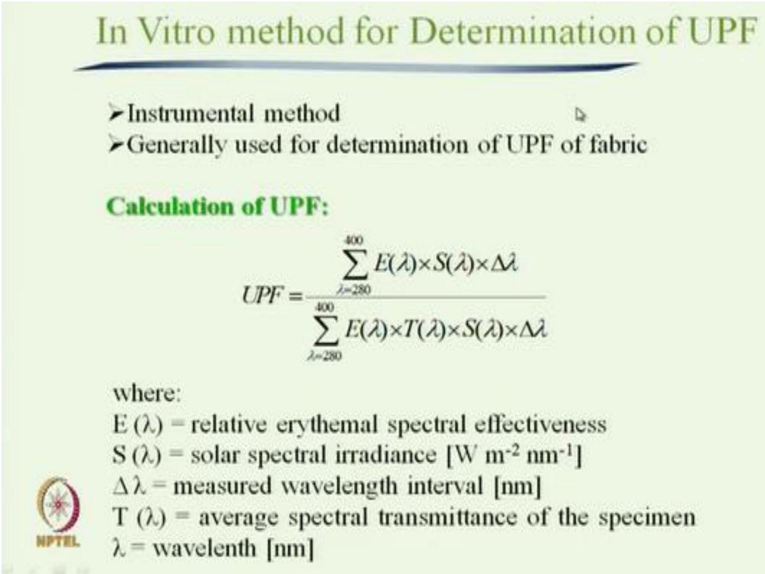

As I have mentioned UPF is basically without any human object it is in vitro measurement where it is a ratio of ultraviolet rays coming this is without any protection in air and this is through the material protective clothing or any sun protection lotion. We can calculate the UPF and one thing we should mention here these are the energy and wavelength but this multiplication here it is E lambda is relative erythemal spectral effectiveness.

S lambda solar spectral irradiance and Delta lambda measured wavelength interval in nanometer. So here if we see lambda ranging from 280 to 400 these are the ranges which are coming through the ozone layer. SPF measurement needs the human object because we have to see the skin redness generally used to determine the SPF of sunscreen required human subject based on minimal erythemal dose MED.

So radiation dose to produce just perceptible erythemal under fabric cover or any other sunscreen cover and divided by the radiation dose to produce just perceptible erythemal of uncovered skin, so for at certain time did this radiation we dose we change and then we measure the dose intensity. Now coming to the calculation of UV index this is standard method followed internationally to know the UV index. So if we listen that it is a UV index for a particular city he said 5 so what does it mean:

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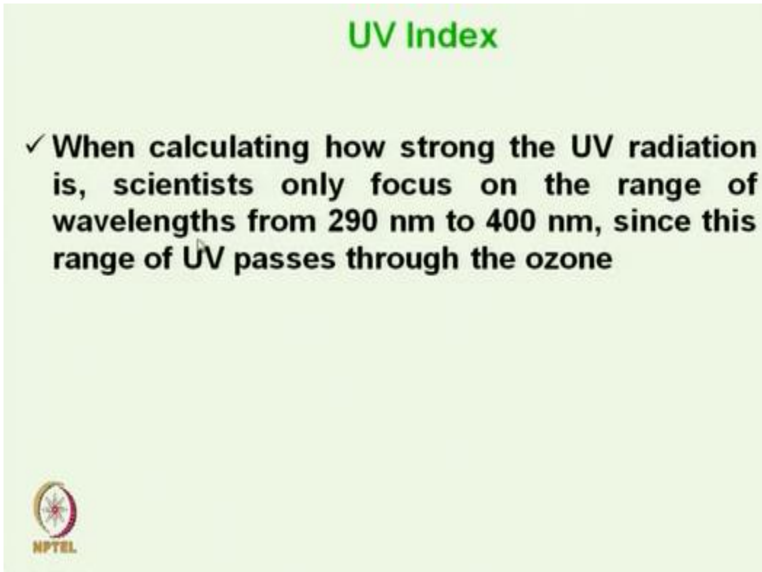

So when calculating how strong the UV radiation is in a particular place scientists only focus on the range of wavelength between 290 nanometer to 400 nanometer since this range of UV passes through the ozone layer. The range of ozone layer those which are absorbed those are not taken into account because those are not reaching to the environment.

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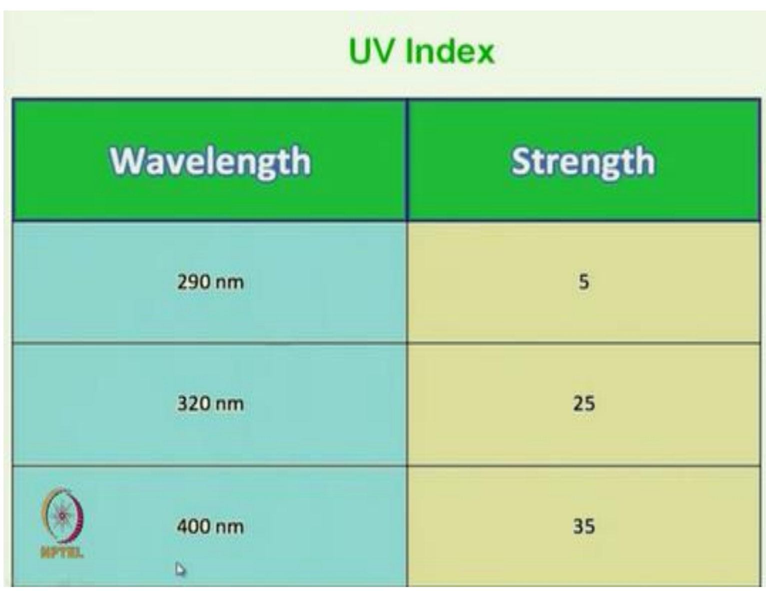

UV Index

Wavelength	Strength
290 nm	5
320 nm	25
400 nm	35

Now the strengths are arbitrarily given for different wavelengths of UV. So 290, 320, 400 we can subdivide also and strength is 5, 25 and 35.

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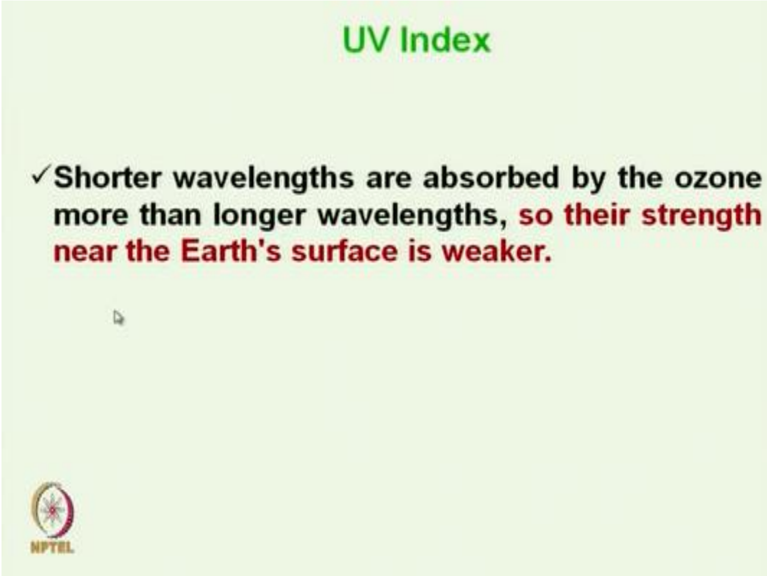

The stronger the shorter wavelengths are absorbed by ozone more than the longer, so their strength near the Earth's surface is weaker. So depending on the wavelength so these are absorbed by ozone layer maximum 290 nanometer wavelength that is why their strain arbitrarily given lower whereas longer wavelength they reach to the Earth's surface maximum so that is why their strength is given higher.

So this strength is based on the absorption of this UV rays by the ozone layer. These values what we have seen earlier 5, 25, 35 these are hypothetical value and may not be exactly identical to how different agencies calculate UV index. So different agencies are there to calculate UV index so different agencies they may give slightly different value but having the strength weighted with the smaller value for shorter wavelength is accurate.

Because shorter wavelength reaches minimum quantity to the earth because they are maximum absorbed by the ozone layer so for any calculation if the values hypothetical values are different but there trend will be same.

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Wavelength	Strength	Weight
290 nm	5	17
320 nm	25	7
400 nm	35	2

And then the third column added which is given weightage here if we see the weighted are just reversed to that of strength 290 nanometer the strength was 5 because it is amount proportion reaching towards earth after absorption was 5 but weightage shows the it is severity on the human health or any other matter, lower wavelength is more harmful than the higher wavelength. So as the wavelength increases this weightage is depending on the harmfulness.

So these are 290 nanometer wavelength are very harmful that is why they are given higher weightage.

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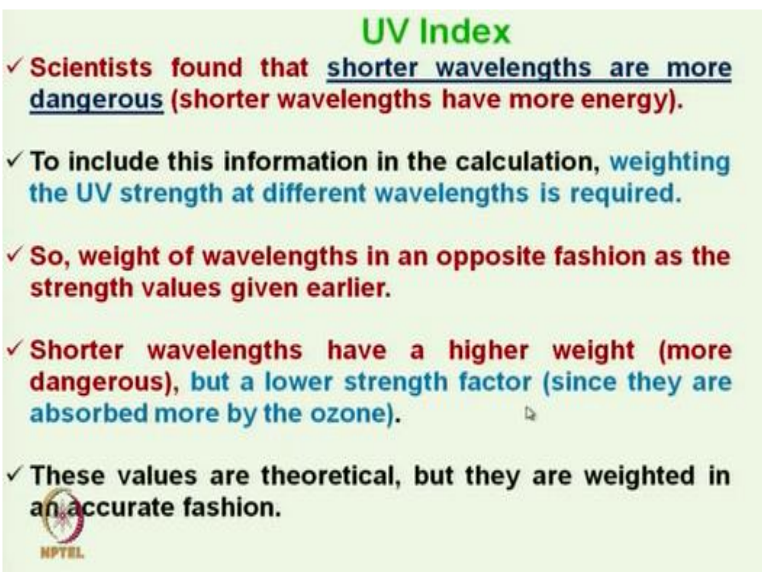

So scientists found that shorter wavelengths are more dangerous because they have got higher energy, so shorter wavelength with higher energy are more dangerous towards human health, to include this and this shorter wavelength also affects the material at higher rate to include this information in calculation weighting the UV strength at different wavelength is required so that is why it has been weighted.

So weight of wavelengths is opposite fashion as the strength of the value is given earlier, shorter wavelength have a higher weight because they are more dangerous but lower strength factor since they are absorbed more by ozone layers. These values are theoretical and they are weighted at accurate fashion by different agencies then what we have to do?

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Wavelength	Strength	Weight	Result
290 nm	5	17	85
320 nm	25	7	175
400 nm	35	2	70

We have to multiply the strength with the weight, so we get result 85 for 290 nanometer, 175 for 320 nanometers and 400 for 70 nanometers. So, this result is a combination of amount and it is effect on human health or any effect on any material, so it is a quantity and the energy multiplication after doing so, what we have to do?

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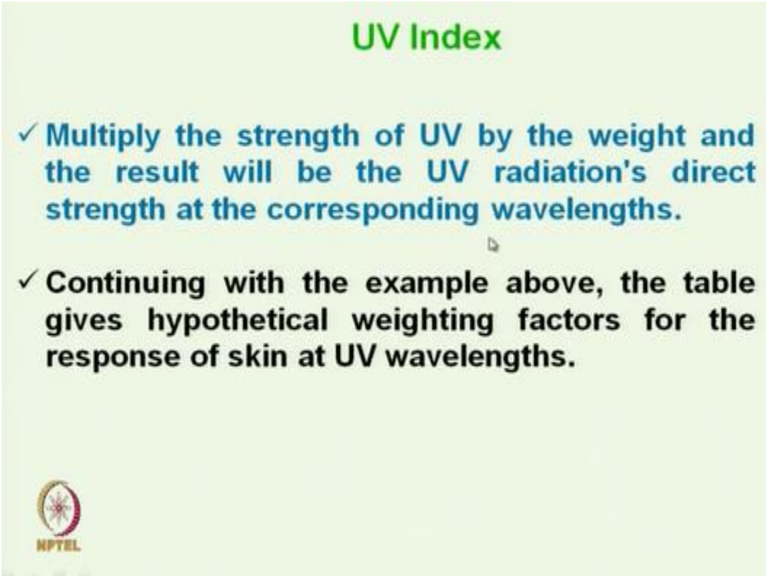

We have to add to get the total radiation, so multiply the strength of UV by weight and the result will be UV radiations direct strength at the corresponding wavelength. So this result is direct strength of the UV, so 85 is the direct strength of UV of 290 nanometer.

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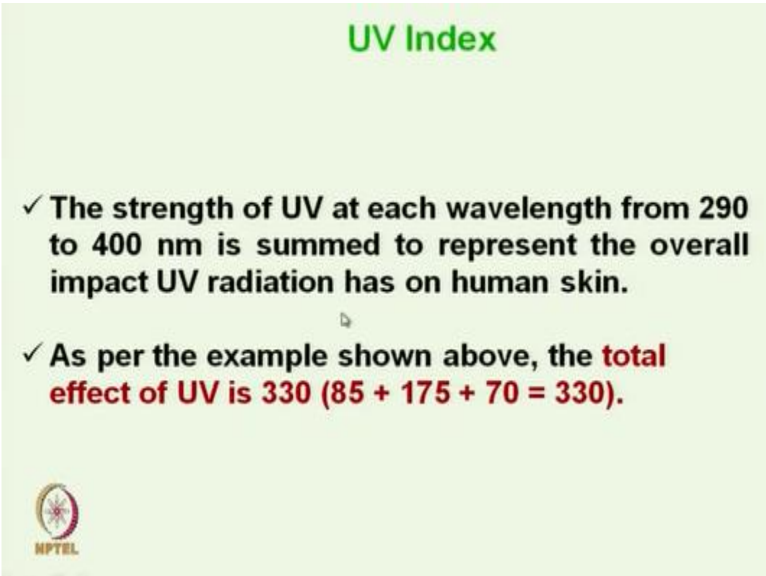

And after that what we get so we have to add the results the strength of UV at each wavelength from 290 to 400 nanometer is summed up to represent the overall impact of UV radiation has on the human skin. So what we get? We get if we add we will get 330 is a value.

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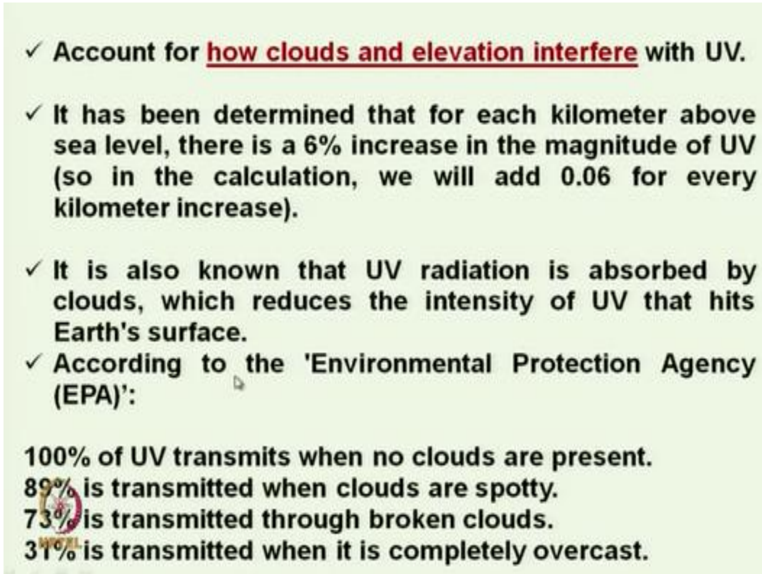

Then the 330 value if we divide this 330 with 25 then we will get the UV index for that particular place, so before doing that what we do we can take into account two aspects one is the altitude aspect another is the cloud cover that if we want to incorporate that we do otherwise we can directly divide by 25 how the clouds and elevation interferes so it has been determined that for each kilometer above the sea level there will be 6% increase in magnitude of UV.

So if it is one kilometer above the sea it will be 6% increase that means that we have to add 0.06 for every kilometer it is also known that UV radiation is absorbed by cloud which reduces the intensity of UV rays which is coming towards Earth. According to Environmental Protection energy there are they have different standards when there is no cloud there will be a 100% UV ray coming to the Earth's surface which is coming through the ozone layer.

So there is no restriction or reduction but for spotty clouds there will be 89% transmission and completely overcast sky there will be 31% reduction then the 31% will reach and typically that 69% will be absorbed there. So if you take these two aspects of elevation and cloud interference.

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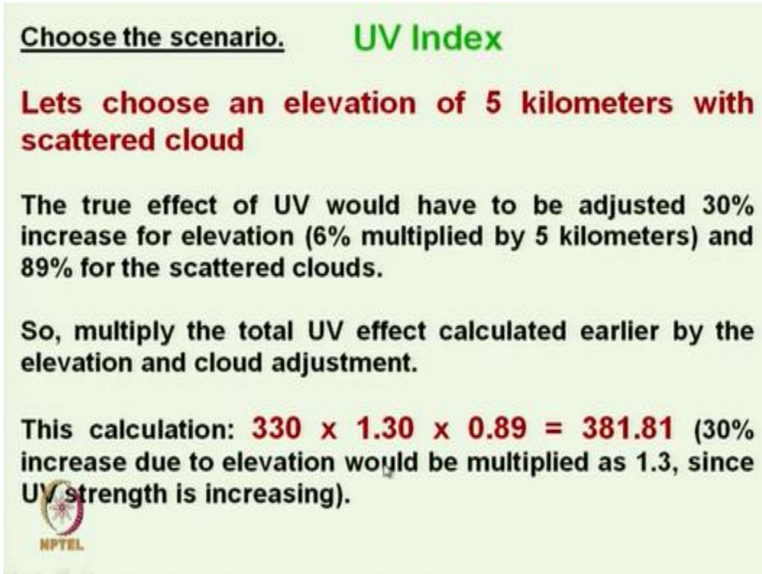

We can readjust our data so let us choose elevation of 5 kilometer with scattered cloud. So if we try to see the UV index for a particular place which is say for example 5 kilometer above the sea level and it is scattered clouds are there so to take the 5 kilometer that means 6% for each kilometer the true effect of UV would have been have to be and just a 30% increase in elevation for the elevation so 6% increase in every kilometer.

So there will be 30% total increase in UV rays at that location and 89% of that because of the scattered clouds. So if you take both these two aspects into consideration, the calculation will be 330 which we have got earlier 1.30 that means 30% increase due to the elevation 5 kilometer elevation and 0.89 means due to scattered cloud so it is coming out to be 381.81.

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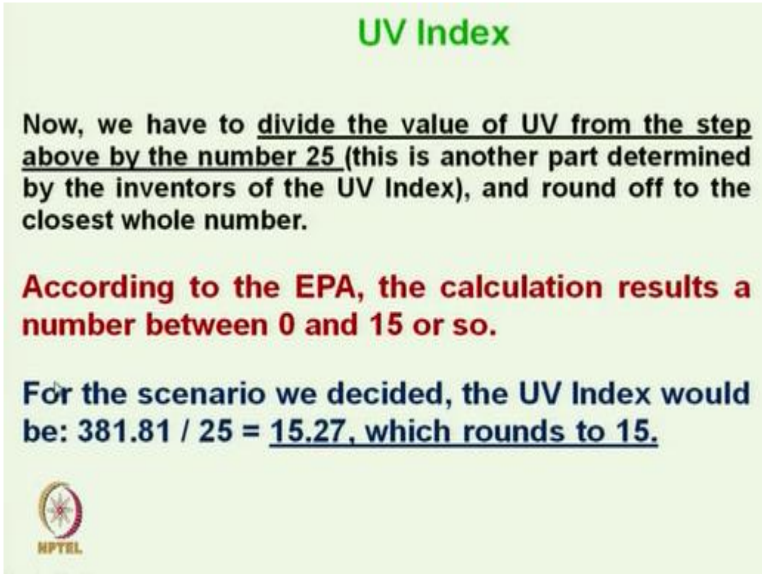

And this 381.81 if we divide by 25 we will get 15.27 with a round off it will be 15, so at that particular place the UV index will be 15 because this to have a whole number which is we can compare and zero UV index means there is no UV rays and as we UV index increases there will be more and more UV ray coming from the Sun.

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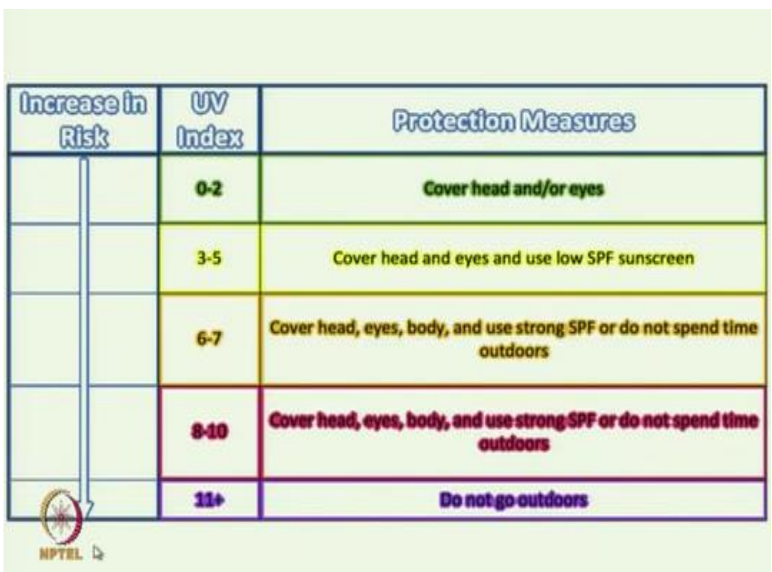

Increase in Risk	UV Index	Protection Measures
	0-2	Cover head and/or eyes
	3-5	Cover head and eyes and use low SPF sunscreen
	6-7	Cover head, eyes, body, and use strong SPF or do not spend time outdoors
	8-10	Cover head, eyes, body, and use strong SPF or do not spend time outdoors
	11+	Do not go outdoors

So increase in UV index that means increase in risk, so UV index 0-2, so what are the protections required for different UV index of environment, so 0-2 so for that it is a lower threat lower risk so cover head and or eyes. So just by covering head or eyes we can be protected we can cover by cap, 3-5 we have to cover head eyes and we have to use low SPF sunscreen, we do not need any other protection low Sun Protection factor sunscreen is enough.

6-7 we have to cover head eyes body and we have to use strong SPF sun protection factor that sunscreen we have to use and we should not spend long time in outdoor, 8-10 which is very strong we have to cover head eyes body and use strong SPF or do not spend time in outdoor and we have to take sufficient protective measure, so we can use clothing with UV protection higher UPF.

So UV protective clothing we must use during this and above 11 we should not go out because it is extremely dangerous. So accordingly we can select clothing our protection so anything above 3 we should use our protective clothing.

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There are different standards available so European standard EN 13758 there are variants so one two so Australian standard, AATCC, ASTM, ASTM D. So different standards available to measure the UV protection in clothing.

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Effects of various textile parameters

Factors	Effects on UPF
Material.	UPFs of cotton, viscose rayon and linen are usually lower than UPFs of nylon, wool and silk; polyester provides usually high UPF.
Porosity, Weight and Thickness.	UPF increases with decreasing porosity and increasing fabric weight and thickness.
Colour.	UPF increases with darker colours.
UV absorbers.	UPF is improved by UV absorbers.
Stretch.	UPF decreases under stretch.
Wetness.	UPF decreases when cotton becomes wet.
Washing.	UPF increases for cotton fabrics.

Now we will discuss the effects of various textile parameters on ultraviolet ray protection. These factors are material related factor we can use different materials for making textile for UV protection. So if we see UPF of cotton, viscose and linen these fibers give lower UPF than the synthetic fibers like nylon and polyester, wool also wool and silk these protein fibers they give higher UPF then the cellulosic fibers.

Polyester provides usually high UPF, so in terms of material selection as far as UPF is concerned so UV protective textile is concern we must use this type of clothing, so you polyester is preferable here if we want to use cotton or viscose we must use extra UPF ultraviolet protective finish we can use. Porosity, areal density and thickness are also important, so we can change the porosity of yarn and fabrics.

So if they increase in the porosity the UPF decreases so if we increase the porosity that means the fabric become porous so through that the ultraviolet ray will pass so UPF increases with the decrease in porosity and increasing fabric weight and thickness. So as the fabric thickness increases or fabric mass per unit area increases it will protect the UV ray. More thickness or higher weight means there will be more number of fibers coming in to protect the UV transmission.

Fabric dyed with dark color gives higher UPF value, if we use UV absorber as finished material that will increase the UPF value when we stretch the fabric that means it is pore size will increase and through which the ultraviolet ray can penetrate. So if we have decreases so UPF decreases under stress condition. So stretch ability of fabric we have to see for say knitted fabric under stretched condition it reduces the UPF value.

With wetness UPF decreases when cotton becomes wet. So through wet cloth ultraviolet ray can pass through easily. Washing increases the UPF it means during laundering what happens the fabric get actually that shrinkage occurs shrinkage in fabric occurs. So effective pores between the yarns reduces due to shrinkage so that effectively increase the UPF value.

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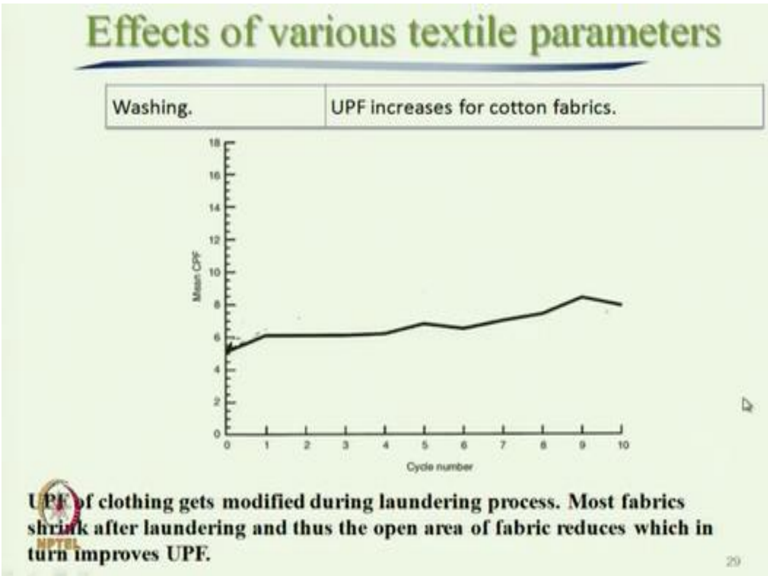

Here we can see number of laundering cycle here, if we increase the laundering cycle the UPF value increases. So UPF of clothing gets modified during laundering process most fabrics shrink after laundering and thus open area of fabric reduces which in turn improves UPF value.

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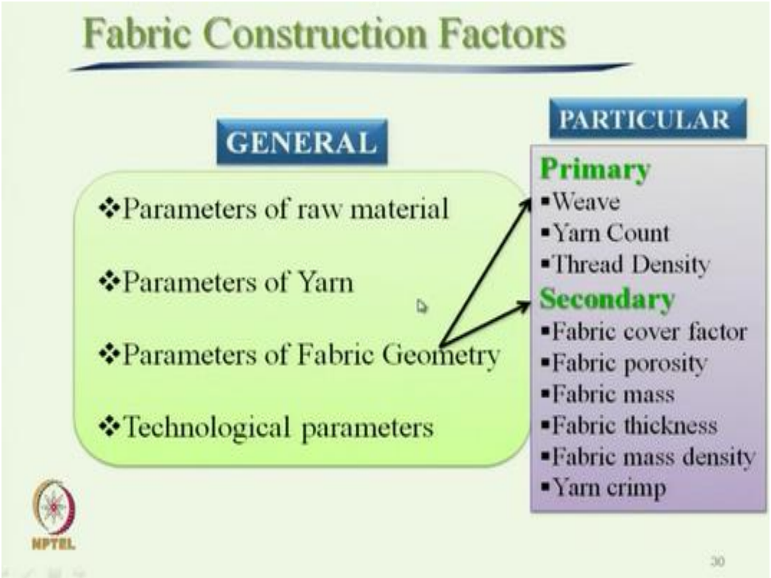

There are various factors basically the factors are raw materials that we have discussed yarn related factors we have discussed this yarn related factors are there like type of yarn and yarn twist, so they affect the UPF and fabric related parameter fabric geometry there are two types of effects one primary effect. Primary effects are based on weave structure, yarn count and thread density.

So different weave gives different type of that UV radiation UV protection, yarn count, so finer count keeping everything constant using finer yarn count means more open area so that will allow more and more this UV ray to pass through and thread density if we want to prevent the UV rate to pass through so we must use the compact thread density the closer thread density. So thread density should be high.

And depending on the weave, yarn count and thread density there are secondary factors which are dependent on the primary factors like fabric cover factor. They are dependent on mainly yarn count and thread density, fabric porosity, fabric mass per unit area, fabric thickness depending on the yarn count, mass per unit area again yarn count and thread density and yarn crimp, yarn count, thread density and weave pattern.

So, all these factors directly or indirectly affect the UV protective performance of textile material. So in the next class we will discuss all these factors in detail like raw material related factors, parameters of yarn, parameters of fabric geometry and technological parameters in detail. So till then thank you.