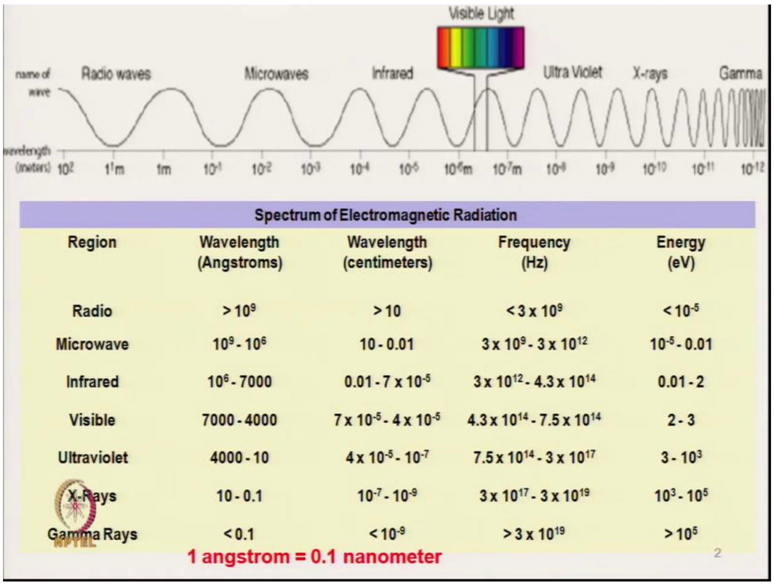
Testing of Functional & Technical Textiles
Prof. Apurba Das
Department of Textile Technology
Indian Institute of Technology, Delhi

Lecture – 22
Testing of UV Radiation Protective Textiles

Hello everyone, we will start a new topic today. So, till now in this course we have discussed the testing of functional textiles. In testing of technical textile we have discussed testing of fibre reinforced composite materials, then testing of filter fabrics after that we have discussed testing methods of geotextiles. And, in last class we have discussed testing of ballistic protective clothing.

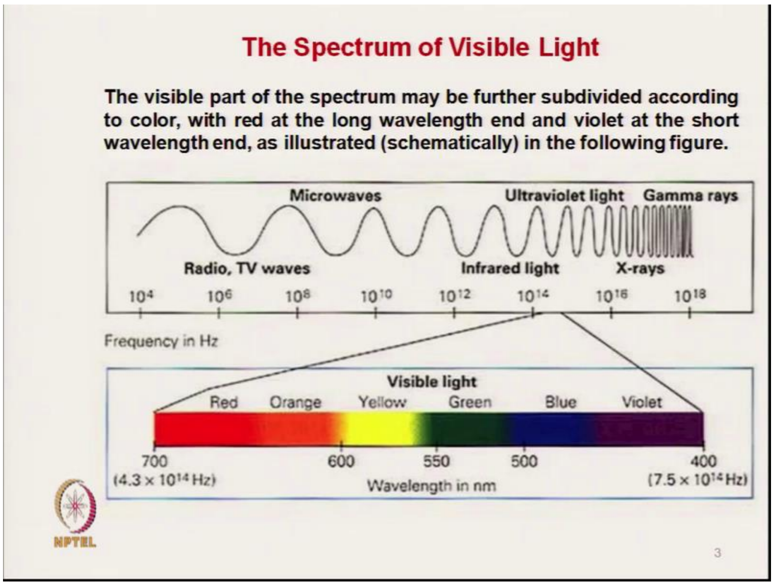
Today we will discuss another area of technical textiles that is Testing methods of UV rays Radiation Protective Textiles. That is UV radiation protective textiles are gradually becoming more and more popular so, that we can protect ourself from UV radiation. So, first we will try to understand what are UV radiation and what are the factors of fabric which will affect the UV radiation protective performance of textiles.

(Refer Slide Time: 02:03)



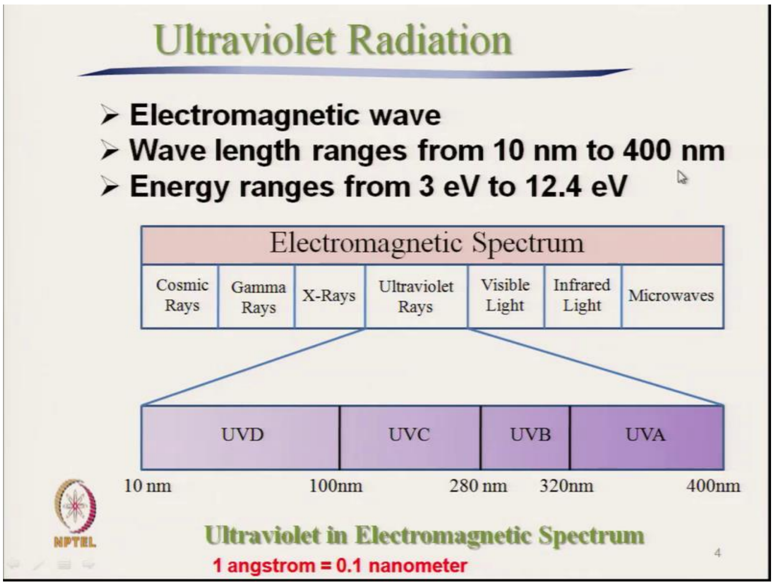
So, if we see total spectrum of electromagnetic radiation starting from radio wave to gamma ray so, gradually the wavelength reduces. So, for gamma ray its very low whereas, in radio wave its as high as say 1 metre or maybe more, but our area of discussion here is ultraviolet ray which affect the human body adversely. So, these are the wavelengths. So, radio wave is more than 10 to the power 9 angstrom whereas, ultraviolet ray its around between 10 to 4000 angstrom.

(Refer Slide Time: 03:13)



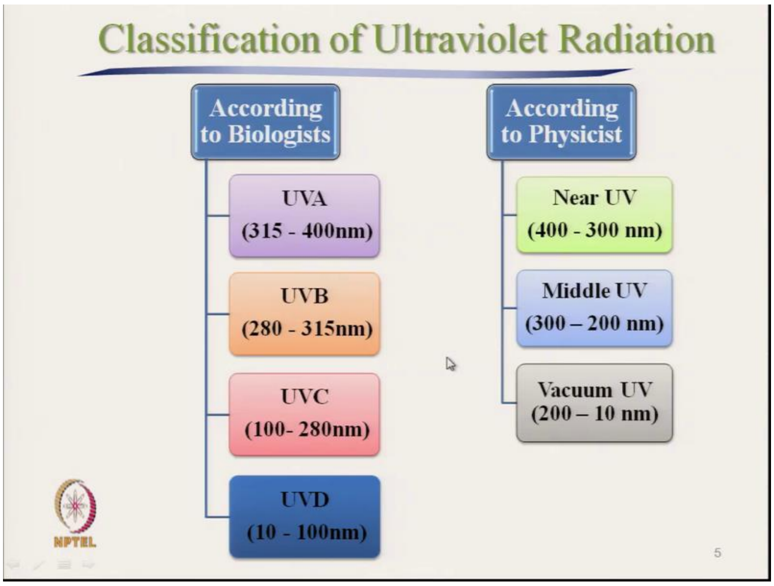
So, before UV ray if we see here just before ultraviolet ray, there is visible light spectra. So, the visible light part of the spectrum is divided into different subsections based on colour with red at the longest wavelength and violet at the short wavelength. If we cross the violet then the ultraviolet UV ray will come which actually affect our human body.

(Refer Slide Time: 04:21)



So, ultraviolet radiation it is an electromagnetic wave, the wavelength ranges from 10 nanometre to 400 nanometre within this range it works and it has got 4 subdivisions also it is classified in 4 subgroups. So, starting from UVD then UVC UVB UVA; UVD being the least wavelength and ultraviolet A is a longest wavelength or of 400 nanometre. We will see the effects of this wavelength on our human body. The energy ranges from 3 electron volt to 12.4 electron volt.

(Refer Slide Time: 05:31)



Now, UV ray can be classified in two ways. So, this radiation as per the biologist it can be classified as UVA UVB UVC and UVD depending on the effect on our biological species. And, according to physicist this can be subdivided in different ways like near UV, middle UV, vacuum UV like that. So, UVD ranges between 10 nanometre to 100 nanometre that is the wavelength range, UVC 100 nanometre to 280 nanometre, UVB 280 to 315 nanometre, UVA 315 to 400 nanometre.

So, effectively we will see that UVC and UVD they normally get absorbed by the ozone layer. Whereas, the UV ray with higher wavelength get penetrated through the ozone layer and effectively UVA with higher wavelength, in this spectrum does not get absorbed by ozone layer it enters into a earth surface.

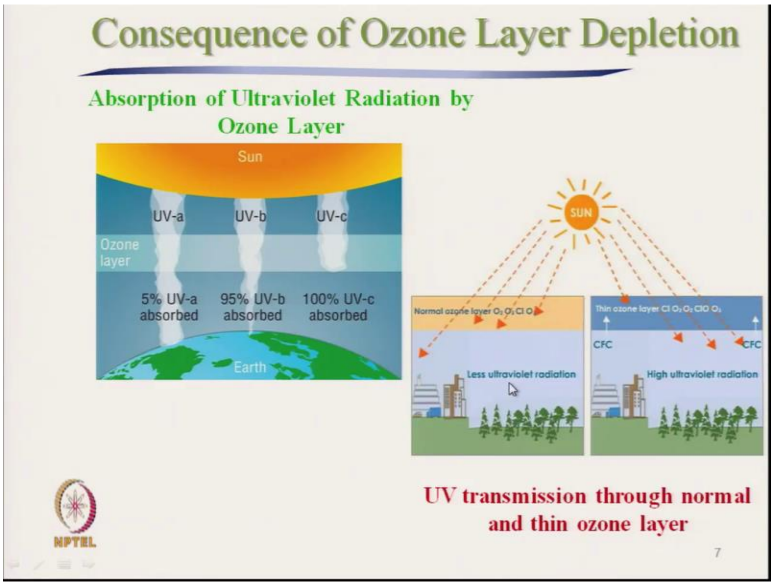
(Refer Slide Time: 07:29)

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, black light, 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	visible to birds, insects and fish
Middle Ultraviolet	MUV	300 – 200 nm	4.13 – 6.20 eV	
Far Ultraviolet	FUV	200 – 122 nm	6.20 – 10.16 eV	
Vacuum Ultraviolet	VUV	200 – 10 nm	6.20 – 12.4 eV	strongly absorbed by atmospheric oxygen, though 150–200 nm wavelengths can propagate through nitrogen
Extreme Ultraviolet	EUV	121 – 10 nm	10.25 – 12.4 eV	ionizing radiation, completely absorbed by the atmosphere

So, if we see this table UVA the wavelength ranges from 315 to 400 nanometre with energy 3.1 to 3.94 electron volt, that energy is less here although, but they are longer wavelength black light, they are not absorbed by the ozone layer. So, that is the cause of worry. So, we have to protect our self although the energy is least here.

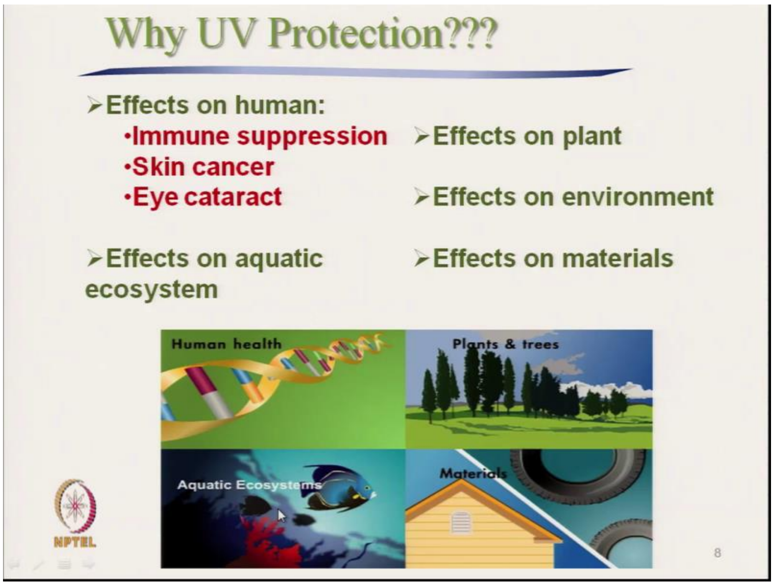
So, UVB with energy range 3.94 to 4.43, they are medium wave mostly they are absorbed, but partially they penetrate through ozone layer. UVC and UVD they are shortwave, they are completely absorbed by ozone layer and the atmosphere. Nearly, 100 percent of this UVC or UVD get absorbed by this ozone layer in the atmosphere. Similarly, if we see the other UV ray depending on their wavelength they get absorbed.

(Refer Slide Time: 09:17)



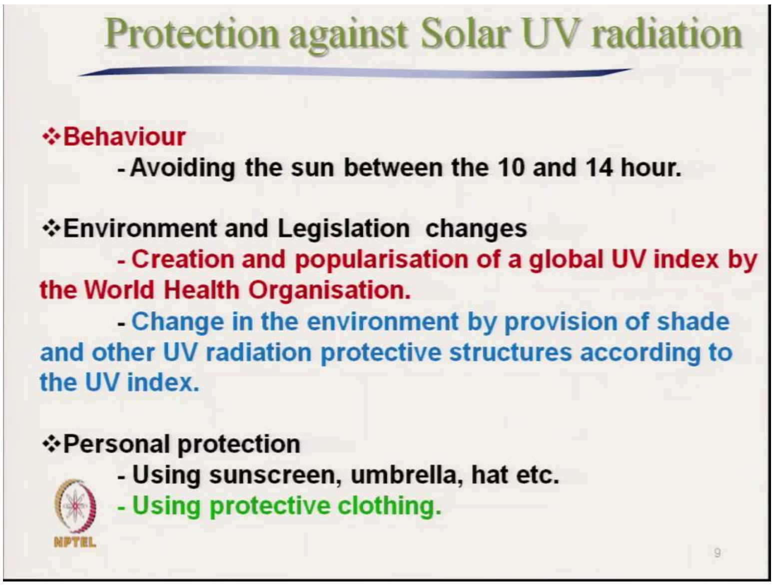
This picture shows that UVA mostly they are transmitted through the ozone layer. UVB they are 95 percent of them are absorbed, 5 percent they penetrate, UVA 95 percent they penetrate and only 5 percent get absorbed and UVC almost 100 percent are absorbed. So, this picture also shows here. So, how they are getting absorbed and penetrated?

(Refer Slide Time: 10:03)



So, why do we need UV protection? So, if we see UV protection is extremely important because this UV ray affects the total ecosystem, total all this not only human but plant, the environment, other materials and aquatic ecosystem everything gets effected. As far as human effect is concerned their immune system suppression is there. Skin cancer is very common, eye cataract may take place. So, we need UV protection.

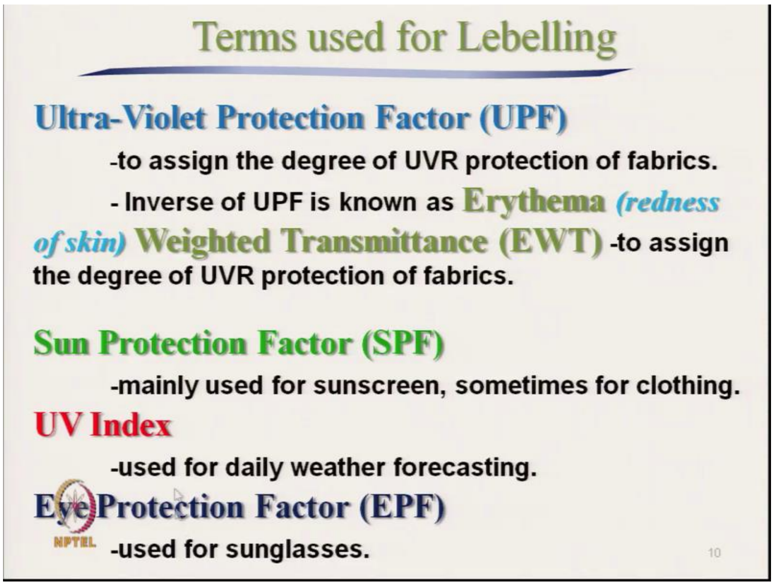
(Refer Slide Time: 10:55)



So, protection against solar UV radiation its as far as its behaviour if we see the maximum UV rays coming to the earth from the sun is in between 10 to 14 hours. So, you must avoid direct sun ray during this time and also for protection that environment and legislation changes should be there. So, creation and popularization of global UV index by world health organisation has been initiated. So, there must be some global UV index should be there; so, that people are aware of that. Change in the environment by provision of shade and other UV radiation protective structure according to UV index.

So, UV index is the indicator of presence of UV radiation in a particular place, depending on the UV index of a particular place one must know the UV index of that particular place where they are living; he should take precaution. Precaution by providing shade or providing UV radiation protective structures and, in addition to this shades and structure, we can have personal protection also depending on the UV index value. So, personal protection by using sunscreen, umbrella, hat to prevent our self from direct radiation and also most important way that we can use UV protective clothing.

(Refer Slide Time: 13:27)

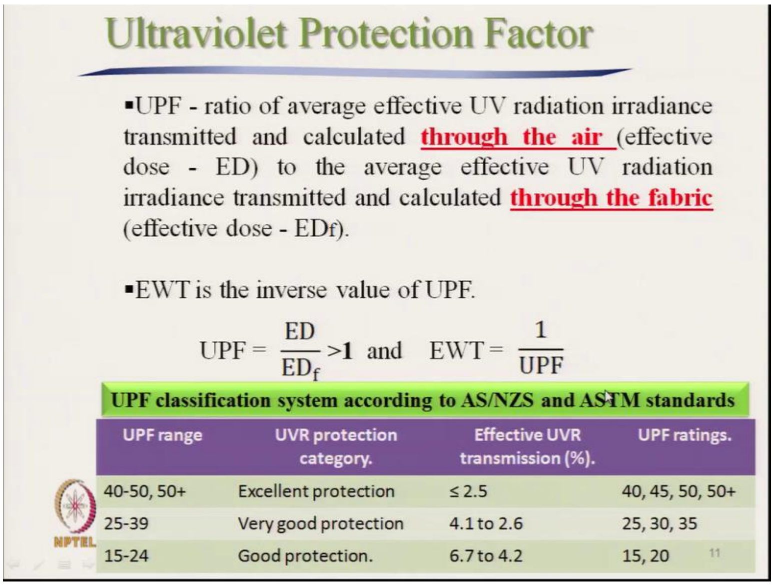


So, the terms used for lebelling are UPF is a very common term. So, Ultraviolet Protection Factor what is this? It is actually a factor I will discuss to assign the degree of UV radiation protection of fabrics. So, this is the factor. So, higher is UPF value, higher is the level of protection of fabric. So, for fabric we use UPF value. So, if we take inverse of UPF which is known as EWT: Erythema Weighted Transmittance. So, UPF is the protection, which prevent the penetration of the UV ray and EWT shows the transmission of level of transmission of UV ray ok, and this also gives the idea about the UV protection of fabrics.

Apart from UPF another most commonly used term is SPF: Sun Protection Factor. We normally see in the sunscreen lotion they use the term SPF value. So, mainly used for sunscreen lotions or sometime for clothing we can use SPF. And another term which we use very commonly used it its a UV index. It is used for daily weather forecasting like temperature, humidity we can forecast the UV index of particular place.

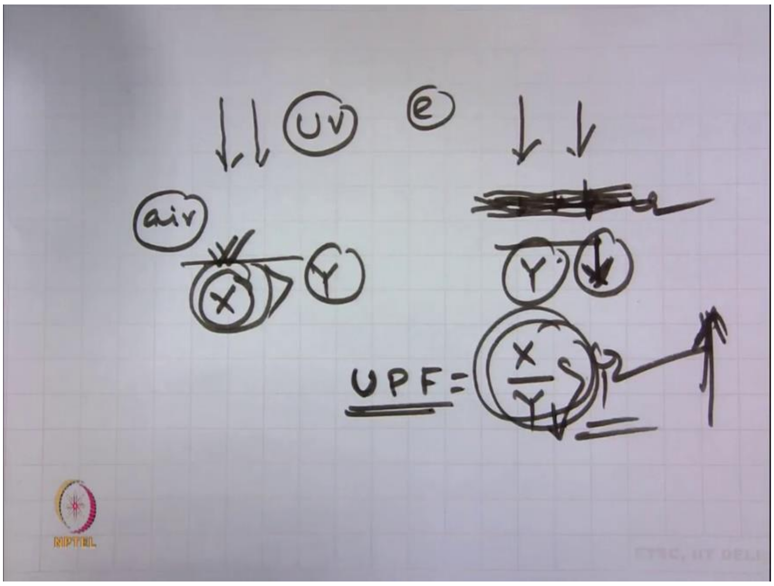
Because, UV index depend on elevation of a particular place, in addition to that depending on the type of cloud or type of other environmental factors. So, UV index for a particular place may change depending on the weather condition; another factor is the Eye Protection Factor: EPF which is used for sunglasses. So, these are the common terms, which is related to UV ray protection.

(Refer Slide Time: 16:17)



First, we will discuss what is UPF: Ultraviolet Protection Factor. This is normally we use for our clothing. UPF it is the ratio of average effective UV radiation transmitted and calculated through the air and it is taken ratio to the average effective UV radiation transmitted through the fabric.

(Refer Slide Time: 16:59)



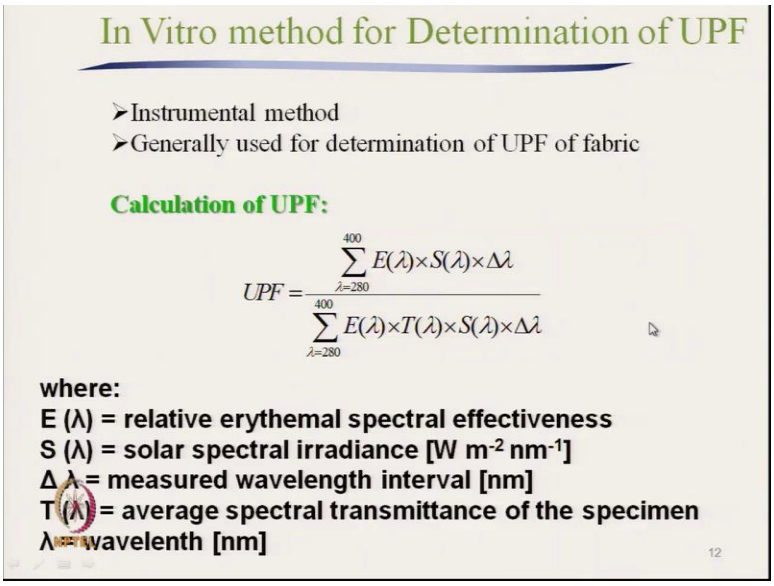
Now, suppose there is UV radiation. We know the energy of UV radiation through air suppose it is going X, X value is through air there is no obstruction. Same UV ray we are placing on fabric and fabric will absorb certain energy UV radiation and Y is coming with the fabric. So, UPF: Ultraviolet Protection Factor so, this X value, value of X through air only through air it will be more than the value because, fabric will absorb little bit. So, UPF is X by Y. So, through air what is the ultraviolet ray is coming to a receiver and through fabric how much it is coming; the ratio if we take this is called UPF which is value is typically more than 1.

So, higher the protection higher the protection of fabric the value of Y will gradually reduce because, X will remain constant X value will remain constant. So, a fabric with higher UPF higher ultraviolet protection it will allow less and less transmission. So, Y value will reduce. So, if Y value reduces this UPF value will keep on increasing so; that means, for fabric with higher UPF, the UPF value will be more. So, that is why ED is the dose through air and ED f is the effective dose through fabric. So, UPF is ED divided by EP f which is more than 1 and the reciprocal of this is EWT ok; that we have already seen.

Now, if we see the typical range of UPF if it is between 40 to 50, 40 to 50 or more the protection level is excellent and effective the transmission through the fabric will be less than 2.5 percent. If it is 40, if we calculate it will be 2.5 percent that is 40 times; that means, 2.5 percent. So, if you have rating is 40, 45, 50, 50 plus like this more than 50. So, only 2.5 percent radiation is getting transmitted through fabric between 25 to 39 it is very good. Typically, 4.1 to 2.6 percent that is the transmission and 15 to 24 it is a good protection.

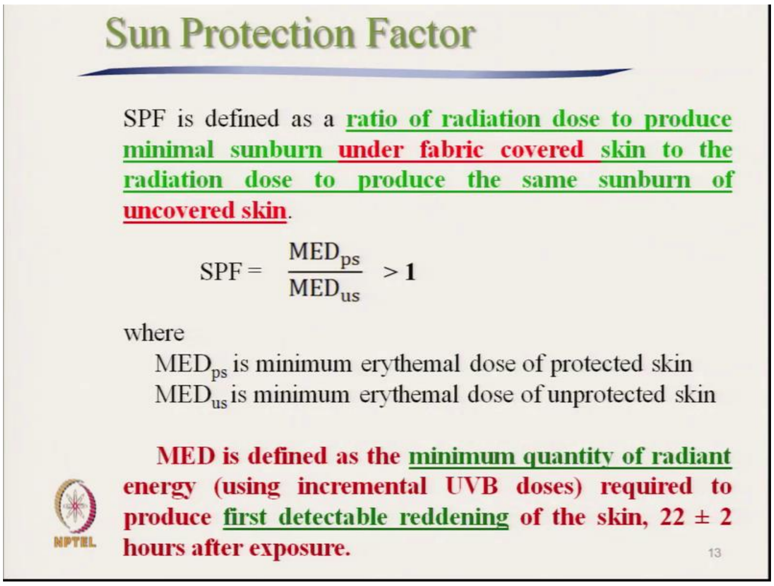
So, minimum that should be at least 15 UPF value and the transmission level is typically around 6 percent 6 to 7 percent. So, 15, 20 these are the UPF getting. So, higher the rating better is the protection.

(Refer Slide Time: 20:45)



And the UPF value we can determine in vitro method; that means, we can use instrument to measure this UPF value. So, where we measure the transmission, the energy without the fabric and take the ratio with fabric. So, we can calculate the UPF value by using this formula ok.

(Refer Slide Time: 21:25)



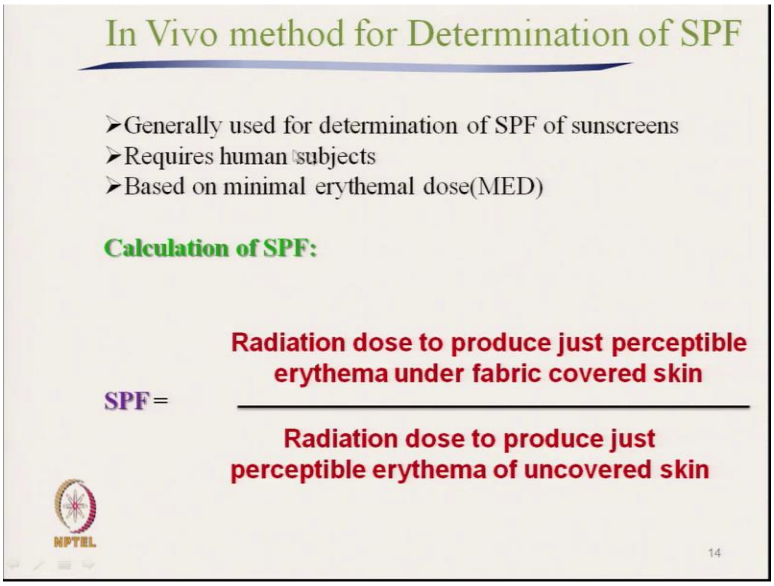
Next is sun protection factor ok; sun protection factor is defined as the ratio of radiation dose to produce minimal sunburn under fabric covered, it maybe fabric or maybe covered with sunscreen lotion. So, fabric covered skin to the radiation dose to produce the same sunburn of uncovered skin; that is it is the actually the ratio of the radiation dose that is the energy ok. Once we cover the fabric, the level of radiation required to have minimum sunburn on our skin and if we take ratio of the doses without cover; that means, MEDps means protected skin.

This protection maybe by fabric or protection maybe by the sun screen. So, MEDps means minimum erythemal dose of protection. What does it mean? We need to increase the dose gradually and that dosing will be around 22 hours, 22 plus minus 2 hour for a certain time the continuous exposure should be there. And, the dose value that is the energy will measure when minimum changes in colour, minimum sunburn will be there that value is recorded that is called MEDps. And, MEDus means minimum erythemal dose of unprotected skin. So, there is no protection, the dose is being applied for same time.

In that case we will see the amount of dose that is the energy will be much less than the protected skin to have same level of sunburn. So, MEDus is much less than MEDps that is why the ratio is more than 1, this is the sun protection factor as in this process we measure the skin burn the minimum skin burn. So, we require the human as object. So, MED is defined as minimum quantity of radiant energy ok; it is actually UVB doses ok. This UVB doses given which required to produce first detectable reddening of the skin after 22 plus minus 2 hours of exposure.

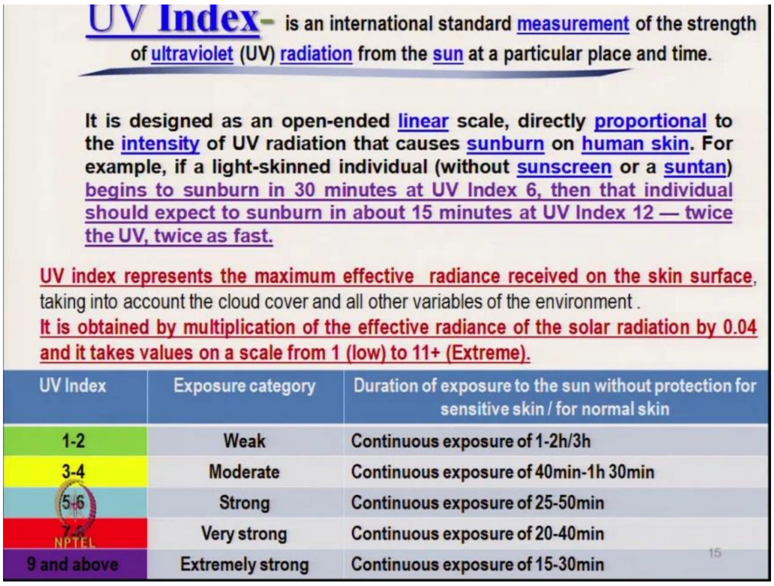
So, continuously the skin is being exposed: one is with protection another is without protection, but level of exposure is changed. And, we measure the level of exposure once the noticeable sunburn is identified and that ratio is known as the SPF which is typically more than 1.

(Refer Slide Time: 26:05)



So, generally used for determination of SPF of sunscreen, required human subjects that that is why it is in vivo method, based on Minimal Erythemal Doses: MED. So, this is the ratio radiation dose to produce just perceptible erythemal under fabric cover. So, this erythema it should be perceptible undercover skin. That is it maybe fabric covered skin or maybe covered with the sunscreen lotion and the same is with uncovered skin. So, the ratio is SPF.

(Refer Slide Time: 27:03)

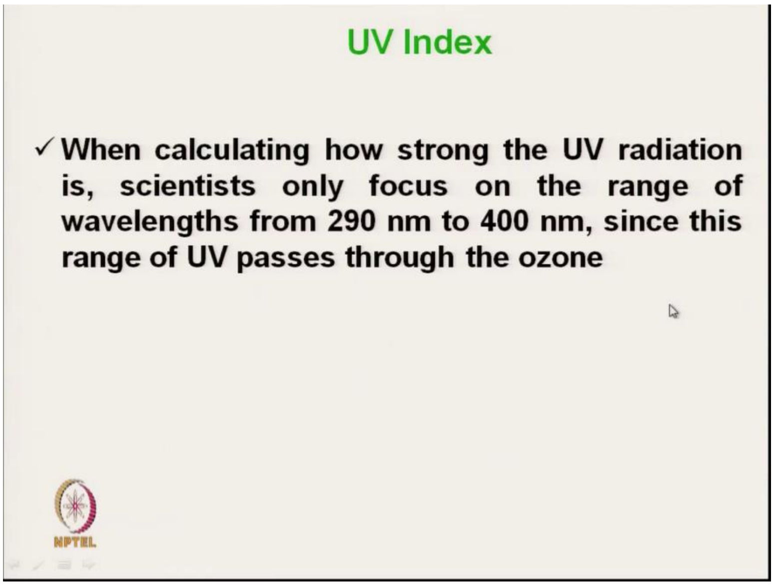


Next most important parameter which is UV index. UV index it is an international standard measurement of the strength of UV radiation from sun at a particular place. So, that is a internationally accepted method where, we can measure the strength of UV ray in a particular place. It is designed as an open ended linear scale; that means, directly proportional to the intensity of the UV radiation that causes sunburn on human skin. That means for example, if the light skinned human without sunscreen or suntan begins to sunburn at 30 minutes at UV index of 6. So, UV index higher UV index means higher intensity.

So, at 6 UV index if he starts sunburn at 30 minutes then the individual should expect to sunburn in about 15 minutes with double the index; so, in UV index of 12. So, as the UV index increases the time required for sunburn will be less. So, that is the UV index value its typically 1 to 15 is the range, 1 to 15 is normal range and sometime we consider as 11 is the maximum range possible. But for in world few places are there, where we can have more than 11 also which is extreme condition. So, UV index represents the minimum effective radiance received on the skin surface.

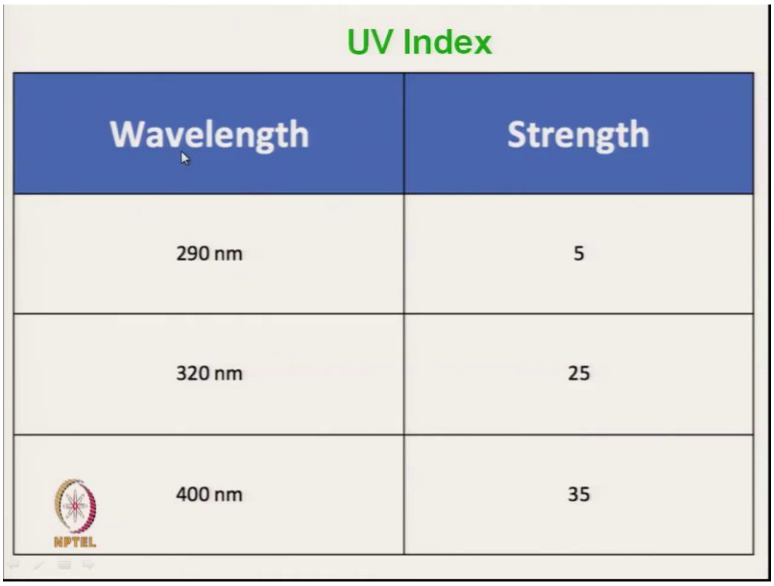
So, how much radiation we receive taking into account the cloud condition and other variables of environment. And, if we take the total radiance and then if we multiply by 0.04 to get the value within 1 to 15 range, we multiply it by 0.04 or divide by 25 to get a value within this range ok. So, 1 to 2 UV index means it is very weak, 3 to 4 it is moderate, 5 to 6 is a strong, 7 to 8 means it is a very strong and 9 and above it is extremely strong where, we have to take precaution ok.

(Refer Slide Time: 30:19)



Now, will discuss, how to calculate the UV index value. So, what is UV index we have discussed? Now, try to see how to calculate the UV index in a particular place. When calculating how strong the UV radiation is, scientists only focus on the range of wavelengths between 290 to 400, that is typically between UVA and UVB range. Since, this range of UV passes through the ozone ok. We do not take care other range UVC and UVD we do not take into account in calculating the UV index because, they are absorbed in ozone layer.

(Refer Slide Time: 31:17)

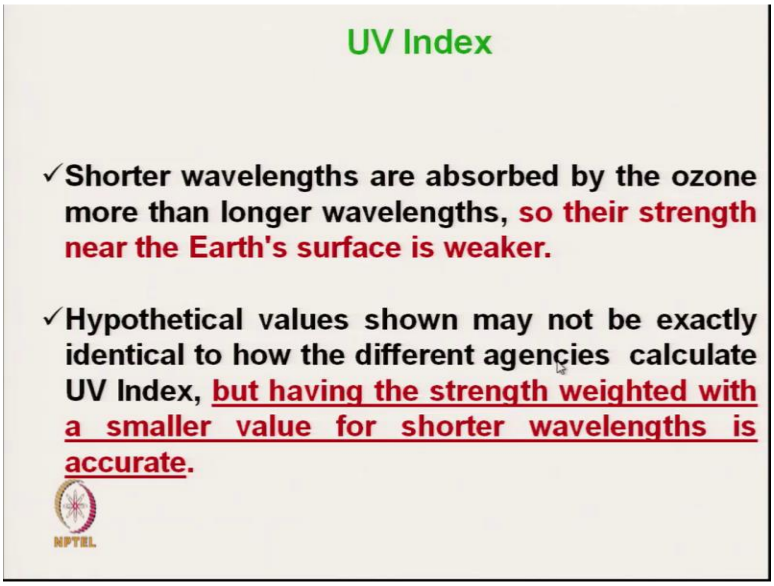


Wavelength	Strength
290 nm	5
320 nm	25
400 nm	35

So, these are the different wavelengths. This is just one typical example you can take other wavelengths also. So, wavelength 290 nanometre 320 nanometre and 400 nanometre has been taken and their strengths have been specified then, it is actually little bit based on the experience and here the strength means the amount of UV ray coming into the earth.

So, this strength the longer wavelength UV ray the more quantity higher quantity is coming into the earth. So that means, that is why the weightage here it is giving high and shorter wavelength 290 say weightage is given less. So, strength is 5 because the quantity of UV ray with 290 it is less. So, 5, 25 and 35 the strength is given. So, there are standard methods of calculation. So, from that we can take 5, 25 and 35.

(Refer Slide Time: 32:47)



So, here it has been explained the shorter wavelengths are absorbed by ozone more than the longer wavelength. So, their strength near the earth's surface is weaker. Hypothetical values shown by this earlier table may not be exactly identical to how the different agencies calculate UV index, that earlier table shows some hypothetical value. Different international agencies are there to who calculate the UV index.

These hypothetical values may not be exactly identical, but they will be definitely close to that the strength will be same. But, having the strength weighted with the smaller value for shorter wavelength is accurate that is what I have just mentioned.

(Refer Slide Time: 33:49)

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

Now, with the strengths another parameter is weight parameter. Here we will see the weight value is just reversed to that of strength value. The weight indicates here the effective impact on human body. Short wavelength although the quantity of ray coming to the earth is less, but its effect on human body it is very high, its impact that is why it has been weighted with 17, 7 and 2 for 400 nanometre.

(Refer Slide Time: 34:43)

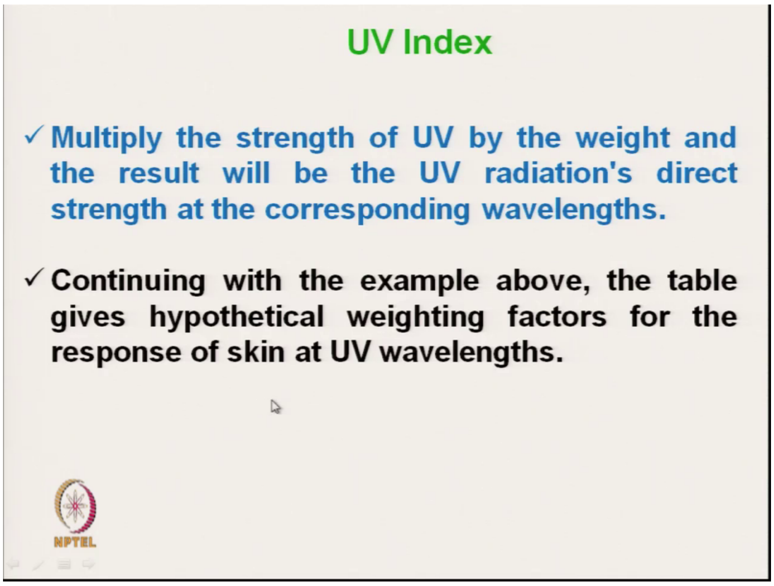
UV Index

- ✓ Scientists found that shorter wavelengths were more dangerous (shorter wavelengths have more energy).
- ✓ To include this information in the calculation, weighting the UV strength at different wavelengths is required.
- ✓ This is done using the McKinlay-Diffey erythema action spectrum
- ✓ So, weight of wavelengths in an opposite fashion as the strength values given earlier.
- ✓ Shorter wavelengths have a higher weight (more dangerous), but a lower strength factor (since they are absorbed more by the ozone). Again these values are theoretical, but they are weighted in an accurate fashion.

The scientists found that shorter wavelengths were more dangerous ok, shorter wavelength have more energy. So, that is effect on human body is more. To include this information in the calculation, weighting the UV strength at different wavelength is required. So, at different wavelength the weighting was made. This is done using the McKinlay-Diffey erythema action spectrum; so, this is the method. So, weight of wavelengths in is in an proportion opposite fashion to that of strength value.

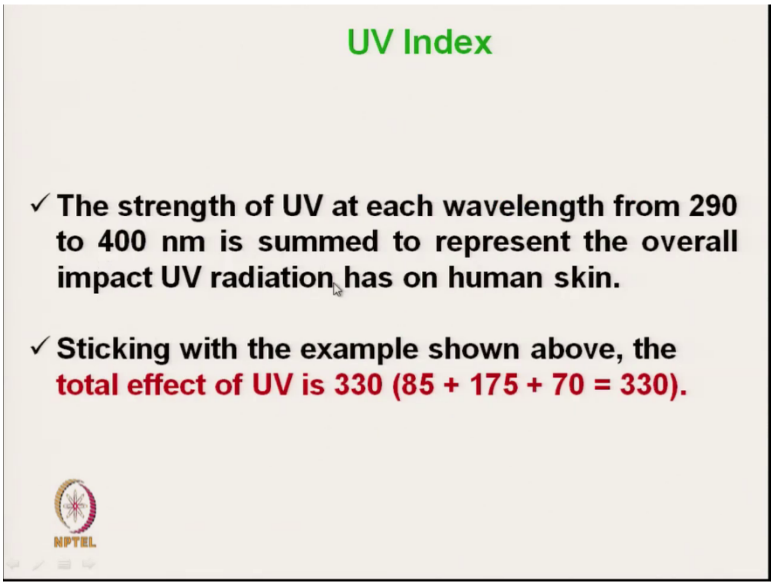
Shorter wavelength have higher weight ok, that is what I have discussed. Now, we simply multiply the strength with weight. Here we have taken only three wavelengths, we can take other wavelengths also; we multiply this strength with weight and this is the effective result. So, effective result of wavelength 290 nanometre on human body or other environment is 85. So, 320 nanometre it is 175 400 nanometre it is 70 and if we to simply add all this. So, will get total cumulative effect.

(Refer Slide Time: 36:39)



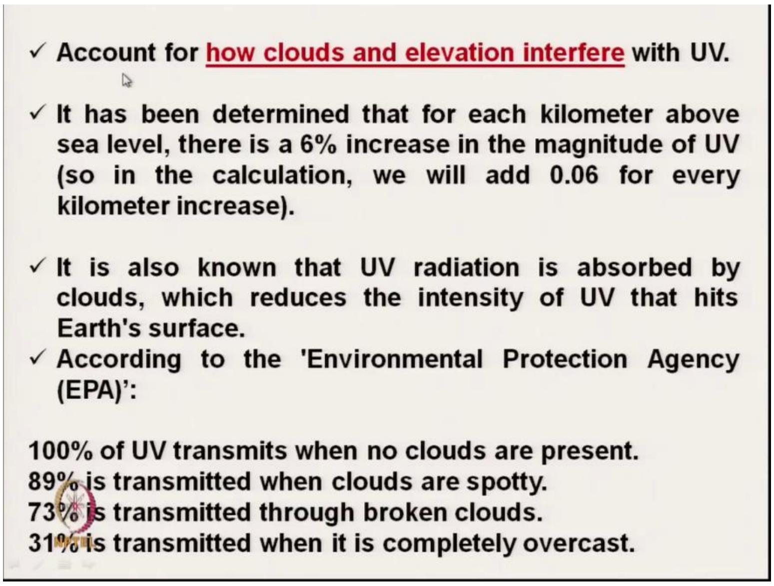
So, multiply the strength of UV by weight and the result will be the UV radiations direct strength at that corresponding wavelength continuing with the example, the table given hypothetical weighting factor for the response of skin at UV wavelength particular wavelength.

(Refer Slide Time: 37:09)



The strength of UV at each wavelength from 290 to 400 nanometre is then added to get overall impact of UV radiation on human skin. So, we will simply add this. So, total effective UV is 330. So, this is the 330 is the total effective UV. Now, we have to take the consideration of the elevation and the effect of cloud. The elevation means as we go above the earth's surface the impact or energy of UV ray is higher ok. And, at the same time if the earth surface is covered with cloud, the energy of UV ray reduces proportionally. So, this effect can be incorporated here.

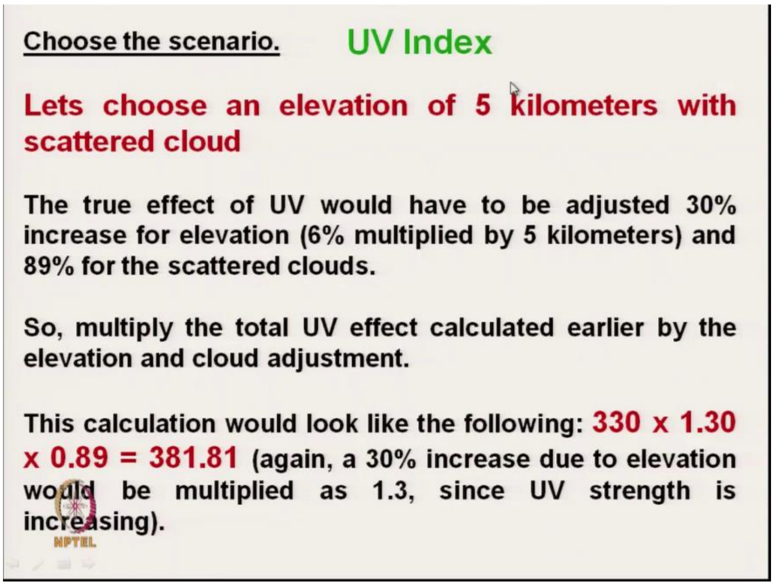
(Refer Slide Time: 38:27)



Now, account for how cloud and elevation interfere with UV that we have to take care. So, internationally it has been accepted and it has been determined that for each kilometre above sea level there is a 6 percent increase in magnitude of UV. So, in calculation we will add 0.6 for every kilometre increase, so that we have to keep adding. It is also known that UV radiation is absorbed by cloud which reduces the intensity of UV that hits the earth surface.

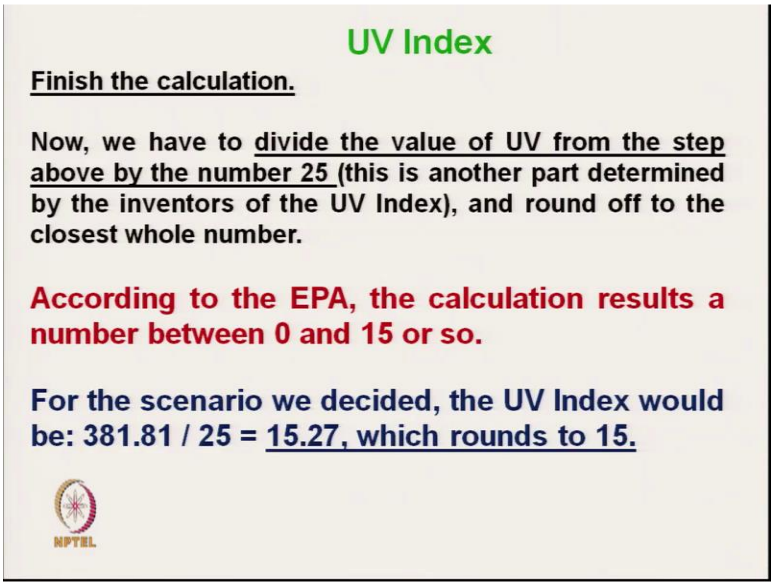
So, according to EPA which is Environmental Protection Agency they have specified that 100 percent UV transmission is there when there is no cloud, 89 percent is transmitted when there is a spotty cloud, 73 percent transmitted broken cloud and completely overcast sky there is a 31 percent transmission. So, this transmission level we have to consider based on the type of clouds.

(Refer Slide Time: 39:57)



So, let us see one scenario. So, we can select one place with an elevation of 5 kilometre from sea level with scattered cloud condition ok. So, the true effective UV would have to be adjusted 30 percent because, 6 percent per kilometre per 5 kilometres that is 30 percent and scattered that is spotted cloud it is 89 percent. So, this two we have to adjust; so, effective calculation will be that effective UV strength will be 330 multiplied by for 30 percent increase that is 1.3 and 89 percent of the transmission due to scattered cloud 0.89. So, it is coming out to be 381.81 ok. So, considering the elevation and cloud that is the effective dose effective strength of the UV.

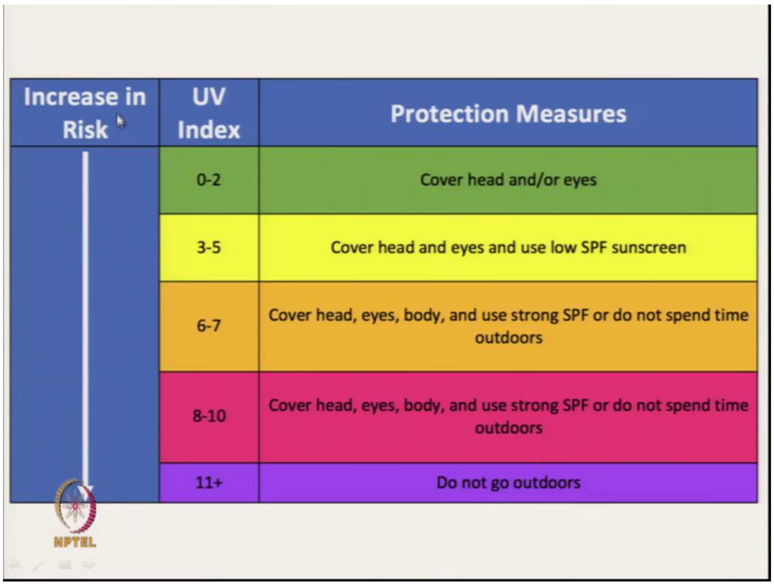
(Refer Slide Time: 41:25)



And this now we have to divide the value of UV from the step earlier by 25. So, total value which we are getting we have to divide by 25 or earlier I have mentioned multiply by 0.04. This is another part of determination accepted by different agency and then round off to the closest whole number. This 25 is just to get value of range between 0 to 15 through the world; so, we can get this value. So, this is the position where its a maximum value we are getting around 15.

So, 381.81 divided by 25 its 15.27 and its round off we are getting 15. So, we have seen how to calculate the UV index in a particular place which is very important to select the type of protection we require. So, in the normal in the sea level in a ground level which we get the UV, if we go above say in the hill area the UV index will be much higher and there we need more protection.

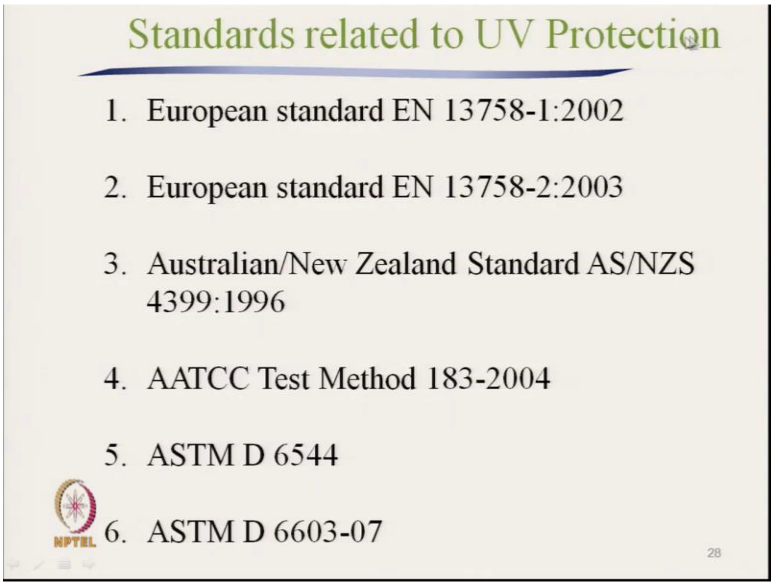
(Refer Slide Time: 42:59)



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

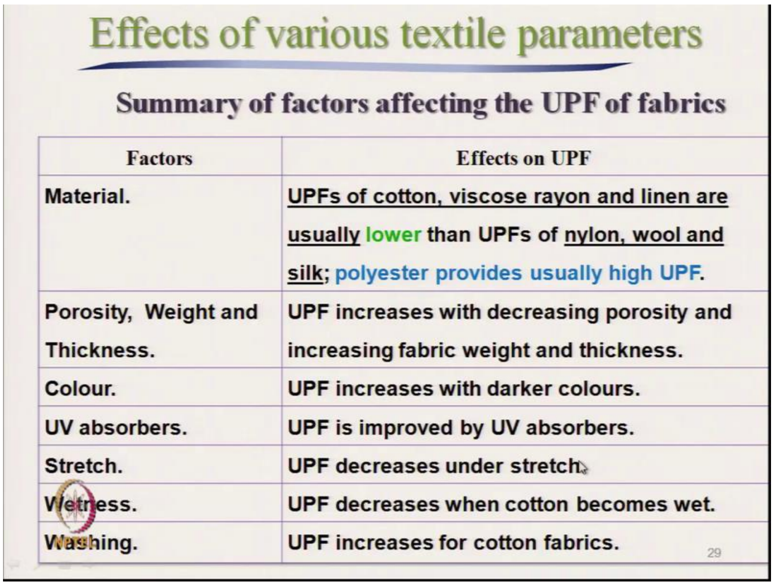
So, increasing risk with increase in UV value and the protection we can have different types of protection. So, for 0 to 2 we simply cover head or eyes, but in case where the risk is very high UV index 11 plus they suggest do not go out. So, we have different level of protection measure for different UV index value.

(Refer Slide Time: 43:41)



These are the standard related to UV protection so, European standard, Australian and New Zealand standard, AATCC test method for UV UPF test, ASTM test methods.

(Refer Slide Time: 43:59)

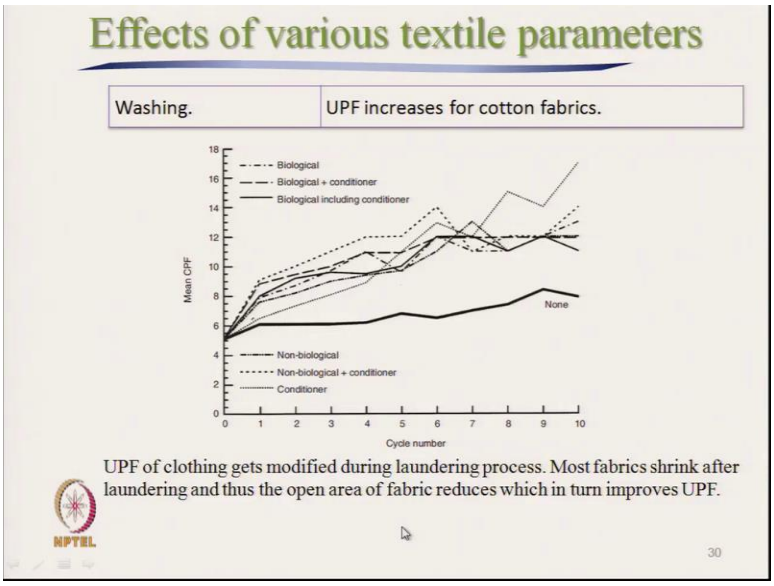


Now, we will discuss the effects of various textile parameters. So, as far as materials are concerned UPF value changes with the different types of materials. So, UPF of cotton, viscose rayon and linen are usually lower value. So, as far as the materials, these are the cellulosic material their UPF values are lower than nylon, wool and silk ok. But, polyester is found to be having high UPF value; porosity, weight and thickness UPF increases with decrease in porosity and increase with increase in fabric weight and thickness.

So, thicker fabric or heavier fabric will have higher UPF value, but fabric with higher porosity will have lower UPF value. UPF also increases with the depth of set. So, if we have material with higher depth darker shade so, that will have higher UPF value. If we increase the UV absorber so, UV absorbers there are different UV absorber absorbers are available.

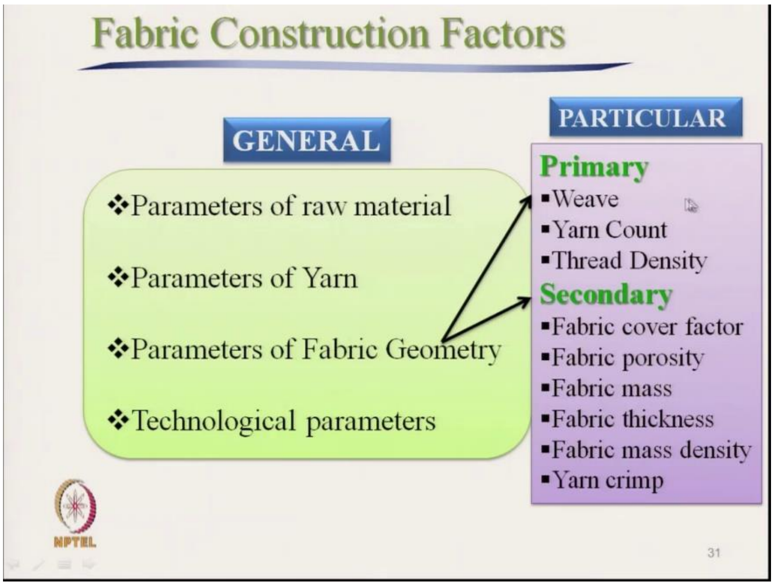
So, that will improve the UPF value, increasing stretch will decrease UPF value because, if we stretch a fabric that will create larger pores and UV ray will penetrate through that ok. UPF decreases with the wetness of fabric. So, if fabric is wet the UPF decreases and for different washing UPF is found to be increasing particularly for cotton its nothing, but the reason is that here once we wash and the fabric gets shrunk and its compactness increases the UPF value.

(Refer Slide Time: 46:31)



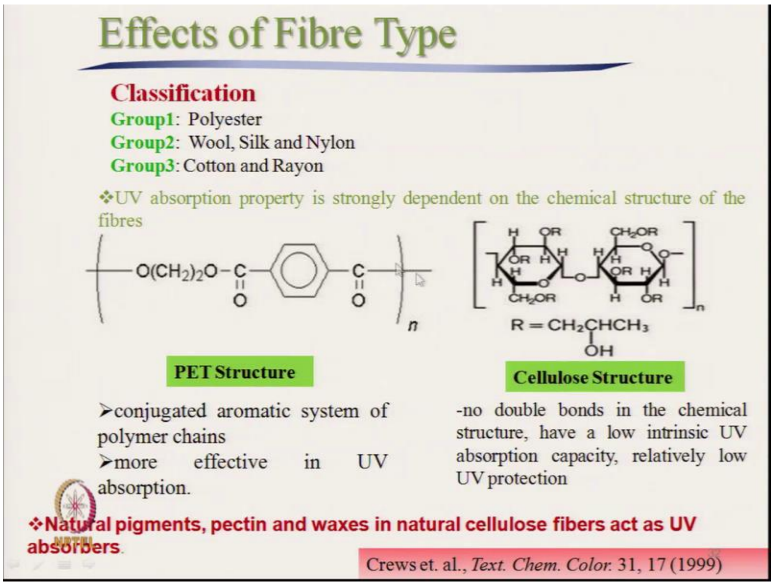
So, this diagram shows that as a number of cycle of washing UPF increases ok.

(Refer Slide Time: 46:47)



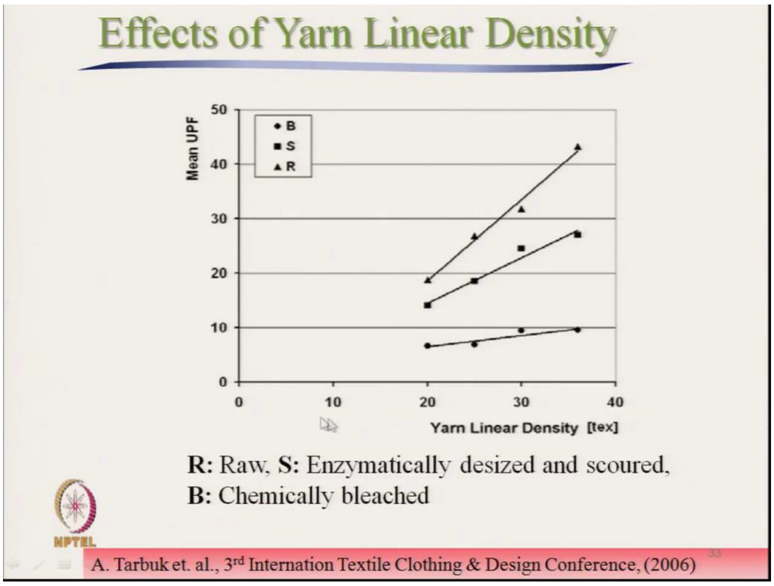
And fabric geometry it is a weave, yarn count, thread count it is a primary factors and in secondary which depend on this weave, yarn count, thread density as a fabric cover factor, fabric porosity, fabric mass, fabric thickness, fabric mass density, yarn crimp they affect actually they affect the UPF of fabric.

(Refer Slide Time: 47:21)



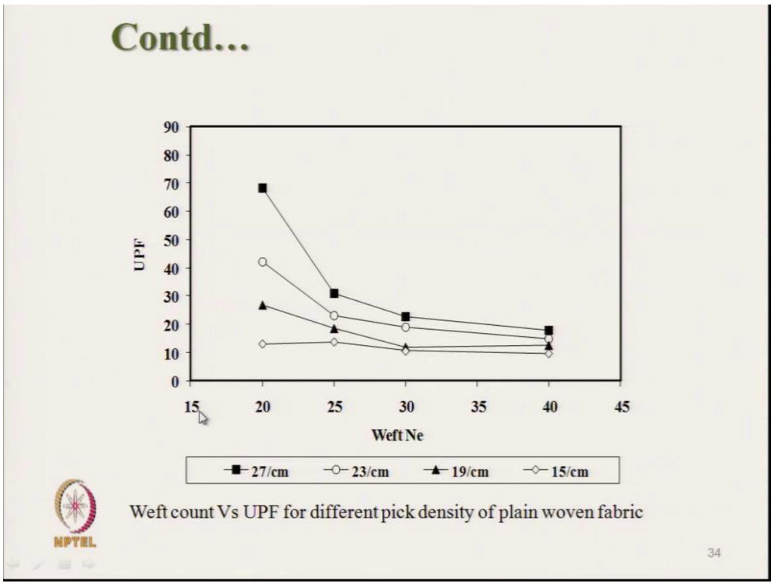
So, if you see the type of fabric fibre here it is a PET due to its conjugated aromatic system the bond the UPF value is high for polyester whereas, in case of cellulose this is absent. So, for cellulose UPF value is less. But natural pigments, pectin's wax in the natural cellulosic fibres acts as UV absorbers. So, if we see the UV absorbance characteristics UPF value for untreated cotton, natural cotton fabric is higher than the washed or bleached or scoured cotton because, during scouring this pigments, pectin's or wax they are sometime removes wax we remove.

(Refer Slide Time: 48:29)



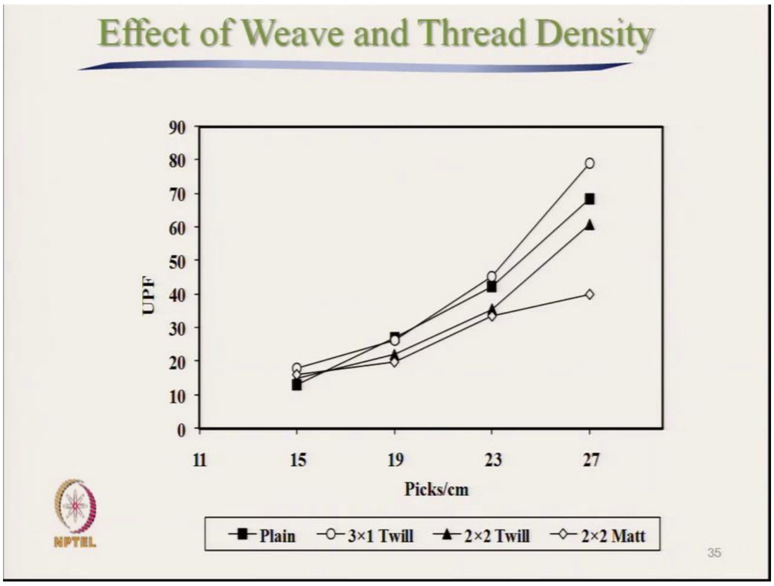
The yarn linear density as the yarn linear density increases tex increases yarns become I mean coarser, the UPF value increases keeping all other parameters constant. But, if you compare the raw fabric enzymatically desized fabric and chemically bleached fabric; the raw fabric is having higher UPF because of presence of wax and other material.

(Refer Slide Time: 49:03)



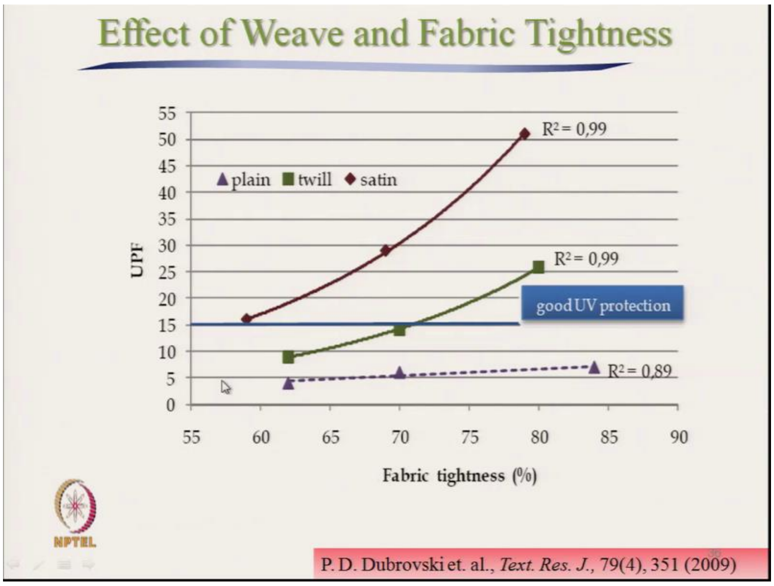
And this is same trend here in weft count, in English count that is weft as weft become finer keeping all other parameters constant; if a value reduces because the finer yarn produces the open fabric structure and thickness also is less.

(Refer Slide Time: 49:27)



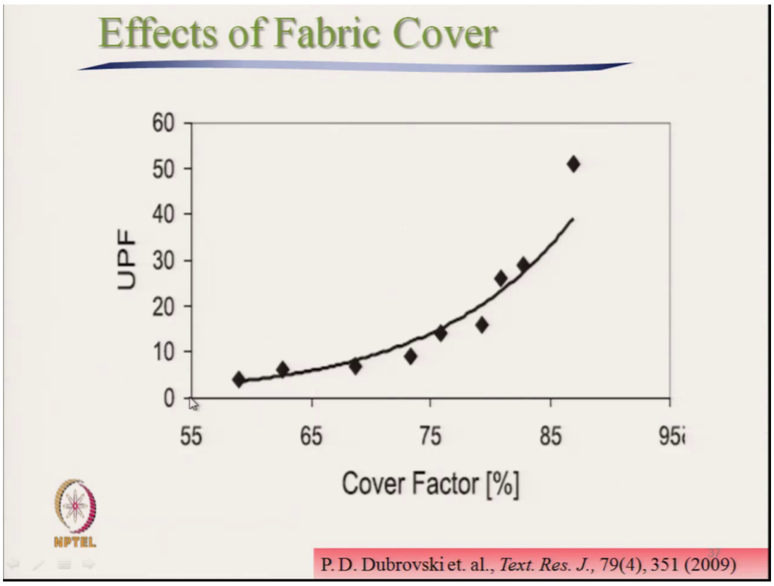
Pick density, if the fabric because becomes more and more compact that will result higher UPF value. So, that is why the compact fabric is having higher UPF value.

(Refer Slide Time: 49:45)



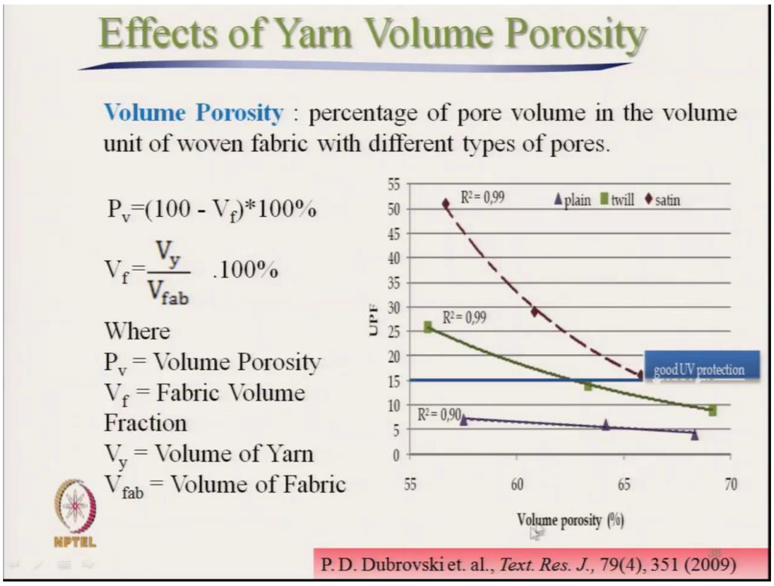
Fabric tightness here. So, tighter fabric will have higher f UPF value and this effect is more in case of here it is a satin fabric. Satin has got higher UPF than the plain fabric.

(Refer Slide Time: 50:05)



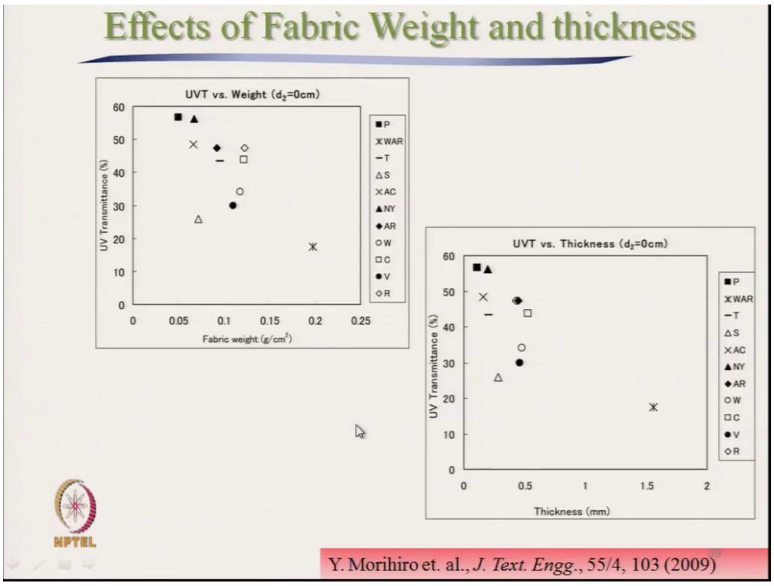
Cover factor with a increase in cover factor the UPF value increases. As I have mentioned this will the compact fabric will cover will prevent the UV radiation to pass through.

(Refer Slide Time: 50:25)



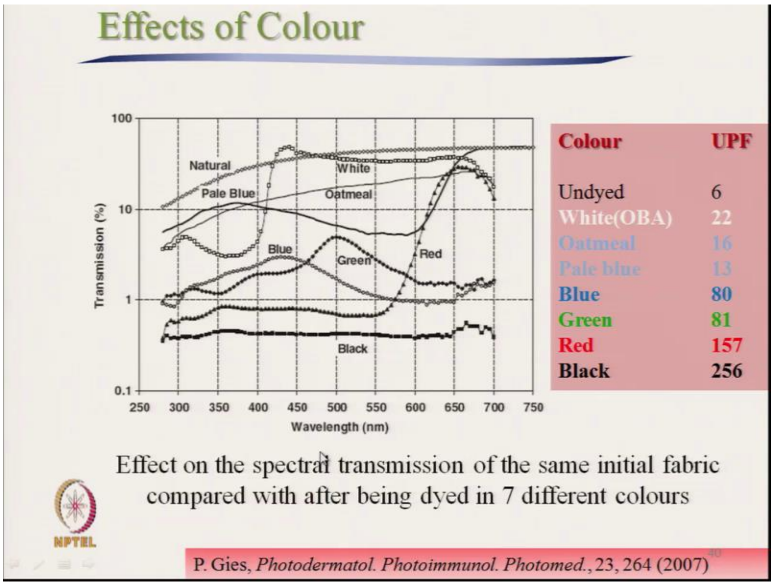
And volume porosity the porous fabric will allow more and more the UV ray to pass through that is why the volume porosity as volume porosity increases UPF value reduces gradually.

(Refer Slide Time: 50:45)



And here this is these curves showing the UV transmission characteristics. So, in x axis it is a fabric mass per unit area. So, as the mass per unit area of fabric is low there will be high transmission. So, high transmission means lower UPF value. Similarly, for thickness so, lower thickness will have higher transmission value.

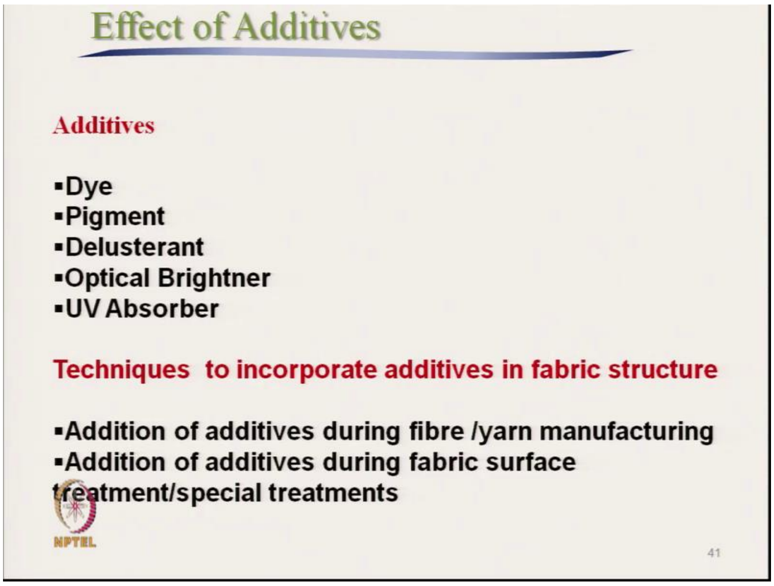
(Refer Slide Time: 51:17)



And this picture shows that effect of colour. So, as I have already mentioned the darker colour will have higher UPF value; that means, the penetration will be missed. So, here we can see in this picture the black has got least transmission throughout the wavelength. So, at different wavelength if we use a fabric with black colour the UPF value is least there whereas, for natural or white its highest UPF value increases.

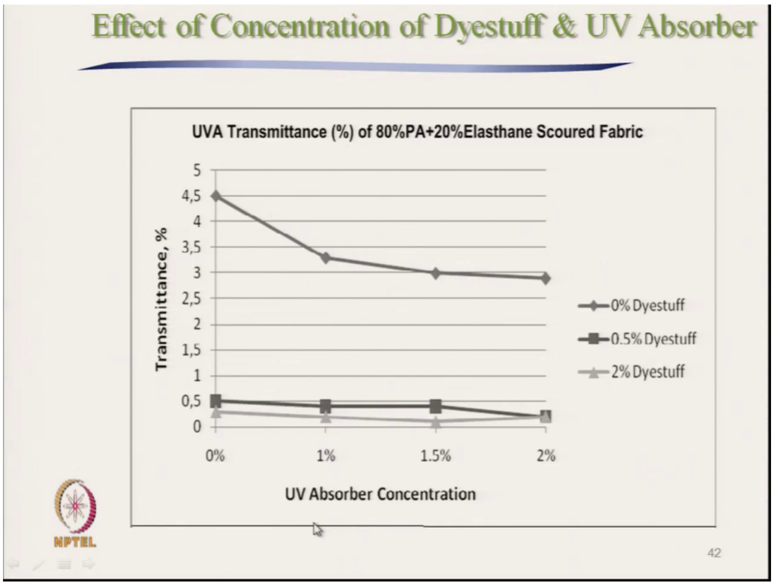
And, typically in most of the cases the, with the increase in wavelength the UPF value transmission is increasing ok. So, we have discussed various factors which affect the UPF value. We have also discussed various parameters to define the UV strength, to define the UV rate of UV transmission or how to characterize the ultraviolet protection factor.

(Refer Slide Time: 52:49)



And there are different additives which will increase the UPF value. So, these additives are dye, pigments, delusterant like TiO 2, optical brightener UV absorbers are there ok. There are different techniques to incorporate the additives in the fabric structures.

(Refer Slide Time: 53:19)



So, these absorbers if we see UV absorber concentration, if we increase the UV absorber concentration in the fabric the transmittance; the transmission percentage reduces. So, here in this picture it shows UVA transmission 80 percent of PA 20 percent elastane scoured fabric. So, UVA transmission it is measured here at the bottom it is showing with the 2 percent dyestuff. Here it is a 0.5 percent dyestuff and here it is a undyed. So, if the undyed fabric transmission is more and here with the dyed fabric transmission is least.

But, as we increase the UV absorber with the 0 percent dyestuff although it is a very high, but with the increase in concentration of UV absorber the transmittance reduces gradually. So, the both the dyestuff and the UV absorber they have impact on transmission percentage of UV radiation. So, we will stop here. We have completed this segment and in next class we will start another topic.

Till then, thank you.