Municipal Solid Waste Management
Prof. Ajay Kalamdhad
Department of Civil Engineering
Indian Institute of Technology – Guwahati

Lecture - 28
Compost Quality

Hello students, so we will continue the module 9 biological treatment that we were discussing about composting. So, today's lecture is on compost quality. So, in the previous lecture, I was talking about for sustainability of the compost plant is very important to look upon the compost quality because the product has to be marketable and the many times these kinds of discussion, you can see that whether this compost can be replaced by chemical fertilizer. Is it possible especially in the agricultural sector?

I personally believe that this compost if it is of good quality; when I say good quality means it contains good nutrients, not harmful effects into that final product. But if you just compare with the nutrient values, is not comparable with the chemical fertilizers, take the example of urea where 30 to 40% nitrogen is available, but in the compost maximum amount of nitrogen could be possible maybe we can reach up to 2%, 2.5% if you are using for earthworms or vermicomposting process.

But by a normal composting process like conventional composting is very difficult to reach up to even 1% nitrogen also in-vessel composting also in the last lecture I discussed where we can reach up to 2% 2.5% but it is not comparable with the chemical fertilizer. So, when these questions will come up whether we can replace the chemical fertilizer with compost I do not think so, is possible to replace that with a complete replacement of chemical fertilizer.

But it is possible that the farmers can use these compost in different percentage maybe 15%, 20% replacement could be possible or a mix of chemical fertilizer along with the compost could also possible and especially for the flower production, especially for the vegetable production, I think these compost are highly beneficial compared to the chemical fertilizer, maybe the yield from the chemical fertilizer will be very high, but the kind of vegetable will get produced out of that it could consist of a lot of chemicals into the final product.

But if you use the very good quality compost the especially for vegetable growth or vegetable production, I think the quality is also very good, but the yield will go that will not be very high. But if you are using for the continuously this kind of compost may be for 4 years, 5 years, or 6 years then the yield also will be very high because your soil also will be very good. Good soil could be possible after 4 to 5 years. And if you are continuously using chemical fertilizer your soil quality also will be reduced.

And not only the carbon content but even the nutrient content will be also very low by the utilization of more amount of chemical fertilizer. But again, I think this discussion is on the comparison of chemical fertilizer with the compost, but even for the centralized composting or decentralized composting facility the operation maintenance cost is very high. So, in that case, we required the good quality of the product which could be marketable at least it could sell by 5 rupees or 10 rupees at least in 1 kg, then the sustainability could be possible for such kind of composting plants. So that is why it is very important to talk about compost quality.

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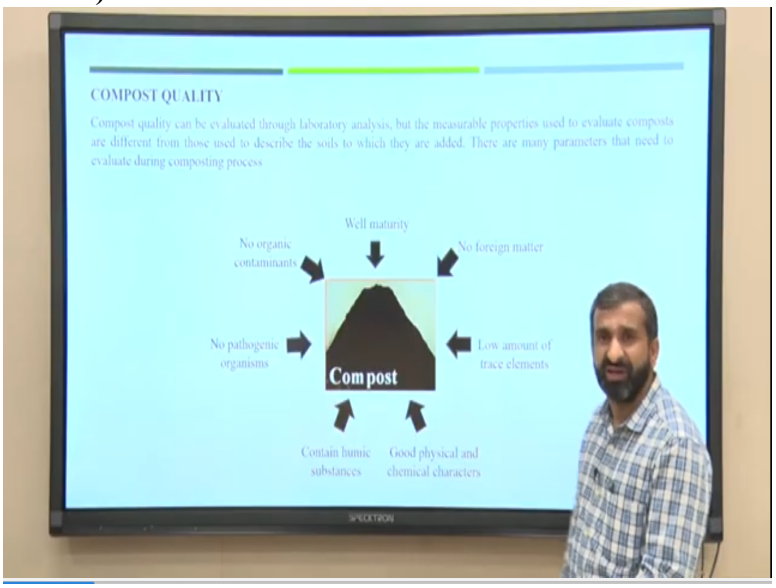

So, when you say the compost quality, what do we mean by this compost quality can be evaluated through laboratory analysis. There are a lot of parameters that need to be analyzed in the laboratory and also need to be described. How best it can be beneficial for the soil? By the addition of nutrients and also how the physical property of the soil could be increase or could be benefited for the soil by addition of compost that also needs to be discussed very well.

So, when I say compost quality, the first point will come into your mind that is it should be good physical and chemical characteristics means your physical property and chemical property should be very good that the first point will come up and the second point it also contained the humic substances. Now, see these humic substances, you will not get it into the chemical fertilizer.

But if you are using the compost obviously, also need to see that how much amount of humic substances could be possible into the compost material. And also the final product should be well matured. So, see again this maturity or stability is one of the very important parameters of the compost because if it is not matured enough, so, it will create problem into the soil I suppose, taken one example like the complete degradation or complete mature compost is not available, it is possible that it will utilize the soil nitrogen.

For whatever the microbes are available into the compost, it will take it out that nitrogen. So, obviously, it is a problematic one. So, your compost should be highly matured enough and also I think this is one of the positive factors which is required for any kind of compost which is getting produced, but also, low amount of trace elements are required, but what do you mean by trace elements I think these are very the concentration is very low.

There is a metal concentration from where these metal will come up because the organic material huge amount of metals are available especially some of the weeds like water hyacinth even paper mill waste material, these kinds of organic material will have a large number of metals like take an example of Sewage sludge also its content large amount of metal content, but the amount of trace but is a highly problematic for the not only for the soil but also for the plant.

So, that is why the trace element should be low in the final product and also no foreign matters. Foreign matter means I think like which we saw in the last lecture if you are going for the non-segregated waste material into the windrow composting facility and after filtering, there are a lot of foreign matters that could be possible to add into the final product, also no pathogenic

organism that is also very important, that is why we talked the last I think 3, 4 lectures I was talking about thermophilic composting.

So that not pathogens could not be available should not be available into the compost and these all pathogens are available into almost all kinds of organic matter which is including kitchen waste, obviously, in Sewage sludge, the pathogens will be there, but other industrial organic waste also the pathogens will be available and no organic contaminants or inorganic contaminants should not be there. So, now the first is that good physical and chemical characteristics. So, what is the parameter has to be analyzed to know the good physical and chemical characteristics.

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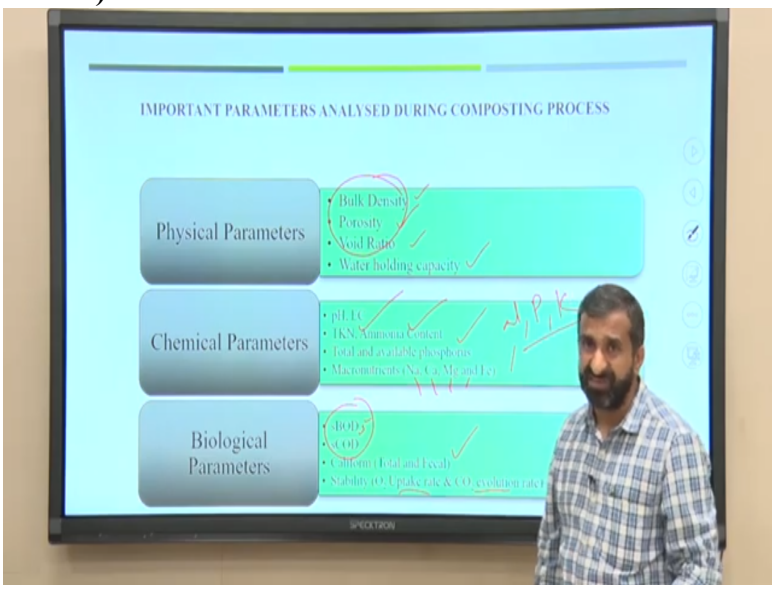

So, there are 3 major properties or characteristics that have to be analyzed. First is a physical parameter which is including bulk density, porosity, void ratio, water holding capacity. See now the bulk density, porosity, void ratio. This is a very important physical characteristic or physical properties of the composed because we are required to add such kind of material into the soil which will increase the porosity increase the void ratio, because of that, the water holding capacity will be very high.

So, that the more amount of water will be available for the plant growth into that particular soil by addition of compost and bulk density is also very important. If you add low-density materials like compost into the soil, because the soil is a high-density material. So, by the addition of

compost, the density also will be low. So that for these very important for the growth of the plant. Next is the chemical parameter like Total Kjeldahl Nitrogen,

This is very important ammonia content, total and available phosphorus micronutrients, this is another nutrients. So, normally when you say the compost normally these nutrients will come up N, P and K. So, this is what is available in the chemical fertilizers also NPK based chemical fertilizer like the urea is a nitrogen-based, phosphate is a phosphorus base, and specially the NPK fertilizer, where nitrogen, phosphorus and potassium will be available.

That is also and apart from that there will be other micronutrients is highly beneficial for the soil and plants that is sodium, calcium, magnesium and also the trace amount of iron is also very important for the soil and plant growth and along with that the biological parameter like soluble BOD and COD. BOD_5 and COD, this also very important one where we can know that how much amount of organic matters are available into the final product.

This is also the similar way we can analyze as we are analyzing for the sewage only we have to list out the water from the compost under the same sample can be analyzed for soluble BOD_5 and COD also. Similarly, the coliform, i.e., the fecal coliform to know that how many pathogenic microorganisms are available, this also we can easily do. And finally, the stability or maturity can be analyzed by two major parameters one is the oxygen uptake rate and CO_2 evolution rate.

Now, this is very important to know that normally in India nobody discusses much about the stability of compost or maturity of compost. So, we here the idea of analyzing these parameters to know that how much amount of oxygen is getting uptake by the compost means is whatever the air we are adding and air addition in the industrial composting, but by simply in the rotary drum composting, by the rotation how much amount of oxygen is getting uptake by the material.

And because of that, how much amount of oxygen is getting evolved from that particular mass that needs to be known that because in the final matured material, there will not be a much amount of organic matter means there will not be much amount of microorganism. So your oxygen uptake rate also will be low and similarly, carbon dioxide evolution rate also will be very

low. So, this is all parameters are very important to know that the physical and chemical characteristics of the final product.

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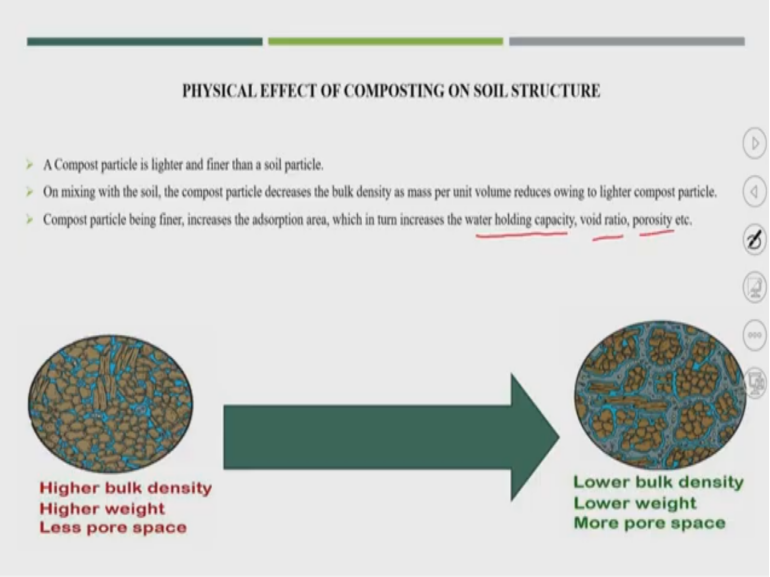

Now physical effects of composting on soil structure. So, a compost particle is lighter and finer than a soil particle on mixing with the soil the compost particle decreases the bulk density as mass per unit volume reduces owing to lighter compost material. Compost particle being finer increase the absorption area which is interns increase the water holding capacity, void ratio and porosity. So, this is what in the bulk material, there will not be many voids into the mass or into the soil.

But by the addition of compost, you will see here a lot of voids have been created because of the addition of lighter material like compost. So, because of that, there will be increasing water holding capacity, void ratio and porosity of the particular soil.

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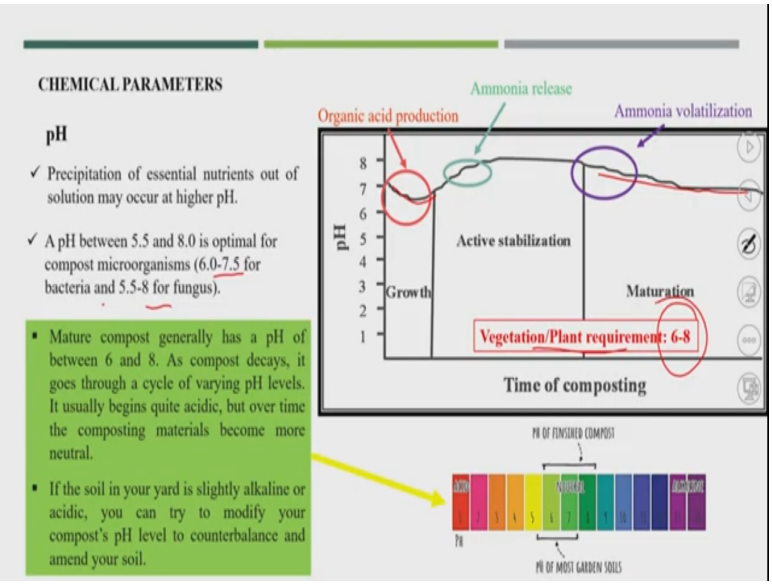

Now the chemical parameters one by one will go. So, while in the composting process, I think before looking on to the final product, we also need to be analyzed during composting, how these chemical parameters are changing with the composting period. So, the pH is important because the precipitation of essential nutrients out of solution may occur at high pH. And a pH between 5.5 to 8 is optimal for compost microorganisms. So obviously, 6 to 7.5 is very good for the bacteria and 5.5 to 8 for the fungus.

So your raw material also needs to be how the proper neutral pH for the degradation process and if you see the changes into the pH initially it will lower down because of organic acid production and after that it will increase because of ammonia release and finally, ammonia will be volatile into the mass. So, that will get more amount of total nitrogen into the final product. So, because of that pH will be neutral. So, normally we called it not composting process itself is a buffering capacity.

So, it will maintain the pH in the compost mass. So, for vegetation and plant growth in agriculture pH 6 to 8 is very good for vegetable growth and soil microorganism. So, mature compost generally has a pH of between 6 to 8 as compost decay it goes through a cycle of varying pH levels it usually begins quite acidic, but more time the composting metal become more neutral, if the soil in your yard is slightly alkaline or acidic, you can try to modify your compost pH level to counterbalance and amend your soil.

This is also possible under you see that by addition of more amount of chemical fertilizers soil become acidic and because of acidity of the soil, there are a lot of nutrients is getting leached out in the form of runoff. So because of that soil quality will also be reduced. So, to maintain the pH of proper pH into the soil, if you add such kind of alkaline pH compost where pH is around 7.5 to 8, this kind of compost will be able to modify the pH of the soil also and it will come up or stable at neutral pH. So, this is where we can analyze the pH. So, this the neutral pH required for the finished compost.

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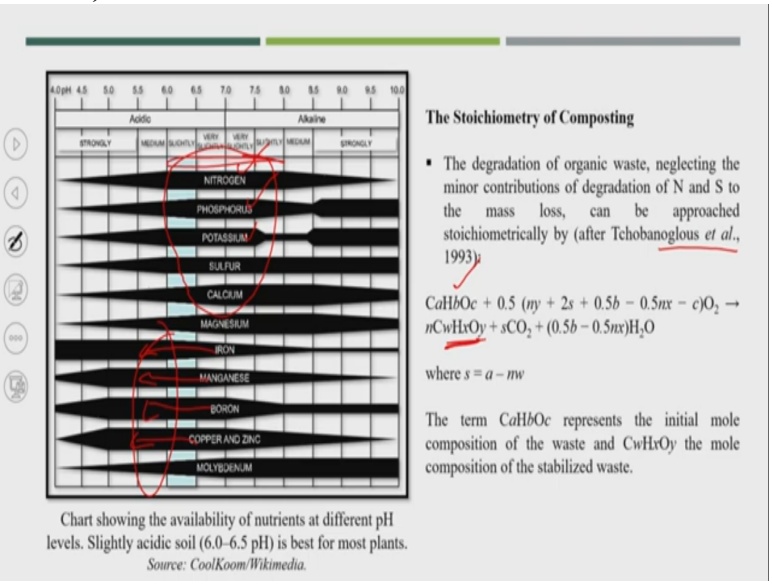

Chart showing the availability of nutrients at different pH levels. Slightly acidic soil (6.0–6.5 pH) is best for most plants.
Source: CoolKoom/Wikimedia.

Now, you see here it the different pH I think the quality of the products also sees at the neutral pH your nitrogen will be very high, phosphorus will be very high, potassium sees here this is the this the way where all the nutrients are very good. So, pH from 6 to 7.5 or up to 8 is very good to maintain the nutrient quality of the product. But similarly in the same the lower pH your iron will be more, manganese will be more, boron, copper, and zinc, this is all metal.

Its acidic pH will be in a large concentration. So, if you maintain the proper pH even the trace elements also will be in a low concentration. So, if you see the stoichiometry of the composting process, the degradation of organic waste neglecting the minor contribution of degradation of nitrogen and sulfur to the mass loss can be approached Stoichiometry. So, this is one author who has been given this particular equation, this is the chemical formula of organic material.

And finally, this is what the compost chemical formula can produce out of that. So, the CaHbOc represents the initial mole composition of the waste and this one is the mole composition of the stabilized waste. But, again, I think by Stoichiometry we can we will know about how much amount of carbon, hydrogen, oxygen could be possible to produce in the final product, but still, I think there is a lot of minor contribution should be neglected into this Stoichiometry.

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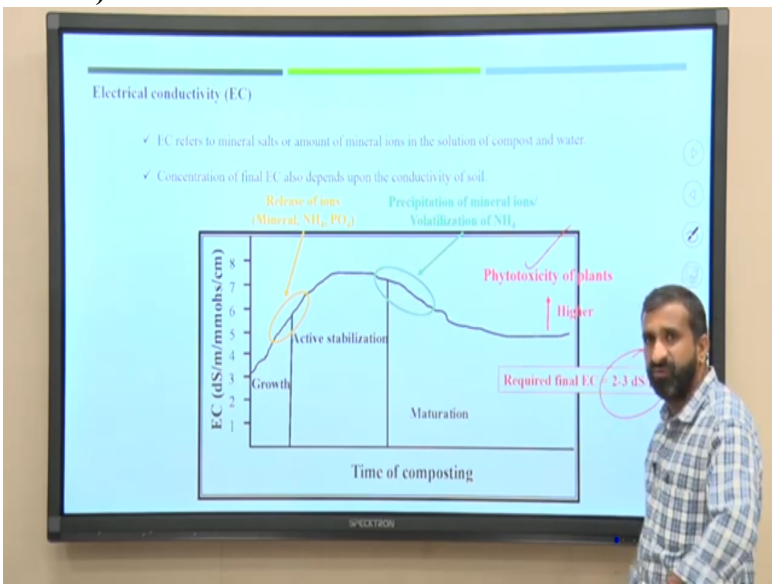

So, another parameter that electrical conductivity so electrical conductivity I refer to mineral salts or the number of mineral ions in the solution of the compost and water. So, it is very important the concentration of final electrical conductivity also depends upon the conductivity of the soil. So, while in the composting process, so, this will be the flow of the electrical conductivity. So, initially, it will increase by the release of ions.

And finally, these all ions will be precipitate under the volatilization of ammonium ion it will reduce the electrical conductivity on this electrical conductivity is very important to know the Phytotoxicity of the plants. So, more amount of salts mineral salts are available into the final product is not good for the plant growth and it will be phytotoxic to that particular product. So, you see should be required is around I think less will be more beneficial it could be 2 to 3 decisiemens per meter (dS/m). I think it is good for the final product compost.

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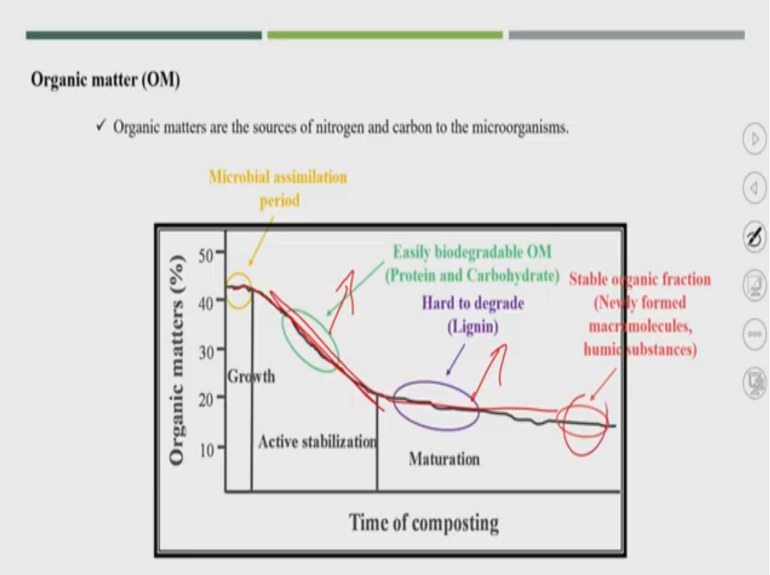

Next parameter is the organic matter. So, obviously organic matters are the source of nitrogen and carbon to the microorganism. So, this is the flow, so initially it will be reduced more and finally, the reduction will be slower. So, this is the thermophilic temperature, thermophilic condition this is in the maturation condition. So, the first microbial assimilation period, so, this is the first thermophilic that is formed from the easily biodegradable organic matter.

And finally, this is reduced because of degradation of lignin or hemicellulose which is very difficult and where maximum the fungus will work for this degradation and finally, a stable organic fraction which is including newly formed micromolecules and humic substances. So, in a particular time period, this organic matter will not reduce.

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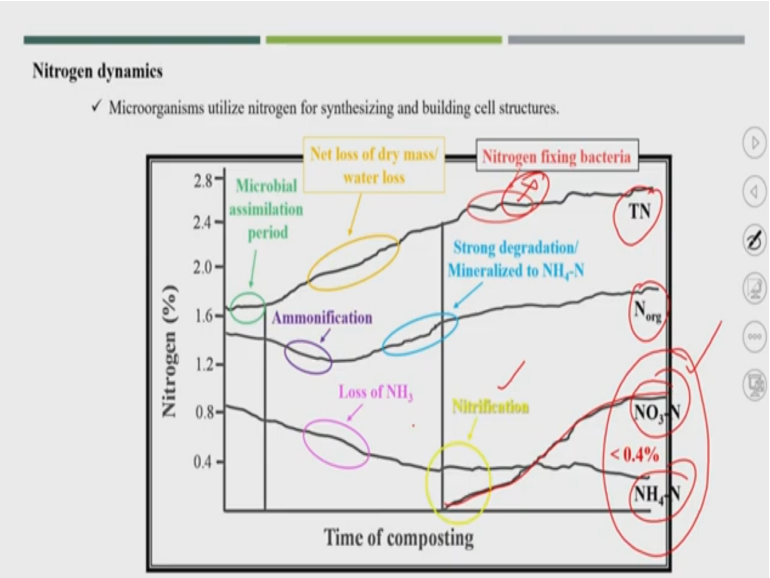

Next is the nitrogen dynamic, this is very important to know that because there are different kinds of nitrogen changes that could be possible. So, the microorganism utilized nitrogen for synthesizing its building cell structure. So, this is the particular graph you can see that this graph is between, time of composting period versus nitrogen. So, it will allow 4 different nitrogens. So, it is the total nitrogen, this is organic nitrogen, this is nitrate nitrogen, and this is ammonical nitrogen.

And which is required to be less than 0.4%, that percentage should not be high because this ammonia is not good for the soil, also is not good for the soil microbes not good for the plant growth and why these changes could be possible because the total nitrogen is increasing because of net loss of dry mass or water loss. And finally, maybe some of the author studies that there could be a nitrogen-fixing bacteria which will increase the total nitrogen, but it is not completely true, but I think some of the literature shows that is possible.

Now, this organic nitrogen also will increase because of the strong degradation of mineralized ones to ammonia, and initially, there will be a loss of ammonia and once the thermophilic phase will get over in the maturation, there will be nitrification, then the nitrate will get started to grow and obviously, see the plant is required inorganic form of nutrients. So, this is what the plants will be utilized nitrate and ammonia for the synthesis of the microbial consortia. So, your nitrate

concentration should be more and your ammonium concentration will be low in the final product.

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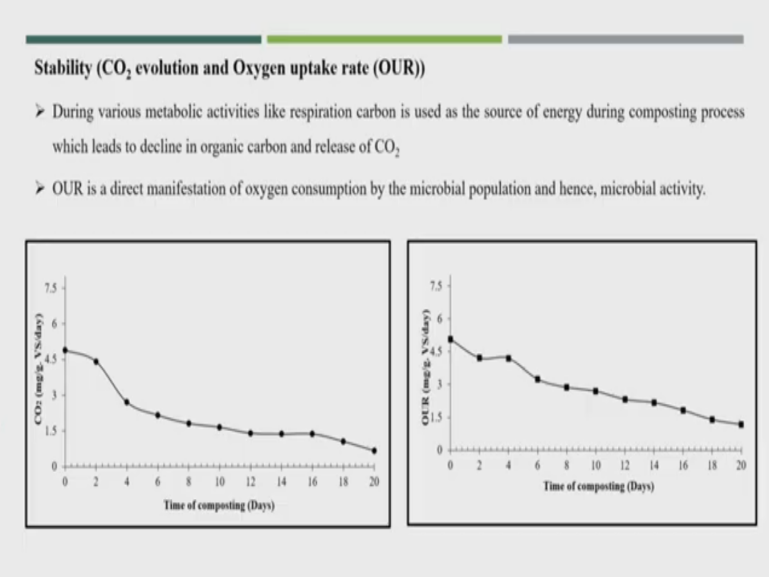

Now, next is stability. So, this stability is normally analyzed by CO_2 relation rate and oxygen uptake rate. So, during various metabolic activities like respiration carbon is used as a source of energy during the composting process which leads to decline in organic carbon and release CO_2 and oxygen uptake rate is direct manifestation of oxygen consumption by the microbial population and hence microbial activity. So, this is what the flow of carbon dioxide, the reduction of carbon dioxide evolution and this is for oxygen uptake rate. Obviously, your oxygen uptake rate will be more compared to the carbon dioxide evolution rate.

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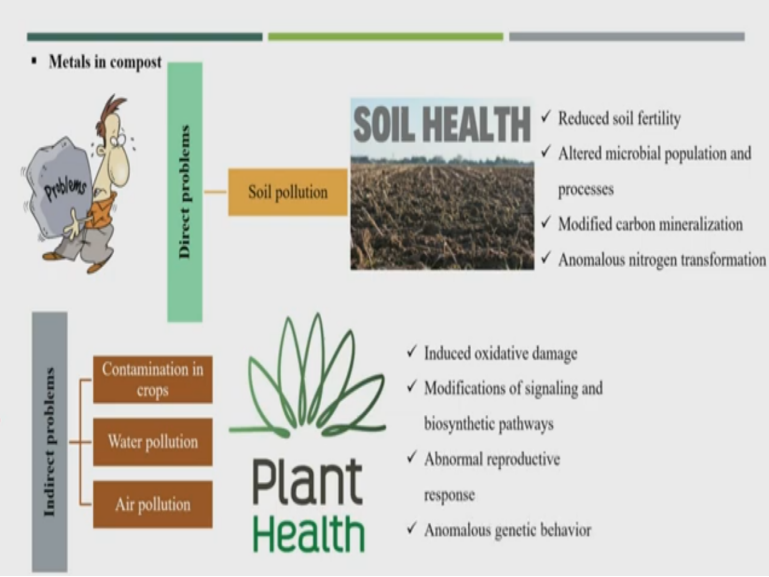

Now, the metals in compost, this is one of the most important discussions when you discuss the compost quality because these metals are inorganic in nature. Because in the entire composting process, only organics will get degrade, your inorganic concentration will be the same. So because of that entire, your mass is getting reduced. So, whatever amounts of inorganic materials are there especially metals in the final product, you will get a large amount of that particular metal.

That is what needs to be analyzed, the metal concentration into the substrate or in the feed material, how much amount of metals are available, if the metals are more obviously in the final product also metals will be more because finally, mass is reducing. So, this is an inorganic one there will not be any degradation. So, final product also you will have more amount of metal concentration in the final product. So, like in the example, like water hyacinth, which is very well known for the metal absorption from the water for their growth.

So, if you produce compost out of that, this compost will contain a large amount of metals. Similarly, with the Sewage sludge which contains a large amount of metals in the final product also you will get a large amount of metals and what will be the problem with these metals, there will be a direct problem within the soil also there will be an indirect problem for the crop, there could be a problem for water pollution and also possible indirectly.

So, directly for the soil health, it will reduce the soil fertility, it will alter the microbial population and processes and it will modify carbon mineralization in the soil and also the nitrogen transformation also will be changed. Similarly, the indirect problem for the plant health could be induced oxidative damage, could modification of signaling and biosynthetic pathway, abnormal reproductive response, and also anomalous genetic behavior could be possible into the plants.

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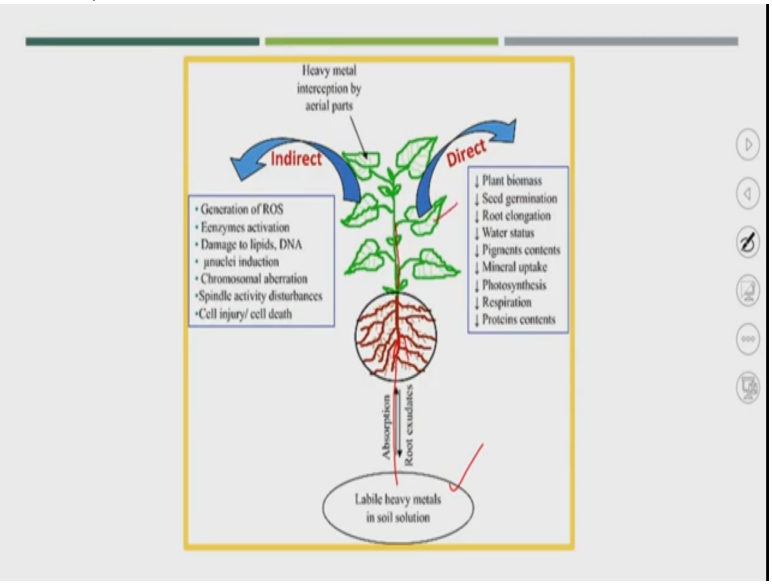

Under this also you can see that the direct impact and indirect impact could be possible for the plant. So, because, if that particular soil after addition of compost, if that soil is having more amount of metals, obviously, these metals will be absorbed through the root of the plant and finally, from the root it will go to the stem to the leaves and fruit. So, more amount of metals will be available not only in the leaves but also in the fruit. Also, you will have more amount of metals. This is not good for human health.

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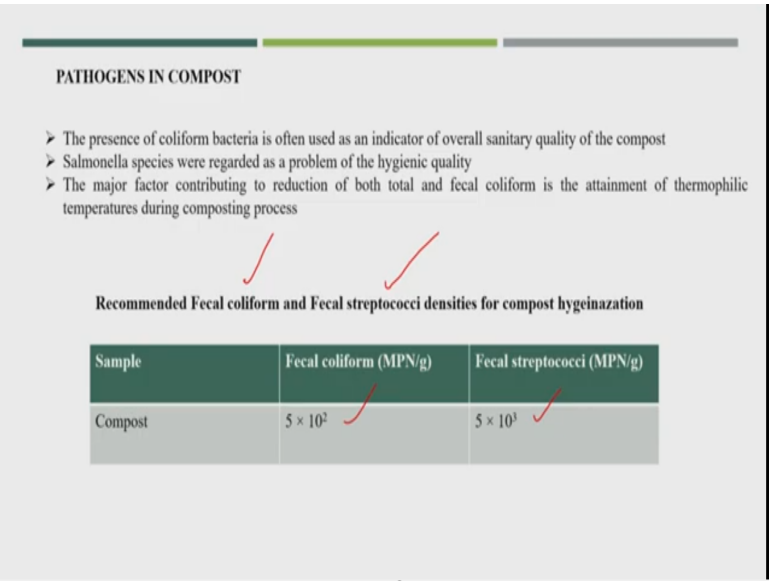

Now, the pathogens in the compost. So, the presence of coliform bacteria is often used as an indicator for overall sanitary quality of the compost. So, Salmonella species were regarded as a problem of the hygienic quality. And the major factor contributing to the reduction of both total and fecal coliform is the attainment of thermophilic temperature during the composting process, which I discuss in the first lecture of the composite also.

How this thermophilic temperature or how these pathogens will be inactive by achieving thermophilic temperature into the compost mass. So, normally that recommended fecal coliform and fecal streptococci, so the source of fecal coliform is a human and fecal streptococci the sources animal. So in this case now, if you are using the sewage sludge so in the sewage sludge, more amount of fecal coliform could be possible.

And if you are using cow dung or any animal dung for compost production, your streptococci could be possible. So, as such, there is no standardization of the pathogenic bacteria, but there are a number of studies has been done in the academic institutes and they suggested that the fecal coliform should not be more than 100 or 500 and should not be more than 5000 this quantity in the final product. But these quantities also will not be possible if you are able to achieve a temperature of 60 degree or 65 degrees centigrade into the compost mass. So the pathogens will not be possible to survive at this high temperature.

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One more important point for the compost qualities phytotoxicity, one phytotoxicity we saw with the electrical conductivity, we should not be more than 2 to 3 Decisiemens per meter that is based on the mineral material. Now, this phytotoxicity is because a lot of chemicals could be possible specially the hallow loop chemicals could be possible into the organic matter and specially when we are doing the composting of weed.

Specially terrestrial weed or any water weed, there are always possibilities of toxic hallow loop chemicals and this toxicity also will be also come up through the metal also, if metal is more it will be toxic to the plants. So, that Phytotoxicity or toxicity has to be analyzed for the final product, I took the example of this Mikania micrantha this well-known weed soil weed normally we find it the at the tea plantation.

So, if you produce the compost through even further in-vessel composting by rotating composting and where we are able to achieve 60°C temperature and if you do the toxicity test, you see the when you 100% compost were using and if you compare with the control the growth is very poor. You see here control without compost is the growth is good, but by addition of compost, growth is low. That is why toxicity is very important, even though the nutrient quality is more toxic; it needs to be studied before application into the soil.

So, this is another study of phytotoxicity the simple test we can do in the laboratory by Vigna radiata and *Alium cepa* by that way we can study you will see here the growth of the moong sets in by the addition of 100% and by control and a 25% the growth is more, this is for the *Vigna radiata* or moong beans, and this is for *Alium cepa* you see here the growth. So, here the 100% growth is low compared to 25%. See here, so, this is control, this is control this is 25%. So, this is highly beneficial for 25% addition for the growth of particular plants.

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But suppose whatever the final product will come up, if it is toxic also and if it is content more amount of metal, then what could be the solution. So, what is the solution if compost made is not good and metal content is high means like in the specially these problems will come up in the centralized composting facility where they are not able to produce very good quality compost. So the nitrogen content is 0.5% or less than 1%.

Other nutrients also would not be possible. So why not some corporations add chemical fertilizers in order to increase the quality of compost. So, it is possible that by the addition of some chemical fertilizer in the compost, the nutrient quality can be increase, but is not suggestible. But I think many corporations are doing that way, I do not have much literature onto that even the private operators also but for increasing the nutrient quality of the compost.

They are adding chemical fertilizers there is not good anyway, by additional chemical fertilizer in the compost, I think you will see that how these microbes will get affected by the addition of

chemical fertilizer but for an increase of nutrient quality that people are doing that and to lower down the metal concentration by addition of some chelating agent like lime, zeolite, biochar could be possible to add into the composting process.

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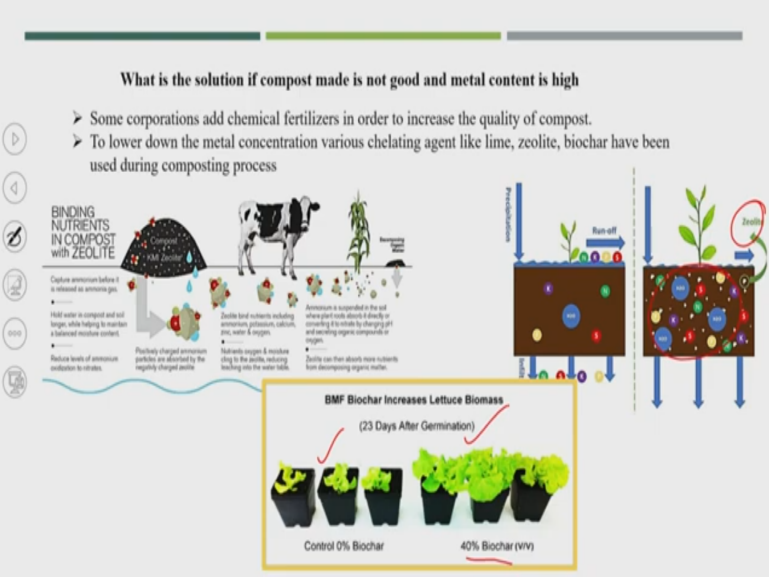

So, what will be the effect of the addition of lime or zeolite now initially because there are a lot of nutrients are getting leached out? Because of content more amount of metal. So, by the addition of zeolite or lime, the slight pH will increase of the compost. So slight means the pH could be up to 8. So, because of that, under these chemical like lime and zeolite is able to absorb on to the nutrients. Nutrients will be absorbed into these kinds of material.

These kinds of chemicals, so the entire nutrients will be possible to into the compost mass, it will not be leached out and if you add the biochar are also I think here you can see that by simple control you can see the leaf of the lettuce biomass, but an addition of 40% biochar you see the lettuce know how it has been grown. So, this is also a good idea, I think this I accepted that if the more quantity of metals is there in the final product by addition of a very small quantity of lime maybe 2%, 3% or in the similar ways zeolite also if you can add or even biochar addition also could improve the quality of your compost especially, it can reduce the solubility of metals.

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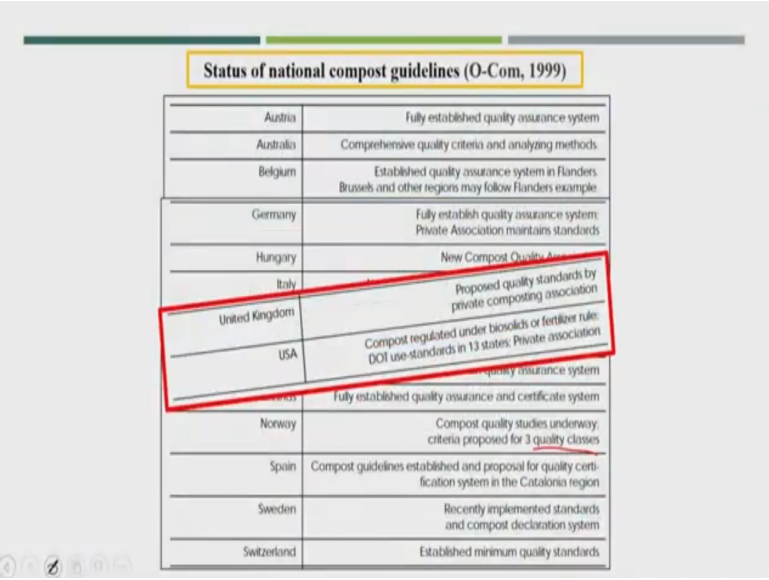

Now, there is some status I found for national compost guidelines, like how the guidelines have been prepared in various countries like Austria, Australia, Belgium, Canada, Denmark, France, Greece. So, like Greece, basic solid waste rules are available, but no official compost standards like for other like, Hungary new compost quality our solution they prepared like Luxembourg, some compost plants follow German quality assurance system, Netherland fully established quality assurance.

And certificate system like in Norway the Compost quality studies underway criteria proposed for 3 quality classes. So, the many countries they talked about type 1, type 2, type 3 quality composter class 1, class 2, and class 3. So is a simple understanding type 1 or class 1 means highly matured class 2 means is a medium quality or medium maturity compost there is a class B or type 2 and type 3 or class C is consider he matured composed under even the purposes are different were to add these kinds of composts like class 1 or type 1 can be utilized for the agriculture purpose.

But type 3 or class C should not be used for the agriculture purpose could be possible to the addition of soil improvement in other areas, because there is not well matured composed or not good quality compost. So should not be used for the agriculture area that kind of guideline says prepared by various countries. So, like in the UK, the proposed quality standards by private

composting associations and the USA compost regulated under biosolids or fertilizer rule and different rules in the different states.

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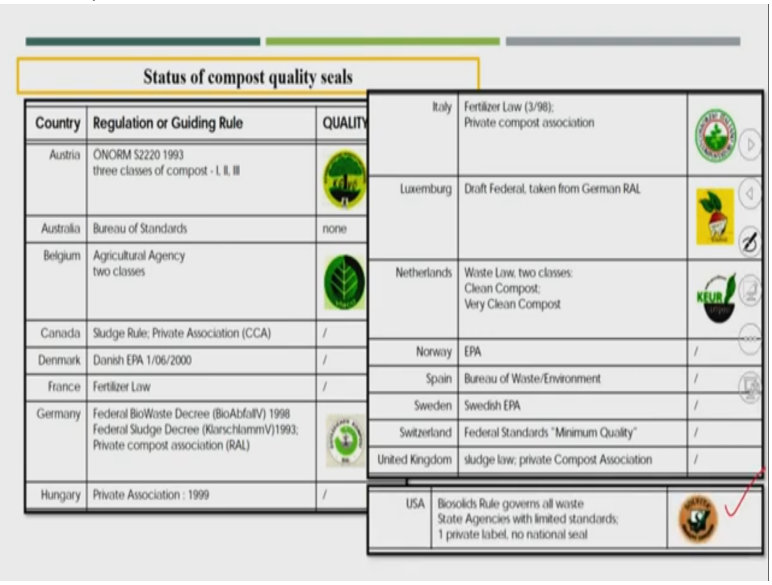

Now, I think some of the countries also come up with the status of compost quality seal. So, whatever product you can put a particular seal onto the product. So, now for Australia, there were 3 classes of compost 1, 2, 3 and you see the particular seal they prepared like in the Belgium agriculture agency 2 classes different similarly with the Germany federal biowaste decree in 1998 and they have private compost association also and they are particular quality seal they put it onto the product.

Similarly, Italy, Luxembourg, Netherland. So, Netherland like waste law 2 classes, like clean compost, very clean compost, you can put particular seal onto the product. Similarly, USA also one particular seal is available.

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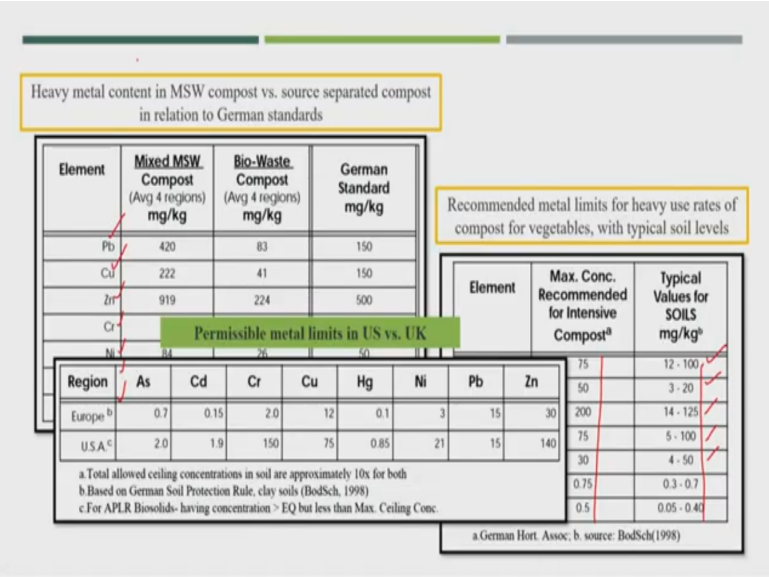

This is some special standardization for heavy metal content in MSW compost versus source-separated compost in relation to the German standard. So, is a mix MSW compost these are the major important metals could be possible to available into the metal like lead, copper, zinc, cadmium, chromium, nickel is possible and they produce a different kind of standard like German standards.

What is the concentration of milligram per kg of compost? Similarly, bio waste compost what should be the maximum concentration of metal is only allowable in the final product if the metal concentration is more so, this kind of product will not be acceptable in the agriculture area. This is another one like recommended limits for heavy metals uses rates of compost for a vegetable with typical soil level this is especially for the vegetable.

So, this is a German standard. So, this was for the based on the different feed or different substrate different material this is especially for the utilization purpose for the vegetation purposes these are the metal standards are given and they say typically for the soil. So, once you add into the soil the metal concentrates should not be more than, this percentage this is the permissible metal limit for us in the UK. So, Europe has different concentrations and in the USA our different concentrations are again dependent upon the quality of soil and quality of product or quality of vegetation into that particular soil.

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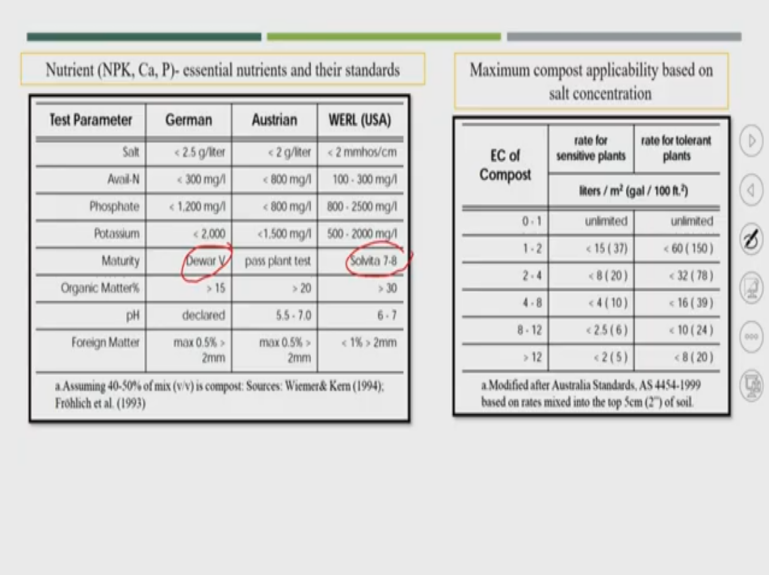

Now, this is the NPK and calcium and phosphorus essential nutrient their standards. So, here you can see the test parameters like salt available nitrogen and phosphate, potassium maturity, organic matter pH, foreign matter. So, this is a comparison between Germans, Australia, and the USA. So, here in Germany, they use this maturity that particular Dewar stability test, and in the USA they studied the Solvita maturity index which I had shown one graph for stability or Solvita maturation index.

If you are interested to know more about that, you can read some research papers because there are a lot of issues which we can discuss more in these classes. Because if anyone is interested you can read more on to the maturity how to analyze the maturity and to know more about the maturity indexes. This is the electrical conductivity or compost is explained this is the rate of sensitive plant and rate for tolerance plant. So, this unit is liter per meter square of that particular soil area and these standards are available.

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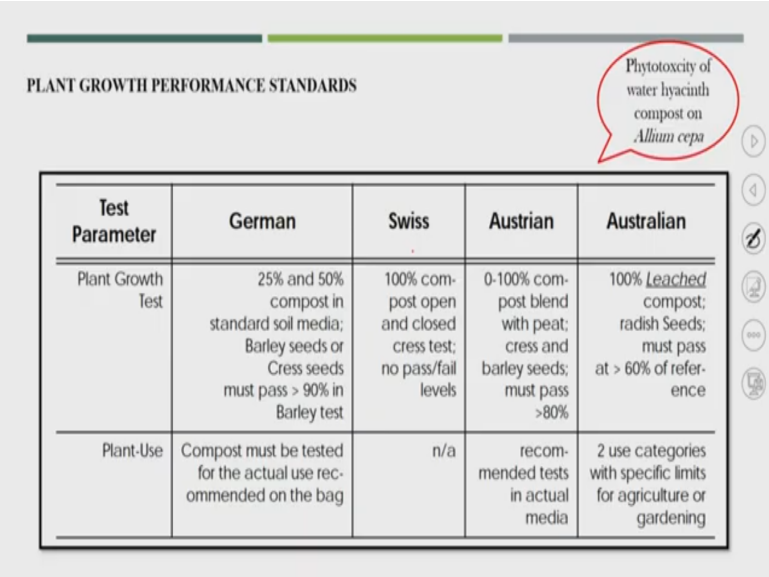

Test Parameter	German	Swiss	Austrian	Australian
Plant Growth Test	25% and 50% compost in standard soil media; Barley seeds or Cress seeds must pass > 90% in Barley test	100% compost open and closed cress test; no pass/fail levels	0-100% compost blend with peat; cress and barley seeds; must pass >80%	100% Leached compost; radish Seeds; must pass at > 60% of reference
Plant-Use	Compost must be tested for the actual use recommended on the bag	n/a	recommended tests in actual media	2 use categories with specific limits for agriculture or gardening

Now, plant growth performance standards, like this especially based on the phytotoxicity test. So, plant growth test like in the German 25 to 50% compost in standard soil media barely seed or Cress seeds must pass greater than 90% in barley test. So they have different kinds of standard seeds available like plant use compost must be tested for the actual use recommended on the bag like in Austrian recommended testing the actual media, in Australian to use categories with a specific limit for agriculture and gardening purpose. So these are a few plant growth-based performance standards.

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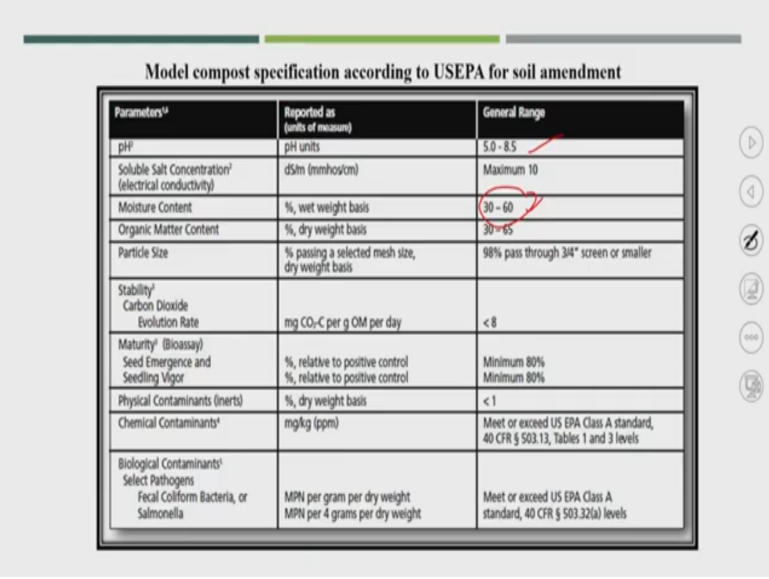

Parameters[1,4]	Reported as (units of measure)	General Range
pH[2]	pH units	5.0 - 8.5
Soluble Salt Concentration[2] (electrical conductivity)	dS/m (mmhos/cm)	Maximum 10
Moisture Content	%, wet weight basis	30 – 60
Organic Matter Content	%, dry weight basis	30 – 65
Particle Size	% passing a selected mesh size, dry weight basis	98% pass through 3/4" screen or smaller
Stability[3] Carbon Dioxide Evolution Rate	mg CO_2-C per g OM per day	< 8
Maturity[3] (Bioassay) Seed Emergence and Seedling Vigor	%, relative to positive control %, relative to positive control	Minimum 80% Minimum 80%
Physical Contaminants (inerts)	%, dry weight basis	< 1
Chemical Contaminants[4]	mg/kg (ppm)	Meet or exceed US EPA Class A standard, 40 CFR § 503.13, Tables 1 and 3 levels
Biological Contaminants[5] Select Pathogens Fecal Coliform Bacteria, or Salmonella	MPN per gram per dry weight MPN per 4 grams per dry weight	Meet or exceed US EPA Class A standard, 40 CFR § 503.32(a) levels

Now again for the model compost specification according to USEPA for soil amendment, so this is especially for the standards provided by USEPA. US Environmental Protection Agency which

explained about the pH should be neutral 5 to 8.5 soluble salt concentration should be maximum 10 that is electrical conductivity decisiemens per meter, in one of the slides I showed 2 to 3, but in the USEPA they suggested up to maximum 10, moisture content 30 to 60%.

Because we required moisture to be available into the final product to the survival of those microorganisms, organic matter is also required the particle size. So, here they suggested 98% pass through three fourth inch screen or smaller stability. So, they also explained about carbon dioxide evolution rate should be less than 8 milligram, carbon dioxide production per gram of organic matter per day to maturity also required minimum 80%. Similarly, the biological parameter like fecal coliform particular day of standardization is required and also Salmonella standards are also available.

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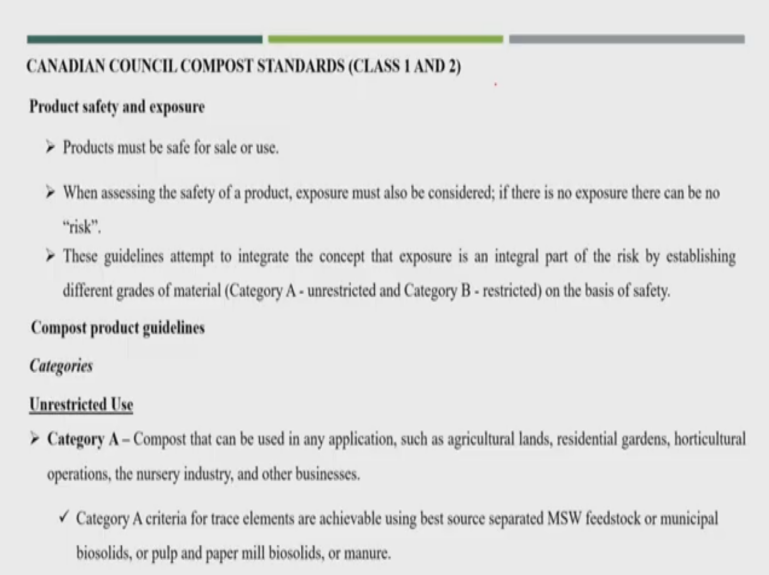

Now, the Canadian compost council came up with Canadian council compost standards, they come up with class 1 and class 2. So, for product safety and exposure, the product must be safe for sale and or use when assessing the safety of the product the exposure must also be considered if there is no exposure there can be no risk. These guidelines attempt to categorize the concept that exposure is an integral part of the risk by establishing different grades of material like category A unrestricted, category B we are restricted on the basis of safety.

So, the compost product guidelines they prepared by unrestricted use like compost that can be used in any application such as agriculture land, residential garden, horticulture operation, some

nursery industries or other businesses that is category A. So, Category A criteria for trace elements are achievable using the best source-separated MSW feedstock or municipal biosolids or pulp and paper biosolids or manure. So, Category 1 and Category B have very restricted purposes and therefore, the quality is also not that good.

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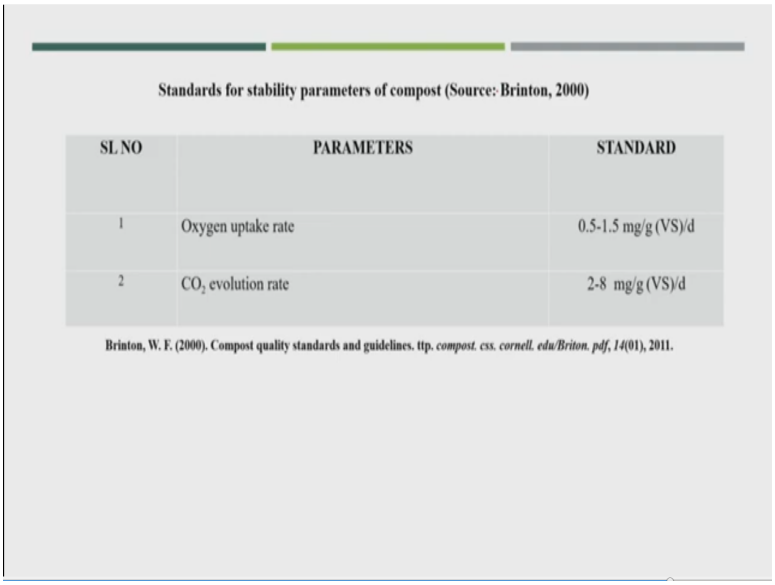

Now, the standard for stability, I think there is a cert there is no standardization, but I think you can find this particular source they come up with the oxygen uptake rate should in between 0.5 to 1.5 milligram per gram of volatile solids per day and CO_2 evolution rate also should be in between 2 to 8 milligram per gram VS per day. So, here the minimum is 0.5 means is a highly mature composed, highly sterilized composed, and if it is 8 or 1.5 means is not that that very good matured compost or you can say immature compost.

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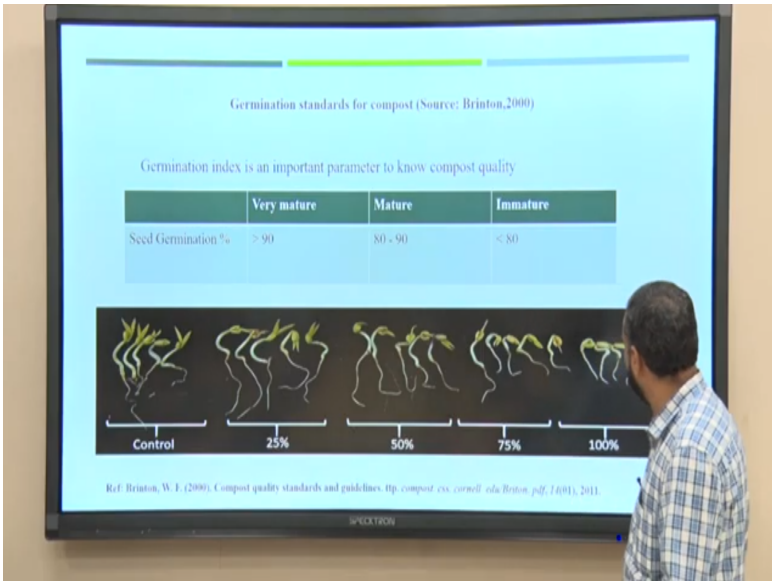

Now is another germination standard. So, seed germination, which I showed few slides of moong beans and *Vigna radiata*, where germination index, we can analyze our seed germination we can do so if there is 90% of seed germination means is very matured and less than 80% considered as immature compost. So, likewise here, we can see.

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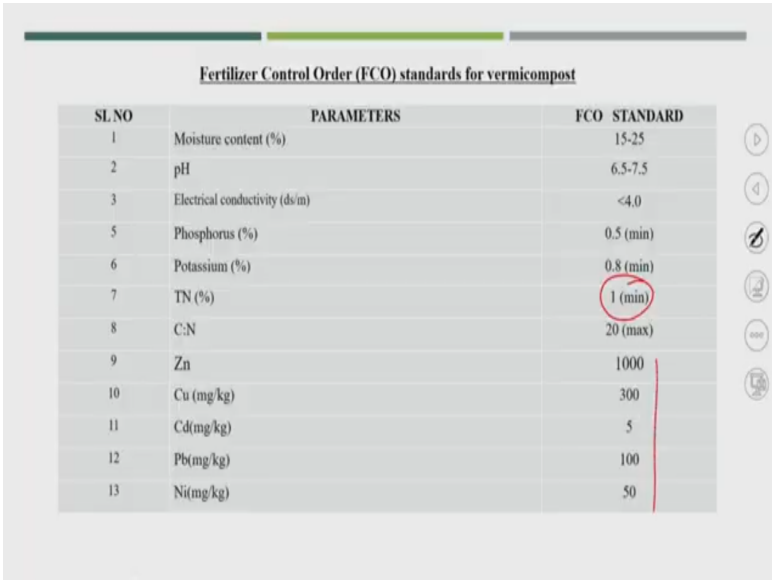

Fertilizer Control Order (FCO) standards for vermicompost

SL NO	PARAMETERS	FCO STANDARD
1	Moisture content (%)	15-25
2	pH	6.5-7.5
3	Electrical conductivity (ds/m)	<4.0
5	Phosphorus (%)	0.5 (min)
6	Potassium (%)	0.8 (min)
7	TN (%)	1 (min)
8	C:N	20 (max)
9	Zn	1000
10	Cu (mg/kg)	300
11	Cd(mg/kg)	5
12	Pb(mg/kg)	100
13	Ni(mg/kg)	50

Now come to the Indian standards. So, Central Pollution Control Board in 2006, they come up with heavy metal standards 1 milligram per gram dry basis of the compost. So, various metals they consider, and we are in India Normally these fertilizer control order are available for the Compose now by in 2016 in the solid waste manual, these standards are given. Now if you want to market your compost in India, you have to follow the FCO standards quality standards.

So which is including the moisture content, pH, electrical conductivity, total nitrogen, phosphorus, potassium, carbon to nitrogen ratio and few metals. So these suggested only 0.5% of nitrogen could be possible to sell into the market or is marketable. That is why see the even the standard is very low 0.5% nitrogen in India and if you see for vermicomposting There they mentioned the total nitrogen maximum 1%.

So mean, then again, I think I am saying that if this kind of compost, which is good under the FCO standards, but cannot replace the chemical fertilizer by having and these, I think why these kinds of standards have been come up as per my understanding because the centralized composting facility is not able to produce that kind of good quality compost. So that is why the nitrogen concentration was also mentioned as very low.

That is why I think if you want to purchase any compost from in the market, you will not receive or you will not get very good quality compost and I think now because there is e-marketing, e-commerce has come up now. So, even on amazon also you can find several companies are selling compost and the cost is very high that cost goes to sometimes 400 rupees per kg. But if you see the quality of such compose is not good.

The nitrogen is very poor, why I am saying nitrogen because nitrogen is the major nutrient in the final product and even the metal standards also no I think these kinds of companies, they also never mentioned how much is the metal concentration in the final product.

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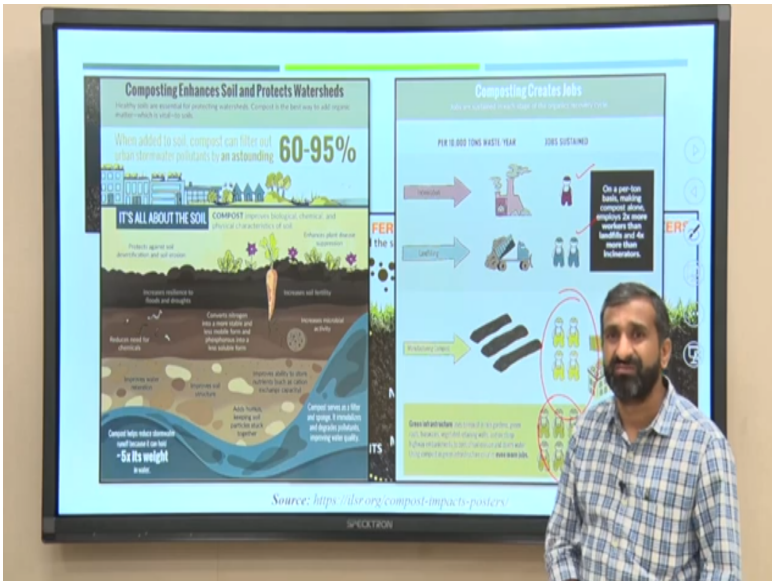

Now, finally, the why to use the organic fertilizer, because already in India under Swatch Bharat mission, the many states came forward and trying to become organic nature and you know that Sikkim becomes the first state of India which completely converted into the organic agriculture farming they started, so 100% organic farming they are doing it. So, to go for organic farming obviously will be required apart from biofertilizer will be required a large amount of compost and good quality compost which can be utilized for the agriculture area.

So, there are a lot of advantages of organic fertilizers not only for soil nutrition but also for plant growth. So, the compost enhances the soil and protects the watershed, if you are utilizing it in the soil and also we can create a lot of jobs in the composting facility. Because if you are going for incineration or landfilling, like incineration there, you will not require the manpower to run those particular technologies.

Even for the landfilling will be required less manpower, but for compost manufacturing, you will be required a lot of manpower a lot of people will be required whether you go for centralizing facility or decentralized facility. Now, you can ask me, sir, you are saying the operation costs in the decentralized composting is not much, but see this manpower cost in India is not that very high.

So, we can engage many people, even though we can engage females, we can give more jobs into such kind of facility because the task is very easy to do simple filtration task or addition or different kind of mixes of that particular substrate it is required into that particular decentralized facility. So, obviously is good for the market also. So, finally, the quality is very important, if any compost plant wants to be sustainable, so, is obvious it required a very good quality product has to be produced, then only I think such kind of plants could survive for a minimum of 15 years or 20 years.

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So, finally, in the final slide the compost quality, good or bad, so, which I explained a lot of parameters has to be evaluated in the laboratory. A number of facilities are required to analyze the nitrogen, phosphorus, nutrient quality, metal quality, the toxicity of compost stability of compost, but by simple layman person, how they can know that good quality and bad quality. So, the bad compost means the foul smell, the smell will be foul indicate the presence of toxic compounds mostly ammonia smell.

And if you squeeze the compost squeeze in the hand the water will come out. So means that compose is not matured compose is not prepared composed that is a simple understanding. So, you visit any compost facility to take the smell and if you get a good smell, this good smell is a particular bacteria actinomycetes, so you know that actinomycetes are production in just before the maturation stage means your thermophilic condition is lower downing.

So, that is mean just like soil smell. I think that smell has to become out in the final product and also the water should not be leached out from when you are squeezing the compost when we can say is that good compost is a proper texture color no foul smell there should not be any smell or ammonia appropriate moisture content, it should not be sticky. When you squeeze it into the hand, the color dark brown color indicates mature and stable compost it should be free from insects and nematodes.

So if you find some kind of mites in the final product or some nematodes will be there means I think is still the maturation has not been over the compost has not been prepared yet by that way simple layman understanding also we can come to know without doing the chemical experiments. So thank you.