NIDISI Fiber Extraction Factory

Composting Procedure Handbook

1st edition – 30/08 – by Haruto Nakao

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There will be a lot of "I" and "my" in the sentence, it means "Haruto"

1. Overall procedure & compost favor condition

1-1. Overall procedure

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- Waste and Amendments mixing
- Pile making
- Pile turning (temperature dependent)
- Daily Temperature measurement
- Turning procedure
- Moisture measurement
- Watered procedure (depending on the result of moisture measurement)
- pH measurement (together with Moisture measurement)

1-2. Favor condition of compost (IMPORTANT★)

This is the favor condition of the compost. Let's try to stick with it!

Table 1. Favorable Conditions for Composting

Table 3.1 Favorable conditions for composting.

Condition	Reasonable range[a]	Preferred range
Moisture content	40%–65%	50%–60%
Carbon to nitrogen (C:N) ratio	20:1–60:1[b]	25:1–40:1
Oxygen, minimum concentration within the interior pore spaces	Greater than 5%	Greater than 10%
Temperature[c]	45–70°C (113–160°F)	50–65°C (120–150°F)
Ph	5.5–9.0	6.5–8.0
Particle size	3–50 mm (1/8 to 2 in.)	Depends on feedstocks and use for compost
Bulk density	Less than 700 kg/m^3 (1200 lbs/yd^3)	400–600 kg/m^3 (700–1000 lbs/yd^3)

[a] *Generally for rapid composting. Composting can still be successful outside of these ranges.*
[b] *Some feedstocks can be composted successfully even at C:N ratios greater than 60:1, although the composting rate is slow and the time period is long.*
[c] *Temperatures as low as below 45°C are conducive to rapid composting, but sanitization specifications require temperatures to be held at 55°C or above for a period of time (e.g., three days). See Section 4.10.*

1-3. Process monitoring guide.

- This is overall quick process monitoring guide. When you observe the weird / unusual / undesired process, you can use this process monitoring sheet and estimate what is the possible cause of that problem.
- However, if you observe some weirdness, please contact Haruto, and we discuss what to do next!

Table 2. Process Monitoring Guide

Process indicator	Possible causes
Temperature	
Low temperatures at the start of composting	• Drop in pH inhibiting microbial activity • Poorly degradable feedstocks • Feedstocks too dense or too wet
Consistently lower than normal temperatures throughout	• Materials too dry • Materials too wet or dense • Insufficient aeration • Windrow/pile is too small
Consistently higher than normal temperatures throughout	• Highly degradable feedstocks • Low C:N ratio • Moderately low moisture • Insufficient forced aeration • Large and well insulated pile (e.g., wood chips)
Highly variable temperatures readings	• Feedstocks poorly mixed • Development of aeration channels • Forced aeration poorly distributed
Large temperature difference between outer layer and inner core	• Windrow/pile compacted, needs turning • Low rate of forced aeration
Sharp drop or rise in temperature	• Something is amiss • Possibly a mechanical problem with forced aeration; a strong cooling wind; or sudden drying of the windrow/pile
Very high temperature readings (>70°C or 160°F)	• Insufficient cooling due to moderately low moisture, insufficient forced aeration rate, intermittent aeration off-time too long; and/or an overactive process due to highly degradable feedstocks
One or more temperature readings above 75°C (170°F)	• The process of spontaneous combustion might have started in one or more sections of the pile. Pile may be too large.
Temperature fails to increase after turning	• Moisture content is very low or very high • Active composting phase is nearing completion

Moisture	
Moisture content >65%–70% throughout	• Windrow/pile is too wet. It needs to be dried by turning and/or mixed with dry amendments
Moisture content <45%–50% throughout	• Windrow/pile is too dry. Water or wet feedstocks need to be added.
Variable moisture readings	• Feedstocks are poorly mixed. Turning needed.

Oxygen	
O_2 measurements <5%–10% throughout	• Anaerobic or anoxic conditions due to: • Highly degradable feedstocks • Insufficient forced aeration • Pile too large
O_2 measurements <5%–10% near center but higher near surface	• Windrow/pile compacted, needs turning • Low rate of forced aeration
Highly variable O_2 measurements	• Feedstocks poorly mixed • Development of aeration channels • Forced aeration poorly distributed
Consistently high O_2 measurement (>16%)	• Over-aggressive forced aeration • Microbial activity slowed by low moisture, high C:N ratio, lack of secondary nutrient or some toxic factor
Sharp drop or rise O_2	• Something is amiss • Possibly a mechanical problem with forced aeration; a strong cooling wind; or sudden drying of the windrow/pile

pH and EC	
pH < 5.5 during the first few days of composting	• Accumulation of organic acid due to highly degradable feedstocks and/or insufficient aeration
pH > 8.5 to 9 near the end of active composting	• Abundance of high pH and/or high N feedstocks
Higher than desired EC measurements in finished compost	• Feedstocks are rich in nutrients (e.g., NH_4, NO_3, PO_4, K) and/or have high concentrations of chemical elements and compounds that form salts (e.g., Na, Ca, Cl, SO_4) • Frequent irrigation of piles and windrows without drenching precipitation

2. Waste and Amendments

1. Banana Leaves

- Not much moisture
- Pretty light compare with volume → easy to move around

2. Banana Trunk unusable part & heart

- Hard to move. (Heavy)
- There is a lot of fiber.
- Pretty wet.

3. Slurry (after extraction of fiber)

- Hard to move/ (Heavy)
- Pretty wet. (More than 60% moisture)

4. **Sugarcane Bagasse (amendment)**

- We will not need to use this anymore for compost.
- Use for biochar making > need to dry out.

3. Biochar material and Production

- When you make biochar, **the materials must be well dried.**
- Always make the biochar with a single material, do not mix the materials.
- The name of the kiln we have is "**Soil pit Kon-Tiki kiln.**"

3-1. Potential Biochar Materials

1. Bamboo
2. Sugarcane bagasse
3. Banana leaves

3-2. Biochar Production with soil pit Kon-Tiki

There is the article and YouTube videos. I will list them down here, so please watch those videos.

I recommend you watch and read those first 3 I listed below. So, you will get the idea of it.

- **The pdf how to make biochar with "soil pit Kon-Tiki kiln" (same as what we have)**
  - https://www.ithaka-institut.org/ithaka/media/doc/1462795288103.pdf

- **The YouTube video from the guy in Ithaka Institute (where I learned how to make) – they use "Metal kiln Kon-Tiki".**
  - https://youtu.be/1o0QqePtNM4?si=-K38Os3gNQff8L07

- **The YouTube video which uses "Soik pit Kon-Tiki".**
  - https://youtu.be/lZlJSo8RNAY?si=7LsCY_H_0j3Uid8e

Biochar is an amazing material which has so many potential usages. If you are interested, I recommend you watch this TED talk.

- https://youtu.be/p0YNFn9Dloc?si=f4un6ebnF_NqqYy5
- https://youtu.be/uEOK3fk45Rg?si=VrRdXxybdTLRxTBc

4. Waste Material preparation (shredding etc)

1. Banana Leaves

- Banana Leaves need to be **cut 2 times.**
- Cut with chaff cutter.

2. Banana Trunk unusable part & heart

- **Cut only 1 time**.
- Easier to cut immediately after producing this waste (still stiff).
- Hard to cut with a chaff cutter.
- There will be a new machine soon.

3. Slurry

- **No need to cut** at all.
- **However , this should be pressed to decrease the moisture content.**

4. Biochar crushing

- Bamboo
- Bagasse > no need to crush.

5. Waste and Amendments Mixture and pile size

Here, I explain how much ratio of each waste is inside those Mixture I calculated.

Also, I explain what the Pile ID is.

5-1. What is Pile ID?

For the research purpose, I made the Pile ID A~C for now. The table below explain what each piles indicate.

Table 3. Pile ID

Group	info	pile ID	biochar content [vol. %]
A	Biochar amount influence check (without any amendments)	A-0	0
		A-5	5
		A-10	10
		A-15	15
Group	**info**	**pile ID**	**explanation**
B	Amendments influence check (wihout any biocahr)	A-0	no amendments
		B	with sugarcane bagasse
Group	**info**	**pile ID**	**biochar type**
C	Biochar type influence (with all the amendments and 10 vol% biochar)	C-1	bamboo
		C-2	Sugarcane bagasse
		C-3	Banana tree waste

5-2. Mixture 8 (with Bagasse – Pile B) & Mixture 9 (without amendments – pile A)

Table 4. Waste Ratio of Each Mixture

Mixture explanation		Mixture 9 (pile A)	Mixture 8 (pile B)
ratio of each waste [%]	Leave	40	30
	Slurry	25	25
	Unusable + heart	35	40
	Bagasse	0	5

Table 5. C:N ratio of each Mixture

C : N ratio of each Mixture	moisture	Carbon	Nitrogen	C:N ratio
Mixture 8	49.39	27.30	0.62	44.10
Mixture 9	47.08	23.85	0.60	39.52

6. Pile making and Turning

Here I explain how to build up the pile, how much each waste you need to put and how to tune when it is necessary.

6-1. Pile Size (weight)

- Haruto made the calculation of the pile size (Triangle column) and each Waste materials' weight according to the Mixture mentioned above.
- **However**, I found out that the pile Haruto theoretically calculated is too big/heavy for human labor to mix and turn thus we will make the pile 1/2 size (by weight) of that calculation.
  - **so, prepare each material according to the red bold value!!**

Table 7. Pile with Mixture 9 – Pile A

Pile with Mixture 9	unit	value	
base low	m	1.5	
base high	m	0.5	
height	m	1	
Cross-section area	m2	1	
length	m	2	
volume	m3	2	
1 pile weight	[kg]	1194	1/2 size (by weight)
Leave	[kg]	478	**239**
Slurry	[kg]	299	**149**
unusable +heart	[kg]	418	**209**

Table 6. Pile with Mixture 8 -Pile B

Pile with Mixture 8	unit	value	
base low	m	1.5	
base high	m	0.5	
height	m	1	
Cross-section area	m2	1	
length	m	2	
volume	m3	2	
maximum number of piles	[-]	20	
maximum volume	m3	40	
1 pile weight	[kg]	1125	1/2 size (by weight)
Leave (Mix 8)	[kg]	338	**169**
Slurry(Mix 8)	[kg]	281	**141**
Trunk residue(Mix 8)	[kg]	450	**225**
Bagasse (Mix 8)	[kg]	56	**28**

6-2. Weight the Waste material

6-2-1. Weight with green bucket (25L)

- I used the green bucket (25L) which is biggest bucket we have currently to calculate each material.
- The table below shows the weight of each material per green bucket (25L)
  - **Caution!!** : the weight of each waste per bucket changes easily depending on pressing (compressing) the waste or not, and moisture content of waste (for moisture, especially "unusable + heart" changes a lot.).
  - **Thus, I recommend you measure the first (maybe also second) bucket for each waste every time, and get the sense of each materials' weight of that day**
  - **The table below is the value without pressing!**

Table 8. Weight of each Waste material per green bucket without compressing

1 green bucket test	25.08.23																
Material	weight [kg]																average [kg]
Leave	6.19	6.20	6.16	5.90	6.13	5.84	6.10	6.23	6.30	6.10	6.10	6.50	5.90	6.04	6.00	6.76	**6.11**
Slurry	18.90	20.50	18.20														**19.20**
Unusable	12.80	12.22	12.81	13.94	13.30	11.40	12.30	13.20									**12.75**

6-2-2. Assume the weight by volume.

Measuring the bucket all the time for 500 kg of Waste is SOOO much painstaking, and composting doesn't need to be that precise. Thus, I recommend you assuming the weight of each waste by volume. How to do? I will explain here.

- Prepare 1/4 weight of each waste material (or it can be even smaller), by green bucket measurement mentioned above.
- And just prepare each waste, almost the same volume as 1/4 weight of each waste material by looking (by shovel etc) and prepare 3 more!
- Then you will get amount you need!! Easy-Peasy-Lemon squeezy

6-3. Pile building and Mixing the materials

6-3-1. Pile making

- As my experience, when you make new pile according to the Mixture 8 or Mixture 9, water does not need to be add as it is already pretty wet,
- But do the Hand Squeeze Test (Chap 8 - **Hand Squeeze moisture measurement**) and decide you need to put the water or not.

6-3-2. Mixing each Waste

- Try to mix homogeneously as much as possible.
- Slurry is usually so condensed and making the shape of ball ("Slurry ball" I call), so please try to break it as much as possible by Hand.
- When you make the pile, the slurry ball always accumulate at the bottom of pile as it fall down the steep of pile, thus try to put the slurry inside the compost as much as possible.

6-4. Turning (Mixing)- sometime after the pile is made

Turning will be necessary sometimes during first phase of composting according to the temperature measurement result, as well as uniform the compost pile again. If you want to know more read the "Composting Handbook 5-4.2 Turning Principle"

6-4-1. How to turn?

- Same as how to mix the waste when you make new one (mix like cement).
- Important thing is that try to put the outside layer wase to inside layer .
  - As outside layer waste hasn't experienced the degradation and sanitization much.

6-4-2. When to turn?

If you feel like we need to turn the pile, please discuss with Haruto before do that.

We use the temperature based turning principle. (Actually temperature should not be the only factor of decision of when to turn, but that is the only choice we have now.)

Temperature based turning is listed below.

- Temperature pattern shows a steady drop in temperature over several days (e.g., an average of 1℃ [2°F] per day over 7-10 days).
- The average temperature of the center of the windrow drops from a high temperature, about 65℃ (150°F), for example, to below a desired level, such as 50℃ (120°F).
- The temperatures measured at the same depth at several spots in the windrow are highly variable.
- The average temperature at the core of the windrow diverges from the average temperature 15 cm (6 in.) below the surface (e.g., the core becomes more than 10℃ cooler).

7. Temperature Measurement

- **Because the heat produced during composting is directly related to the microbial activity, temperature is the primary benchmark for assessing the status and condition of the composting process.**
- Temperature of the compost must be **higher than 55℃ at least 15days in total.**

7-1. Composting Temperature Guideline

Table 11.2 Composting temperature guidelines.

Transition from mesophilic to thermophilic microbial populations	40 to 45°C 104 to 113°F
Healthy range for thermophilic composting (considering pathogen and weed seed destruction)	55 to 65°C 131 to 150°F
Minimum temperature for sanitization or pasteurization (depending on the jurisdiction and feedstock)	55 or 60°C 131 to 140°F 65°C (149°F) in certain cases
Minimum temperatures recommended for destroying most weed seeds at 24-hour exposure. (Dahlquist et al., 2007)	50°C or 122°F
Level at which microbial populations suffer the effects of high temperatures and the process slows	Roughly 70°C or 160°F

7-2. Temperature Monitoring Procedure (★)

7-2-1. First things needs to know

- **First 2~3 weeks after making new pile, we must measure the temperature every day at several point. (Tale the measurement 2 times a day- morning and evening (if not possible, at least 1 time)**
- For the best indication of trends and changes within the pile, measure temperatures at roughly the same locations and depths each time temperatures are recorded.
- Insert the thermometer at a height of about two-thirds to three-quarters the height of the pile and angle it toward the midpoint of the pile's core. (**Figure 2.** The point of Temperature Measurement on the pile
- Each pile should be monitored, preferably in at least two different locations and at two different depths.
- **Note the time you take the measure, as well as ambient temperature and moisture.**

7-2-2. How to take temperature with our pile?

We will always measure at 2 different spot (point 1 & point 2), and 2 different depths (25cm & 50cm) which is explained and shown in the Figure **1** below.

- Point 1 : The side of the pile which faces factory.
- Point 2 : The side of the pile which faces rice field (so facing biochar making point)
- 25 cm of Thermometer is marked with black tape on the thermometer. (Down edge of black tape)
- 50 cm of Thermometer is not marked but put the probe completely then it is 50cm. (**Figure 3. Long**

stem thermometer below)

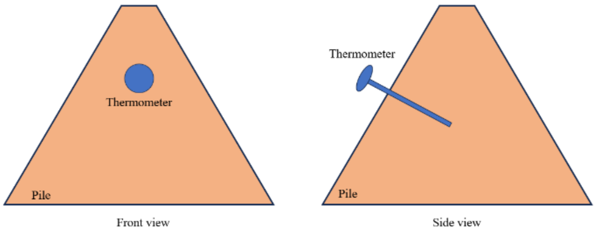

Figure 2**.** The point of Temperature Measurement on the

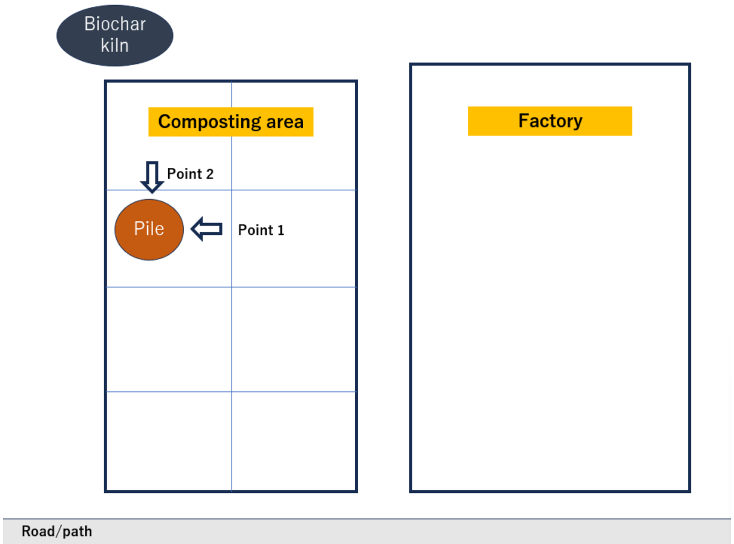

Figure 1. Point of Temp Measurement 1 and 2

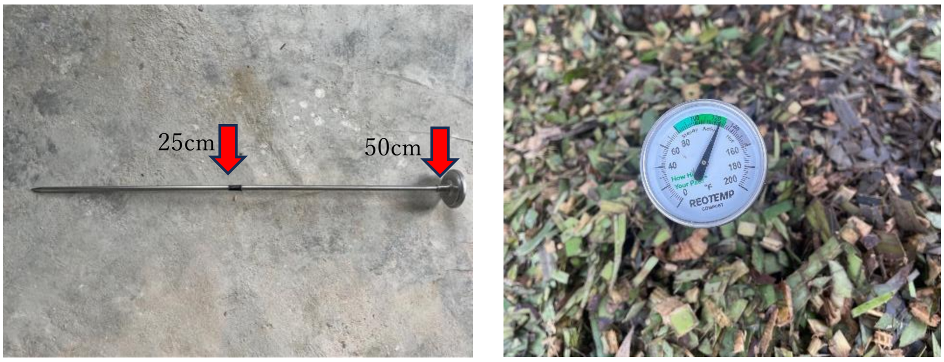

Figure 3. Long stem thermometer

7-2-3. <u>Monitoring value and sending every day to Haruto</u>

I made the composting Monitoring sheet for 150 days. Use that sheet to write down all the value daily. **Make sure your handwritten can be read** by anyone else.

Monitoring values are listed below.

- **Time of measurement**
- **Ambient temperature and moisture of that time**
- **Compost temperature at each point**
- **If you observe something weird, or if you do something you don’t do usually, write down to the memo.**
- Random point is not necessary to be filled daily. This will be needed when we are wondering we need to turn or not.

Send all those value (picture of monitoring sheet is also okay) to Haruto every day, especially first 3~4 weeks after built up. Then I will be able to tell what to do next if necessary.

8. Moisture Measurement

- The composting pile should be moisturized around 45~60%. (Preferred range 50~60%)
- When you conduct the Air-Dry Moisture measurement, conduct the pH measurement at the same time because the sample needs to be dry for the pH measurement.
- Depending on this measurement, you may need to add water to tested compost pile (check **9. Water adding to the compost.**)

8-1. Hand Squeeze moisture measurement

The Hand squeeze moisture measurement test is the simplest but most inaccurate test, as it uses only the hands.

8-1-1. Procedure

1. Reach into the pile or composite sample bucket and grab a handful of composting material.
2. Squeeze the material hard with your hand, check for drips.
3. Release your grip and allow the material to stay in your hand, smear some between your finger and thumb.
4. Inspect the material and your hand.
5. Use the table below to estimate the percentage of moisture content.

8-1-2. Observation

Table 9. Estimation of moisture content by the hand-squeeze test

Table 11.3 Rules of Thumb for estimating moisture content by the hand-squeeze test.

Observation—description	Estimated moisture content
• Water flows freely out of your hand	Greater than 65%
• A few drops of water are visible between your fingers	60%–65%
• You don't see any water between your fingers. When you open your hand, a sheen of moisture is clearly visible.	55%–60%
• No sheen of water is visible and a ball of compost remains in your hand. If you tap the ball gently, it remains intact.	50%–55%
• A ball of compost forms but break apart during tapping.	45%–50%
• After squeezing, the compost does not remain in a ball when opening your hand	40%–50%
• No ball forms and a dry talcum-like feel remains on your hand after discarding the material.	Less than 40%

Source: *Oshins, C., 2021. COTC Compost Operator Training Notes. Compost Research and Education Foundation, Raleigh, VA.*

8-2. Air-Dry moisture test

The Air-Dry moisture test takes more time but is much more accurate than the Hand Squeeze test.

7-2-1. Apparatus (pic below)

- Plate > I bought the metal plate for this.

- Degital scale (small one)
- Sample compost – not much (make sure it is well mixed with all the material)
- Air-Dry moisture test sheet

7-2-2. Procedure

Turn off the fan during the measurement with digital scale as the wind created by fan affects the digital scale value.

1. **Turn on the digital scale without anything on top.**
    - The value of digital scale is hard to see after putting the metal plate, thus I recommend you put something on digital scale to make the place you put the metal plate higher.
    - In that case, after putting the thing to make it higher, you press the button to make it 0.
2. **Measure the weight of the plate. ("plate" weight is obtained) > do not make it 0.**
3. **Put the sample of compost, spread in the thin layer on the plate and measure the value ("wet + plate" weight is obtained)**
4. **Place it on top of the shelf.**
5. **Stir it occasionally until it is dried (To see the sample is dry or not, check "7-2-3")**
    - to obtain uniform drying of all particles.
6. **Weight dry sample ("Dry + plate" weight is obtained) and calculate the moisture content.**

7-2-3. How do we know the sample is fully dry

The sample is dry when its weight remains constant between two consecutive measurements. For composting purposes, the sample can be considered dry if its weight changes by less than 1% of the original wet weight. (For example, 1g change for 100g wet sample)

7-2-4. Calculation

$$Wet\ weight = (Wet\ + plate) - plate\ [g]$$

$$Dry\ weight = (Dry\ + plate) - plate\ [g]$$

$$Weight\ of\ watet = Wet\ wegiht - Dry\ weight\ [g]$$

$$Moisture\ content\ (as\ a\ fraction) = Weight\ of\ water\ \div Wet\ weight\ [\%]$$

$$Dry\ Matter\ or\ Solids\ (as\ a\ fraction) = Dry\ weight\ \div Wet\ weight\ [\%]$$

9. Water adding to the compost.

- This process will take place when the Air-Dry moisture test shows less than 40% of moisture content of a pile.
- We aim for 50% Moisture content.
- The best time to add the water to the pile is when you turn the compost pile.
    - However, you can also simply add water to the pile without turning.

9-1. How much water do we need to add? (Calculation)

$$W_w[kg] = \frac{DM}{(1 - M_t)} - \frac{DM}{(1 - M_i)}$$

$$DM\ [kg] = TM_i * (1 - M_i)$$

- W_w : weight of water we need to add. [kg] (1kg of water is equivalent to 1L of water)
- DM : Dry Mass (weight) in the pile
- M_t : Target moisture content of the pile (50% thus 0.5)
- M_i : Initial or current moisture content of the pile
- TM_i : Initial Total Mass of the compost pile (material)

9-2. Example Calculation (together with Moisture measurements)

1. Moisture Measurement

Moisture content calculation	8月23日		
plate [g]	**plate + waste (wet) [g]**	**plate + waste (dry) [g]**	**Moisture [%]**
466.2	540	515.3	**33.5**

The result of Air-Dry moisture measurements shows the moisture content of the pile 33.5% thus we need to put the water to the pile.

2. Water amount calculation.

Water added calculation	8月24日	using the value from practical	
pile volume : V [m3]	**initial total mass (practical) : TM_i [kg]**	**current moisture M_i [%]**	**Dry mass : DM [kg]**
0.728	281	33.5	187.1
Targeted mositure : M_t [%]	**amount of water needed : W_w [kg]**	**amount of watet volume : V_w [L]**	**number of green bucket [-]**
50	**93**	93	**4.6**

- This time the amount of water we needed was 93L.
- The green bucket (biggest bucket) we have is around 20~25, thus around 4.5 times of that bucket of water we need to add.

10. pH measurement

There are two ways of conducting pH measurement with pH paper.
One method takes time and the other doesn't.

We are still experimenting phase which one is better, thus take the two measurements for same period of compost and later we decide which one is better.

10-1. Easy pH measurement (real quick)

Just stick the pH paper into the compost pile (not the surface) and leave it few minutes until the pH paper soak the moisture from compost.

Then compare pH paper with standard.

10-2. pH measurement with Air- Dry (takes more time)

The pH measurement is recommended to conduct with dry sample thus,

- we conduct the Air-Dry Moisture Test at the same time.
- As it takes 2~3 days for a sample to dry, the value of the sample is taken as input on the day it is collected, not on the day the sample is tested.
  (So even the sample was tested after 2~3 days after collected, the sample's pH value represents the day collected)

10-2-1. Apparatus

- pH paper
- container
- Distilled water
- Dried Compost sample
- Digital scale

10-2-2. Procedure

TMECC recommends making an extract that is 5-part water to 1-part dry matter (by weight).

1. Take 5 g of compost sample. (if the particle is big, crush it then put it)
2. Add 5 times (25ml) more distilled water than that sample (by weight)
3. Mix well.
4. Wait until the solid particles settle down.
5. Put the pH paper into the supernatant (liquid on top).
6. Compare the pH paper color with standard.