Aerated Compost Tea: A Field Guide to Production Methods, Formulas and Application Protocols- Appendices Only

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ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

TEL: 831-724-5422
FAX: 831-724-3188
www.compostlab.com

Account #: 6070748-1/1-9056
Group: Jul16E #44
Reporting Date: August 9, 2016

Attachment D: Test results, Soil Control Laboratory

North Valley Organics (Albuquerque)
P.O. Box 6848
Albuquerque, NM 87197
Attn: Minor Morgan

CT-SO - 7/26/16 - 7/14/16

Date Received: 26 Jul. 16
Sample Identification: Soilutions Compost Tea
Sample ID #: 6070748 - 1/1

Pathogen Reduction Indicator Species

Bacteria		Results	Units	Date Tested
Fecal Coliform	Less than	7.5	MPN/10mL	26 Jul. 16
Salmonella	Less than	3	MPN/40mL	26 Jul. 16

Method (Fecal Coliform): Standard Methods 9221E
Method (Salmonella): TMECC 07.02-A, EPA 1682

Analyst: Assaf Sadeh

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Date Received: 26 Jul. 16
Sample Identification: Soilutions Compost Tea
Sample ID #: 6070748 - 1/1

Bacteriological Examination of Material for E. coli O157:H7

Sample Identification	Sampling Date	E. coli O157:H7
Soilutions Compost Tea	25 Jul. 16	Absent

Method of Analysis: AOAC996.09

Analyst: Assaf Sadeh

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Attn: Minor Morgan

Date Received: 26 Jul. 16
Sample Identification: Soilutions Compost Tea
Sample ID #: 6070748 - 1/1

Bateriological Examination of Material for Listeria

Sample Identification	Sampling Date	Listeria
Soilutions Compost Tea	25 Jul. 16	Absent

Method of Analysis: AOAC 997.03

Analyst: Assaf Sadeh

Attachment E: Test results, well water, Hall Environmental

Analytical Report
Lab Order **1612991**

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **1/4/2017**

CLIENT: Minor Morgan
Project: Field 1 Well
Lab ID: 1612991-001 **Matrix:** AQUEOUS

Client Sample ID: Well Water
Collection Date: 12/19/2016 1:00:00 PM
Received Date: 12/19/2016 2:13:00 PM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
EPA METHOD 300.0: ANIONS						Analyst: **LGT**
Chloride	17	0.50		mg/L	1	12/20/2016 2:46:39 PM
Nitrogen, Nitrite (As N)	ND	0.10		mg/L	1	12/20/2016 2:46:39 PM
Nitrogen, Nitrate (As N)	ND	0.10		mg/L	1	12/20/2016 2:46:39 PM
Sulfate	84	10		mg/L	20	12/20/2016 2:59:03 PM
EPA METHOD 200.7: METALS						Analyst: **MED**
Calcium	77	1.0		mg/L	1	12/28/2016 6:35:54 PM
Iron	ND	0.020		mg/L	1	12/28/2016 6:35:54 PM
Magnesium	21	1.0		mg/L	1	12/28/2016 6:35:54 PM
Potassium	11	1.0		mg/L	1	12/28/2016 6:35:54 PM
Sodium	27	1.0		mg/L	1	12/28/2016 6:35:54 PM
EPA 200.8: METALS						Analyst: **JLF**
Arsenic	0.0036	0.0010		mg/L	1	12/22/2016 5:30:57 PM
Lead	ND	0.00050		mg/L	1	12/22/2016 5:30:57 PM
SM 9223B TOTAL COLIFORM						Analyst: **SMS**
Total Coliform	Absent	0		P/A	1	12/20/2016 4:56:00 PM
E. Coli	Absent	0		P/A	1	12/20/2016 4:56:00 PM
CHLORINE: HACH 8167						Analyst: **SMS**
Total Chlorine	ND	0.050	H	mg/L	1	12/27/2016 12:50:00 PM
SM 4500 NH3: AMMONIA						Analyst: **CJS**
Nitrogen, Ammonia	ND	1.0		mg/L	1	12/22/2016 1:22:00 PM
SM4500-H+B: PH						Analyst: **JRR**
pH	7.54	1.68	H	pH units	1	12/21/2016 3:08:10 PM
SM2320B: ALKALINITY						Analyst: **JRR**
Bicarbonate (As CaCO3)	222.1	20.00		mg/L CaCO3	1	12/21/2016 3:08:10 PM
Carbonate (As CaCO3)	ND	2.000		mg/L CaCO3	1	12/21/2016 3:08:10 PM
Total Alkalinity (as CaCO3)	222.1	20.00		mg/L CaCO3	1	12/21/2016 3:08:10 PM
SM2540C MOD: TOTAL DISSOLVED SOLIDS						Analyst: **KS**
Total Dissolved Solids	478	20.0		mg/L	1	12/23/2016 6:39:00 PM
SM 4500 NORG C: TKN						Analyst: **CJS**
Nitrogen, Kjeldahl, Total	ND	1.0		mg/L	1	12/29/2016 10:37:00 AM

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
R	RPD outside accepted recovery limits	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Attachment F: Earthfort compost testing form

TESTING ORDER FORM

for samples from the United States and U.S. Territories

Questions? We're here to help!
Call **(541) 257-2612** or email **info@earthfort.com**

*required information

earthfort

March 2016

Mail Samples To Earthfort at:

635 SW Western Blvd
Corvallis OR 97333

For detailed assay descriptions and instructions on how to sample, package and ship your materials visit earthfort.com

*Primary Contact's Address (will be printed on test reports)		*Billing Address (☐ Check here if same as primary contact's address)	
*Contact Person		Contact Person	
Organization		Organization	
*Address		Address	
*City, State, Zip		City, State, Zip	
*Phone Number		Phone Number	
*Email (send report)		Email (send receipt)	

☐ Yes! Please add my email to Earthfort's monthly e-newsletter list for special deals, informative articles, and events!

Save on shipping costs! Send 10 oz (250 g) or 10 fl. oz. (300 ml) of material per sample, (double this amount if ordering Biology Package and Crop Nutrients on same sample.)

*Sample Name / Identification	*Material Type	*Date Taken	Plant Type (*for soils only)	Notes (plant health, irrigation, etc.)	*Test/s Requested
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				
	☐ soil ☐ compost ☐ liquid				

Testing Packages and Individual Assays	Price per Sample	*Quantity	*Subtotal
Basic Biology Package - Includes total/active bacteria, total/active fungi.	$80.00		$
Essential Biology Package - Includes total/active bacteria, total/active fungi, and protozoa.	$108.00		$
Advanced Biology Package - Includes total/active bacteria, total/active fungi, protozoa, and nematodes.	$144.00		$
Crop Specific Nutrient Package - Send an extra 2 cups (10 oz) of material. Includes pH, N, P, K, Ca, Mg, B, Mn, Cu, Zn, S, Cl, soluble salts, humus.	$75.00		$
Mycorrhizal Colonization [VAM] - This test is for SOILS ONLY and MUST include 10 inches (26 cm) of fine, young roots in sample.	$42.00		$
E. coli	$30.00		$
Nematodes ONLY - (Do not order separately if you are ordering the Advanced Biology Package.)	$45.00		$
Remediation Consulting - Optional service to consult with our experts about your reports and landmanagement practices.	$30.00 per 15 min.		$

*Payment Method (check one): Check Enclosed ☐ Credit Card ☐ (If paying by VISA MasterCard American Express Discover PayPal please fill out all fields below.)				*GRAND TOTAL: $
*Name on Card:	*Billing Zip:	*Card #:	*Exp. Date:	*CVV#:

Attachment G: Soil food Web compost testing form

Foodweb Biology

Submission Form

(22 April 2016 revision)

Report will be sent by email

Submit Samples to:
Environment Celebration Institute
13193 Oroville Quincy Highway
Berry Creek, CA 95916
530-589-9947
info@environmentcelebration.com

Send 1/4 cup of material per sample, by Next Day Air. Take the sample the same day you ship it. Samples must be shipped on a Monday, Tuesday, or Wednesday to arrive in our lab in time for testing. If samples arrive on a Friday afternoon after 3 PM, there is not enough time for testing since there is no one in the lab after 5 PM on Friday until Monday at 9 AM. If you have liquid fill a plastic water bottle about 1/8 full and then ship it overnight so it arrives before noon the next day so we can be sure to have time to test.

Address	
Contact Person	
Organization	
Address	
City, State	
Zip, Country	
Phone	
Fax	
email	
Sample ID	
Sample Type (Soil or Other)	
Intended Crop	
Date Taken	
Tests Ordered	
Notes	

Qty	Testing Package Includes Assays	Price Per Sample	Subtotal
____	Full Foodweb TB-TF-Prot-Nem	$60.00	____

QT	Individual Asssays	Price Per Sample	Subtotal
____	TB: Total Bacteria	$ 15.00	____
____	TF: Total Fungi	$ 15.00	____
____	Prot: Protozoa	$ 15.00	____
____	Nem: Nematodes	$ 15.00	____

Payment Information: Credit Card ☐ Check or Money Order ☐ **Total Amount Due: $________**

Purchase Order No. ____________

Credit Card No. ________-________-________-________ Expiration _____/_____ CVC Code: ______

Name on Card: ____________________ Billing Address: ______________________________

PLEASE NOTE: all credit card transactions are processed through the Environment Celebration Institute.
Send Check or money orders made out to: ECI, 13193 Oro Quincy Hwy, Berry Creek, CA 95916. 530-589-9947

<u>Attachment H</u>: Farmer self assessment

<u>Farmer Self Assessment regarding use of compost and compost tea on the farm</u>
(produced with support from Western SARE grant # FW15-037)

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Sustainable Agriculture Research & Education

Farm Name and Address:

Farm Operator Name and contact info:

Date Assessment completed: Completed by:

<u>Compost:</u>

1. Do I plan to use compost in my farm operation? _____Yes _____No

If No, skip to Compost Tea section. If Yes, continue

2. How do I plan to use compost on my farm operation?

3. What are the outcomes I expect to see using compost?

4. Is my farm certified organic, or plan to be certified organic? _____Yes _____No

5. What is the source of the compost I plan to use:

    _____ made on the farm. Following organic standards? ____Yes _____No _____NA

    _____ purchased from off-farm. Approved for organic use? ____Yes _____No ____NA

    _____ obtained free off-farm. Approved for organic use? _____Yes _____No ____NA

    _____ both farm made and purchased

6. If purchased/obtained off-farm, name, address and phone of supplier(s):

- Does supplier have any credentials or documentation of compost quality? (i.e. member of US Composting Council, organic certification, compost test results, etc)

_____Yes _____No

- Do I have copies of documents? _____Yes _____No

- How is compost transported to farm?

- Is transport vehicle/container inspected before loading for possible contamination?

_____Yes _____No

- Is compost covered during transportation? _____Yes _____No

7. Upon arrival to farm, is compost used immediately or stored on-farm?

_____ used immediately _____ stored and used later _____ both

If stored, location and manner of storage:

Is stored compost covered: _____Yes _____No

If yes, manner and type of covering:

8. For stored compost, what is maximum length of time before compost is used either as compost or for making compost tea?

_____ Days _____ Weeks _____Months

9. For on-farm produced compost:

Describe your compost making process, including inputs, timeframes, process and storage:

- Storage location of on-farm produced compost and manner of storage:

Is stored compost covered: _____Yes _____No

If yes, manner and type of covering:

- Is on-farm produced compost certified organic? _____Yes _____No

- For on-farm produced compost, what is maximum length of time before compost is used either as compost or for making compost tea?

_____ Days _____ Weeks _____Months

Compost Tea:

1. Do I plan to use compost tea in my farm operation? _____Yes _____No

2. How do I plan to use compost tea on my farm operation?

2A. Do I plan to use a bacterial dominant, fungal dominant or balanced tea? Why?

3. What are the outcomes I expect to see using compost tea?

4. Is my farm certified organic, or plan to be certified organic? _____Yes _____No

5. What is the source of the compost I plan to use in making compost tea:

_____ made on the farm. Following organic standards? ____Yes _____No _____NA

_____ purchased from off-farm. Approved for organic use? ____Yes _____No ____NA

_____ obtained free off-farm. Approved for organic use? _____Yes _____No ____NA

_____ both farm made and brought in

- Have I tested the compost for pathogens? _____Yes _____No

6. What is the water source for making compost tea?

7. Have you tested the water using drinking water standards? _____Yes _____No

- if Yes, name and address of laboratory:

- What was water tested for/what Standards were used?

- Were test results positive for pathogens or prohibited materials? _____Yes _____No
  If Yes, explain:

8. In making compost tea I will use compost that has been:

    _____ Brought to farm fresh with each batch of tea, i.e. not from farm-stored compost

    _____ From compost previously brought/made at farm and stored on-farm.

    - maximum length of time stored compost will be used for tea:____________________

9. I will be using the following brewer (include make, model, description, gallon capacity, air pump capacity):

10. At the completion of the brewing cycle, I will be using the compost tea within____________

hours and ______________ minutes from the time I stop aerating the tea.

11. I will use the following methods for applying the compost tea:

Application method	**Application Equipment**	**Water dilution ratio**
Spray foliar feed plants	4 gal backpack sprayer	3:1
side dress at base of plants	5 gal bucket with pail	5:1
liquid drench of soil	40 gal. tractor mounted sprayer	5:1
injection through drip lines	injector	Not diluted (1:1)
root soak for greenhouse transplant starts	5 gal bucket with pail	Not diluted (1:1)
other application method		

Attachment I: Step-by-Step: Preparation

Step by Step Compost Tea- Preparation
(produced with support from Western SARE grant # FW15-037)

WESTERN SARE
Sustainable Agriculture Research & Education

1. Complete "Compost Self Assessment" to become familiar with the issues regarding brewing compost tea.

2. Decide on type and model of brewer to be used.

- what brand of tea brewer will you use?
  - what are the components of the brewer?
  - what is the air pump capacity in cubic feet/minute (cfm)?
- turbidity level: is pump able to move brew around sufficiently to dislodge microbes?
  - is turbidity level adequate to assure no "low oxygen" zones
- is the brewer easy to clean?
- what type of strainer will you use?
  - what is mesh size of strainer?
- can you obtain more strainers as needed?
  - who is your supplier for strainers?
- besides the brewer, what additional implements are used in the brewing process?

3. Decide on location where brewer and supplies will be located.

- where is the brewer stored?
  - is storage in the open or closed area?
  - is the brewer stored covered or uncovered?
  - is the brewer stored in the same location at all times?
- during brewing, what is the location of the brewer?
  - is the brewer covered during brewing
- what is the power source for the aerator motor?
  - could you lose power from this power source?
    - how would you know if you lost power?
- what is elevation of your brewing location?

4. Decide whether on-farm or off-farm compost will be used. If on-farm compost:

- do you plan to use the compost as compost on the farm, or just to make tea?
- do you have a written log documenting your steps for making compost?
  - are you certain that the minimum temperature is reached?
    - how do you measure this?
    - how do you document this?
  - are you certain that the minimum temperature timeframes are met?
    - how do you measure this?
    - how do you document this?

- Is your operation certified organic?
    - if yes, do you follow the NOP Standards for producing compost?
    - do you have documentation to demonstrate compliance with NOP Standards?
    - If not certified organic, do you follow the FSMA standards for making compost?
        - which Standard do you follow?

Acceptable treatment processes include any scientifically valid controlled physical, chemical, or biological process – or a combination – that is validated to satisfy certain microbial standards. Composting is considered a common biological process, and validated composting methods include:

1. Static composting that maintains aerobic (*i.e.*, oxygenated) conditions at a minimum of 131 °F (55 °C) for 3 consecutive days and is followed by adequate curing; and

2. Turned composting that maintains aerobic conditions at a minimum of 131 °F (55 °C) for 15 days (which do not have to be consecutive), with a minimum of five turnings, and is followed by adequate curing.

Per FDA's definitions, curing may or may not involve insulation, depending on environmental conditions.

5. Decide on off-farm supplier of compost.

- who is the vendor/source of the compost?
- how is compost transported to farm site
    - in a container?
        - was container new/unused or used?
            -if no, was container cleaned/sanitized prior to use?
        - was container covered during transport?
    - if in a truck bed, was bed cleaned or sanitized?
        - was batch covered with a tarp?
    - if delivered by vendor, was batch covered?
    - how is batch offloaded from delivery vehicle?
    - where is compost stored?
    - what was date of delivery?
    - what time of day did delivery occur?
    - what was duration of transport?
- was batch rained/snowed on?
- any unusual occurrences during delivery?
- was sample from batch tested for microbes by supplier?
- was sample from batch tested for pathogens by supplier?
- do you have a written receipt from supplier for purchase?
    - does receipt show:
        - date purchased
        - date delivered
        - amount purchased/delivered
        - cost?
        - vendor name, address, phone #?
        - description of compost/product name?
        - organic designation?
        - other information?

- is receipt stored in a safe place?
    - what is location of stored receipt?
    - how long do you keep the receipt?
- is this batch being used in a certified organic operation?
    - do you have documentation approving this product for organic use?
        - what is location of this documentation?

6. Compost storage at the farm

- what is the location where compost used for compost tea is stored?
    - is it always stored in the same location?
    - is storage out in the open or in a contained building/structure?
- is the compost covered?
    - how is the compost covered, with what material?
        - is the covering applied in such a manner to allow access to air?
        - what assurance is there covering will not be removed/blown away?
    - is the compost completely covered or partially covered?
- do you use the same stored batch as direct applied compost and for compost tea?
- how often is this batch replenished?
- what is the longest timeframe that tea will be made from a batch of compost?

7. Decide on source of water to be used in compost and have water tested.

- what is source of water used in brewing?
    - if city tap water, is it chlorinated?
        - how do you remove the chlorine prior to making compost tea?
        - do you have access to city water reports that document water is safe?
- what laboratory will do the water testing?
- has water been tested for following parameters:
    - PH
    - presence of E coli 0157
    - total coliforms present
    - metals, including arsenic and lead
    - salts
- where do you store the water quality test results?
- what is the temperature of water as it comes from the source?
- is water used in tea brewing directly from source or is it stored prior to brewing?
    - how and where is it stored?
        - is storage covered?
        - has storage container been sanitized prior to storage?

8. Decide on testing methodology for dissolved oxygen (DO) and acquire supplies.

- will you acquire a DO meter?
    - make and model of meter?
    - has meter been calibrated?
    - has meter been compensated for elevation?
- if using test strips, who is supplier of test strips?

- do test strips have adequate range indicators? (0 mg/L through 12 mg/L)
- have you completed a "static test" using water only with your brewer to measure DO levels at beginning of aeration and after one hour of aeration to assure that aeration is actually occurring?

9. Choose which laboratories for pathogen and quality testing.
- will you do both pathogen testing and quality testing?
- which laboratory will you use for pathogen and quality testing?
    - is it necessary to open an account?
    - do you know exactly where to send the sample?
    - do you understand packing and shipping protocols to assure an accurate test?
        - do you have adequate packing and shipping materials?

10. Decide on pretreatment additives and supplier.
- will you be pretreating compost prior to making compost tea
- what additives will you be adding to compost as a pretreatment?
    - what is the proportion of compost, additives and water?
    - who is the supplier or source of additives?
- how long will you pretreat compost?
- where will you store compost during pretreatment?
    - will temperature be adequate for pretreatment? (65-80 degrees F.)
    - will pretreatment be covered, in the dark and undisturbed?

11. Decide on brewing additives to be used and supplier
- will you be adding supplemental foods to brew?
- what materials will you be adding as food during brewing?
    - what is the source/supplier of additives?
- what are the proportions of additives used during brewing?
- at what point in brewing cycle are foods added?

12. Determine application equipment and methods
- what method of application will you use?
    - side dress, foliar spray, drip tape/sprinkler injection, greenhouse starts
- has your application vessel been used with any product that might inhibit microbe growth?
    - was vessel thoroughly cleaned prior to using with tea?
- will tea be diluted or applied at full strength?
    - what is temperature of water used for dilution?
    - is source for dilution water the same as water for brewing?
- will any additional materials be added to tea after brewing is complete?
- if foliar spray, is the spray orifice large enough to pass microbes?
    - does the sprayer have a built-in filter that might restrict tea flow?
        - is the filter finer than 400 micron mesh?
    - does the tea liquid make any 90 degree turns during spraying?
    - do you add any wetting agents to your spray mix?
        - are the wetting agents compatible with living microbes?

- is the exit pressure from any nozzle greater than 20 PSI?
- if foliar spraying, is application during early morning or later afternoon to avoid strong UV radiation?

13. Acquire cleaning materials and equipment

- how do you assure tea liquid does not get into air line?
- do you clean all components with water and detergent prior to sanitizing?
- are all implements used in cleaning labeled for compost cleaning only?
- are all cleaning implements stored in a central location?
- are all implements used for compost cleaning only
- after cleaning components of brewer, are all components sanitized?
    - what brand and type of sanitizer do you use?
    - are brewer components allowed to air dry prior to placing in storage
- are you able to reach and clean all parts of brewer that come into contact with tea?
    - are there invisible or difficult to reach parts of brewer?
        - for membrane diffusers, do you disassemble diffuser?
        - for air stones, do you soak stone in sanitizer?
- do you maintain a "cleaning/sanitizing log"?
- do you clean the brewer and equipment within one hour of completing brewing?

14. Determine location of brewing and brewing procedures

- do operators follow general GAP practices while brewing?
    - i.e., not being sick, sneezing, coughing, etc?
    - do operators wash their hands prior to brewing?
- what is date of brewing?
- is brewing done in a controlled temperature environment or not?
    - is brewing done in a covered environment such as a building?
    - is brewing done in the same location every time?
- what is duration of brewing time?
    - do you have a log that notes batch #, date, brewing time, etc?
        - where is this log kept?
- is your brewer covered during brewing?
    - how is it covered?
- do you aerate the water in the brewer prior to adding compost?
    - how long do you aerate?
- do you measure the dissolved oxygen level in the brew during brewing?
    - at what intervals do you measure the dissolved oxygen level?
    - have you factored in your altitude in calculating oxygen level in your brew?
    - what type of aerator diffuser do you use?
        - have you verified the pores/orifices are not plugged up?
- what is ambient temperature when you begin brewing?
- what is the brew temperature when you begin brewing?
- what is the water temperature when you begin brewing
- what is the maximum temperature swing during brewing time?
    - what is high temp and low temp during brewing?

- how do you add the compost to compost tea brewer?
    - what implements do you use to transfer compost from storage area to brewer?
    - are these implements sanitized prior to use?
- do you use a strainer in the brewer?
    - what mesh size is the strainer
    - what is the configuration of the strainer and location within the brewer?

- what quantity of water do you use?
    - what quantity of compost do you use?
    - what quantity of additives do you use?
    - what is the sequence of steps you take during brewing to add the water, compost and any additives?
    - do you use additives during brewing?
    - how is water added to the brewer?

<u>15. Create Compost tea log and other records as necessary</u>

Attachment J: Step-by-Step: Mailing tea for testing

Step by Step Compost Tea- Mailing Tea for Testing

(produced with support from Western SARE grant # FW15-037)

WESTERN SARE
Sustainable Agriculture Research & Education

Procedure for mailing brew for testing:

Preliminary steps

1. Locate clean one quart plastic bottle (empty water bottle is good) and label bottle with sample date and name

2. obtain and freeze ice packs

3. Obtain packing supplies

4. Fill out lab form and overnight mail address label

When brewing complete

1. Fill up quart bottle approximately half full with compost tea and secure cap

2. Place bottle in fridge and lower temperature to 45 degrees

3. Pack sample in insulated carrier and place in mailing box

4. Mail overnight delivery using USPS. Time overnight mailing so sample is taken to post office on a Monday or Tuesday, assuring sample is received by lab no later than Thursday morning.

E **Attachment L: General information on dissolved oxygen**

General Information on Dissolved Oxygen

by Sheila Murphy

DISSOLVED OXYGEN (DO)

Dissolved Oxygen (DO) is found in microscopic bubbles of oxygen that are mixed in the water and occur between water molecules. DO is a very important indicator of a water body's ability to support aquatic life. Fish "breathe" by absorbing dissolved oxygen through their gills. Oxygen enters the water by absorption directly from the atmosphere or by aquatic plant and algae photosynthesis. Oxygen is removed from the water by respiration and decomposition of organic matter.

Measurement of DO

Dissolved Oxygen can be measured with an electrode and meter or with field test kits. The electronic meter does not measure oxygen directly; rather, it uses electrodes to measure the partial pressure of oxygen in the water, which is converted to oxygen mass weight concentration. The field test kits (such as a drop bottle, a microburet, or a digital titrator) involve adding a solution of known strength to a treated sample of water from the stream. The amount of solution required to change the color of the sample reflects the concentration of DO in the sample. The amount of oxygen dissolved in water is expressed as a concentration, in milligrams per liter (mg/l) of water.

Dissolved oxygen levels are also often reported in percent saturation. Temperature affects DO concentrations, and calculating the percent saturation will factor out the effect of temperature. The "saturation level" is the maximum concentration of dissolved oxygen that would be present in water at a specific temperature, in the absence of other factors. Scientists have determined the saturation DO level for various temperatures. Saturation levels also vary with elevation. Percent saturation is calculated by dividing the measured dissolved oxygen concentration by the saturation level and multiplying by 100.

This equation is shown as:

% Saturation = (DO / Saturation Level) x 100

Factors Affecting DO

Volume and *velocity* of water flowing in the water body

In fast-moving streams, rushing water is aerated by bubbles as it churns over rocks and falls down hundreds of tiny waterfalls. These streams, if unpolluted, are usually saturated with oxygen. In slow, stagnant waters, oxygen only enters the top layer of water, and deeper water is often low in DO concentration due to decomposition of organic matter by bacteria that live on or near the bottom of the reservoir.

Dams slow water down, and therefore can affect the DO concentration of water downstream. If water is released from the top of the reservoir, it can be warmer because the dam has slowed the water, giving it more time to warm up and lose oxygen. If dams release water from the bottom of a reservoir, this water will be cooler, but may be low in DO due to decomposition of organic matter by bacteria.

Climate/Season

The colder the water, the more oxygen can be dissolved in the water. Therefore, DO concentrations at one location are usually higher in the winter than in the summer.

During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls.

More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

The type and number of *organisms* in the water body

During photosynthesis, plants release oxygen into the water. During respiration, plants remove oxygen from the water. Bacteria and fungi use oxygen as they decompose dead organic matter in the stream. The type of organisms present (plant, bacteria, fungi) affect the DO concentration in a water body. If many plants are present, the water can be supersaturated with DO during the day, as photosynthesis occurs. Concentrations of oxygen can decrease significantly during the night, due to respiration. DO concentrations are usually highest in the late afternoon, because photosynthesis has been occurring all day. For an example of how DO can vary from day to night, select here .

Altitude

Oxygen is more easily dissolved into water at low altitudes than at high altitudes, because of higher atmospheric pressure.

Dissolved* or *suspended solids

Oxygen is more easily dissolved into water with low levels of dissolved or suspended solids. Waters with high amounts of salt, such as the ocean (which contains about 35 grams of salt for each 1000 grams of water) have low concentrations of DO. Freshwater lakes, streams, and tap water generally contain much less salt, so DO concentrations are higher. As the amount of salt in any body of water increases, the amount of dissolved oxygen decreases. An increase in salt concentration due to evaporation of water from an ecosystem tends to reduce the dissolved oxygen available to the ecosystem's inhabitants.

Runoff from roads and other paved surfaces can bring salts and sediments into stream water, increasing the dissolved and suspended solids in the water.

Amount of *nutrients* in the water

Nutrients are food for algae, and water with high amounts of nutrients can produce algae in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called eutrophication. DO concentrations can drop too low for fish to breathe, leading to fish kills. However, nutrients can also lead to increased plant growth. This can lead to high DO concentrations during the day as photosynthesis occurs, and low DO concentrations during the night when photosynthesis stops and plants and animals use the oxygen during respiration. For an example of how DO can vary from day to night, select here.

Nitrate and phosphate are nutrients. Nitrate is found in sewage discharge, fertilizer runoff, and leakage from septic systems. Phosphate is found in fertilizer and some detergents.

Organic Wastes

Organic wastes are the remains of any living or once-living organism. Organic wastes that can enter a body of water include leaves, grass clippings, dead plants or animals, animal droppings, and sewage. Organic waste is decomposed by bacteria; these bacteria remove dissolved oxygen from the water when they breathe. If more food (organic waste) is available for the bacteria, more bacteria will grow and use oxygen, and the DO concentration will drop.

Directly downstream from where sewage effluent is discharged to a river, DO content often decreases, because of the increase in growth rate of bacteria that consume the organic matter contained in the effluent. The degree and extent of the DO "sag" depends on the Biological Oxygen Demand (BOD) of the effluent (how much oxygen the effluent can consume) (Giller and Malmqvist, 1998).

Riparian Vegetation

Shading tends to lower average summer temperature and reduce the daily duration of higher temperature. Removing trees reduces shade on the creek, allowing the sun to warm the water. This can affect DO concentrations in different ways. As mentioned above, in general, as water temperature increases, DO drops. Also, the bare soil exposed from removing the tree can erode, increasing the amount of dissolved and suspended solids in the water. This also leads to a decrease in DO concentrations. However, direct sunlight, along with increased nutrients can increase the growth rate of aquatic plants. These plants release oxygen to the water during the day, but then remove oxygen from the water at night. This can cause DO concentrations to become very high during the day, then very low during the night. For an example of how DO can vary from day to night, select here .

Groundwater Inflow

The amount of groundwater entering a river or stream can influence oxygen levels. Groundwater usually has low concentrations of DO, but it is also often colder than stream water. Therefore, groundwater may at first lower the DO concentration, but as groundwater cools the stream or river, the ability of the water to hold oxygen improves.

Water Quality Standards and Other Criteria Regarding DO

Colorado Department of Public Health and Environment Water Quality Control Division (CDPHE-WQCD) regulations (5 CCR 1002-31) state that waters to be used for domestic water supply should not have DO concentrations below 3 milligrams per liter (mg/l) (Reg. 31 - Basic Standards and Methodologies for Surface Water).

CDPHE-WQCD regulations state that waters used for recreation (both primary and secondary contact) should not have DO concentrations below 3 milligrams per liter (mg/l).

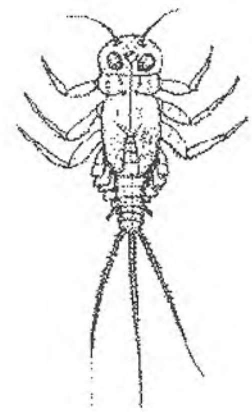
CDPHE-WQCD regulations state that waters classifed as "Class 1 Cold Water Aquatic Life" should not have DO

concentrations below 6 mg/l, and not below 7 mg/l during spawning. Waters classified as "Class 1 Warm Water Aquatic Life" should not have DO concentrations below 5 mg/l. (These are 1-day minima)

Very high DO concentrations can also be harmful to aquatic life. Fish in waters containing excessive dissolved gases may suffer a condition in which bubbles of oxygen block the flow of blood through blood vessels, causing death. Abrupt changes in dissolved oxygen induce stress and subsequently make fish more susceptible to disease.

The ideal dissolved oxygen concentration for many fish is between 7 and 9 mg/l; the optimal DO for adult brown trout is 9-12 mg/l. Most fish cannot survive at concentrations below 3 mg/l of dissolved oxygen.

Other Information about DO



When dissolved oxygen concentrations drop, major changes in the types and amounts of aquatic organisms found living in the water can occur. Species that need high concentrations of dissolved oxygen, such as mayfly nymphs, stonefly nymphs, caddisfly larvae, pike, trout, and bass will move out or die. They will be replaced by organisms such as sludge worms, blackfly larvae, and leeches which can tolerate lower dissolved oxygen concentrations. Waters that have low dissolved oxygen sometimes smell bad because of waste products produced by organisms that live in low oxygen environments.

Because of the relationship between temperature, rate of photosynthesis, and DO, fish kills usually occur in late summer just before dawn.

Very low DO concentrations can result in mobilization of trace metals.

A fish that is under stress caused by low oxygen levels in the water is more susceptible to poisoning by insecticides or heavy metals (Caduto, 1990).

Select here for a list references used in the preparation of this information
Select here for general information about other water quality parameters.
Select here for interpretation of Dissoved Oxygen data in the Boulder Creek Watershed

Attachment K: Air volume conversion (for calculating pump capacity)

Conversion Factors- Air volume ratings for aeration pumps

When evaluating pumps for use in brewing tea it is important to understand the basic concepts of pressure and air movement. The standard commercial rating for air pumps lists the volume of air in cubic feet moved in one minute, abbreviated CFM (cubic feet per minute). However this rating applies to a fixed pressure, which often is not stated. For commercial pumps, the air flow rate is listed as a function of the pressure and is illustrated through a "pump curve" graph which shows how the pump responds at different pressures. Pump graphs are usually available, if you request them.

For smaller pumps sold in the fish tank market, the CFM ratings are usually unstated and turn out to be at 0 PSI. This means that the pump will transfer XX CFM when there is no pressure resistance on the pump. This is rarely the scenario in the real world. The biggest factor influencing the pressure requirements are the porosity of the diffuser and where the diffuser is located in the tank. A diffuser at the bottom of a tank must overcome the weight of the water. Membrane diffusers and air stones that get plugged can easily require 10-20 PSI of pressure to pass air.

Typically to keep water well oxygenated you need:

5 gallon bucket:	1 CFM
10 gallon:	2 CFM
40 gallon:	6 CFM

Pumps are listed in a dizzying number of formats. All need to be converted to CFM to really know what you are getting.

Air Volume:

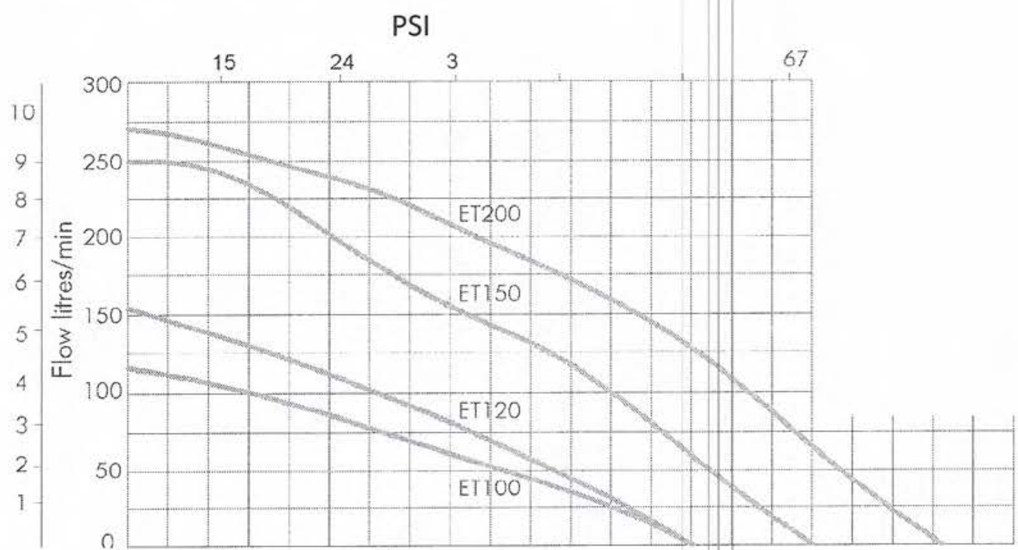
- GPM = gallons per minute (gal/min)
- GPH = gallons per hour (gal/hr)
- CFM = cubic feet per minute (cf/min)

1 cfm= 7.48 gpm	1 gpm= .134 cfm
1 cfm= 60 cfh	1 gph= .0167 gpm

example: How many cfm is a pump rated 1030 gph?

1 gph= .0167 gpm
1030 gph= (.0167) X 1030= 17.2 gpm
1 gpm= .134 cfm
17.2 gpm= (.134) X 17.2= 2.3 cfm

The following is a "pump curve" for the Blue Diamond brand ET Series aerating pumps for ponds and septic systems.



Column on the left shows air flow rate in CFM. Numbers at top show pressure in PSI. We use a ET120 in our 40 gallon brewer and have no problem maintaining a high level of dissolved oxygen.