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ABSTRACT

This lesson is an introduction to sludge conditioning. Topics covered include a brief explanation of colloidal systems, theory of chemical and heat conditioning, and conditioning aids. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains objectives, glossary, text material (presented in sections titled: theory of conditioning, conditioning equipment, conditioning operations, and aids to conditioning), references, and worksheet. (JN)

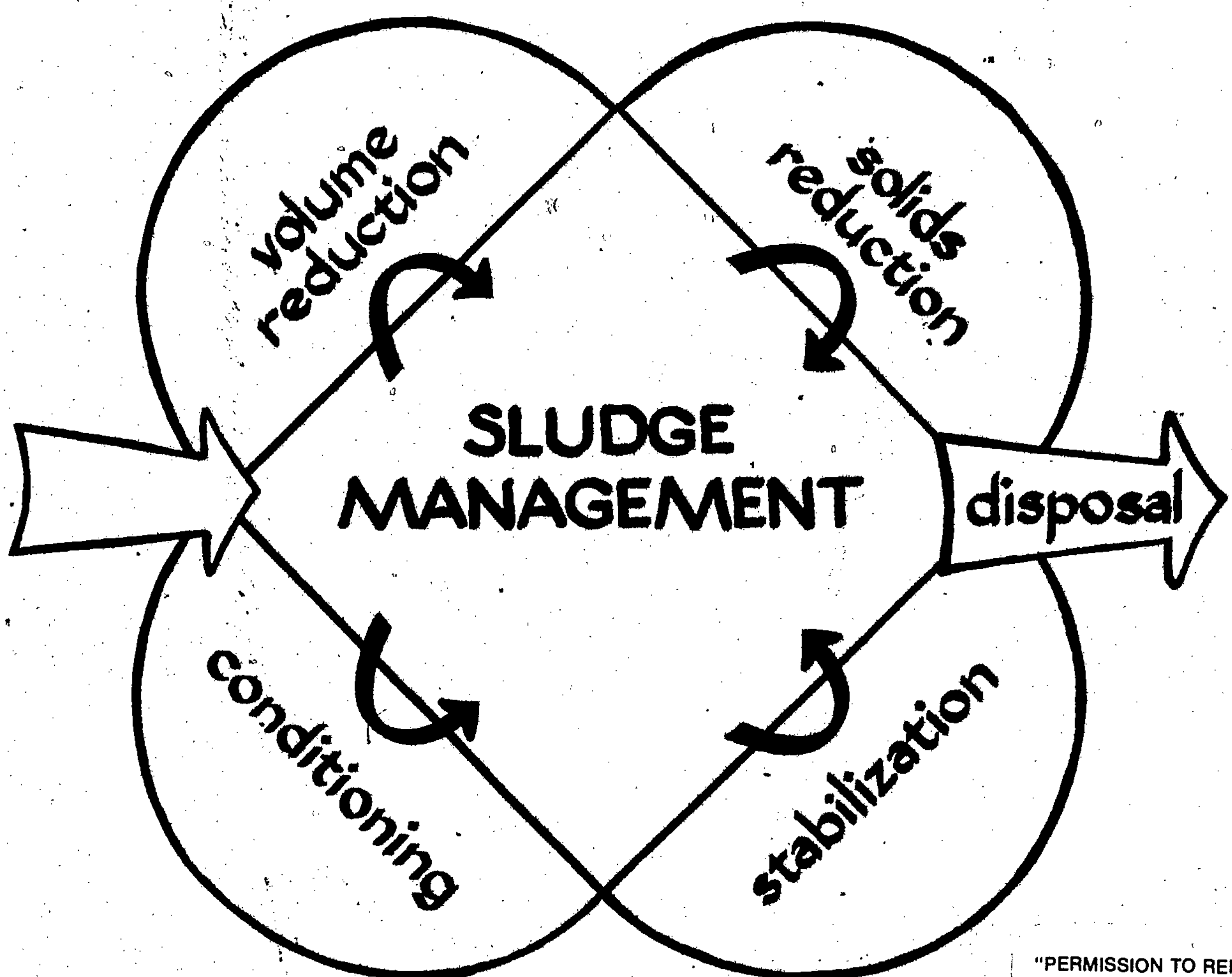
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SLUDGE CONDITIONING



INSTRUCTOR'S GUIDE

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

SLUDGE CONDITIONING

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SLUDGE CONDITIONING

CONTENTS

SLUDGE CONDITIONING

Lesson Description

This lesson is an introduction to conditioning. Reference is made throughout the text to solids handling processes, but is not dependent on a thorough understanding of those processes. Most value would be gained by exposure to this lesson before unit processes and a thorough review following the unit process modules.

The lesson covers a brief explanation of colloidal systems; the theory of chemical and heat conditioning; the equipment used and the basic operational consideration for chemical and heat conditioning, and conditioning aids.

Estimated Time

Student preview of objectives	5-10 minutes
Presentation of material	30-45 minutes
Worksheet	10 minutes
Correct worksheet and discussion	10 minutes

Instructional Materials List

1. Student text "Sludge Conditioning"
2. Slide/tape set "Sludge Conditioning"
3. Slide Projector, 35 mm
4. Tape Player w/synchronization to slide projector
5. Screen
6. Samples of polymers and coagulants.
7. Sample of colloidal suspension (clay or bentonite)

Suggested Sequence of Presentation

1. Assign text to read before class session.
2. Have students review objectives in class.
3. Show slide/tape program or lecture using the slide.
4. Assign worksheet
5. Correct worksheet and discussion questions that arise.

Required Reading

Student text "Sludge Conditioning"

Reference Reading

WPCF Manual of Practice No. 20, Sludge Dewatering

Objectives

Upon completion of this lesson the student should be able to do the following:

1) Describe what is meant by the term sludge conditioning.
2) Give four examples of solids handling processes which conditioning can precede.
3) Give 3 characteristics of wastewater colloidal particles which make them difficult to separate from surrounding water.
4) Describe how a stabilized colloidal system differs from a destabilized colloidal system.
5) Give the names of three inorganic chemicals which can be used for conditioning.
6) Give the names and charge of the three forms of polyelectrolytes.
7) Describe the heat treatment conditioning process.
8) Describe the two major types of chemical feeders.
9) Give the two important items provided for in the conditioner tank.
10) Describe the two functions of the heat exchanger in the heat conditioning process.
11) Describe the function of the reactor in the heat conditioning process.
12) List three laboratory tests which could be used to determine the effectiveness and dosage of chemicals.
13) State three items that an operator must be aware of in order to obtain good chemical conditioning.
14) State the three major operational variables for the heat treatment conditioning operation.
15) Describe elutriation.
16) State three uses of hydrated lime as an aid to conditioning.
17) State two uses of ash as an aid to conditioning.

SLUDGE CONDITIONING

LECTURE OUTLINE

I. Theory of Conditioning

A. Definition of Conditioning

The pre-treatment of sludge to enhance water removal by a subsequent solids handling process.

B. Commonly used prior to thickeners, filters, centrifuges and drying beds.

C. Colloidal particles

1. Sludge is made up of a large portion of colloidal particles.

2. Three characterisitics of colloids

a. extremely small
b. negative surface charge
c. attract water molecule

3. Colloidal particles hard to separate from surrounding water.

4. Stabilized system

a. dispersed particles
b. do not settle

5. Destabilized system

a. particles clump together
b. clumps large enough to settle

D. Destabilization can be brought about by conditioning.

1. Chemical conditioning

a. Inorganic chemicals

i. destabilize by coagulation - the neutralization of surface charges of colloidal particles.

ii. metal ions -

Ferric (Fe^{+++}) ferric chloride
Ferrous (Fe^{++}) ferrous sulfate
Aluminum (Al^{+++}) aluminum sulfate (alum)

iii. metals ions destabilize by neutralizing surface charges.

. Organic chemicals

i. destabilize by coagulation

ii. polyelectrolytes (polymers or poly)

cationic - positively charges
anionic - negatively charges
nonionic - neutral charge

iii. also destabilize by flocculation - the process of coagulated particles sticking together to form larger and larger floc particles.

2. Heat Conditioning

   a. Description - sludge subjected to high temperatures under pressure.

      i. protein and other cellular material released from organisms in sludge.

      ii. capillary, bound, and intracellular water released.

      iii. solids more dense as a result.

II. Conditioning Equipment

A. Equipment for chemical conditioning

1. Dry chemical feeders

   a. Manually prepared batch method

   b. Automatic continuous method

   c. Volumetric or gravimetric

2. Liquid chemical feeders

   a. Feed directly into system

   b. Use metering pump

3. Conditioner

   a. Tank for mixing chemicals with sludge

   b. Provide gentle mixing

   c. Provide visual observation

4. Typical flow pattern

   a. Chemical from storage tank through feeder to conditioner

   b. Sludge and chemical mix in conditioner

   c. Conditoned sludge flows to dewatering unit

   d. Thickened sludge drawn off

   e. Liquid returned to plant as side stream

   f. Chemical may mix with sludge in thickening unit as with gravity thickeners.

B. Equipment for heat conditioning

1. Heat exchanger

   a. Incoming cool sludged preheated by hot sludge leaving the reactor.

   b. Hot conditioned sludge leaving the reactor cooled by incoming cool sludge.

   c. May have internal closed loop of heat exchanging fluid.

2. Reactor

   a. Steam supplied to raise temperature.

b. Pressurized system.

c. Provides for reaction detention time.

3. Typical flow pattern

a. Incoming sludge preheated in heat exchanger.

b. Reaction time in reactor.

c. Hot conditioned sludge cooled in heat exchanger.

d. Sludge thickened in decant tank.

e. Thickened sludge to further solids handling process.

f. Supernatant from decant returned to plant as side stream.

III. Conditioning Operations

A. Chemical conditioning operations

1. Must determine most effective chemical type and dosage.

a. Laboratory tests

i. jar test

ii. specific resistance

iii. filter leaf

iv. capillary suction time

b. feeders in plant set according to tests.

2. Must balance sludge quality with cost.

a. Calculate lbs of chemical/ton of dry sludge produced

b. Calculate cost/ton of dry sludge produced

3. Sludge must be handled carefully before, during and after chemical conditioning.

4. Consider point of chemical application.

5. Consider sequence of chemical addition if adding more than one chemical.

B. Heat treatment conditioning operations.

1. Major operational variable.

a. temperature

b. pressure

c. solids feed rate

2. Higher temperatures and pressures bread down material faster. This can mean:

a. shorter detention time.

b. more easily dewatered sludge.

c. heavier organic load in sidestream.

3. Operator must balance conditions to obtain an easily dewatered sludge but does not result in unacceptable sidestream load.

IV. Aids to Conditioning

A. Elutriation

1. a washing process
2. reduced chemical requirements
3. removed very fine suspended sludge particles.

B. Hydrated lime

1. pH control
2. odor control
3. disinfection

C. Ash

1. absorbs moisture
2. adds mass

TYPICAL CHEMICAL CONDITIONING REQUIREMENTS

SLUDGE TYPE	FERRIC CHLORIDE, lbs./TON	LIME, lbs./TON	POLYMER, lbs./TON
Primary	20 - 40	120 - 200	4 - 24
Primary, WAS	30 - 50	140 - 180	10 - 20
WAS	80 - 200	-	4 - 30
Digested Primary	30 - 100	300 - 600	5 - 40
Digested Primary & WAS	30 - 200	300 - 600	15 - 50
Digested WAS	80 - 200	300 - 600	15 - 40
Digested Elutriated Primary	40 - 80	-	10
Digested Elutriated Primary and WAS	40 - 80	-	15 - 30

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NARRATIVE

Slide #

1. This module discusses Sludge Conditioning. It will present a description of conditioning methods, conditioning equipment and the application of conditioning to solids handling.

2. This module was written by Dr. John W. Carnegie. The instructional development was done by Priscilla Hardin. Mr. Paul Klopping was the project director.

3. Prior to some treatment processes, sludge is subjected to conditioning to enhance water removal. Many types of sludges are not easily dewatered. These same sludges, however, can be more easily dewatered if the characteristics of the sludge are changed by conditioning.

4. Sludge Conditioning is commonly used prior to thickeners, filters, centrifuges, and drying beds. In fact, for some types of sludges, these treatment processes will not work without pretreatment by conditioning.

5. A significant portion of sludge is colloidal particles. Colloids have three characteristics that make them particularly hard to separate from the surrounding water. They are extremely small. A thousand colloidal particles could line up on the head of a pin. They generally have a negative surface charge and they tend to attract water molecules.

6. These three colloidal characteristics tend to keep the colloidal solids dispersed. This dispersed condition is referred to as a stabilized system. In the stabilized system the colloidal particles repel each other because of the surface charges and water molecules. They do not settle because of their small size. The result is that the colloidal particles cannot be separated from the surrounding water.

7. A destabilized system is one in which the dispersed particles come together to form clumps. The clumps form because the surface charges have been reduced and the water molecules released. The clumps become large enough to settle.

8. Destabilization can be brought about by conditioning processes. Destabilization by conditioning helps the flocculation or clumping process which tends to release water from the sludge particles and improves settling characteristics.

9. The sludge conditioning processes can be grouped into three categories: chemical, using inorganic or organic chemicals; and heat treatment, are the tow most common methods. Elutriation and other aids to conditioning make up the third category. We'll first look at the chemical methods.

10. Inorganic metal ions destabilize by a process called coagulation. Coagulation is the neutralization of the surface charges of colloidal particles and the removal of the water molecules. Coagulation will effectively remove capillary water and bound water from the sludge. After coagulation, the destabilized particles settle better and are more easily dewatered.

11. Among the inorganic metal ions commonly used in conditioning as coagulants are ferric iron, ferrous iron and aluminum. Ferric chloride is used as a source of the ferric ions. Ferrous sulfate is used as a source of the ferrous ions, and aluminum sulfate or alum provides aluminum ions.

12. The ferric, ferrous and aluminum ions are all highly positively charged. When these ions are added to a negatively charged colloidal system, destabilization occurs as a result of the neutralization of the negative surface charges by the positively charged metal ions.

13. Large organic chemicals called polyelectrolytes can also be used to destabilize a colloidal system. Polyelectrolytes, also called polymers or poly, are extremely long, highly charged molecules. A positively charged polymer is called cationic and a negatively charged polymer is anionic. Polymers having equal negative and positive charges are called nonionic polymers.

14. Polyelectrolytes destabilize by coagulation. The highly charges polymers neutralize the surface charges of colloidal particles and remove water molecules in manner similar to the inorganic metal ions.

15. Polyelectrolytes also destabilize by aiding flocculation. Flocculation is the process of coagulated particles sticking together to form larger and larger settleable floc particles. Polymers aid flocculation because their long stringy shape forms bridges or webs between coagulated particles.

16. The second common conditioning process is heat treatment.

17. In the heat treatment process sludge is subjected to high temperatures under pressure. This process is quite similar to a pressure cooker. The biological organisms in the sludge break open under these conditions and release proteins and other cellular material.

18. Capillary water, bound water and intracellular water is released. The solids in heated sludge are more dense and can be separated from the water by sedimentation.

19. In summary, inorganic and organic chemicals as well as heat can be used to destabilize sludge, making the dewatering processes that follow more efficient.

20. Now that we have discussed the theory of sludge conditioning, let's take a look at the conditioning equipment. The use of chemical conditioners means that we must feed either dry or liquid chemicals into the system.

21. Dry chemical feed equipment in small plants involves a manually prepared batch process. Dry chemical is carefully measured and added by hand to a solution mixing tank from which it is fed into the system.

22. In larger plants, dry feed equipment is usually automatic. In an automatic setup the chemical is fed from a hopper into a tank. The mixer helps dissolve the chemical and the solution then goes to the system through the feed line. A pre-wetter spray is used to insure quick and complete solution of the dry material.

23. Dry feeders are available that can deliver a controlled quantity of chemical to the mixing tank either on the basis of volume or weight. This gravimetric feeder operates on the basis of weight and is used to deliver alum to a mixing tank.

24. Some types of chemicals are delivered to the plant as liquid and are fed directly into the system with a chemical feed pump.

25. As with the dry chemical feeders, the liquid feed system must have a liquid feed pump or metering pump capable of delivering a precise volume of liquid to the system.

26. Where chemical conditioning is used prior to dewatering processes such as vacum filters or centrifuges, the metering pump feeds chemicals to a mixing tank referred to as a conditioner.

27. In the conditioner unit the chemicals are mixed with the incoming sludge. The destabilizing action of the conditioning chemicals occur in the conditioner.

28. The destabilized or conditioned sludge then flows to the dewatering unit. Thickened sludge is drawn off for further processing and the liquid is returned to the plant as a recycle sidestream.

29. Several types of conditioner units are available. However, regardless of the configuration, the conditioner must provide gentle mixing to disperse the chemical throughout the sludge without tearing the fragile floc. It must also provide visual observation points. The operator should be able to view the action to assure proper dosage and mixing speed.

30. Where chemical conditioning is used prior to gravity thickeners or flotation thickeners, the chemical can be added directly to the sludge line. In this arrangement, the thickener basin serves as the conditioner unit, in which the slow mixing and destabilization of sludge occurs.

31. Now let's turn our attention to the equipment used in the heat treatment process.

32. The hear conditioning process consists of two major components: the heat exchanger and the reactor.

33. Sludge flows through the heat exchanger where it is preheated and then into the reactor where the desired temperature and pressure are attained and the conditioning reaction occurs. Heat conditioned sludge is then cooled in the heat exchanger, decanted, and sent on to a dewatering unit.

34. The reactor is the heart of the operation. Steam is supplied to the reactor to raise the temperature to the desired range. The entire sustem is also pressurized. The reactor provides for the desired reaction detention time.

35. The heat exchanger serves two purposes. Cool, incoming sludge, is preheated by hot sludge leaving the reactor. At the same time, the conditioned sludge is cooled before going to the decant tank.

36. The decant unit is used for intitial dewatering before sludge is passed on to other dewatering processes. Both the decant unit and the dewatering unit produce recycle sidestreams which can result in a significant solid and organic load on the plant.

37. Having discussed both the theory of conditioning and the conditioning equipment, let's now discuss operations. First, the chemical conditioning units.

38. The main operational goal in working with chemical conditioning is to determine the most effective chemical types and dosages. Laboratory tests are performed to determine the most effective chemical types and dosages. The operator then sets the feeders accordingly.

39. In the laboratory, the capillary suction time test, the jar test, the specific resistance test, and the filter leaf test can be used to check various chemical types and to determine optimum dosages.

40. Cost of operation is always any operational concern. The operator should calculate pounds of chemicals used per ton of dry sludge produced and from that number, the cost per ton of dry sludge can be determined. From the calculations, the operator can balance conditioned sludge quality with cost.

41. Sludge must be handled carefully prior to, during and after conditioning. Any vigorous physical processs such as pumping, violent mixing and aging before conditioning can make conditioning more difficult. Rough handling after conditioning can break the flocculated particles and disperse the solids.

42. The point of application and the order of addition of chemicals to the sludge also have an effect. Some chemicals work quickly, some slowly. Some chemicals work best first, others work best as a secondary chemical.

43. Finally, let's turn our attention to the operation of the heat treatment process.

44. In order to obtain optimum dewaterability after heat conditioning, the operators can control these variables: pressure, temperature, and feed rate, which directly effects detention time.

45. These factors are all interrelated. Generally, if pressure and temperature or detention time are increased cell breakdown and thus, dewaterability will improve.

46. But, at the same time, the quality of the sidestream from the decant and dewatering unit deteriorates putting a heavier load on the plant.

47. Therefore, the operator must continually balance improved dewaterability with sidestream quality be controlling pressure, temperature, and feed rate.

48. There are several items that are related to conditioning that are referred to as aids to conditioning. The elutriation process and the use of lime and ash are in this category.

49. Elutriation is a washing process. Its main purpose is to reduce chemical requirements and remove very fine suspended particles from the sludge. These fine sludge particles and some dissolved chemicals are removed by dilution with plant effluent, followed by resettling. The supernatant side stream that results represents a significant load on the plant.

50. Hydrated lime is used as an aid to conditioning. It is used in conjunction with the inorganic metals ions. Although it does have a dehydrating effect on colloids, its main use is for pH control, odor control, and disinfection.

51. Ash is also used as an aid to conditioning. Both fly ash and incinerator ash can be used to absorb moisture and to add mass to light floc.

52. To summarize, many of the sludge handling processes can be made more efficient by conditioning the sludge. Conditioning can be accomplished by the addition of organic and inorganic chemicals and by heat treatment. Elutruation, lime, and ash can be used to aid in the conditioning process.

References

1. Process Design Manual for Sludge Treatment and Disposal, USEPA, EPA 625/1-79-011, Cincinnati, 1979.

2. Operations Manual, Sludge Handling and Conditioning, USEPA, EPA 430/9-78-002, Washington, D.C., 1978.

3. WPCF Manual of Practice No. 20, Sludge Dewatering, Water Pollution Control Federation, Washington, D.C., 1969.

4. Treatment and Disposal of Wastewater Sludges, P. Aarne Vesilind, Ann Arbor Science, Ann Arbor, 1979.

SLUDGE CONDITIONING - WORKSHEET

1. Sludge conditioning is
   - ____ a. The chemical alteration of sludge to improve its fertilizer value.
   - __X__ b. The pre-treatment of sludge to enhance water removal.
   - ____ c. The bacterial stabilization of septic sludge to reduce pathogenicity.
   - ____ d. High speed agitation in a vortex mixer.

2. Place an X by the solids handling processes which are commonly preceded by conditioning.
   - __X__ a. filter presses
   - ____ b. anaerobic digester
   - __X__ c. centrifuge
   - __X__ d. gravity thickener
   - ____ e. sludge lagoon
   - __X__ f. vacuum filter

3. Colloidal particles are:
   - ____ a. heavy, charged, sand
   - ____ b. large, positive, bacteria
   - ____ c. small, positive charged, attract water
   - __X__ d. small, negative charged, attract water

4. Which of the following is a characteristic of a destabilized colloidal system?
   - __X__ a. particles settle well
   - ____ b. dispersed particles
   - ____ c. particles attracting water molecules
   - ____ d. particles highly charged

5. Which of the following are inorganic chemical used for conditioning?
   - __X__ a. ferric chloride
   - __X__ b. aluminum sulfate
   - ____ c. sodium sulfate
   - __X__ d. ferrous sulfate
   - ____ e. potassium nitrate

6. Match the three polyelectrolytes with their appropriate electrical surface charge.

b	cationic	a.	neutral charge
a	nonionic	b.	positive charge
c	anionic	c.	negative charge

7. Conditioning by heat treatment is:

____a. subjecting dewatered sludge to slow drying in a drying bed using the heat of the sun.

____b. is a process which converts all proteins and carbohydrates into easily usable ATP.

__X__c. sludge subjected to high temperatures and pressure.

____d. sludge heat in a multiple hearth furnace

8. Which of the following statements about chemical feeders is <u>not</u> true?

____a. dry chemical feeders can be batch or automatic.

____b. dry chemical feeders can be gravimetric or volumetric.

____c. the two major types of feeders are dry and liquid.

__X__d. both dry and liquid feeders need a mixing tank.

9. A chemical conditioning tank provides for which of the following?

__X__a. slow, gentle mixing

____b. sedimentation of sludge

__X__c. visual observation by operator

____d. mixing of dry chemicals

10. Which two of the following are the major functions of the heat exchanger?

____a. cools the steam coming from the reactor.

__X__b. preheats the sludge going to the reactor.

__X__c. cools the sludge coming from the reactor.

____d. preheats sludge prior to incineration.

11. The heat treatment reactor

__X__a. is a pressurized system

__X__b. provides reaction detention time.

__X__c. is heated by steam.

____d. follows the decant tank.

12. Match the following:

1	a.	handle sludge carefully	1. An operational variable for chemical conditioning.
3	b.	elutriation	2. A use for hydrated lime.
1	c.	consider point of application	3. A washing process.
1	d.	consider sequence of addition	
2	e.	disinfection	
2	f.	odor control	
2	g.	pH control	

13. Match the following:

1	a.	filter leaf	1. A laboratory test used to determine optimum chemical dosages.
2	b.	temperature control	2. An operation variable for heat treatment conditioning.
1	c.	jar test	3. A use for ash.
1	d.	specific resistance	
2	e.	pressure control	
3	f.	adds mass	
2	g.	solids feed rate	
3	h.	absorbs moisture	
1	i.	capillary suction time	

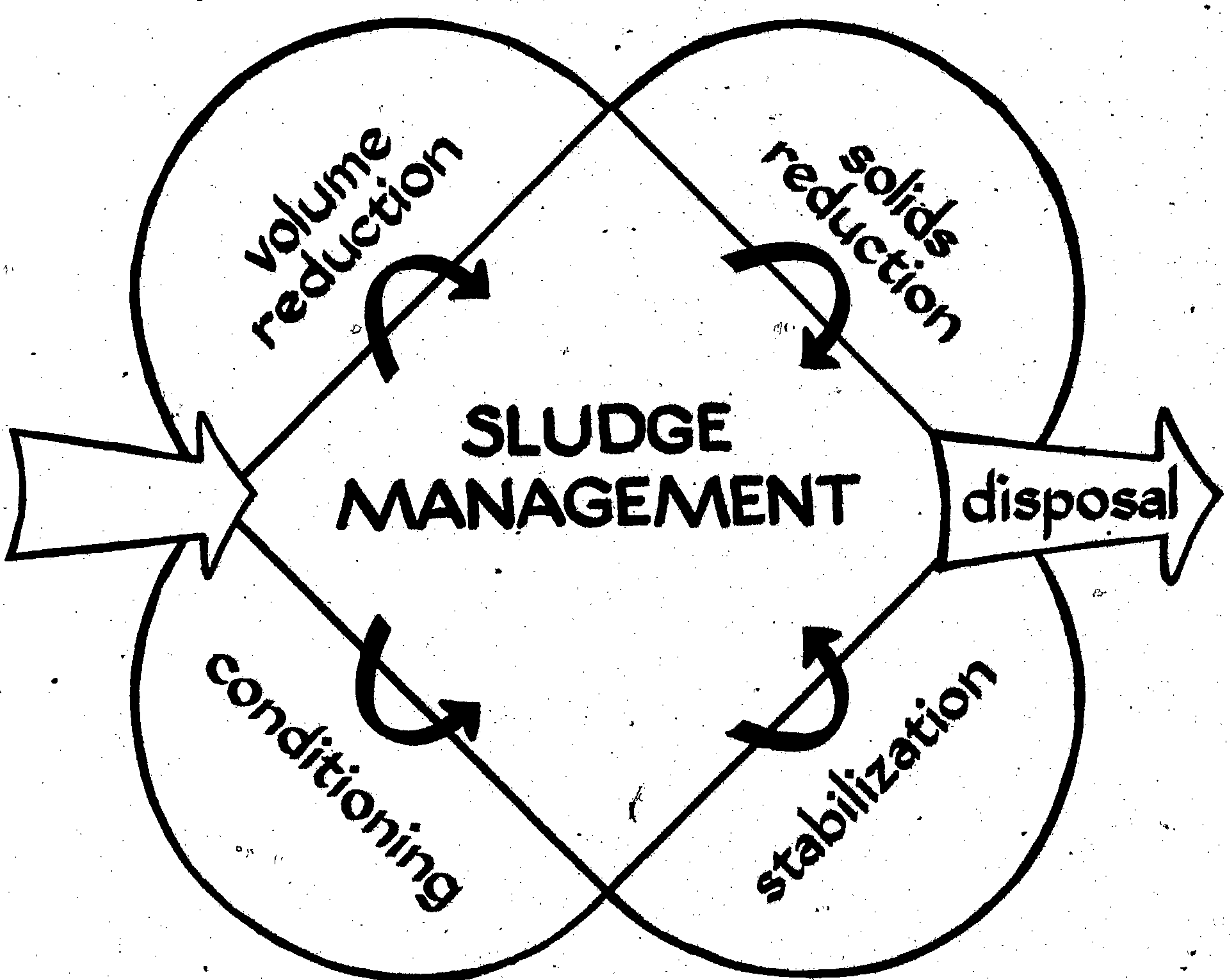
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SLUDGE CONDITIONING



SE041602

STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

SLUDGE CONDITIONING

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CONDITIONING

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Upon completion of this lesson, the student should be able to do the following:

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16. State three uses of hydrated lime as an aid to conditioning.
17. State two uses of ash as an aid to conditioning.

CONDITIONING

GLOSSARY

Coagulation - (1) The agglomeration (clustering) of colloidal and finely divided suspended matter by the addition to the liquid of an appropriate chemical coagulant, by biological processes, or by other means. (2) The process of adding a coagulant and necessary other reacting chemicals.

Colliodal particles - Finely divided solids which will not settle but may be removed by coagulation or biochemical action.

Decant tank - Synonymous with settling tank; used to thicken solids by gravity and remove supernatant.

Floc - Small gelatinous masses formed in a liquid by the reaction of coagulants thereto, through chemical or biochemical processes, or by agglomeration.

Flocculation - The coming together of minute particles in a liquid.

Fly ash - Fine particles removed from the off-gas system in a sludge incinerator.

Gravimeteric - Pertaining to measurement on the basis of weight.

Heat exchanger - A device which provides for transfer of heat from one fluid to another, generally by bringing the two fluids into close proximity in a counter-current arrangement.

Incinerator ash - Inert residue remaining after combustion of sludge in an incineration.

Ion - An atom or group of atoms that carry a positive or negative electric charge as a result of having lost or gained one or more electrons.

Metering pump - A pump designed to accurately deliver specific amounts of material; generally small, positive displacement pumps.

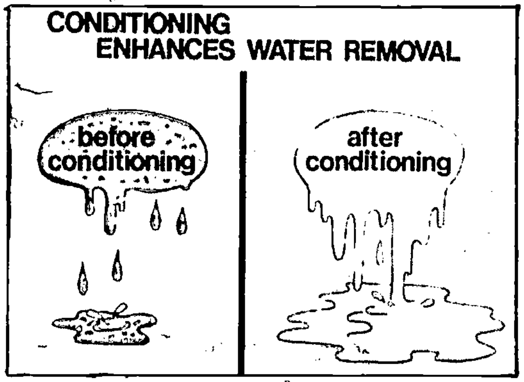
Polymer - A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivitives, and alginates. Synthetic polymers consist of simple substances that have been made into complex, high molecular weight substance. Often called POLY-ELECTROLYTE.

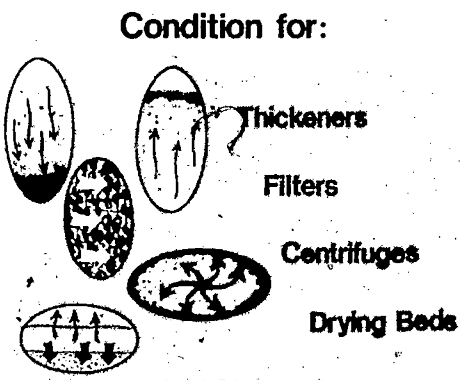
Protein - Biochemical material found in animal and plant tissue. Serves as structural material and enzymes; high in nitrogen. A major organic nutrient in wastewater.

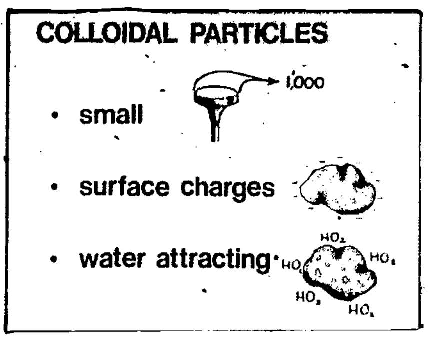
Supernatant - Floating on surface, like oil on water.

Volumetric - Pertaining to measurement on the basis of volume.

SLUDGE CONDITIONING







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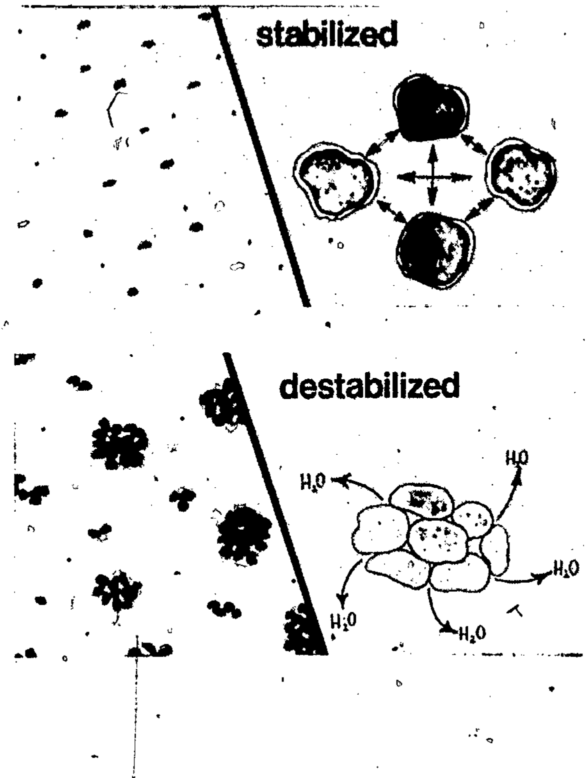
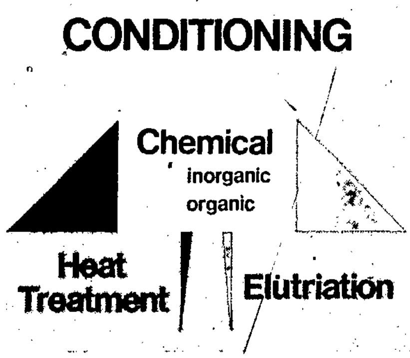
Sludge Conditioning is commonly used prior to thickeners, filters, centrifuges, and drying beds. In fact, for some types of sludges, these treatment processes will not work without pretreatment by conditioning.

A significant portion of sludge is colloidal particles. Colloids have three characteristics that make them particularly hard to separate from the surrounding water. They are extremely small. A thousand colloidal particles could line up on the head of a pin. They generally have a negative surface charge and they tend to attract water molecules.

These three colloidal characteristics tend to keep the colloidal solids dispersed. This dispersed condition is referred to as a stabilized system. In the stabilized system the colloidal particles repel each other because of the surface charges and water molecules





They do not settle because of their small size. The result is that the colloidal particles cannot be separated from the surrounding water.

A destabilized system is one in which the dispersed particles come together to form clumps. The clumps form because the surface charges have been reduced and the water molecules released. The clumps become large enough to settle.

Destabilization can be brought about by conditioning processes. Destabilization by conditioning helps the flocculation or clumping process which tends to release water from the sludge particles and improves settling characteristics.

The sludge conditioning processes can be grouped into three categories: chemical, using inorganic or organic chemicals; and heat treatment, are the two most common methods. Elutriation and other aids to conditioning make up the third category. We'll first look at the chemical methods.

Inorganic metal ions destabilize by a process called coagulation. Coagulation is the neutralization of the surface charges of colloidal particles and the removal of the water molecules. Coagulation will effectively remove capillary water and bound water from the sludge. After coagulation, the destabilized particles settle better and are more easily dewatered.

Among the inorganic metal ions commonly used in conditioning as coagulants are ferric iron, ferrous iron and aluminum. Ferric chloride is used as a source of the ferric ions. Ferrous sulfate is used as a source of the ferrous ions and aluminum sulfate or alum provides aluminum ions.

Inorganic - metal ions

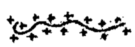
Fe^{+++} ferric chloride

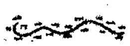
Fe^{++} ferrous sulphate

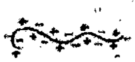
Al^{+++} aluminum sulphate (alum)

The ferric, ferrous and aluminum ions are all highly positively charged. When these ions are added to a negatively charged colliodal system, destabilization occurs as a result of the neutralization of the negative surface charges by the positively charged metal ions.

Organic - polyelectrolytes


cationic


anionic


nonionic

Large organic chemicals called polyelectrolytes can also be used to destabilize a colloidal system. Polyelectrolytes, also called polymers or poly, are extremely long, highly charged molecules. Positively charged polymer is called cationic, the negative charged polymer is anionic, and polymer having equal negative and positive charges is called nonionic polymer.

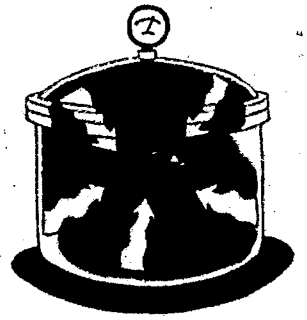
Polyelectrolytes destabilize by coagulation. The highly charged polymers neutralize the surface charges of colloidal particles and remove water molecules in a manner similar to the inorganic metal ions.

POLYELECTROLYTES AND FLOCCULATION

Polyelectrolytes also destabilize by aiding flocculation. Flocculation is the process of coagulated particles sticking together to form larger and larger settleable floc particles. Polymers aid flocculation because their long stringy shape forms bridges or webs between coagulated particles.

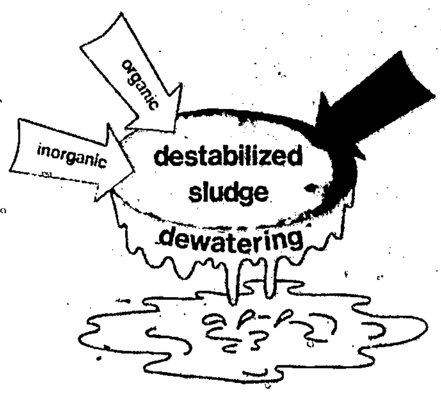
The second common conditioning process is heat treatment.

[redacted]



In the heat treatment process sludge is subjected to high temperatures under pressure. This process is quite similar to a pressure cooker. The biological organisms in the sludge break open under these conditions and release proteins and other cellular material.

Capillary water, bound water and intracellular water is released. The solids in heated sludge are more dense and can be separated from the water by sedimentation.



In summary, inorganic and organic chemicals as well as heat can be used to destabilize sludge, making the dewatering processes that follow more efficient.

Now that we have discussed the theory of sludge conditioning, let's take a look at the conditioning equipment. The use of chemical conditioners means that we must feed either dry or liquid chemicals into the system.

SOLUTION PREPARATION

Typical Conc. (w/w percent)

$FeCl_3$	use directly
Alum	1 - 25%
Polymers	0.05 - 0.5%
Lime	5 - 30%

Dry chemical feed equipment in small plants involves a manually prepared batch process. Dry chemical is carefully measured and added by hand to a solution mixing tank from which it is fed into the system.

In larger plants, dry feed equipment is usually automatic. In an automatic setup the chemical is fed from a hopper into a tank. The mixer helps dissolve the chemical and the solution then goes to the system through the feed line. A pre-wetter spray is often used to insure quick and complete solution of the dry material.

CURING OR MIXING TIME
Necessary for complete solution
Polymers 45 - 60 min.
Lime and Alum 30 min.
Can be shortened for liquid chem.

Dry feeders are available that can deliver a controlled quantity of chemical to the mixing tank either on the basis of volume or weight. This gravimetric feeder operates on the basis of weight and is used to deliver alum to a mixing tank.

Some types of chemicals are delivered to the plant as liquid and are fed directly into the system with a chemical feed pump.

METERING PUMPS

As with the dry chemical feeders, the liquid feed system must have a liquid feed pump or metering pump capable of delivering a precise volume of liquid to the system.

CONDITIONERS
*Gentle Mix
*Observation Point

Where chemical conditioning is used prior to dewatering processes such as vacuum filters or centrifuges, the metering pump feeds chemicals to a mixing tank referred to as a conditioner.

In the conditioner unit the chemicals are mixed with the incoming sludge. The destabilizing action of the conditioning chemicals occurs in the conditioner.

The destabilized or conditioned sludge then flows to the dewatering unit. Thickened sludge is drawn off for further processing and the liquid is returned to the plant as a recycle sidestream.

Several types of conditioner units are available. However, regardless of the configuration, the conditioner must provide gentle mixing to disperse the chemical throughout the sludge without tearing the fragile floc. It must also provide visual observation points. The operator should be able to view the action to assure proper dosage and mixing speed.

Where chemical conditioning is used prior to gravity thickeners or flotation thickeners, the chemical can be added directly to the sludge line. In this arrangement, the thickener basin serves as the conditioner unit, in which the slow mixing and destabilization of sludge occurs.

Now let's turn our attention to the equipment used in the heat treatment process.

HEAT CONDITIONING COMPONENTS

***Heat Exchanger**

***Reactor**

The heat conditioning process consists of two major components: the heat exchanger and the reactor.

Sludge flows through the heat exchanger where it is pre-heated and then into the reactor where the desired temperature and pressure are attained and the conditioning reaction occurs. Heat conditioned sludge is then cooled in the heat exchanger, decanted, and sent on to a dewatering unit.

HEAT TREATMENT

Temperatures - 300 - 500° F

Pressures - 150 - 400 psig

Dentention Time - 20 - 40 minutes

Theory - Breaks open cells to release bound water and solubilize cellular material.

The reactor is the heart of the operation. Steam is supplied to the reactor to raise the temperature to the desired range. The entire system is also pressurized. The reactor provides for the desired reaction detention time.

The heat exchanger serves two purposes. Cool, incoming sludge is preheated by hot sludge leaving the reactor. At the same

DECANT

***Watch the sidestream!**

time, the conditioned sludge is cooled before going to the decant tank.

The main operational goal in working with chemical conditioning is to determine the most effective chemical types and dosages. Laboratory tests are performed to determine the most effective chemical types and dosages. The operator then sets the feeders accordingly.

What are the best lab tests for chemical dosage?

In the laboratory, the capillary suction time test, the jar test, the specific resistance test, and the filter leaf test can be used to check various chemical types and to determine optimum dosages.

ECONOMICS

Cost of operation is always any operational concern. The operator should calculate pounds of chemicals used per ton of dry sludge produced and from that number, the cost per ton of dry sludge produced. From the calculations, the operator can balance conditioned sludge quality with cost.

Sludge must be handled carefully prior to, during and after conditioning. Any vigorous physical process such as pumping, violent mixing and aging before conditioning can make conditioning more difficult. Rough handling after conditioning can break the flocculated particles and disperse the solids.

The point of application and the order of addition of chemicals to the sludge also have an effect. Some chemicals work quickly, some slowly. Some chemicals work best first, others work best as a secondary chemical.

The point of application and the order of addition of chemicals to the sludge also has an effect. Some chemicals work quickly, some slowly. Some chemicals work best first, others work best as a secondary chemical.

OPERATOR CONTROLS:

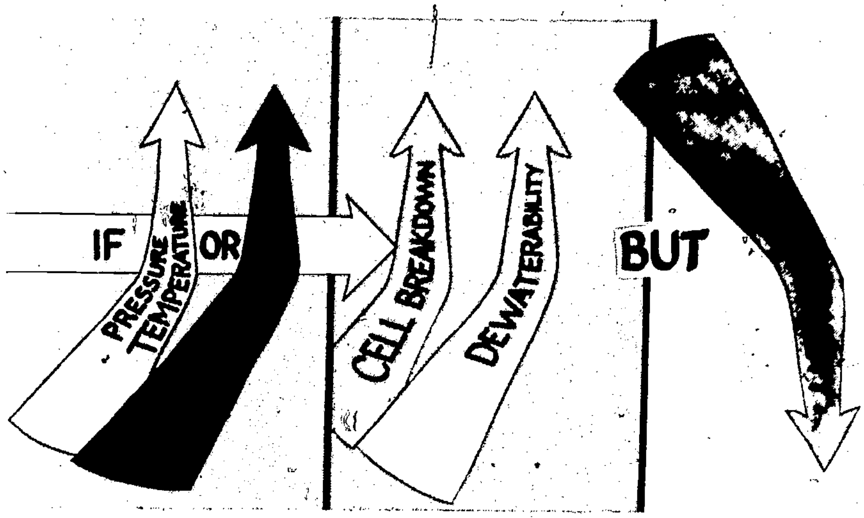
*Pressure

*Temperature

*Feed Rate

In order to obtain optimum dewaterability after heat conditioning, the operators can control these variables: pressure, temperature, and feed rate, which directly effects detention time.

These factors are all interrelated. Generally, if pressure and temperature or detention time are increased cell breadkown and thus, dewaterability will improve.



But, at the same time, the quality of the sidestream from the decant and dewatering unit deteriorate putting a heavier load on the head of the plant.

Therefore, the operator must continually balance improved dewaterability with side-stream quality by controlling pressure, temperature, and feed rate.

There are several items that are related to conditioning that are referred to as aids to conditioning. The elutriation process and the use of lime and ash are in this category.

ELUTRIATION

Elutriation is a washing process. Its main purpose is to reduce chemical requirements and remove very fine suspended particles from the sludge. These fine sludge particles and some dissolved chemicals are removed by dilution with plant effluent, followed by re-settling. The supernatant side stream that results represents significant load on the plant.

OTHER CONDITIONERS

***Hydrated Lime**

***Ash**

Hydrated lime is used as an aid to conditioning. It is used in conjunction with the inorganic metals ions. Although it does have a dehydrating effect on colloids, its main use is for pH control, odor control, and disinfection.

Ash is also used as an aid to conditioning. Both fly ash and incinerator ash can be used to absorb moisture and to add mass to light floc.

To summarize, many of the sludge handling processes can be made more efficient by conditioning the sludge. Conditioning can be accomplished by the addition of organic and inorganic chemicals and by heat treatment. Elutriation, lime, and ash can be used to aid in the conditioning process.

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2. Operations Manual, Sludge Handling and Conditioning, USEPA, EPA 430/9-78-002, Washington, D.C., 1978.

3. WPCF Manual of Practice No. 20, Sludge Dewatering, Water Pollution Control Federation, Washington, D.C., 1969.

4. Treatment and Disposal of Wastewater Sludges, P. Aarne Vesilind, Ann Arbor Science, Ann Arbor, 1979.

SLUDGE CONDITIONING - WORKSHEET

1. Sludge conditioning is

   _____ a. The chemical alteration of sludge to improve its fertilizer value.

   _____ b. The pre-treatment of sludge to enhance water removal.

   _____ c. The bacterial stabilization of septic sludge to reduce pathogenicity.

   _____ d. High speed agitation in a vortex mixer.

2. Place an X by the solids handling processes which are commonly preceded by conditioning.

   _____ a. filter presses

   _____ b. anaerobic digester

   _____ c. centrifuge

   _____ d. gravity thickener

   _____ e. sludge lagoon

   _____ f. vacuum filter

3. Colloidal particles are:

   _____ a. heavy, charged, sand

   _____ b. large, positive, bacteria

   _____ c. small, positive charged, attract water

   _____ d. small, negative charged, attract water

4. Which of the following is a characteristic of a destabilized colloidal system?

   _____ a. particles settle well

   _____ b. dispersed particles

   _____ c. particles attracting water molecules

   _____ d. particles highly charged

5. Which of the following are inorganic chemical used for conditioning?

   _____ a. ferric chloride

   _____ b. aluminum sulfate

   _____ c. sodium sulfate

   _____ d. ferrous sulfate

   _____ e. potassium nitrate

6. Match the three polyelectrolytes with their appropriate electrical surface charge.

_____ cationic — a. neutral charge

_____ nonionic — b. positive charge

_____ anionic — c. negative charge

7. Conditioning by heat treatment is:

_____a. subjecting dewatered sludge to slow drying in a drying bed using the heat of the sun.

_____b. is a process which converts all proteins and carbohydrates into easily usable ATP.

_____c. sludge subjected to high temperatures and pressure.

_____d. sludge heated in a multiple hearth furnace

8. Which of the following statements about chemical feeders is <u>not</u> true?

_____a. dry chemical feeders can be batch or automatic.

_____b. dry chemical feeders can be gravimetric or volumetric.

_____c. the two major types of feeders are dry and liquid.

_____d. both dry and liquid feeders require pre-wetting in mixing tank.

9. A chemical conditioning tank provides for which of the following?

_____a. slow, gentle mixing

_____b. sedimentation of sludge

_____c. visual observation by operator

_____d. mixing of dry chemicals

10. Which two of the following are the major functions of the heat exchanger?

_____a. cools the steam coming from the reactor.

_____b. preheats the sludge going to the reactor.

_____c. cools the sludge coming from the reactor.

_____d. preheats sludge prior to incineration.

11. The heat treatment reactor

_____a. is a pressurized system.

_____b. provides reaction detention time.

_____c. is heated by steam.

_____d. follows the decant tank.

12. Match the following:

_____a. handle sludge carefully

_____b. elutriation

_____c. consider point of application

_____d. consider sequence of addition

_____e. disinfection

_____f. odor control

_____g. pH control

1. An operational variable for chemical conditioning.
2. A use for hydrated lime.
3. A washing process.

13. Match the following:

_____a. filter leaf

_____b. temperature control

_____c. jar test

_____d. specific resistance

_____e. pressure control

_____f. adds mass

_____g. solids feed rate

_____h. absorbs moisture

_____i. capillary suction time

1. A laboratory test used to determine optimum chemical dosages.
2. An operational variable for heat treatment conditioning.
3. A use for ash.