PROCEEDINGS, 46th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 15-17, 2021
SGP-TR-218

The Importance of Cooling Water Treatment System at Lumut Balai Geothermal Power Plant

Erwandi Yanto, Muhammad Abimas Halimzikri, Aris Budiyanto, Andre Tiofami, Dzuriat Khasani, Hadi Suranto

PT. Pertamina Geothermal Energy

Jalan Proklamasi Blok J 24, Lorok Pakjo, Kel. Demang Lebar Daun, Kec. Ilir barat 1, Palembang, South Sumatra 30137

erwandi.yanto@pertamina.com

Keywords: Microorganism, Biocide, Chemical Treatment, Water Quality, Cooling Tower

ABSTRACT

Cooling tower (CT) water treatment is fundamental to minimize the growth of microorganisms, minimize the formation of scaling, minimize corrosion and minimize sediment or solids deposition on the contact area of heat transfer on the surface. The problem that often occurs in cooling water systems with open circulation is the growth of microorganisms. Microorganisms are living bodies that have a very small size (usually less than 1 mm) so that various auxiliary tools are needed to observe them. Some of the factors that can cause the growth of microorganisms are food substances for microorganisms, water temperature, degree of acidity, dissolved oxygen, sunlight, the number of bacteria, turbidity, the volume of moss, level of moss attachment, water flow rate, and others. Treatment of algae and microorganism existences in cooling water can be controlled by using microorganism control agents. The control material is divided into two, namely by using Oxidizing Biocide inhibitors and Non-Oxidizing Biocide Inhibitor. The difference between both of them, in general, is that the oxidizing biocide inhibitor works directly by killing microorganisms. Meanwhile, non-oxidizing biocide inhibitors play a role by suppressing the growth of these microorganisms. On the other hand, the impact of this chemical is foaming appearance in CT basin resulting in a decrease in the vacuum condenser. When there is a decrease in the vacuum condenser, steam consumption will increase, and if the available steam supply is insufficient, in other words, the generation load will decrease. Eventually, the usage of non-surfactant and oxidizing biocide are used to prevent the foaming and microorganism itself. In this case, Lumut Balai Geothermal Power Plant use Biocide N7330 and Biocide YID000009 as the control agent of microbiology growth.

1. INTRODUCTION

The cooling equipment system commonly used in Geothermal Power Plants is a type of cooling water system with an open circulation, which means that the cooling system is directly related to the outside air circulation. The open circulation cooling water system will allow the outside air from the surrounding environment to interact directly with the secondary cooling water in the cooling tower. Cooling tower is a part of the cooling water system equipment that functions to cool the hot condensate water that comes out of the condenser by forcibly contacting it with the surrounding air using a fan or fan.

Cooling tower water treatment is very important, because the process is directly related to the performance of the cooling tower. The principles of cooling tower water treatment are to minimize the growth of microorganisms, minimize the formation of scaling, minimize corrosion and minimize sediment or solids deposition on the contact area of heat transfer or heat transfer surface.

The problem that often occurs in cooling water systems with open circulation is the growth of microorganisms. Microorganisms are living bodies that have a very small size (usually less than 1 mm) so that various supporting tools are needed to observe them. Some of the factors that can cause the growth of microorganisms are food substances for microorganisms, water temperature, degree of acidity, dissolved oxygen, sunlight, number of bacteria, turbidity, volume of moss, level of moss attachment, water flow rate and others.

Treatment of algae and microorganism problems in cooling water can be done by using microorganism control agents. The control material for the growth of microorganisms in the cooling water system is divided into two, namely by using an oxidizing biocide inhibitor (oxidizing bioxide) and a non-oxidizing biocide inhibitor (non-oxidizing bioxide). The difference between the two biocides in general is that the oxidizing biocide inhibitor works directly by killing microorganisms. Meanwhile, non-oxidizing biocide inhibitors play a role by suppressing the growth of these microorganisms.

2. OVERVIEW

2.1 Lumut Balai Geothermal Power Plant Overview

Flash Cycle Plant with a flash steam system draws water high pressure heat from the depths of the earth enters into a low pressure tank and then using steam generated to turn the turbine. This system requires a fluid temperature of at least180 ° C; usually more. This is the most types commonly operated today.

Lumut Balai Geothermal Power Plant is a kind of power plant using the Single Flash Cycle, so take high pressure hot water from the reservoir into the low pressure tank then using the resulting steam to turn the turbine. After turning the steam turbine condensed using direct contact condenser before injection back into the reinjection wells, the condensation process is assisted by using Cooling Tower as Recirculating Cooling Water. So that the Cooling Tower has important role in Power Plant. In addition, Power Plant is also equipped with

Water Treatment Plant which is used as a service water source and additional water at the process of closed circulating cooling water (Auxilary Cooling Water) reinjection to the wells.

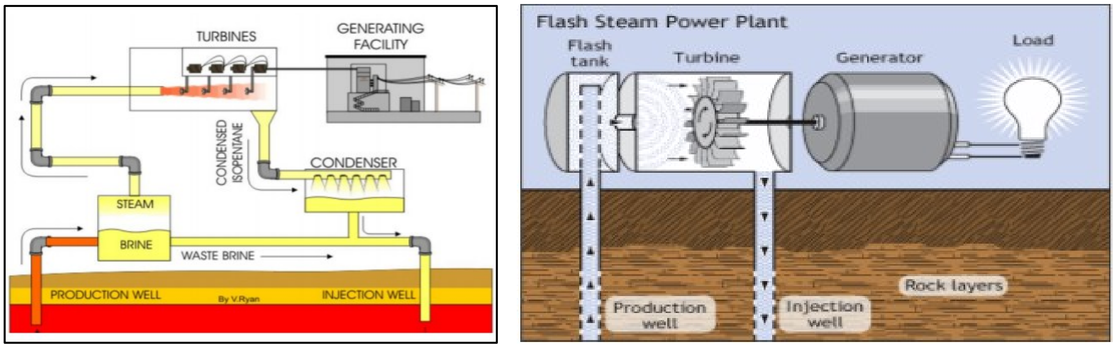


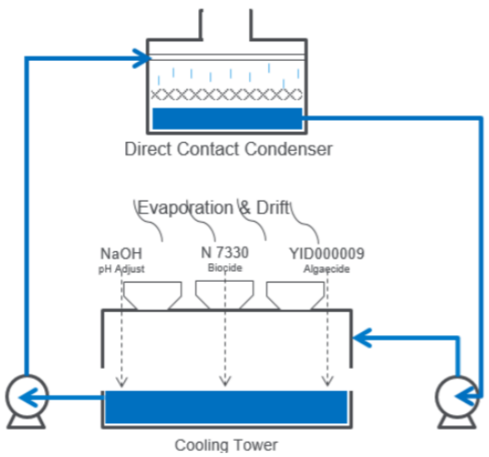
Figure (a,b) Lumut Balai Flash Cycle Plant Type

2.2 Open Cooling System Chemical Treatment

The Open Cooling System is a critical component of the Geothermal Power Plant, The Open Cooling System plays an important role in the efficiency of the steam cycle at the plant geothermal power. The following is an overview of the plant survey from Open Cooling System of Lumut Balai Geothermal Power Plant.

Open Cooling System, which in this case is a cooling tower from Lumut Balai Geothermal Power Plant, still maintained in a good pH so that corrosion can be avoided. However There are other things that need to be considered again in the Cooling Tower besides maintaining pH namely Microbiological Activity.

Microbiological Activity in Cooling Tower is something that must be considered, because moss and algae can thrive in this Cooling Tower system, then the moss will overload the filler pack, so the filler pack will become heavier and can fall and disrupt the Plant production process. In collaboration with Nalco Water (An Ecolab Company), resulted the chemical composition to control microbiology in Cooling Tower System.



Chemical	Description
N 7330	**N 7330** is a broad-spectrum, Non-Oxidizing biocide approved for use in recirculating cooling towers, closed loop cooling systems, air washers and brewery pasteurizers.
YID000009	**YID000009** is a Non-Oxidizing, liquid organic micro biocide containing Algaecide compound formulated for use in industrial once-through or recirculating cooling water systems.
NaOH	**NaOH** is an alkalinity source for Cooling Tower (pH adjustment in Cooling Tower).

Figure (c) Open Cooling System, (d) Chemical Composition Treatment

Biocide YID000009 is a non-oxidizing liquid biocide containing quaternary ammonium compounds and is formulated for industrial use with once-through or recirculation cooling water systems. Biocide YID000009 has the advantage of being biodegradable so that its use at the right concentration can be well accepted by the environment, and with the addition of Biocide YID000009 it does not have an effect on cooling water such as lowering the pH value and causing corrosiveness as found in the chlorination or bromination method.

Biocide N7330 is a non-oxidizing liquid biocide that has been widely used in industry with recirculating cooling water systems, closed cooling water systems and others. The use of N7330 biocide also does not have an effect on cooling water such as decreasing the pH value and causing corrosivity by the product. Cooling tower that maintains normal pH and avoids microbiological conditions can become valuable asset because it can save costs for damages on the components and as a whole.

2.3 Cooling Tower Performance Overview

Cooling Tower Efficiency of Lumut Balai Geothermal Power Plant is still> 70%, this is a good indication of Cooling Tower performance. Therefore, maintaining the cooling tower condition from the mechanical, operational, and Chemicals is critical to maintain maximum heat transfer conditions between air and Cooling Water return.

Formula :

Tower Range Temperature (°C) = CW Return (°C) – CW Supply(°C)

Cooling Tower Approach Temperature (°C) = CW Supply(°C) – Wet Bulb (°C)

Cooling Tower Efficiency % = 100% x (Tower Range Temperature (°C) / (Tower RangeTemperature (°C) + Cooling Tower Approach Temperature (°C)))

Tabel (1) Cooling Tower Performance

Parameter	Cell A	Cell B	Cell C	Cell D	Cell E	Cell F
CW Supply (°C)	23,7	23,7	23,7	23,7	23,7	23,7
CW Return (°C)	33,7	32,2	33,4	31,5	32,5	33,5
DB Temp (°C)	22,5	22,5	22,5	22,5	22,5	22,5
RH (%)	82	82	82	82	82	82
WB Temp (°C)	20,4	19,4	19,4	19,4	19,4	19,4
CT Approach (°C)	3,3	3,3	3,3	3,3	3,3	3,3
Tower Range (°C)	10	9,5	10,7	8,8	9,8	10,8
CT Efficiency (%)	75%	74%	76%	73%	75%	77%

3. ISSUES

At Geothermal Power Plant Lumut Balai Unit 1, the method of handling the problem of moss and microorganisms used is to use a microorganism control agent with a non-oxidizing biocide inhibitor type. The biocide used was obtained from the provision of microorganism control materials with one of the feelings of cooling water treatment. The product names for the biocide used in PLTP Lumut Balai Unit 1 are Biocide YID000009 and Biocide N7330.

Figure (e) Foam Condition of CT Basin

Tabel (2) Water & Microbio Analysis

PARAMATER	STANDARD	COOLING TOWER BASIN	REMARK
pH	6,8 - 7,5	6,59	Ok, On Range
Specific Conductivity (µs/cm)	-	78,33	
Turbidity (NTU)	< 15	0,79	Ok, On Range
Total Iron (ppm Fe)	< 1	trace	Ok, On Range
Copper (ppm Cu)	< 0,2	trace	Ok, On Range
Sulfate (ppm SO_4)	-	16	
Silica (ppm SiO_2)	< 0,8	0,143	Ok, On Range
Zinc (ppm Zn)	-	0,03	
Nitrite (ppm NO2)	-	2,3	
Nitrate (ppm NO3)	-	5,0	
Total Aerobic Bacteria (CFU/mL)	< 10000	< 1000	Ok, On Range
Biofilm Aerobic Bacteria (CFU/mL)	-	90000	

Based on **Table (2)** The pH Cooling Tower Water area is slightly lower than the standard, namely 6.59 (Standard pH cooling tower basin 6.8 - 7.5). Turbidity value is 0.79 NTU (Standard turbidity <15 NTU). Total Iron (Fe) is appropriate standard <1 ppm, Cooper (Cu) is <0.2 ppm, Silica (SiO2) is still <0.8 ppm, Aerobic Count in Cooling Tower Basin according to standard <10,000 CFU / mL, and Sulfate is relatively higher than previous data.

Table (3) in enclosure page shows that basin water quality is free from Organic Content, Oil & Grease, and has value Low COD & BOD. Meanwhile, **Table (4)** represent that quality Water Sample Transmitter has no contain Oil & Grease, There is microbiological activity that can be proven by the content Ammonia, Sulfate, Sulfide, Nitrate. In addition, the COD & BOD amount in the sample is quite high, and has a very low pH, with a high enough Fe content.

4. DISCUSSION

4.1 Aerobic Bacteria Count

Based on the existing data in Water & Microbiology Analysis, the amount of Aerobic Bacteria Count well maintained under the control limit of <10000 CFU / mL. This matter is an indication that the treatment has been going well, regularly visually also the moss that grows on the filler is very little, so that the transfer of heat between cold air and cooling water return occur optimally. It can also be proven by the calculation of Cooling Tower Efficiency which is still> 70%.

Level Transmitter Water Sample Analysis

In analyzing the content of water samples at the level transmitter, it can be seen that there is a high enough organic content as evidenced with the value as follows:

1. TOC : 297 ppm
2. Ammonia : 5 ppm
3. Nitrate : 0.9 ppm
4. Sulfate : 76 ppm
5. Sulfide : 105 ppm
6. COD : 2079 ppm
7. BOD : 1218 ppm

The large number of sulfate values is an indication of the presence of Sulfur Oxidizing Bacteria converting H2S gas into elemental sulfur compounds to react with water forming sulfuric acid which can lower the pH value of the bulk water in cooling Water System according to the reaction below:

$$2H_2S + O_2 \rightarrow 2S\ (solid) + 2H_2O \quad (1)$$

$$2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4 \quad (2)$$

With the sulfuric acid produced by the above reaction, we can see that the pH is These samples were very acidic, and may have been localized corrosion which is also proven from the Iron content value which is> 10 ppm. Meanwhile, Ammonia and Nitrate are nutrients from bacteria in nitrogen cycle, which can be seen from the following figure:

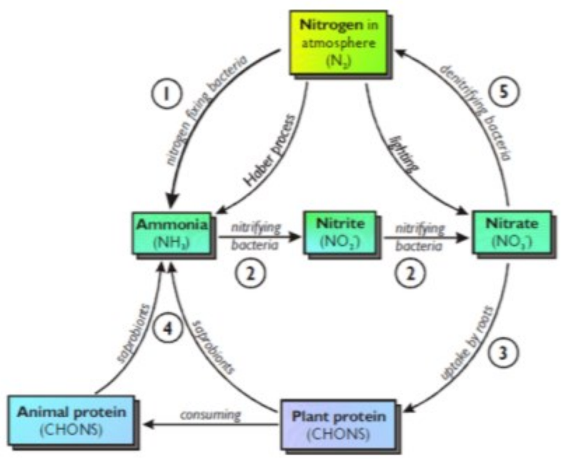


Figure (f) Nitrogen Cycle

The main focus is currently being monitored to the Geothermal Power Plant Lumut Balai cooling tower basin, namely by carrying out the biocide injection process to inhibit the growth of microorganisms and by paying attention to the quality of cooling water and not causing the effect of foaming both on the cooling tower basin and on the condenser.

4.2 Sludge from Foaming

Foaming can be formed due to the presence of chemicals containing surfactants, so that there is air trapped in a thin layer of water. Apart from that because surfactants have a hydrophobic tip and a hydrophilic tip, a hydrophobic tip will bind a suspended solid or dirt like mud together with the ends hydrophylic bound together with water. So that the mud will follow and if trapped in dry areas, water originally contained in mud it will evaporate or come along with the humidity of the air.

The mud is found on the ditch side of the Lumut Balai Cooling Tower, from the analysis results it can be seen that the main component of the mud Silicon Oxide or sand, so the mud is a collection suspended solids such as sand, iron, which bond with the foaming and dry out. It can also be proven that in the ditch that did not occur foaming, not many were found the sludge formed.

5. CONCLUSION & RECOMMENDATION

- At Geothermal Power Plant Lumut Balai Unit 1, the dosage used for one injection a week is 270 liters for Biocide YID000009 and 320 liters for Biocide N7330. The biocide injection process is carried out on the header pipe section with a size of DN1800 output from the Hot Water Pump to the Cooling Tower, where the pipe has a turbulent type of water flow and it is assumed that the injected biocide will be evenly distributed to all parts of the Cooling Tower. The recommended injection process is to inject the biocides with one injection stage. Meanwhile, the injection process carried out at Geothermal Power Plant Lumut Balai Unit 1 is to divide it into three injection stages for Biocide YID000009 and one injection stage directly for Biocide N7330.

- The distribution of injection stages in Biocide YID000009 is carried out because in the Biocide there are surfactant compounds that can cause foaming to form in the cooling tower basin. Foaming can be formed when there are three elements in a solution or what is commonly known as a foam triangle. Where in the foam triangle other factors that influence the formation of foam are air, water and contaminants. Contaminants that are meant by other words are the biocides used.
- The foaming formed is indicated not only in the cooling tower basin but also in the condenser. This can be attributed to when the Biocide YID000009 injection process is carried out, foaming will form in the cooling tower basin and cause the vacuum condenser to decrease. When there is a decrease in the vacuum condenser, steam consumption will increase, and if the available steam supply is insufficient, in other words, the generation load will decrease.
- It is better if the observation of microbiological analysis is carried out periodically to find out the trend of the decrease in the value of Aerobic Bacteria Count, so that the value can be kept below the standard, which is 10000 CFU / ml.
- Contamination in the CT basin is at the transmitter level is a microorganism carried from the cooling tower basin which is trapped in level transmitter. These microorganisms are carried in the form of sludge that is formed due to being bound by the surfactants present in one of the chemical treatments in cooling tower.

REFERENCES

Nalco Water, Technical Visit Service Report, An Ecolab Company, Lumut Balai Area (2020).

Nontoxic Biofouling Control Technologies, EPRI, Palo Alto, CA: 1998. Report TR-111830

Power station cooling tower water systems—Management of legionnaires' disease health risk. AS 5059—2006

SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks), Assessment of the Antibiotic Resistance Effects of Biocides, 19 January 2009 vii Selby, Anthony Cooling System Microbiological Control and Monitoring Power Plant Chemistry (2011) 13(7)

The Nalco water handbook Third Edition McGraw Hill pp 21.23 (2009)

Water Treatment Strategies: Microorganism Control, EPRI, Palo Alto, CA: 2004. 1009598

Williams, Terry The Mechanism of Action of Isothiazolone Biocides Power Plant Chemistry (2007), 9(1)

ENCLOSURE

Table (3) Laboratory Analysis – Full Water Properties
Cooling Tower Basin

SAMPLE IDENTIFICATION				
SAMPLE CODE				732.2
SAMPLE NAME				BASIN
ANALYSIS DESCRIPTION	UNIT	LIMIT OF DETECTION METHOD	TEST METHOD	RESULT
pH (25°C)		-	APHA4500-H-B	6.37
Conductivity	umhos	-	APHA2510B	70.60
P-Alkalinity	mg/L $CaCO_3$	2.00	AP-59	<2.00
M-Alkalinity	mg/L $CaCO_3$	2.00	AP-59	4.40
Sulfate	mg/L SO_4	2.00	AP-08	12.00
Chloride LL	mg/L Cl^-	0.10	METHODE 8113	0.90
Ammonia	mg/L $N\text{-}NH_3$	0.04	AP-73	0.20
Nitrate HR	mg/L $N\text{-}NO_3$	0.30	APHA 4500-NO_3E	0.50
Nitrite	mg/L $N\text{-}NO_2$	3.00	AP-03	<3.00
Fluoride	mg/L F^-	0.02	APHA 4500- F^-D	<0.02
Turbidity	NTU	0.02	APHA2130B	2.24
Color	PtCo	15.00	APHA 2120C	<15.00
TDS	mg/L Solid	5.00	APHA 2540C	35.30
TSS	mg/L Solid	5.00	8006	<5.00
COD	mg/L O_2	5.00	APHA 5220D	<5.00
BOD	mg/L O_2	5.00	DIN 38409-H52	<5.00
Total Organic Content	mg/L O_2	5.00	APHA 5220-D	<5.00
Sulfide	µg/L S^{2-}	10.00	AP-56	<10.00
Oil & Grease	mg/L Oil	5.00	APHA 5520-B	<5.00
$Iron^{2+}$ (ppb level)	µg/L Fe	3.00	AP-22	9.00
Aluminium	mg/L Al	0.020	APHA3120B	<0.02
Barium	mg/L Ba	0.015	APHA3120B	<0.015
Copper	mg/L Cu	0.015	APHA3120B	<0.015
Iron	mg/L Fe	0.015	APHA3120B	<0.015
Zinc	mg/L Zn	0.010	APHA3120B	<0.010
Potassium	mg/L K	0.030	APHA3120B	0.77
Natrium	mg/L Na	0.015	APHA3120B	0.53
Silica	mg/L SiO_2	0.015	APHA3120B	0.24
Calcium	mg/L Ca	0.005	APHA3120B	0.43
Magnesium	mg/L Mg	0.010	APHA3120B	0.10
Ca- Hardness (By Calculation)	mg/L $CaCO_3$	0.005	APHA3120B	1.07
Total- Hardness (By Calculation)	mg/L $CaCO_3$	0.050	APHA3120B	1.50

Table (4) Laboratory Analysis – Full Water Properties
Level Transmitter Water

SAMPLE IDENTIFICATION				
SAMPLE CODE				732.1
SAMPLE NAME				LEVEL TRANSMITTER
ANALYSIS DESCRIPTION	UNIT	LIMIT OF DETECTION METHOD	TEST METHOD	RESULT
pH (25°C)		-	APHA4500-H-B	3.35
Conductivity	umhos	-	APHA2510B	317.00
P-Alkalinity	mg/L $CaCO_3$	2.00	AP-59	<2.00
M-Alkalinity	mg/L $CaCO_3$	2.00	AP-59	<2.00
Sulfate	mg/L SO_4	2.00	AP-08	76.00
Chloride LL	mg/L Cl^-	0.10	METHODE 8113	1.60
Ammonia	mg/L N-NH_3	0.04	AP-73	5.00
Nitrate HR	mg/L N-NO_3	0.30	APHA 4500-NO_3E	0.90
Nitrite	mg/L N-NO_2	3.00	AP-03	<3.00
Fluoride	mg/L F^-	0.02	APHA 4500- F^-D	0.03
Turbidity	NTU	0.02	APHA2130B	520.00
Color	PtCo	15.00	APHA 2120C	12.00
TDS	mg/L Solid	5.00	APHA 2540C	158.50
TSS	mg/L Solid	5.00	8006	1758.00
COD	mg/L O_2	5.00	APHA 5220D	2079.00
BOD	mg/L O_2	5.00	DIN 38409-H52	1218.00
Total Organic Content	mg/L O_2	5.00	APHA 5220-D	297.00
Sulfide	µg/L S^{2-}	10.00	AP-56	105.00
Oil & Grease	mg/L Oil	5.00	APHA 5520-B	<5.00
$Iron^{2+}$ (ppb level)	µg/L Fe	3.00	AP-22	12350.00
Aluminium	mg/L Al	0.020	APHA3120B	3.48
Barium	mg/L Ba	0.015	APHA3120B	<0.015
Copper	mg/L Cu	0.015	APHA3120B	<0.015
Iron	mg/L Fe	0.015	APHA3120B	10.69
Zinc	mg/L Zn	0.010	APHA3120B	0.01
Potassium	mg/L K	0.030	APHA3120B	0.33
Natrium	mg/L Na	0.015	APHA3120B	0.57
Silica	mg/L SiO_2	0.015	APHA3120B	2.89
Calcium	mg/L Ca	0.005	APHA3120B	1.55
Magnesium	mg/L Mg	0.010	APHA3120B	0.36
Ca- Hardness (By Calculation)	mg/L $CaCO_3$	0.005	APHA3120B	3.87
Total- Hardness (By Calculation)	mg/L $CaCO_3$	0.050	APHA3120B	5.36

Table (5) Laboratory Analysis – Deposit Analysis
Cooling Tower Sludge

Elemental analysis by X-ray Fluorescence

The sample preparation was: Dried at 105 °C

Silicon (SiO_2)		13 wt %
Iron (Fe_2O_3)		12 wt %
Aluminum (Al_2O_3)		6 wt %
Copper (CuO)		2 wt %
Phosphorus (P_2O_5)		1 wt %
	Total From XRF: 36	wt %

Total From XRF + Loss at 925 °C = 100%

The following elements were not detected or were below the reporting limit (< 0.5%):

Sb As Ba Bi B Br Cd Ca Ce Cs Cl Cr Co Cu Dy Er Eu F Gd Ga Ge Au Hf Ho In I Ir Fe La Pb Li Lu Mg Mn Hg Mo Nd Ni Nb Os Pd Pt K Pr Re Rh Rb Ru Sc Sm Se Ag Na Sr S Ta Te Tb Sn Tm Ti W Tl Th U V Yb Y Zn Zr

Gravimetric Tests

Carbonate (CO_2)	<1 wt %
Dichloromethane extract	11 wt %
Loss at 925°C	64 wt %

The Loss at 925 °C includes water of hydration, CH_2Cl_2 extractables, all organics (carbon, hydrogen, nitrogen), many sulfur compounds and the CO_2 from most carbonates, and some volatile compounds.

Additional Tests

CHNS Analysis

Carbon	43 wt %
Hydrogen	6 wt %
Nitrogen	4 wt %
Sulphur	4 wt %