

## Lesson Plan: Black Carbon and its Impact on Earth's Climate

A teacher-contributed lesson plan by Dr. Shefali Shukla, Sri Venkateswara College (University of Delhi), India.

As a **High School** or **Undergraduate Chemistry** or **Environmental Sciences** teacher, you can use this set of computer-based tools to teach about **allotropy**, various **allotropes of carbon** and their **structural and physical properties**, **black carbon**, **sources of black carbon** and its **impact on Earth's climate**.

This lesson plan will help students understand the concept of allotropy and various allotropes of carbons. Students will learn about black carbon, the effect of black carbon on the Earth's albedo and therefore, its impact on the climate. This lesson plan will also help students to understand how the immediate effect of controlling black carbon emission can potentially slow down the rate of global warming.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in **Chemistry** or **Environmental Sciences**.

Use this lesson plan to help your students find answers to:

- What are allotropes? What are the various allotropes of carbon and their properties?
- What are the sources of black carbon?
- What are the different effects of black carbon on clouds? How does it modify rainfall pattern?
- How does the deposition of black carbon on ice caps affect melting of the ice?
- Explain how black carbon can have a cooling or warming effect on the planet?
- What is the effect of black carbon on human health?

### About the Lesson Plan

**Grade Level:** High School, Undergraduate

**Discipline:** Chemistry, Environmental Sciences

**Topic(s) in Discipline:** Allotropy, Allotropes of carbon, Black Carbon, Sources of Black Carbon, Heating and Cooling Effects of Black Carbon, Effect of Black Carbon on Human Health, Black Carbon Albedo, Black Carbon Emission

**Climate Topic:** Climate and the Atmosphere, The Greenhouse Gas Effect, Climate and the Anthroposphere

**Location:** Global

**Access:** Online, Offline

**Language(s):** English

**Approximate Time Required:** 90-120 min

## 1 Contents

### 1. Reading (~15 min)

A reading that defines what is allotropy and describes some allotropes of carbon with their properties and uses.

This reading can be accessed at:

<https://courses.lumenlearning.com/introchem/chapter/allotropes-of-carbon/>

### 2. Video (~6 min)

A video that introduces black carbon, an allotrope of carbon and describes its impact on health and climate.

This video can be accessed at:

<http://www.nbclearn.com/climate/cuecard/52513>

### 3. Reading (~10 min)

A reading that describes the albedo effect of black carbon and how it affects the nature and formation of clouds, resulting in both, a warming and cooling effect on the Earth's surface.

This reading can be accessed at:

[https://e360.yale.edu/features/carl\\_zimmer\\_black\\_carbon\\_and\\_global\\_warming\\_worse\\_than\\_thought](https://e360.yale.edu/features/carl_zimmer_black_carbon_and_global_warming_worse_than_thought)

### 4. Classroom/Laboratory Activity (~60-90 min)

For high school students:

A laboratory activity to demonstrate the effect of black carbon on surface temperatures.

This activity can be accessed at:

[https://www.windows2universe.org/?page=/teacher\\_resources/black\\_carbon.html](https://www.windows2universe.org/?page=/teacher_resources/black_carbon.html)

For undergraduates:

A classroom activity to discuss the implications of black carbon emissions on health and climate.

This activity can be accessed at:

<https://serc.carleton.edu/NAGTWorkshops/energy/activities/32421.html>

### 5. Suggested questions/assignments for learning evaluation

- What are allotropes? What are the various allotropes of carbon and their properties?
- What are the sources of black carbon?
- What are the different effects of black carbon on clouds? How does it modify rainfall pattern?
- How the deposition of black carbon on ice caps affects the melting of ice?
- Explain how black carbon can have a cooling or warming effect on the planet?
- What is the effect of black carbon on human health?

## 2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

### 1. Topic introduction and discussion

Use this textbook reading, '[Allotropes of Carbon](#)', provided by Lumen Learning, to introduce allotropy and discuss the various allotropes of carbon. Use this tool to explain the structural details of carbon allotropes, their physical and chemical properties and their applications, especially in materials science.

This reading is available at:

<https://courses.lumenlearning.com/introchem/chapter/allotropes-of-carbon/>

### 2. Discuss an allotrope of carbon- Black Carbon

Use the video, '[Black Carbon](#)' by NBC News Learn, to introduce the topic of black carbon, an allotrope of carbon and describe its sources. Use the video to describe its impact on health and climate. Explain using the video, how black carbon contributes to global warming by altering the albedo of clouds and land and ice surfaces. Discuss how cutting down black carbon emissions can have an immediate impact on the greenhouse effect caused by it.

This video can be accessed at:

<http://www.nbclearn.com/climate/cuecard/52513>

### 3. Develop the topic further

Use the feature article, '[Black Carbon and Warming: It's Worse than We Thought](#)', by Carl Zimmer in *YaleEnvironment360*, published by the Yale School of Forestry & Environmental Studies, to discuss a report that suggests that black carbon is second only to carbon dioxide in its heat trapping power. Use the reading to explain to your students, the various ways in which clouds are affected by soot or black carbon. Discuss how the albedo effect of black carbon, especially in clouds, affects Earth's atmosphere as well as its surface temperatures. Emphasize how black

carbon deposition is speeding up the melting of Himalayan Glaciers. Finally, explain why a reduction in black carbon emissions could cause an immediate slowdown of the planet's warming.

This reading is available at:

[https://e360.yale.edu/features/carl\\_zimmer\\_black\\_carbon\\_and\\_global\\_warming\\_worse\\_than\\_thought](https://e360.yale.edu/features/carl_zimmer_black_carbon_and_global_warming_worse_than_thought)

#### 4. Classroom/Laboratory Activity

For high school students:

Use this inquiry-based hands on laboratory activity, '[Changing Planet: Black Carbon- A Dusty Situation](#)', adapted by Missy Holzer, Jennifer Bergman, and Roberta Johnson of the NESTA/Windows to the Universe team, to help the students to understand the albedo effect of black carbon. Follow the instructions to obtain data for the surface heat absorption capacity of varying concentrations of black carbon on paper. Materials for set-up including students' worksheets are listed in the right-hand column of the summary table. Use the graphed data to discuss with your students the influence of black carbon on the heat absorption ability of the Earth's surface. Discuss how cutting down of black carbon emissions can reduce global surface temperatures.

This activity can be accessed at:

[https://www.windows2universe.org/?page=/teacher\\_resources/black\\_carbon.html](https://www.windows2universe.org/?page=/teacher_resources/black_carbon.html)

For undergraduates:

Use this group activity, '[Energy and the Poor- Black Carbon in the Developing Nations](#)', by Science Education Research Center at Carleton College (SERC Carleton), to discuss how the burning of fossil fuels and biomass-based fuels results in black carbon emissions in developing countries. Use this activity to enable students to 'critically evaluate the impacts of varied household energy sources, synthesize a wide range of social, health and environmental impacts and generate solutions to these problems'. The plan includes downloadable notes for students and teachers with suggested points for discussion. Use the activity plan to direct a 'jigsaw'-method of discussion where individuals within groups research and summarize their findings on varied selected topics related to black carbon, its impacts, and solutions and then re-group to summarize their findings in a 'concept-map' to represent all the aspects of discussion.

This activity can be accessed at:

<https://serc.carleton.edu/NAGTWorkshops/energy/activities/32421.html>

## 5. Questions/Assignments

Use the tools and the concepts learned so far to discuss and determine answers to the following questions:

- What are allotropes? What are the various allotropes of carbon and their properties?
- What are the sources of black carbon?
- What are the different effects of black carbon on clouds? How does it modify rainfall pattern?
- How the deposition of black carbon on ice caps affects the melting of ice?
- Explain how black carbon can have a cooling or warming effect on the planet?
- What is the effect of black carbon on human health?

## 3 Learning Outcomes

The tools in this lesson plan will enable students to:

- define allotropy and describe some allotropes of carbon and their structural properties
- explain what black carbon is and elaborate on its sources
- describe how black carbon affects clouds and cloud formation
- explain the mechanisms of the cooling or heating of the Earth's atmosphere due to black carbon
- describe how glaciers are melting faster because of black carbon
- understand the importance of controlling black carbon emissions to reduce global warming

## 4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

### 1. Reading

A review, 'Black carbon semi-direct effects on cloud cover' by D.Koch and A.D. Del Genio, Atmos. Chem. Phys., 10, 7685–7696, 2010.

This can be accessed at:

[https://pubs.giss.nasa.gov/docs/2010/2010\\_Koch\\_ko04300u.pdf](https://pubs.giss.nasa.gov/docs/2010/2010_Koch_ko04300u.pdf)

### 2. Visualisation

An infographic, 'Black Carbon', by Climate & Clean Air Coalition (CCAC) that explains what black carbon is, its sources, emission rates, impacts on health and climate, and solutions to reduce its emission.

This can be accessed at:

<http://ccacoalition.org/en/slcp/black-carbon>

## 5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided.

We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

### **1. Reading; 'Allotropes of Carbon'**

Provided by [Lumen Learning](#).

### **2. Video; 'Black Carbon'**

Brought by [NBC News Learn](#)- the education division of NBC News.

### **3. Reading; 'Black Carbon and Warming: It's Worse than We Thought'**

A feature article by Carl Zimmer at [YaleEnvironment360](#). Published by the Yale School of Forestry & Environmental Studies.

### **4. Laboratory Activity; 'Changing Planet: Black Carbon- A Dusty Situation'**

Activity adapted by Missy Holzer, Jennifer Bergman, and Roberta Johnson of the [NESTA/Windows to the Universe](#) team. Source: '[Looking into surface albedo](#)' activity by Lisa Gardiner, [UCAR Education and Outreach](#) hosted on [Windows to the Universe](#).

### **5. Classroom Activity; 'Energy and the Poor- Black Carbon in the Developing Nations'**

Activity brought by the [Science Education Resource Center at Carleton College \(SERC\)](#).

### **6. Additional Resources**

Review authored by D. Koch and A.D. Del Genio, Atmos. Chem. Phys., 10, 7685–7696, 2010 (Journal: [Atmospheric Chemistry and Physics](#))

Infographic published by [Climate & Clean Air Coalition \(CCAC\)](#)