street spectra

TEACHING MATERIALS

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INTRODUCTION

This lesson plan is to be used in the classroom of 12 and 13 years old students and aims to educate its users on the topic of light pollution.

Aside from gaining awareness, the students will be introduced to the Street Spectra citizen science project through which they will learn how to analyze and classify sources of light pollution contributing to science as a citizen scientist.

https://streetspectra.actionproject.eu/

These pages will discuss: artificial light at night in general, different types of light pollution, their negative effects as well as the most efficient way to install lighting sources in such a way that any negative impact is minimized.

The Street Spectra project with its objectives as well as its relationship to citizen science are explained during the course. Theory is accompanied with suggested activities adapted to the level of the students.

With this unit the authors intend to gather contents that can be implemented in the classroom, and which can serve as a guide so that both students and teachers can participate in this citizen science project.

In order for a citizen science project to grow the input of researchers, disseminators and a wide range of volunteers are needed. The participation of the students and teachers will directly help the study of light pollution.

street spectra

The creation of the project has been motivated by the global switch out of the older street lighting to new LEDs usually richer in blue-rich white light emission.

Street Spectra is asking citizen scientists - including school pupils! - to help collect data on what kind of street lighting is used around the globe. This data goes into a database that everyone has contributed to. It is public and will allow scientist to study the effects of this change on technology onto light pollution.

Street Spectra joined the ACTION team as pilot initiative at the beginning of 2019. It is currently using epicollect5 as tool for gathering the information although an ad hoc mobile application is being developed to improve citizens experience.

It also includes a gallery that gathers appealing photographs, the full database of the project, a space for schools to show their experience involving young students and a blog with a base of articles to serve as source of updates for the community.

1- WHAT IS LIGHT POLLUTION?

Did you know that in addition to soil, air and noise pollution, artificial light can have serious environmental consequences for humans, wildlife, and our climate?

Artificial lighting alters the environment's natural pattern of light and darkness. It is considered light pollution when light is excessively bright, misdirected, it dazzles people or when a specific area is unevenly lit (not uniform).

We can estimate the amount of **light pollution** by looking at the brightness of the sky at night. Light from artificial sources at night brightens the atmosphere, which is called skyglow. Cities produce artificial light not only due to their **street lamps**, but also due to the use of ornamental lights that illuminate facades, buildings and monuments.

Aside from cities, there are numerous sources of light pollution outside the cities as well, such as **airports, industrial areas, motorways, vehicle headlights and fishing boats out at sea.**

In order to lengthen the day artificially, our most common reaction to the sun setting is to turn on the lights. We illuminate houses, parks, streets and roads. We illuminate the interior of the factories where we work 24 hours a day and we illuminate greenhouses and farms to increase productivity.

We install artificial lighting excessively, wasting energy and money without being aware that it causes harmful effects on the health of people, who no longer get their nights sleep in complete darkness.

In addition, artificial light also **negatively affects** animals and plants, damaging nocturnal habitats by altering the biological rhythms of many species. And disorienting migratory animals, which again can have a severe impact on an ecosystem.

2- NEGATIVE EFFECTS OF ARTIFICIAL LIGHT

Light pollution not only prevents us from seeing the stars, but it is also a waste of energy that affects our health, safety and the environment

AFFECTS SAFETY AND SECURITY

The negative effects of the loss of darkness may seem intangible, but they generate a series of negative consequences.

Strong lighting generates a psychological sense of safety and security, but this **does not necessarily mean that real safety and real security have actually increased**.

For example, **if the lighting is not uniform** and dark areas are combined with strongly lit areas **it takes us more effort to distinguish objects** around us and this can consequently decrease our safety. On top of that, too bright or poorly directed lighting can cause glare, which is especially dangerous on roads.

Another aspect to consider is that **light can make us feel secure in unsecure situations** creating a false sense of safety.

ALTERS ECOSYSTEMS

The vast majority of living beings use natural **light and dark cycles to regulate some of their behaviors** related to reproduction, feeding, sleeping or finding protection against predators. Artificial light at night has negative and sometimes fatal effects on many creatures including mammals, amphibians, fish, insects and birds.

THE STARS ARE VANISHING

For those of us who live in cities, **the night is no longer dark** and many of us have forgotten that above our heads we should be able to see thousands of stars. Many people have never seen the Milky Way and do not know that a starry sky without moon emits enough light to be able to go for a walk in the countryside. Just the light of the stars is enough to make you cast a shadow. And a dark sky can be so spectacular it can turn any random place into a holiday destination.

The increase in sky glow, caused by the dispersion of artificial light in the gases and particles of the atmosphere, causes deterioration in astronomical observation conditions. Migratory species that use the stars to orient themselves are negatively affected as well.

ENERGY WASTE

Excessive bright lighting leads to unnecessary expenses. And such a waste of energy carries great economic and environmental consequences. If humanity invested in increasing the quality of artificial lighting at night, millions of living beings would be saved and we would reduce CO_2 emissions at the same time.

Natural darkness is disappearing as artificial light floods the cities and lights up the sky.

EFFECTS ON HEALTH

Humans need light by day and darkness by night in order for our biological clocks to work properly. Only when we are in the dark does our body secrete a hormone called **melatonin** that plays an important role in the regulation of circadian rhythms and sleep.

Computer and television screens as well as other electronic devices emit artificial light. Using these devices until late at night **alters and can prevent us from generating the melatonin we need.**

The mismatches in the segregation of melatonin can lead to problems such as stress, insomnia, diabetes and even obesity.

Have you ever noticed how hard it is to fall asleep after having used your cellphone in bed for a while?

If you want to minimize these effects, you should install **warm light bulbs** at home and use special applications to change the color temperature of your electronic screens so that they emit **cold light during the day and warm light at night.**

Using **any type of device with a bright display minutes before sleep can affect the quality of our rest** and cause insomnia.

3- TYPES OF LIGHT POLLUTION

A large portion of outdoor lighting is currently designed in a way that is not very efficient. It is usually either too bright, poorly directed and sometimes even completely unnecessary.

Among the different types of light pollution there are:

GLARE

Glare is caused by a light intensity that is too high or by badly directed light. It can cause discomfort and partially impaired vision. Dazzle is extreme glare, for example the flash of a camera or lightning during a thunderstorm, which can cause a photochemical reaction to occur on the retina of the eye causing temporary opsin bleaching, which can take several seconds to recover from.

LIGHT TRESPASS

While street lights are meant to illuminate the streets, **many poorly directed street lights shine into our homes** and prevent us from sleeping in darkness.

Although, using blinds to cover the windows can stop the light from coming in, in hotter regions they are not convenient during the summer when the heat forces people to open windows and shutters during the night.

CLUTTER

Too much luminous advertising on roads can be dangerous as it might distract drivers.

Increasing the light intensity does not necessarily make roads safer. Installing an evenly spread uniform illumination definitely does make them safer as it allows people to see more clearly.

Las Vegas, Nevada (USA) is one of the most illuminated cities on the planet. Its brightness can be observed from 400 km away.

Artificial city light emitted upwards towards the sky is reflected by the clouds

BRIGHTNESS OF THE SKY

Cities are generally bright. The light, when refracted in the molecules of our atmosphere, becomes diffuse and this prevents us from seeing the stars.

Out in nature where it's dark, **night clouds** appear to be black in color. In large cities, however, they **reflect the light directed towards the sky**, consequently the clouds will start to appear orange or blue depending on the color of the city lights.

Astronomers measure the sky brightness to determine the quality of the observations that can be made in a specific place. Such measures are usually expressed in magnitudes/arcsecond^2.

The highest sky brightness values correspond to the darkest skies, such as those in rural areas located far away from cities. Let us explain why this happens.

The ancient Greek astronomers named the brightest stars visible after sunset 'stars of the first magnitude', and they classified the other stars as 'stars of second magnitude' and so on with the weakest stars being 'stars of sixth magnitude'.

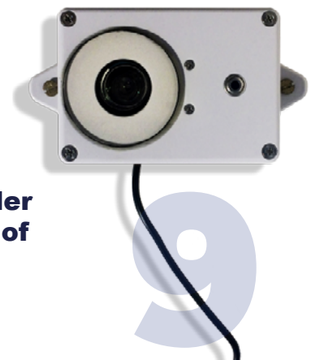
Although modified, the Greek system is still used today. The modern scale of magnitudes includes stars of magnitude 0, but the brightest celestial bodies are still categorized as those of lesser magnitude. In fact, the Sun has a magnitude of -26.74.

In terms of magnitude, the brightness of the sky behaves the same as the brightness of the stars.

In astronomy, it is not practical or possible to handle ordinary longitude units like m. or Km. Instead, we use angles to measure from star A to star B. In many situations, where stars are very, very close to our eyes or eyepieces, we use tiny longitudes such as arc seconds (1/3600 degree). Likewise, areas are not expressed in ordinary flat area units (m^2) but in spherical units. Tiny areas are expressed in arcsec^2.

In a city environment with a sky heavily affected by light pollution, the measures would be around 17 mag / arcsec^2, while in places where there are fewer sources of light pollution and with darker skies the values could be up to 21 mag/arcsec^2.

Scientists use devices called photometers to obtain sky brightness measurements which help to evaluate the quality of astronomical observations.



TESS photometers can be installed for months or years in order to study the evolution of light pollution.

4- HOW TO INSTALL EFFICIENT LIGHTING

Every place and situation has different lighting needs. Our bedroom just before going to sleep does not need the same light as an operation room in a hospital just before a procedure.

To **use only the necessary light for each place and situation**, so that its use is sustainable and generates the minimum negative impact, a series of guidelines must be followed according to its different characteristics.

POWER

Light bulbs consume electricity. The energy consumed every second is called **power, and it is measured in watts (W)** is the International System of Units.

Of all the electrical energy consumed by a lamp while on, only a fraction becomes light. **Some of the energy is emitted as heat** and some as non-visible radiation.

The fraction of **energy that is transformed into visible light, every second, is called radiant flow** and its unit, in the International System, is the watt.

The sensitivity of the human eye varies according to light intensity. **The perceived light power is called flux luminous,** and in the International System of Units it is measured in lumen (lm).

DIRECTION

Artificial light must be aimed properly at its target. Directing the light only to the place where it is needed is very important, especially outdoors, since emitting light in other directions is not only a waste of energy but has negative impacts for both the sky and ecosystems.

Street lamps are meant to illuminate roads or public outdoor spaces. And **when lighting up a building the light should never point upwards** so to avoid lighting up the sky with the reflection onto the facade.

“Balloon-type” street lamps are extremely inefficient. It is better to **use shielded street lamps with the bulb installed horizontally and the flux luminous directed downwards.**

COLOR TEMPERATURE

Light is an electromagnetic wave whose energy depends on its wavelength. In the case of visible light, **the most energetic is the blue one and the least energetic is the red one.**

Bulbs can emit light with different “color temperature”, which is measured in Kelvin. **The light is warm if its color is orange or reddish and cold if white or blue colors predominate.**

If we install **warm lighting in our bedrooms** and in relaxing areas we will help our body to generate the melatonin it needs to rest. Ideally, 2700K light bulbs should be chosen for the rooms where there is some activity while 2200K light bulbs are more adequate to use just before bedtime.

Note that is pretty counter-intuitive that the warm lights have the smaller color temperature

When performing activities that require a lot of precision or that are performed in the light of day the use of **cooler lighting will help us as it allows us to make a clearer distinction between colors.**

In the end it is about imitating natural light. On a clear day, the sunlight has a color temperature of approximately 5800K. The light of fire used by our ancestors to light up their living spaces was between 2000K and 2200K.

The advent of new lighting technologies, particularly light-emitting diodes (LEDs), has raised blue-rich white light emission.

Scientist are interested on study these lamps and map their locations so light pollution models can be refined

TIME OF USE

Light emitted by cities is a clear indicator of the activity of its inhabitants as our first reaction to the sun setting is to switch on all our lights, hence trying to artificially lengthen our day.

The first places where we tend to turn on the lights are in our homes, shops and places of work. Street Lamps are switched on shortly before sunset while boutiques try to draw our attention to their shop windows by lighting up their windows. Not long after that, the ornamental lights are switched on illuminating monuments and building facades.

The vast majority of light sources remain on all night, even if they are not being used. We could lower energy consumption by turning off or dimming the unnecessary lights at certain time slots and installing presence sensors on roads and streets with low traffic conditions.

UNIFORMITY

Uniformity is defined by the way the light flow is distributed on a lit surface. **An adequate lighting design makes surfaces look evenly illuminated** with the same intensity at all points, avoiding a strong contrast between bright spots and shadows.

EFFICIENCY

Efficiency is defined as the relationship between the luminous flux emitted by a bulb and the power that it consumes.

It is expressed in lumens per watt (lm/W). To minimize the energy spent on the production of artificial light and minimize the watts while obtaining the same lumens more efficient lamps should be used.

Technology	Efficiency (lm/W)
LED	4.5 - 200
High pressure sodium	85 - 150
Low pressure sodium	100 - 120
Fluorescent	60 - 104
Metal halides	80
Mercury vapor	40 - 55
Tungsten incandescent	5 - 17.5

5- STREET LIGHTS HUNTING

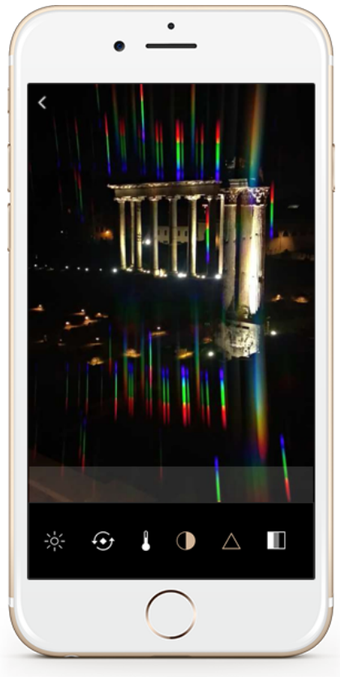
Join Street Spectra team to fight light pollution and allow stars to awake while the rest of the world sleeps!

If you wonder about the efficiency of the lamp posts of your neighborhood **Street Spectra** citizen science project will help you classifying them using your phone.

1 Read this tutorial

2 Get your diffraction grating

3 Place your grating on top of your phone camera



4 Download epicollect5 application on your phone

5 Take pictures of different light sources

6 Upload your pictures to our database

Street Spectra is a citizen science project to map and characterize public lighting sources. To participate, **students should use a 500 lines/mm diffraction grating** on top of their smartphones' camera and take pictures of the street lamps and their emission spectra.

A diffraction grating is **an optical component with a periodic structure** that splits and diffracts light into several beams travelling in different directions so the emerging coloration is **a form of structural coloration** associated to any light source.

They can be bought online in places such as Edmund Optics, Jeulin, AliExpress or Amazon.

6- CLASSIFY STREET LIGHT SPECTRA

Look for spectral features

Rainbow of colors?

Yes

LED lamp

No

Compare the emisson lines with spectrum templates

Bright in the yellow region?

Yes

High pressure sodium lamp

No

Metal Halide lamp

Something different

No

Bright violet line?

Yes

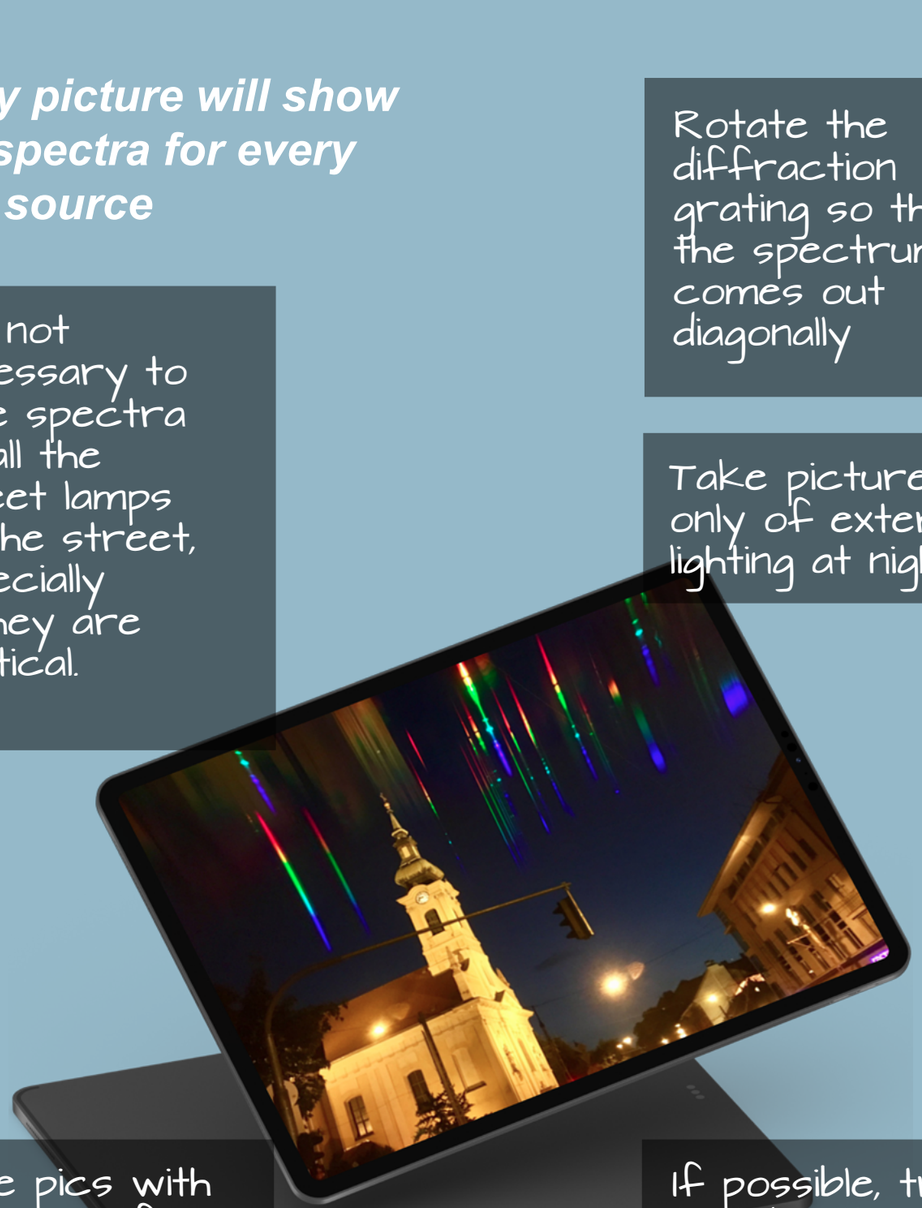
Mercury vapor lamp

Every picture will show one spectra for every light source

It is not necessary to take spectra of all the street lamps on the street, especially if they are identical.

Rotate the diffraction grating so that the spectrum comes out diagonally

Take pictures only of exterior lighting at night



Take pics with lampposts far away (15-20m) so they do not saturate the images

If possible, try to take the second order spectrum.

Use the automatic exposure of the mobile

Write down additional characteristics that get your attention

7- ADDING YOUR LAMPS TO THE DATABASE

epicollect5

You will need to use epicollect5 app as tool for gathering the information and sharing it with the Street Spectra project.

1.- Download the app

Epicollect5 is a completely free app that is available for Android phones and tablets, iPhones and iPads.

GET IT ON Google play Available on the App Store

2.- Add Street Spectra project

Just click “Add project” on the app home page, search for “Action Street Spectra” and tap on it to download it.

3.- Collect data

Select the project and add entries to it.
Collect data online or offline.
Upload your data to the server the next time you are online. View and download your data from the server.

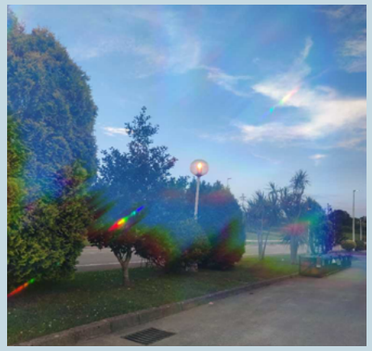
More information in the manual available at the website.

https://streetspectra.actionproject.eu

6- ACTIVITIES

Exercise 1

Identify the technology of the following lamps.
Comment on both positive features of the pictures and how them could have been improved.



Spectra 1:

- The moon
- High presure sodium
- Mercury vapor
- 2 Led lamps

Comments:

Amazing picture!

Spectra 2:

Comments:

Spectra 3:

Comments:

Spectra 4:

Comments:

Spectra 5:

Comments:

Spectra 6:

Comments:

Exercise 2

Collaborate on Street Spectra project by adding new entries on the Epicollect5 database.
Photograph some streetlamps nearby home or school using a diffraction grate.

Starting time:

Ending time:

What is your nickname on Epicollect5?

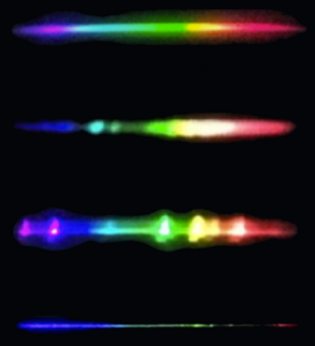
What area did you explore?

How could the streetlamps in this area be improved?

Exercise 3

Write down below what kind of street lamps correspond to the spectra on the left according with the pages 14-15 and count how many you found of each type while collaborating on Street spectra.

street spectra



Lamp technology	Count with tally marks	Final number

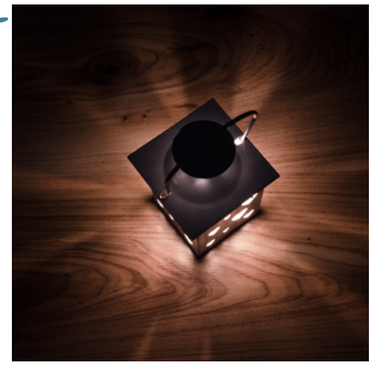
Exercise 4

The color temperature must be adequate for each situation. What color temperature light bulbs do you think should be installed in the following places? Why?

The kitchen	A bedroom
Your street	The park

Exercise 5

The shape of the street lamp is very important to minimize light pollution.
Among the lanterns that you can see in the following images, which ones would you choose for your back garden? Why?



Write your answer here:

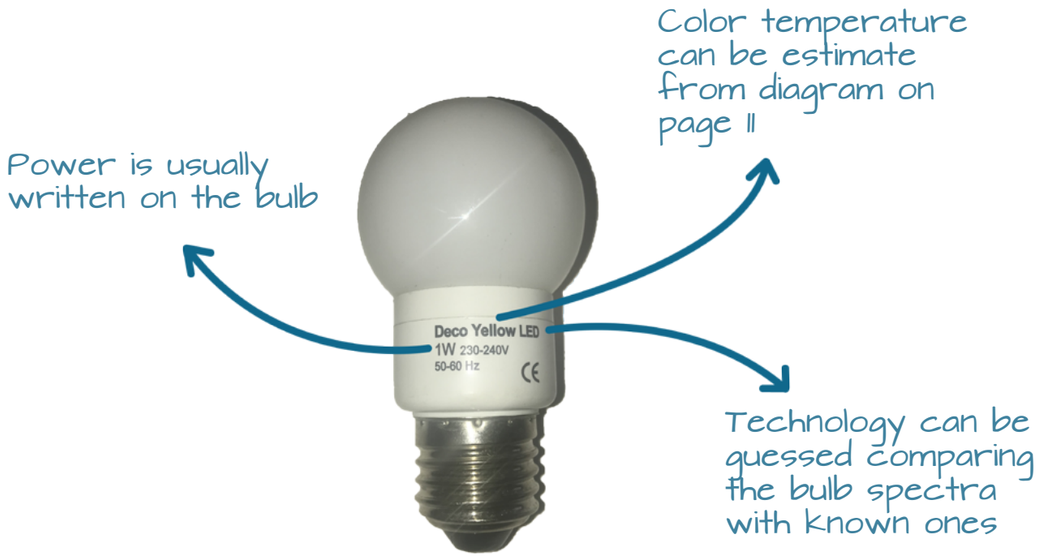
Exercise 6

Discuss the lighting problems you see in the following images. If you would want to reduce the light pollution, how could the lighting be improved in each case?

Write your answer here:

Exercise 7

Make a list that includes some bulbs that you have installed in your home or in your school. Write down the place where they are installed, their power, the technology they use, their color temperature and indicate how you could improve the lighting in these places.



Bulb	Place	Power	Tech.	Color Temperature	How would you improve it?
0	Living room	1W	LED	Yellow ≈ 2400K	This is a nice bulb to have in the living room
1					
2					
3					
4					
5					
6					
7					

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824603

The content of this didactic unit related to light pollution has been taken from:

Ciencia Ciudadana para localizar las fuentes de contaminación lumínica

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Editorial Q
ISBN: 978-84-15575-12-2