Department
for Education

Environmental science

GCE AS and A level subject content

December 2015

Contents

The content for environmental science AS and A level

Introduction

1. AS and A level subject content sets out the knowledge, understanding and skills common to all AS and A level specifications in environmental science.

Aims and objectives

2. AS and A level specifications in environmental science must encourage students to:

- develop essential knowledge and understanding of different areas of environmental science and how they relate to each other
- develop and demonstrate a deep appreciation of the skills, knowledge and understanding of the scientific methods used to investigate the environment
- develop competence and confidence in a variety of practical, mathematical and problem solving skills related to environmental issues and the sustainable use of resources
- understand the importance of basing decisions on reliable data which allows evidence-based analysis of environmental issues
- develop interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject
- understand how society makes decisions about environmental issues and how these contribute to the success of the economy and society

Subject content

3. AS and A level specifications in environmental science must build on the skills, knowledge and understanding set out in the GCSE content for science.

4. The skills, knowledge and understanding for AS environmental science must comprise 100% of AS specifications. The skills, knowledge and understanding for A level must comprise 100% of an A level specification. For both AS and A level this would include the practical skills requirements and the mathematical requirements.

5. AS and A level specifications in environmental science must include applications and implications of scientific ideas across a range of contemporary and other contexts.

6. AS and A level specifications in environmental science must require students to study the areas of the subject as set out in the knowledge and understanding, the practical skills requirements (appendix 1) and the mathematical requirements (appendix 2).

Subject principles

7. The scope of coverage of each area of study must include:

- how human activities interconnect with natural systems
- the scientific knowledge needed to understand these interconnections
- the changes in human activities needed to develop sustainable industries and lifestyles

8. The understanding of natural systems must focus on the following principles:

- most natural systems are regulated by dynamic equilibria
- natural systems are driven by renewable energy
- the materials that sustain life are cycled by natural processes

9. The skills, knowledge and understanding of each specification in environmental science must include the requirements set out below, and be integrated into the mandatory content indicated in theoretical and practical contexts where appropriate:

- use theories, models and ideas to develop scientific explanations of environmental processes
- use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas related to the environment
- use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
- undertake experimental and investigative activities, including appropriate risk management, in a range of environmental contexts
- analyse and interpret quantitative and qualitative data to provide evidence, recognising correlations and causal relationships
- evaluate methodology, evidence and data, and resolve conflicting evidence to:
    - make judgements and reach conclusions
    - develop and refine practical design and procedures
- know that scientific knowledge and understanding of the environment develops over time
- communicate information and ideas in appropriate ways using appropriate terminology
- consider applications and implications of environmental science and evaluate their associated benefits and risks
- consider ethical issues in the treatment of humans, other organisms and the environment
- evaluate the role of the scientific community in validating new knowledge and ensuring integrity

- evaluate the ways in which society uses environmental science to inform decision making

Knowledge and understanding

10. The knowledge and understanding must be read in conjunction with paragraphs 3-9 of this content.

11. All of the knowledge and understanding shown below is required for the A level. The knowledge and understanding required for AS is shown in normal (non-bold) text; the knowledge and understanding in bold and contained in square brackets is only required for the A level.

12. Environmental science specifications must ensure students apply knowledge and understanding of all the Earth's main systems (atmosphere, hydrosphere, lithosphere, and biosphere) and their interconnected nature across a range of contexts.

13. Environmental science specifications must ensure that students develop a strong understanding of how humans interact with the environment, building on prior knowledge from science at GCSE. This will require students to also have an understanding of the breadth of different aspects of environmental science and to draw on assumed prior knowledge from science GCSE to extend knowledge or consider new scientific principles at level 3.

14. Students must investigate and critically evaluate the quality and nature of scientific evidence for human impact on the environment (both positive and negative) to inform argument and decision making.

15. Students must appreciate how environmental scientists investigate environmental issues and their role in planning and implementing strategies.

Areas of study

16. The areas of study have been divided into six main subsections.

The living environment

17. The emphasis should be placed on the interaction of living organisms with each other and their abiotic environment, and how an understanding of this can inform decisions that lead to sustainable human activities. Students must apply their understanding of these interactions in a wide range of contexts throughout this area.

Conditions for life on Earth

- how the main conditions, which allowed early life to develop and survive on planet Earth, came about, including:

    - atmosphere, insolation, position in solar system, orbital behaviour and magnetosphere

- how the presence of life on Earth has brought about environmental change:

    - how biota have helped maintained stability through oxygen production and the formation of the ozone layer, carbon sequestration and biogeochemical cycles

    - how conditions for life were monitored historically and how these methods have developed over time

Conservation of biodiversity

- the importance of the conservation of biodiversity: resources and how sustainable habitat management strategies can be used to secure future supplies:

    - wood, fibres, oils, fuels and new foods

- the importance of the conservation of biodiversity: knowledge and how decisions over habitat conservation can be made to protect those species that have not yet been investigated:

    - biomimetics, medicines, physiological research, pest control species and genetic resources

- the importance of the conservation of biodiversity: ecosystem services and their interaction with each other, applied through a range of different contexts:

    - atmospheric composition, biogeochemical cycles, interspecies relationships and soil maintenance

- how humans influence biodiversity, with examples in a range of different contexts
- methods of conserving biodiversity:

    - setting conservation priorities: IUCN criteria, evolutionary uniqueness, endemic species and keystone species
    - legislation/protocols: protection of habitats and species, trade controls and regulation of sustainable exploitation
    - captive breeding and release programmes (CBR): methods of increasing breeding success, and soft and hard release programmes
    - habitat conservation: habitat creation, management and conservation of habitats including:

        - temperate broadleaf woodland
        - tropical rainforest
        - coral reefs

        - oceanic islands
        - mangroves
        - Antarctica
    - the importance of ecological monitoring in conservation planning
    - the use of new technologies in ecological monitoring e.g. satellite/radio tracking, DNA databases and image recognition

Life processes in the biosphere and conservation planning

- how adaptation to the environment affects species' habitat requirements and influences conservation decision-making
- the control of ecological succession in conserving plagioclimax habitats
- population control and management of desired and undesired species
- **[biocapacity and ecological footprints:**
    - **a comparison of the factors controlling the biocapacity of different regions**
    - **the impact of different ecological footprints on biocapacity]**

The physical environment

18. The emphasis should be placed on understanding how anthropogenic activities are interconnected with physical processes, to formulate management strategies and plan sustainable activities.

The atmosphere

- how atmospheric energy processes involving ultra violet (UV), infra red (IR) and visible light in the stratosphere and troposphere affect life-support systems
- global climate change: how interconnected natural systems cause environmental change: negative and positive feedback mechanisms and tipping points
    - changes in ocean currents
    - changes in the cryosphere
    - changes in climatic processes
    - the difficulties of monitoring and predicting climate change
- **[carbon footprints and sustainable development]**
- ozone depletion:
    - the scientific basis of the Rowland-Molina hypothesis
    - the collection, analysis and interpretation of data
    - an evaluation of the data collection methods available and the reliability of the data produced
    - why ozone depletion has been greatest over Antarctica

    - the restoration of the ozone layer
    - an evaluation of the effectiveness of the methods used to restore the ozone layer

The hydrosphere

- the impact of unsustainable exploitation of water resources
- analysis and evaluation of sustainable management of water resources
- ocean currents: the importance of thermohaline circulation in distributing heat and regulating climate

Mineral resources

- the main groups of resources extracted from the lithosphere: metal ores, industrial minerals, construction materials
- geological processes that produced localised concentrations of recoverable mineral deposits: hydrothermal deposition, proterozoic marine sediments, physical and biological sediments
- reserves and resource, including Lasky's principle of lognormal mineral distribution
- how a range of different exploratory techniques work: satellite imagery, seismic surveys, gravimetry, magnetometry, resistivity and trial drilling
- factors affecting mine viability:

    - ore purity and chemical form
    - associated geology: overburden and hydrology
    - economics: cut-off ore grade and mining costs

- control of the environmental effects of mineral exploitation: turbid drainage water, spoil and leachate, site management and restoration
- strategies to secure future mineral supplies

    - improvements in exploratory techniques
    - bioleaching with acidophilic bacteria and phytomining
    - Cradle to Cradle design

Biogeochemical cycles

- the carbon, nitrogen and phosphorus cycles, including human influences
- the sustainable management of the carbon, nitrogen and phosphorus cycles

Soils

- how human activities affect soil fertility
- the causes of soil degradation and erosion
- soil management strategies to increase sustainability

Energy resources

19. [Students should understand how improvements in technology can provide increasing amounts of energy from sustainable sources. Students should understand how quantitative data are used to compare and evaluate new and existing technologies.

- **the importance of energy supplies for the development of societies. The impact of the properties of energy resources: abundance, locational constraints, intermittency, energy density and need for energy conversions**
- **the sustainability of current energy resource exploitation: impact of extraction/harnessing, pollution and depletion of reserves**
- **strategies to secure future energy supplies:**
  - **evaluation of new extraction/harnessing technologies relating to:**
    - **fossil fuels**
    - **nuclear power: fission and fusion**
    - **renewable energy technologies**
    - **new energy storage systems**
  - **new energy conservation technologies**
    - **vehicle design for use and end of life**
    - **building design]**

Pollution

20. [Students should understand how the properties of materials and energy forms interact to result in environmental change. They should apply this knowledge to suggest solutions to minimise current pollution problems and prevent future problems. Students should apply their understanding through a range of different historic and contemporary pollution events.

- **the properties of pollutants:**
  - **state of matter/energy form, density persistence/degradability, toxicity, reactivity, adsorption, solubility in lipids/water, bioaccumulation, biomagnification, synergism, mutagenic action, carcinogenic action and teratogenic action**
- **how environmental features affect pollution events:**
  - **dispersal: air/water currents, velocity and direction**
  - **features affecting degradation: temperature, light, oxygen, pH and presence of other chemicals**

  - temperature inversions
  - presence of adsorbant materials

- strategies to control pollutants based on their properties and features of the environment:

  - critical pathway analysis: to predict pollutant mobility and inform monitoring programmes
  - critical group monitoring: to identify members of the public most at risk
  - emission location
  - emission timing
  - selection of control technologies: to reduce production, reduce release and mitigate damage caused
  - the use of scientific knowledge to develop new pollution control technologies e.g. adsorption of heavy metals using polymers, phytoremediation of land contaminated with heavy metals and bioremediation of hydrocarbon spills]

Biological resources

21. [Students must develop an understanding of the challenge of providing food and forest resources for a growing human population without damaging the planet's life-support systems. Interaction with other areas should be emphasised, including energy resources, pollution and the physical environment.

Agriculture

- agroecosystems and agricultural energetics: the selection of species, control of predators and control of abiotic factors to maximise food production
- manipulation of food species to increase productivity: the advantages and disadvantages of the methods that are available to improve crop and livestock gene pools
- environmental impacts of agriculture
- social/economic/ political factors which influence agricultural production
- strategies to increase the sustainability of agriculture: pest control, nutrient supplies, energy inputs and social impacts

Aquatic food production systems

- marine productivity

  - the role of nutrients in controlling biological productivity
  - a comparison of productivity in open oceans, coastal areas and areas with upwelling

- fishing
    - the advantages and disadvantages of the main fishing methods: catch effectiveness, energy inputs and environmental impacts
    - methods of estimating fish populations and Maximum Sustainable Yield
    - methods of reducing environmental impacts of fishing
- aquaculture
    - relative merits of extensive and intensive aquaculture: productivity, energetics and environmental impacts
    - the extent to which aquaculture can replace fishing
    - methods of reducing environmental changes caused by aquaculture

Forest resources

- the resources and life-support services gained from forests
- the relationship between forestry and productivity and biodiversity
- the causes of deforestation
- the effect of deforestation on biodiversity, hydrology, soil and climate
- sustainable forest management]

Sustainability

22. [The subject principles that are the focus in all topics should be used to develop a holistic understanding of sustainability and the circular economy. Examples should be taken from throughout the areas of study to gain an understanding of the interconnected nature of:

- environmental problems
- solutions to these problems

Dynamic equilibria

- negative feedback mechanisms which resist change
- positive feedback mechanisms which increase change
- equilibrium tipping points which lead to new equilibria
- diverse systems are more likely to be resistant to change

Energy

- natural systems are driven by energy in very different ways from anthropogenic systems
- natural systems are driven by renewable energy, especially solar power
- natural processes use low energy-density resources
- most natural processes occur at low temperatures

Material cycles

- **the linear nature of human systems which lead to resource depletion and waste generation**
- **natural processes often link together in sequences that create cycles, with the waste products of one process being the raw materials for other processes**
- **natural waste products are either non-toxic or do not build up to cause toxicity**

The circular economy

23. A circular economy should be evaluated as a possible development strategy that engages in a benign way with natural systems. The main features of the circular economy must be considered in terms of the development of sustainable lifestyles:

- **cycling of materials**
- **energy derived from renewable sources**
- **human activities should support ecosystems**
- **separation of technical and biological materials**
- **how diverse systems are more resistant to change**
- **connected systems where the waste product of one process is the raw material for another process**
- **design of products for end of life reuse**
- **optimum production rather than maximum production**
- **technologies to design new products and improve system effectiveness**

Appendix 1 - working scientifically

Specifications in environmental science must encourage the development of the skills, knowledge and understanding in science through teaching and learning opportunities for regular hands-on practical work.

Although not directly assessed, students are expected to carry out investigative/ practical activities, including fieldwork, appropriate to the study of a range of environmental systems.

AS and A level specifications must require students to undertake fieldwork which meets the minimum requirements of 2 days of fieldwork for AS and 4 days for A level. If a mixture of fieldwork and laboratory-based activities is chosen then the equivalent minimum requirement would be 1 day of fieldwork plus 6 lab-based activities[1] for AS and 2 days of fieldwork plus 12 lab-based activities for A level.

At AS and A level students should have first-hand experience of[2]:

- sampling: including at least 3 different sampling techniques and at least 3 different methodologies at AS and at least 6 different sampling techniques and at least 6 different methodologies at A Level:
    - examples of sampling techniques: pitfall traps, Tüllgren funnel, soil texture analysis, water turbidity, light traps
    - examples of methodologies: the selection of suitable methodologies to collect representative, statistically significant data: random sampling, systematic sampling; suitable timing of sampling; sample details: size, number; standardisation of technique
- measuring abiotic factors: for example, light intensity, temperature, humidity, edaphic factors
- measuring biotic factors: for example, population size, species richness, species distribution, biodiversity
- measuring abiotic and biotic factors related to anthropogenic influences for example:
    - the effect of water turbidity on light penetration and the distribution of benthic organisms

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[1] A lab based activity is an activity in which students collect, measure or analyse data, factors or substances in a laboratory setting

[2] The examples listed below are neither compulsory nor exhaustive but illustrate the types of activities to be included.

- the effect of slope angle and vegetation cover on rain splash soil erosion
- the effectiveness of noise reduction methods on noise pollution around an airport / near a road

Specifications in environmental science must signpost investigative/practical activities integrated into the subject knowledge and understanding that will allow students the opportunity to develop the required practical skills.

Practical skills identified for indirect assessment and developed through teaching and learning

Practical work undertaken throughout the course will enable students to develop the following skills:

Independent thinking

- solve problems set in practical contexts
- analyse and evaluate existing scientific knowledge
- apply scientific knowledge to practical contexts
- plan scientific investigations and apply investigative approaches and methods to practical work

Use and application of scientific methods and practices

- comment on experimental design and evaluate scientific methods
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled
- know how to safely and correctly use a range of practical equipment and materials
- collect and present information and data in a scientific way

Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical requirements
- consider margins of error, accuracy and precision of data

Instruments and equipment

- know and understand how to use experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification, including:

- using appropriate apparatus/ instruments to record quantitative measurements (for example temperature, length and pH)
- using appropriate apparatus/ instruments and methodologies to measure abiotic and biotic factors (for example, light intensity, humidity, population size)
- sampling techniques (for example pitfall traps, Tüllgren funnel, soil texture analysis, water turbidity, light traps)

Appendix 2 - mathematical requirements and exemplifications

In order to be able to develop their skills, knowledge and understanding in science, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

All mathematical content must be assessed within the lifetime of the specification.

The assessment of mathematical skills must be embedded in the assessment of environmental science skills and be set in the context of environmental issues.

The following tables illustrate where these mathematical skills may be developed. Those shown in bold type would only be tested in the full A level course.

This list of examples is not exhaustive. These skills could be developed in other areas of specification content.

Ref.	Mathematical skills	Exemplification of mathematical skill in the context of A level environmental science (examples are not limited to those given below)
Arithmetic and numerical computation		
1	Recognise and make use of appropriate units in calculations	Candidates should demonstrate their ability to: • convert between units such as length and volume e.g. calculating surface area:volume ratios in energy conservation • select appropriate units and values for a calculation e.g. estimating water and organic matter content of soils
2	Recognise and use expressions in decimal and standard form	Candidates should demonstrate their ability to: • use an appropriate number of decimal places in calculations e.g. calculating mean population density from multiple sample sites in a habitat • carry out calculations using numbers in standard and ordinary form e.g. when comparing production of different energy resources • convert between numbers in standard and ordinary form e.g. when using masses in biogeochemical cycles

3	Use ratios, fractions and percentages	Candidates should demonstrate their ability to: • calculate percentage yields e.g. in pollution control • calculate surface area to volume ratios and relate this to heat loss • calculate and compare percentage loss e.g. of rain forests over a given time period or of declining populations of endangered species
4	Estimate results	Candidates should demonstrate their ability to: • estimate results to sense check that the calculated values are appropriate, such as when calculating residence times in different water reservoirs
5	Use calculators to find and use power, exponential **[and logarithmic functions]**	Candidates should demonstrate their ability to: • interpret population growth curves • compare noise values quoted in decibel units
Handling data		
6	Use an appropriate number of significant figures	Candidates should demonstrate their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures e.g. in calculating indices of biodiversity • understand that calculated results can only be reported to the limits of the least accurate measurement e.g. in estimating lifetimes of mineral reserves
7	Find arithmetic means	Candidates should demonstrate their ability to: • find the mean of a range of data e.g. mean power output of a wind farm

8	Construct and interpret frequency tables and diagrams, bar charts and histograms	Candidates should demonstrate their ability to: • represent a range of data in a table with clear headings, units and consistent decimal places e.g. to compare the energy density, production cost, carbon intensity and mean load factor for a range of energy resources • interpret data from a variety of tables e.g. data relating to aquifer flow rates • plot a range of data in an appropriate format e.g. atmospheric carbon dioxide levels, atmospheric temperature and solar output over time represented on a graph • interpret data from a variety of graphs e.g. change in electricity cost from renewable energy sources, industrial output and level of financial incentives/tax over a number of years
9	Understand simple probability	Candidates should demonstrate their ability to: • use the term probability appropriately when investigating causal relationships such as the link between human health problems and urban pollutants
10	Understand the principles of sampling as applied to scientific data	Candidates should demonstrate their ability to: • analyse random data collected by an appropriate means e.g. use Simpson's index of diversity to compare the biodiversity of habitats exposed to different pollution types or management regimes • analyse systematic data along a transect to monitor impacts of pollution with increasing distance from a copper smelter
11	Understand the terms mean, median and mode	Candidates should demonstrate their ability to: • calculate or compare the mean, median and mode of a set of data e.g. of yields of fish farmed under different conditions or fish from commercial catches

12	Use a scatter diagram to identify a correlation between two variables	Candidates should demonstrate their ability to: • interpret a scatter graph e.g. to compare human development index with environmental footprint of different countries
13	Make order of magnitude calculations	Candidates should demonstrate their ability to: • compare storage volumes of natural water reservoirs and transfer rates • calculate national energy use from population and individual use data
14	**[Select and use a statistical test]**	**[Candidates should demonstrate their ability to select and use:** • **the chi-squared test (goodness of fit and association)** • **the Student's t-test** • **Spearman's rank** • **Mann-Whitney U test]**
15	Understand measures of dispersion, including standard deviation and range	Candidates should demonstrate their ability to: • calculate the standard deviation e.g. of crop yield for a given nutrient input • understand why standard deviation is a useful measure of dispersion for a given set of data e.g. for comparison with other data sets with different means such as populations of endangered species under different management regimes
16	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Candidates should demonstrate their ability to: • calculate percentage error where there are uncertainties in measurement e.g. estimating total population using sub-samples in a preliminary study
Algebra		
17	Understand and use the symbols: =, <, <<, >>, > and ~.	No exemplification required

18	Change the subject of an equation	Candidates should demonstrate their ability to: • use and manipulate equations e.g. nutrient transfer rates, energy conversion efficiencies and fish maximum sustainable yields
19	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates should demonstrate their ability to: • use a given equation e.g. Simpson's- index of diversity: $\mathbf{D}= \frac{N\,(N-1)}{\Sigma\, n\,(n-1)}$ to assess the impact of a new habitat management regime
20	Solve algebraic equations	Candidates should demonstrate their ability to: • solve equations in an environmental context e.g. calculations using the universal soil loss equation to assess the effectiveness of soil conservation programmes
21	**[Use logarithms in relation to quantities that range over several orders of magnitude]**	**[Candidates should demonstrate their ability to:** • **use a logarithmic scale in the context e.g. of noise pollution levels]**
Graphs		
22	Understand data presented in a variety of graphical forms	Candidates should demonstrate their ability to: • interpret data in a range of graphical forms, including line graphs, which may involve logarithmic scales, bar charts, stacked bar charts, histograms, kite diagrams, pie graphs, scatter graphs, 3-dimensional graphs, flow diagrams, Sankey diagrams and circular (radar) diagrams to enable a wide variety of data to be analysed
23	Translate information between graphical, numerical and algebraic forms	Candidates should demonstrate their ability to: • understand that data may be presented in a number of formats and be able to use these data e.g. dissolved oxygen levels, soil erosion rates

24	Plot two variables from experimental or other data	Candidates should demonstrate their ability to: • select an appropriate format for presenting data, bar charts, histograms, graphs and scatter graphs e.g. organic matter and oxygen depletion, nutrient inputs and yield increase
25	Understand that $y = mx + c$ represents a linear relationship	Candidates should demonstrate their ability to: • predict/sketch the shape of a graph with a linear relationship, whether with a positive or negative correlation e.g. the relationship between insolation and solar panel output
26	**[Determine the intercept of a graph]**	**[Candidates should demonstrate their ability to:** • **read an intercept point from a graph e.g. the temperature at which oxygen levels fall too low to support particular aquatic species]**
27	Calculate rate of change from a graph showing a linear relationship	Candidates should demonstrate their ability to: • calculate a rate from a graph e.g. rate of infiltration through rocks with different permeabilities
28	Draw and use the slope of a tangent to a curve as a measure of rate of change	Candidates should demonstrate their ability to: • use this method to measure the gradient of a point on a curve e.g. rate of heat loss through double glazing with varying gaps
Geometry and trigonometry		
29	Calculate the circumferences, surface areas and volumes of regular and irregular shapes	Candidates should demonstrate their ability to: • calculate the circumference and area of nature reserves to assess the impact of the edge effect on wildlife conservation programmes • calculate the surface area and volume of cylinders or spheres e.g. to estimate rates of heat loss in energy conservation programmes

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Reference: DFE-00198-2015

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