LEVEL 3 DIPLOMA

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DIPLOMA IN ENVIRONMENTAL SCIENCE

EXTENDED DIPLOMA IN ENVIRONMENTAL SCIENCE

UNIT 4: Scientific principles and the environment

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Pre-release Article

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Keeping cool

The mean global temperature is increasing, though the causes of this are still debated by scientists. As the climate changes, more homes and businesses are seeking solutions to create comfortable indoor temperatures.

Three-quarters of all homes in the USA have air conditioners, the highest percentage in the world; and in the UK 65% of offices are now air-conditioned.

Traditional air conditioners

Traditional air conditioners work in a very similar way to refrigerators. Heat in the air is absorbed by a circulated chemical (called the refrigerant) and then transferred to air in another location as shown in **Figure 1**.

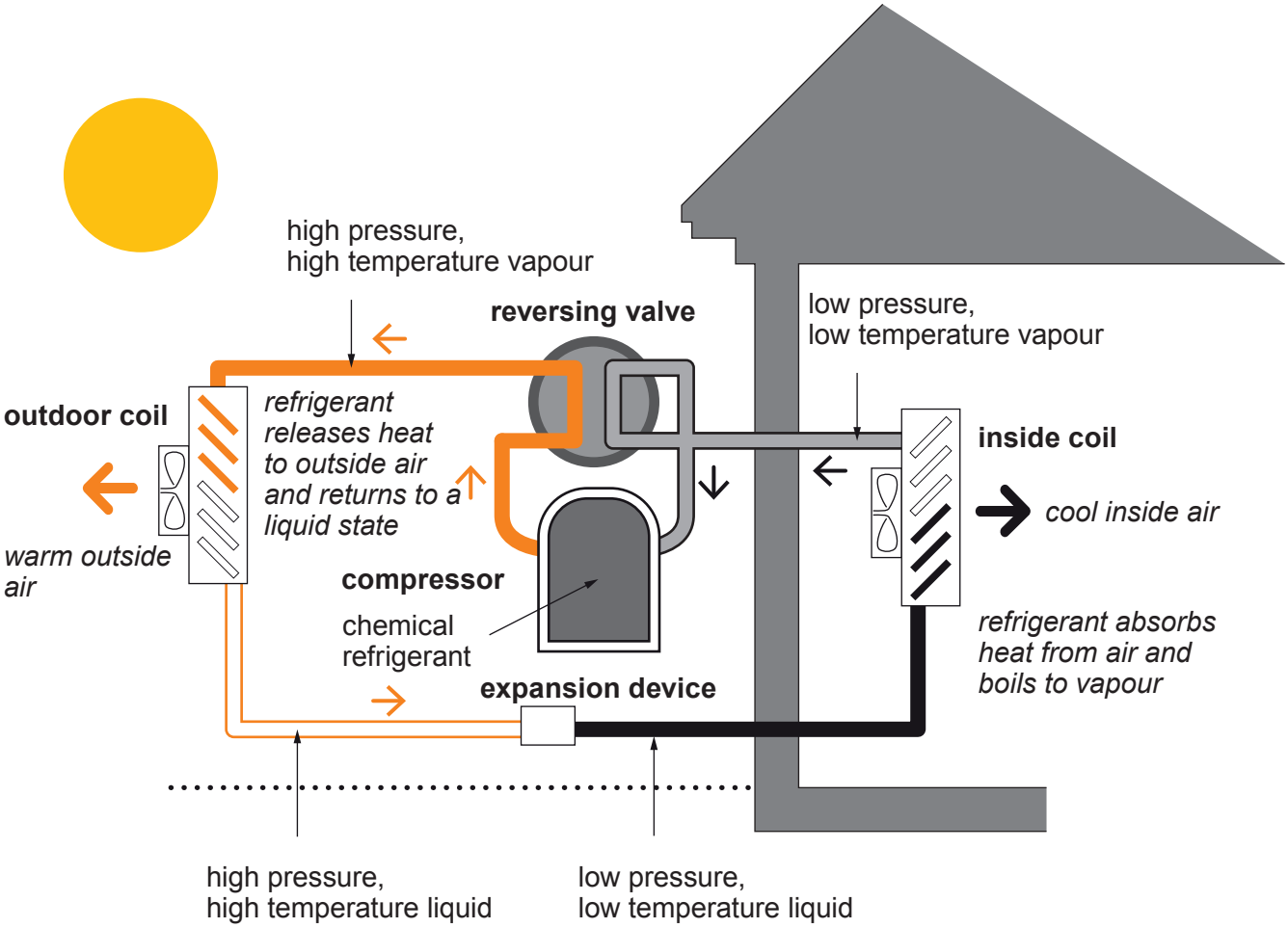

Figure 1: Schematic diagram of a traditional air-conditioning system

Source: www.kendallcountyair.com/learn/heat-pumps

10 The most common refrigerant used in air-conditioning systems before the year 2000 was a CFC (chlorofluorocarbon) called R-22, also known as Freon. The structure of R-22 is shown in **Figure 2**. Despite a total ban on CFCs coming into effect in 2014 many companies are still replacing their cooling systems and consequently there are plenty of air-conditioning systems still using R-22.

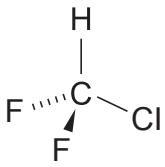

Figure 2: Structure of R-22

15 CFCs have been banned due to the damage they cause to the ozone layer. The location of the hole over the South Pole can be seen in **Figure 3**. The size of the hole in the ozone layer over the South Pole is continually measured by NASA using satellites. The purple and blue colours are where there is the least ozone, and the yellow and red colours are where there is more ozone.

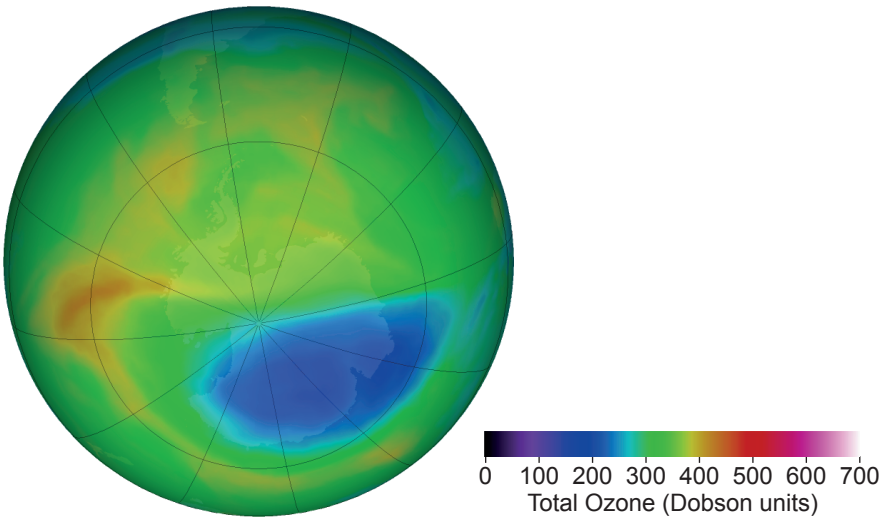

Figure 3: A view of the ozone hole 15th November 2017

20 A graph showing how the maximum ozone hole area has changed since 1979 is shown in **Figure 4**.

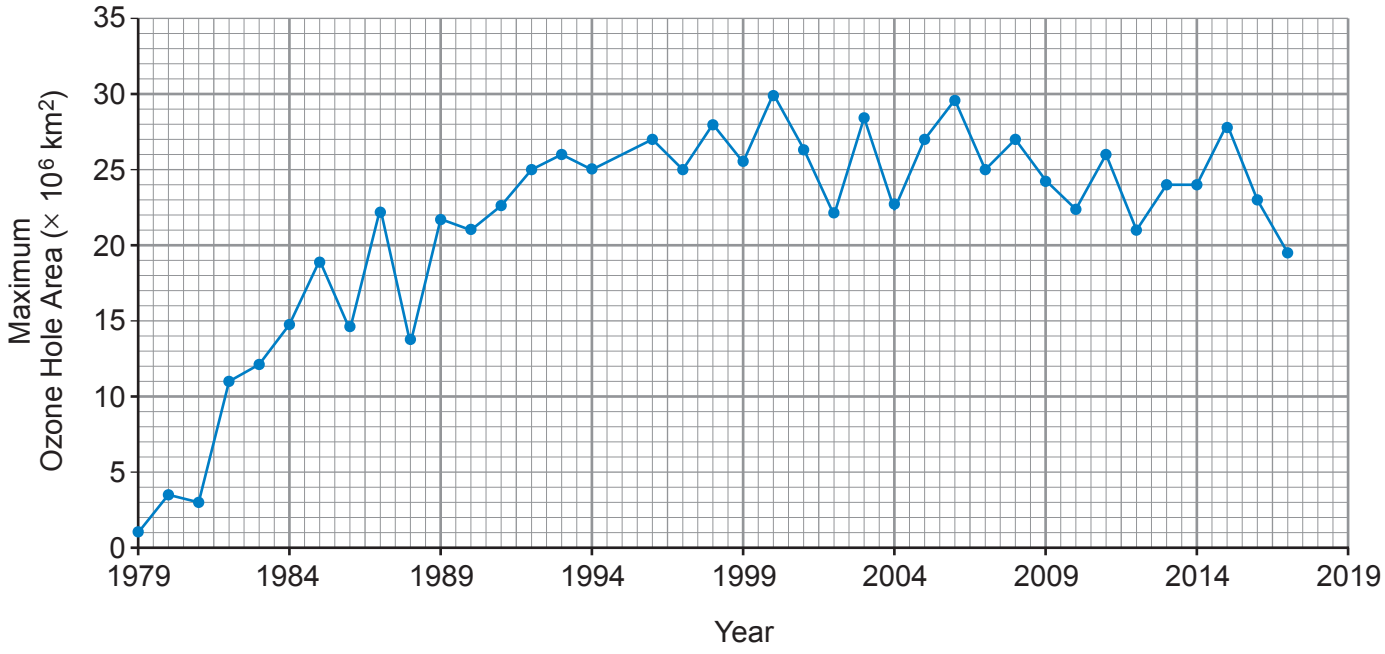

Figure 4: Maximum ozone hole area.

Source: https://ozonewatch.gsfc.nasa.gov/statistics/annual_data.html

As CFCs are phased out, ozone-safe hydrofluorocarbons (HFCs) are expected to dominate the market, as well as alternative refrigerants such as ammonia.

Adiabatic cooling systems

25 One alternative to traditional air-conditioning is an adiabatic cooling system, where there is no transfer of heat energy between the warm input air (from outside) and the surroundings, as the air cools. Cooling is achieved by evaporating water, and the energy needed to do this is taken from the warm input air. A diagram illustrating a simple adiabatic cooling system is shown in **Figure 5**.

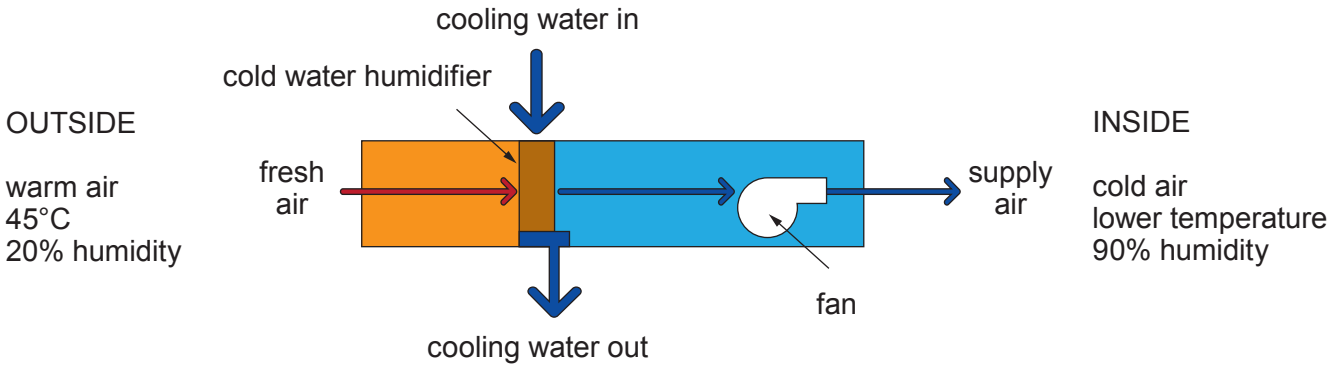

Figure 5: A simplified adiabatic air-conditioning system

Adiabatic cooling relies on the fact that different amounts of water vapour can be held in the air (called the humidity), at different temperatures. In **Figure 5**, warm air at a lower relative humidity (expressed as a percentage of the maximum humidity at any given temperature), is drawn into the air conditioner and passes through cold water droplets sprayed at high pressure into a humidifier. The heat energy from the warm air is used to evaporate some of the water, increasing the humidity of the air, but lowering its temperature. The colder air is then passed into the room. As the overall energy of the air remains constant during the cooling, the process is adiabatic.

Figure 6 shows that air in the system remains at a constant internal energy as it cools. As the humidity rises, so the temperature decreases and the air follows one of the red lines of constant energy.

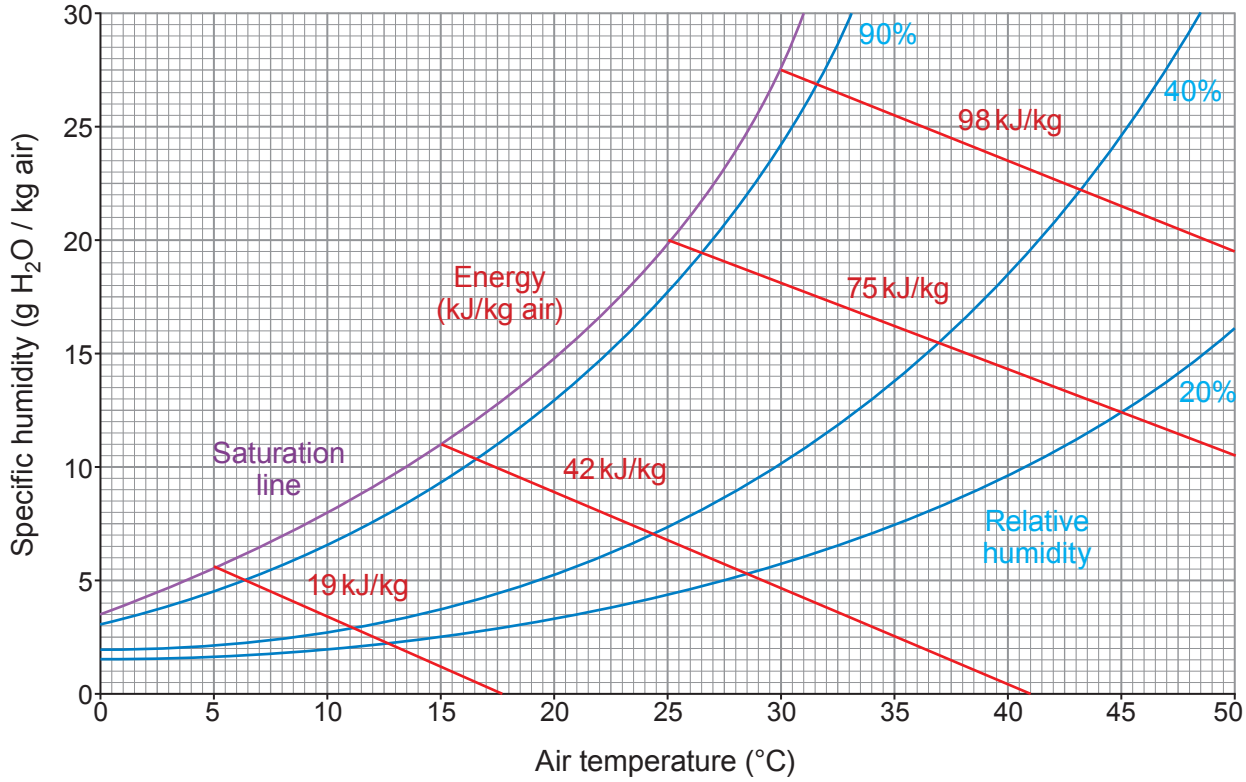

Figure 6: Simplified humidity-temperature chart. The red lines are examples of lines of constant internal energy; the purple line shows the line of water vapour saturation (100 % humidity); and the blue lines show lines of constant relative humidity.

Health issues

A problem with poorly maintained air-conditioning units is the potential for microbial growth. This includes the 39 species of *Legionella* bacteria which thrive in temperatures between 20°C and 45°C and prefer slow moving or stagnant water. Their optimum range is pH 5.5 - 8.1 and their growth is aided by the presence of iron(III) ions (Fe^{3+}). These ions are often present in poorly-maintained systems due to corrosion of pipes. Biocide treatment such as chlorine can accelerate corrosion. *Legionella* also flourish in the presence of ions of zinc, calcium, magnesium and within limescale. All these conditions can lead to the formation of biofilms as shown in **Figure 7**.

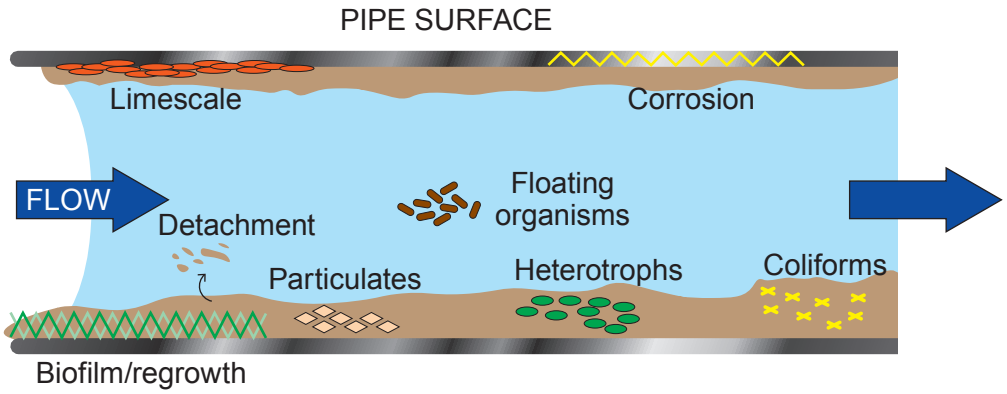

Figure 7: Factors affecting biofilm formation

Most biofilms have a maximum depth of 20 microns, so are not visible to the human eye or are only seen as an orange or brown tint. The timescale of biofilm formation is shown in **Figure 8**.

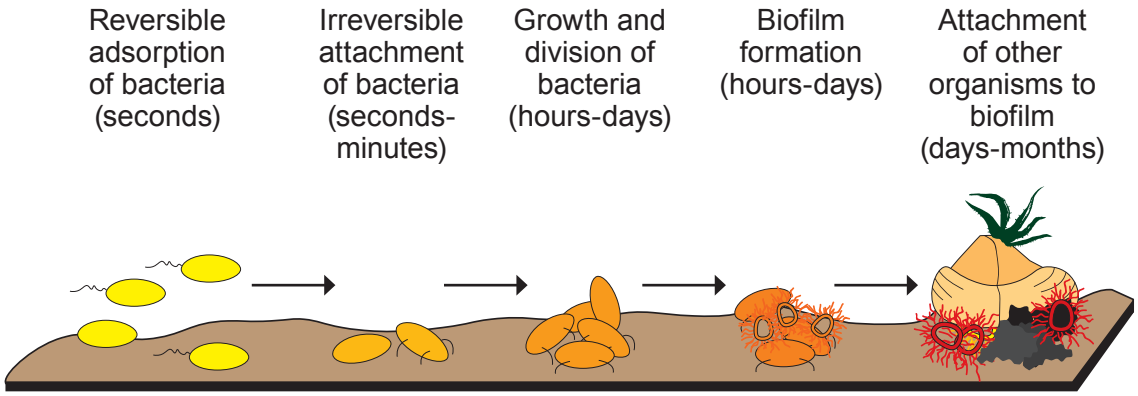

Figure 8: The timescale of formation of a biofilm

Factors that prevent *Legionella* growth are constant water streaming, keeping the temperature under 20°C or over 50°C, and the presence of silver, copper or bromate ions. Well maintained air-conditioning systems ensure that water is not allowed to pool at all, so microbial growth is minimised.

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