

Royal Society of Chemistry response to the Royal Commission on Environmental Pollution study on “Adapting the UK to climate change”

The RSC welcomes the opportunity to comment on the scoping of the Royal Commission on Environmental Pollution’s study on adapting the UK to climate change.

The RSC is the UK Professional Body for chemical scientists and an international Learned Society for advancing the chemical sciences. Supported by a network of over 44,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public.

This document represents the views of the RSC. The RSC’s Royal Charter obliges it to serve the public interest by acting in an independent advisory capacity, and we would therefore be very happy for this submission to be put into the public domain.

The document has been written from the perspective of the Royal Society of Chemistry and consequently our comments relate to only parts of the consultation document.

If you would like further information or need anything in this document clarified, please do not hesitate to contact me.

Yours sincerely,

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Introduction

In scoping this study the RSC recommends that the RCEP must first be clear as to what impact climate change will have in the UK. It is generally accepted that climate change will result in different changes to weather conditions in different regions; for example, a particular contrast between the northwest and southeast was identified in UKCIP02 report. It is therefore sensible that measures to adapt to climate change are reviewed according to the needs in different regions.

When adapting to climate change there are two different aspects to be considered: firstly what are the associated risks such as flooding, droughts, and secondly how do those effects influence different areas like agriculture and water management.

Key source:

Sustainable water: Chemical Science Priorities, published by the RSC

Food Security and Sustainability, published by the RSC

Chemical Science Priorities for Sustainable Energy Solutions, published by the RSC

Fuelling the future, published by the RSC

Health effects of climate change on the UK, published by the Department of Health

London's warming: Impact of climate change on London

Climate change scenarios for the United Kingdom

Climate change and greenhouse effect, A briefing from the Hadley Centre

Effects of climate change

Temperature^{1,2,3} – Globally temperatures have risen over the past decade and further temperature rise is predicted due to climate change. Depending on the scenario that was chosen to model UK temperatures, the average rise in temperature has been predicted to be between 1 °C and 5 °C by 2080. However, the local temperature rise is likely to be higher in the southeast than in the northwest. Warming is likely to be stronger in the summer and autumn than in the winter and spring. Heat waves are predicted to become more frequent and more severe.

¹ <http://data.ukcip.org.uk/resources/publications/documents/14.pdf>

² http://www.london.gov.uk/gla/publications/environment/londons_warming_tech_rpt_all.pdf

³ http://www.metoffice.gov.uk/research/hadleycentre/pubs/brochures/2005/climate_greenhouse.pdf

Sea Level^{1,2,3} – Due to thermal expansion of ocean water and the melting of mountain glaciers, the sea level is predicted to rise as a consequence of global warming. Depending on the scenario this rise could be between 9 cm and 69 cm globally by 2080. This rise in sea level would lead to more storm flooding and changes in tidal surge. As a consequence, sea water might penetrate freshwater tributaries and change the soil properties. Increased wave heights will cause damage to the coast line, leading to accelerated coastal erosion. This is damaging for coastal defences and may cause hazards to shipping.

Precipitation^{1,2,3} – Winter precipitation is predicted to rise, depending on the scenario, between 5% and 30%. Summer precipitation is predicted to decrease, leaving parts of the UK drier and rainfall is modelled to decrease between 20% and 40%, with the south and east being most severely effected. There is likely to be little change in autumn and spring precipitation. By 2080 the UK will most likely experience greater instances of flooding and drought. Risk of flooding is expected to increase because the rainfall intensity is predicted to rise. It has been suggested that drought frequency and severity will increase in most UK regions by the 2080s, but particularly in the south and east of the UK. Changes in precipitation will have consequences for river flows, ground water levels and hence pose new challenges for water management, agriculture, health, waste management, construction and infrastructure and transport.

Floods^{1,2,3,4,5} – Changes in precipitation and a rise in sea levels mean that under global warming there is a higher probability of floods in the UK. One obvious area for adaptation is flood management. The UK has traditionally favoured hard-engineered defences but a shift in thinking towards a more holistic approach involving whole catchments and risk-driven adaptability to climate needs to be considered.

Flash summer flooding, relating to high intensity rainfall and surface runoff, will cause increased erosion and transfer of soluble and sediment bound pollutants to water bodies. Floods mobilise sediment and its entrained heavy metals and other pollutants as well as flush pesticides, parasites and nutrients from farmland into the

⁴ <http://www.rsc.org/ScienceAndTechnology/Policy/Documents/water.asp>

⁵ <http://www.rsc.org/ScienceAndTechnology/Policy/Seminars/FoodSecurity.asp>

watercourses. Increased flood frequency and extent will result in redistribution of contaminants around the environment, potentially including a range of contaminants from industrial sites. Changing flow patterns will cause remobilization of river banks and the release of a range of historic contaminants from river floodplain deposits. Summer storms and wetter winters will increase the frequency and severity of diffuse pollution events as contaminants are washed into water bodies.

This will have consequences for the reliability of raw water sources by changing the frequency of low flows and recharge, increasing the frequency of floods which may inundate bank side facilities, increasing the frequency of highly turbid flows and threatening abstraction points. The reliability of the supply infrastructure, by for example altering reservoir safety, might be altered. It may alter the ability to treat raw water to potable standards by water treatment works and by changing the quality of the abstracted water. It may change the demand for water and the ability to distribute water to meet customers' needs, particularly at times of peak demand. The effect of changes in river flows and recharge on water supply reliability, however, depends on how water resources are managed. There will be a great need for improved monitoring systems for both water quality and soil constitution. Water treatment may have to be improved to cope with an increased level of contaminants in the water.

Increase in rain water runoff and flood water events into surface water drains, or combined rainwater sewers, needs to be considered in relation to flooding of the surface as well as discharges to the water environment (rivers, lakes and ponds) due to overloading of the systems.

Floods cause major disruptions in the infrastructure – not only public transport, but also energy distribution and food supply. Most of the energy grid in the UK is above ground. To prevent power cuts due to the disruption of cables the energy grid may need to be upgraded and possibly moved below ground. Another issue is the potential flooding of power stations that could lead to a shortage of energy supply. To reduce vulnerability to power cuts across the UK, the UK needs to move towards a diverse mixture of energy sources.

Methods need to be devised to control high levels of water. A challenge to the material sciences is to create surfaces that allow quick permeation of water in order to reduce the risk of flooding within urban areas. There is also a need to examine how rain water can be used more effectively.

Droughts^{1,2,3,4} – It is predicted that drought frequency and severity are going to increase in most UK regions by 2080, particularly in the south and east of the UK. Short-term droughts may decrease in duration but drought severity may increase for some regions. Projected changes in longer droughts are highly uncertain, particularly for the south of England, although the longest droughts are projected to become shorter and less severe by most models. This suggests that many UK water supply companies may need to plan for more intense short-term droughts but may experience fewer longer duration events under future climate change.

Droughts will increase the risk of saline intrusion into groundwater which is used for public water supply by boreholes. In the South East of England 43% of drinking water is provided by boreholes to supply potable water by groundwater sources. Current treatment in use at these site, will not be able to provide water to potable standards if the groundwater is contaminated by saline water due to a lowering of the water table.

Lower summer water flows will mean less dilution of point sources of contaminants, whilst summer storms and wetter winters will result in increasing frequency and severity of diffuse pollution events. Droughts and increasing imbalances between demand and available resource will force use of more contaminated (including saline) water sources. This puts a higher burden on water treatment processes, leading to lower water quality and will ultimately make water management more expensive and challenging. This could have further environmental effects as well as affects on chemical processes used to treat water and sewage and water course discharges.

Long periods of dry and hot weather lead to an increased risk of fire. The risk of fire outbreaks in the UK needs to be investigated.

Humidity^{1,2,3} – The humidity might rise as a consequence of higher temperatures and increased precipitation levels, leading to ideal growth conditions for fungi, insects and weeds. Pests that are common in the Mediterranean region might become more common in the UK. High downpours can cause crops to rot prematurely, having a significant effect on the crop yield and consequently food security. The chemical sciences will be at the forefront in developing novel pest control measures and improving the resistance of plants to fungal, bacterial and viral diseases. Early warning systems and better monitoring techniques need to be developed in order to combat invasive species most effectively.

Changes in the weather patterns mean that traditional crops might not be best suited in order to satisfy the growing demand in food. Selective breeding and changes in the type of crops that are grown under changed climate conditions need to be considered.

Cloud Cover^{1,2,3} – Climate change is likely to have effects on cloud cover. However, there is great uncertainty about the resulting cloud characteristics. More research is needed in this area as depending on the cloud characteristics, they are predicted to have further warming or indeed cooling effects.

There is still a poor understanding of the role of aerosols in cloud formation for climate change modelling. This needs to be investigated and novel trace gas sensors need to be developed to study the effects of aerosols closer.

Gales^{1,2,3} – The effect of climate change on gales is currently unclear. In order to make predictions on the impact of gales, more research is needed.

Adaptation Measures by area

Water management^{4,5} – One of the major climate change effects is likely to be in changes in precipitation levels, frequencies and duration. This will cause different flow patterns in water courses. These changes are critical for the management of water resource systems.

Catchments have to be managed as a system, and a system whose behaviour is dynamic both in time and in space. As a system, it involves interactions between land and water not only in terms of water but also of soil through erosion and deposition, as well as of pollutants. Whilst all water is recycled over the long term, a significant proportion of surface water in a catchment is reused within the catchment, accumulating salts and minerals as it does. Because it is a system, interventions in one time and place, and to one purpose, generally have repercussions downstream, at other times, and upon other functions of the catchment. In a system, there are, by definition, externalities. The dynamic nature of catchments increases the extent of some risks to health; floods move sediment in which are entrained heavy metals and other pollutants.

Similarly, floods flush pesticides, helminths and nutrients from farmland into the water courses. At the same time, the rate of most treatment processes cannot be rapidly changed to adjust to loads so that storage is necessary to provide a buffer between the changing load and the relatively constant processing capacity. Similarly, the capacity of rivers to self-purify some pollutants is dependent on the flow and temperature all of which vary over the seasons. Hence, a key problem in water management is to cope with the increased variability due to the predicted effects of climate change.

Chemistry plays a major role in all aspects of water treatment and supply, from allowing us to characterize source water quality, including quantifying pollutant load, removing particles, organic and inorganic pollutants, and providing a disinfectant residual; to controlling water quality in the distribution system. Key future challenges for suppliers of water include water scarcity, the need to treat poorer quality water and energy usage. Water scarcity might lead to increased interest in energy intensive desalination and water reuse and recycling; these sources have a wider range of contaminants that require treatment. Microfiltration and reverse osmosis technologies are expected to be important in treating poor quality water. Those procedures are generally more energy intensive, making it more expensive to treat water with poorer quality.

Climatic factors (temperature, precipitation, solar radiation, humidity, wind) operate in combination to influence the amount of water consumed by all sectors, but particularly by agriculture. Their effects differ with location and can fluctuate both seasonally and from year to year. Temperature is the climatic factor that most influences water consumption. Water scarcity and shortage will require new approaches to treating and supplying water. Scarcity has led to more interest in water recycling and reuse and the need to treat non pristine sources of waters such as sea water, impaired surface water sources or even wastewater effluent. The challenge in treating these alternative water sources is that they contain a wider range of contaminants at concentrations above the regulatory limits such as salts, metals, chemicals, radionuclides, emerging contaminants such as pharmaceuticals and biological species.

What contaminants should we remove from our water is a moving target in that as time passes we improve our understanding of not only what contaminants are present and at what concentration but also how they affect people. Broadly speaking, our understanding of the behaviour of conventional contaminants is well developed after years of study. Emerging contaminants of concern, including pharmaceuticals, veterinary medicines, personal care products and nano-materials, are far less well studied. The processes most often involved in the breakdown of contaminants are photodegradation and aerobic and anaerobic action. All these processes can form a range of degradation products and consequently, the environment may be exposed to a mixture of the parent compound and any resulting transformation products. Additionally, there are biochemical transformations which are not necessarily classified as degradation; for example, the in situ methylation of heavy metals leading to the formation of toxic organometallic compounds. Whilst the fate and effects of many major groups of synthetic chemicals are relatively well understood, the behaviour and effects of transformation products are less well studied. Information about the mechanisms and properties (e.g. persistence, mobility and toxicity) of transformation products is critical if we are to fully understand the behaviour of contaminants in the environment.

How future weather patterns will affect contaminant fate and transport is also not known. Temperature and precipitation changes due to global warming may affect the input of chemicals into the environment and their fate and transport in aquatic systems. There is a need to identify the potential impact of climate change on contaminant fate and behaviour.

Energy makes up 34% of the costs of producing potable water. Energy savings are possible through better management and operation of the water treatment works. However, if new regulations require additional treatment processes to be installed or if the quality of the raw water deteriorates, then energy costs are likely to increase.

Agriculture^{4,5,6} – Severe weather conditions (drought, heat waves, strong gales, floods) affect the quality and quantity of crop yields. In order to prevent poor harvests, farmers may need to adapt the types of crops they grow to changing weather conditions. Science and technology have contributed significantly to high farm yields, large scale continuous processing, sophisticated preservation methods and global distribution of finished products. However, this model is based on assumptions that the Earth performs as a limitless energy supply and waste disposal sink. Fertilisers, soil nitrogen and manure management all give rise to nitrous oxide and methane emissions, which are greenhouse gases. This will limit their use in the future and novel fertilisers have to be developed that do not act as greenhouse gases or put an additional burden on water management when floods occur. This is an area where scientific research could make a considerable contribution and the chemical sciences need to be at the centre of efforts to design improved agrochemicals. As part of this effort, crops should be developed which use nitrogen more efficiently and novel fertilisers need to be designed.

Higher humidity will provide the ideal growth conditions for fungal growth, bacteria and viral diseases. Floods can wash out nutrients from the soil and leave an excess of contaminants on the fields. All these parameters will influence the crop harvest. The chemical sciences have to play a major role in adapting agricultural techniques to

⁶ http://www.fao.org/ag/ags/agse/agse_s/3ero/namibia1/c18.htm

climate change. The use of chemical signalling to deter new pests is only one option to secure food supplies. The natural resistance of crops needs to be improved and selection and breeding of improved varieties needs to be advocated. Higher yields could be achieved through improved treatments and nutrients for intensive production. However, one result has been water pollution as a result of the excess nitrogen and phosphorus being carried off in runoff or infiltrating the groundwater. It also needs to be ensured that neither of these nutrients or toxins affects the quality and safety of food products.

Arable land is already scarce and much of the available land, in addition to already being in some environmental or other use, is limited by chemical factors. In addition to food, land is increasingly needed for energy production, and science provides new techniques to use crops for materials too, as a substitute for oil-based products. Additionally, land is now viewed as a potential carbon sink, but climate change is predicted to put even more pressure on land as it could get increasingly contaminated as a consequence of floods or through pollution from the poor management of nitrogen, from fertilizers and manures. To realise the most potential from a given piece of land a multifunctional approach is needed. Multifunctional agriculture provides food products for consumers, livelihoods and incomes for producers, and a range of public and private goods and services for citizens and the environment, including ecosystem functions. Managing resources such as soil and water associated with the land will be a crucial requirement for sustainability.

Minimum tillage is both a measure to adapt to climate change by reducing soil erosion from extreme events and a measure to mitigate climate change through sequestration of carbon dioxide in the soil. It aims to maintain and enhance soil productivity by preventing land degradation. An undesirable side effect of tillage is soil compaction as energy from farm equipment traffic is directly transmitted to the soil. Minimum tillage aims to reduce soil disturbance for preparing a seedbed by reducing cultivation and the use of a plough. It can involve direct drilling, broadcasting into existing stubbles or adopting a strategy of reduced tillage. The main benefits are the reduction of tillage energy consumption, the conservation of moisture and soil structure, the reduction of disturbance on soil organisms and the retention of plant cover to

minimize erosion. Tillage in conventional agriculture is used to remove weeds. When reducing tillage, herbicides are often used for effective weed management during seedbed preparation. It is therefore important to ensure that those herbicides do not put a strain on water sources. Conservation tillage (also known as no-till conservation or zero tillage) includes any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water.

High nitrogen concentrations in the soil can increase the sensitivity of plants to UV-B radiation and thus put a strain on their development. It is therefore essential that supplements that are used to increase the crop yield do not have negative effects under changed weather conditions.

Changes in Weather patterns can lead to an invasion of new insects. This has implications for public health and agriculture, because of the diseases the insects can carry e.g. malaria, and blue tongue disease. The chemical sciences should be at the centre of efforts to mitigate the risk for crops and human health by developing measures for pest control and new pharmaceuticals.

Energy supply⁷ – Another consequence of climate change might be a higher energy demand in the summer due to air conditioning. Chemical and material sciences are at the forefront of developing novel materials that improve thermal insulation of buildings, to reduce the burden on energy supply.

Places which are currently prime locations for harnessing wind energy might be exposed to gales that exceed the operation levels of turbines. This means that the location for some of the wind turbines might need to be revised and changed.

Construction⁸ – Exposure of construction materials to more extreme weather conditions are predicted to shorten their life time. This is particularly true for materials such as plastics, rubber and wood which serve as building materials and are exposed to high temperatures or moist climates. It is therefore important to improve

⁷ <http://www.rsc.org/ScienceAndTechnology/Policy/Documents/SustainableEnergySolutions.asp>

⁸ A. L. Andradya, H. S. Hamidb and A. Torikaic (2003) *Photochem. Photobiol. Sci.*, **2**, 68 - 72

the properties of materials used in construction of outdoor facilities to withstand these weather conditions.

Health^{4,5,9,10} – Water borne diseases have historically had the greatest impact upon human health and continue to contribute to millions of deaths globally per year. Water transports contaminants, including inorganic, organic and biological materials, from various sources, both natural and man-made. Such contaminants can enter the human body via water by ingestion, inhalation of water droplets and contact, particularly with broken skin. Water use and sanitation in the form of hygiene practices act as an important barrier to disease transmission. An increasingly recognised long term health consequence of flooding, in addition to the disease burden, are the psychological and psychiatric impacts of flooding both on the individual household but also on the wider community. As extreme flows, floods also play a crucial role in the remobilisation and deposition of sediment contaminated with heavy metals and other pollutants. The chemical sciences will be essential in providing better tools for environmental monitoring and early warning systems for biological and chemical pollutants. Improved water treatment techniques need to be developed using the knowledge of the chemical sciences and engineering.

Flooding events which overwhelm surface water and storm water systems can have an effect on health due to mobilisation of contaminants within these systems as well as on the surface. However, the greatest risk is associated with storm water overwhelming combined surface water sewage systems or intruding into sewage systems, resulting in a discharge of water potentially contaminated with pathogens and chemical contaminants.

Solar radiation might increase depending on changes in cloud characteristics. An increase in UV-B radiation rises the potential of several forms of skin cancer, eye conditions and even autoimmune diseases (for example multiple sclerosis). The use of

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http://www.rsc.org/delivery/_ArticleLinking/ArticleLinking.cfm?JournalCode=PP&Year=2008&ManuscriptID=b717166h&Iss=Advance_Article

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http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4007935

sunscreens that can reduce the risk of contracting skin cancer, might however lead to lower vitamin D levels. It has also been suggested that compounds that activate the tanning pathway could also reduce inflammation and promote DNA repair. There is however a great need for more research in those areas. The chemical sciences need to play a major role in the development of novel sunscreen products, and new forms of treatment of those diseases. It is also important to develop improved screening tools for the early detection of cancer and other diseases. Chemical scientists, biologists and medical scientists need to work closely together on these issues.

A rise in solar radiation leads to the transformation of chemicals that affects the concentration of pollutants in the troposphere. This leads to a drop in air quality which has got significant effects on human health. Conditions such as asthma and allergies might rise as a consequence of reduced air quality. Again, the chemical sciences need to develop treatments for these conditions and monitoring tools.

Waste management – A large proportion of landfill is generated by food waste. Waste may increasingly become a valuable resource in response to real price rises in global commodities and demand-side pressures. The looming shortfall in electrical energy supply emerging in the UK as ageing capacity is shut down is another factor.

Further questions that need to be asked are: Do landfills become more hazardous due to higher temperatures and increases in humidity? Do the emissions from landfill change and therefore become more toxic to the environment or human health?

Mitigation measures

Measures to mitigate climate change need to be established and not be forgotten over measures to adapt to climate change. Processes need to be more energy efficient, sustainable and ultimately we need to move towards a zero-carbon emission approach. We need to act now in order to soften the effects of climate change for future generations.

Looking towards the future¹¹

¹¹ <http://www.sd-commission.org.uk/publications/downloads/SDC-Home-Truths.pdf>

Adapting the UK to climate change means investing in research and development now in order to receive a reward in the future. The earlier measures to mitigate climate change are successful in reducing greenhouse gas emission, the less severe the adaptation measures and reduction in quality of life will have to be. However, although action needs to be taken now, there is a great need for further development and it will take time for results to be incorporated. Today, 75% of all houses that will be inhabited in 2050 are already built. This means that most adaptation measures need to be targeted at upgrading existing buildings. New developments need to be constructed according to the highest standards possible under inclusion of our current knowledge of climate change.

We need more accurate models of what will happen in the future on a local scale. It is not enough to know the effects of climate change on a global scale. Adaptation measures that are required in the southeast of the UK, for example, might not be appropriate for changes in the northwest. It is therefore vital to improve our knowledge of greenhouse gas emissions on the local scale to be able to improve the scenarios used to model climate change and therefore reduce the uncertainties in those models. The better our understanding of the effects of climate change are the better we can adapt to those changes.

Systems approach and sustainable development

Any adaptation to climate change means human interactions with nature. It therefore needs to be ensured that any measures that are taken do not shift the burden from one area into another. Adapting the UK to climate change means not only the possible introduction of novel materials and chemicals into the environment but also the possibility of using existing materials to exhibit altered characteristics due to higher temperatures, more humid climate or the influence of increased UV radiation.

This former case offers the opportunity to develop sustainable manufacturing processes and sustainable supply chains. The latter however means, that life-cycle analysis have to be performed under changed conditions. To understand fully the implications of the manufacture, use and end-of-life of novel and advanced materials the RSC recommends that life cycle assessment is applied during their development

and used to minimise environmental impacts and maximise economic and societal benefits. It is also important to study positive and negative feedback loops, as for example adding nutrients to boost the growth of crops could end up increasing the burden on water treatment if they enter into the water cycle.