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Can water efficiency measures influence construction technology and ensure potable water sustainability?

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Abstract

Climate change has been a source of much discussion at government level and in the media for many years, with estimates showing that current levels of greenhouse gas emissions will lead to a rise in global temperatures of 2-5 degrees celsius sometime within the next twenty to fifty years. The consequences of climate change are varied but perhaps chief amongst them is the trend for less predictable weather patterns with many hotter summers than those currently experienced, which are likely to lead onto water shortages. It may surprise people to discover that the UK can be considered to have water supply problems. While the situation in the United Kingdom could not be considered to be as severe as that in Africa, many parts of the country, particularly in the South-East of England, are seeing water demand exceeding abstraction rates.

This paper will initially via a literature search establish the actual levels of water usage and the Government allowed levels of water usage per person per day. Then, by evaluation of a case study based on a notional housing development, see whether these limits are achievable or whether the introduction of additional technical solutions such as rainwater and greywater recycling will facilitate any advance towards limiting water usage. If successful these initiatives could then be considered by other countries. The paper will then conclude on the effectiveness of these initiatives which are needed to secure a sustainable domestic water supply, with the overall long term goal of water neutrality i.e. where water demand equals water supply.

Keywords

Climate change**,** sustainability, water efficiency, construction technology

1. Introduction

Climate change has been a source of much discussion at international level and in the media for many years now. Reports such as the United Kingdom's Government commissioned Stern Review of 2006 (HM Treasury, 2006) estimate that current levels of greenhouse gas emissions will lead to a rise in global temperatures of 2-5 degrees celsius sometime within the next twenty to fifty years. The consequences of climate change are many and varied but perhaps chief amongst them is the trend for less predictable weather patterns with many hotter summers, which are likely to lead onto water shortages.

The impression may be held that water shortages are only a problem found in the hotter countries of the world, particularly in Africa, however it may surprise many people to discover that the United Kingdom (UK) has water supply problems. While the situation in the UK could not be considered to be as severe as that in Africa, many UK areas, particularly in the South-East of England, are seeing water demand exceeding abstraction rates. This has been partly attributed to climate change, with the UK's Environment Agency's 'Water Resources Planning Guideline' (Environment Agency, 2008) stating that water suppliers should assess and monitor the potential impact of climate change on water supplies. When these climate change implications are combined with the figures for increasing housing demand due to population growth, resulting in approximately 138,000 new homes a year needed to be built in the UK (HM Treasury, 2004). One thing emerges from this and that is the problem of water shortages will become increasingly severe if it not addressed.

In order to investigate this problem and produce a workable strategy to address it, the UK Government in the report 'Future Water' (DEFRA, 2008), investigated the source of water shortage problems and considered how it can be ensured that the nation's use of potable water is sustained. As a result the UK Government published amended legal guidance for constructors of new dwellings via the Building Regulations, (using Approved Document G). This key legislative document contains measures to limit the use of potable water consumed in newly constructed homes to 125 litres per person per day.

The purpose of this paper is to examine the effectiveness of these legislative changes for limiting domestic water consumption by evaluating the results from case studies based on notional housing developments. The case studies will establish what the impact of the new legislation will be on the design and specification of elements of houses and whether the requirements for water usage will be met as a result of this or whether the introduction of additional technical solutions utilising rainwater and greywater recycling will be needed, in order to facilitate the advance towards limiting water usage, moving towards water neutrality and sustaining the domestic water supply.

2. Supporting evidence

It is generally accepted across that the demands on water resources in the UK have met, and in some geographical areas, exceeded supply (Villareal and Dixon, 2004). It is worth noting that over-abstraction does not merely lead to water shortages but also has a negative impact on the eco-systems in and around the rivers and the water sources that these supplies are taken from (Elliott, 2009a).

It is tempting to look at climate change as the sole reason for dwindling water resources. Indeed, Rajger (2006) suggests that changing global weather conditions mean that water shortages are 'inevitable', regardless of other factors. This is a view supported by the influential Intergovernmental Panel on Climate Change which, after research undertaken in 2007, released its report (Intergovernmental Panel on Climate Change, 2007) stating that the warning of the climate system was 'unequivocal'. Additionally, the Department of Communities and Local Government report on water efficiency in new buildings (DEFRA, 2007) states that if carbon dioxide emissions were reduced immediately, there would still be significant climate change over the next forty years as a result of past human activity resulting in a less predictable climate and water supply.

Even without any additional housing, water use in the UK is already considered to be excessive, with the average water use per person per day currently at 150 litres (Heywood, 2008), compared with figures of 127 litres in Germany and 125 litres in the Netherlands (Elliott, 2009a). These figures show that the UK needs to make major advances in water efficiency and this is further illustrated when

specific figures, rather than averages, are used with a figure of 164 litres is cited for usage per person per day across the South of England (Elliott, 2009a).

Burkhard et al. (2000) calculated that of all water fit for human consumption supplied to homes each year, 33% is used to flush toilets and 21% used in washing machines. Reporting on the feasibility of efficient domestic water usage, Wood (2003) identified sustainability as a way of meeting present needs without the compromising the ability of future generations to meet their needs. No method for doing this was given but it was concluded that either present water consumption must be changed or new sources found or different technological solutions implemented to reduce water usage in dwellings.

Measures have already been taken to reduce the amount of water used in dwellings with the majority of new UK homes connected to water meters. This is a move which has had a positive impact on water use according to Elliott (2009a) as metered houses on average use at least 15% less water per annum than non-metered houses. This figure can rise to as high as 40% in houses occupied by just one or two people. Consequently, the UK's Environment Agency called for all homes to be fitted with compulsory water meters within the next six years (Elliott, 2009b).

However sustainability measures such as these do come at a cost, with O'Connor (2009) reporting estimates that meeting the UK Government water usage standards typically adds around US$10000 to the cost of a new home. Some of this cost is regained by the homebuyer in cheaper running costs but Blackwood (2008) believes that this additional cost to the construction, coupled with the recent downturn in the housing market, has a negative effect on the willingness of house builders to incorporate water sustainability measures in the design of dwellings.

As a result of both this unwillingness by house developers to voluntarily reduce water usage levels and continued indication that water demand will outstrip supply, the UK Government, in 2009, announced major legal revisions affecting the construction of new houses, stating that any new dwelling should be designed to give a maximum water usage of 125 litres per person per day. To achieve this a water use calculation is to be carried out which takes account of the water use of all fixtures and fittings, from baths and washing machines to individual taps, to give a per person per day figure for a specific building type. Without meeting these water usage rates, permission to build would not be granted.

Gilg and Bark (2006) had already raised concerns over the use of such approaches to promoting environmental action as they do not take into account the 'lived experiences' of the people they are supposed to represent and influence. It was not made clear how the stated figure of 125 litres had been decided, so doubts emerged as to the effectiveness of the proposed changes as there are uncertainties on the basis of the stated figure in terms of likely water use and consumer behaviour (Market Transformation Programme, 2008).

Further doubts were raised on the control of water usage through the specification and use of water efficient appliances and fittings. Even if usage levels were achievable, they may not be a viable long-term solution as house fittings are neither permanent nor an integral part of the structure and their easy removal and replacement with units of equal performance (Heywood, 2008) is not guaranteed. Such replacements could render the initial water usage exercise useless and incapable of monitoring water usage levels without great expense, whilst not reducing overall usage.

If the required water efficiency for a dwelling cannot be guaranteed using standard fixtures and fittings, it may however be offset by providing water for non-potable uses through recycled rainwater and greywater. Mussett (2009) believes that as well attempting to minimise water use, the UK Government

now has a clear policy of promoting the reuse of rainwater and greywater. According to Furumai (2008), a move towards fuller understanding of the potential of recycling domestic water is almost inevitable as concern about the sustainability of urban water use grows.

Rainwater is generally the more straightforward of the two to recycle but its use is very poorly understood. Again, the UK is some way behind their European neighbours with countries such as Germany currently having an uptake of 50,000 rainwater recycling plants in new homes per year (Nolde, 2007). Such an uptake suggests that there are significant benefits to the use of these systems but Hatt *el al.* (2006) feel that no long-term survey of rainwater reuse systems has been carried out on a scale wide enough to give a clear picture of their worth.

Greywater refers to waste water which has been used in the home, through appliances such as washing machines and showers, but can be treated and reused to flush toilets. Minimal literature exists to show the use of greywater systems domestically, considered to be due to their physical size and complexity. Naisby (1997) believes that greywater recycling is not viable in the domestic market due to the initial set-up cost when taken in relation to the relatively low cost of water. Perceived difficulties with the maintenance of these systems viewed their widespread use as unacceptable to the domestic market (Wise and Swaffield, 2002).

There are figures to indicate that storm water reuse can have significant benefits. The research of Simms (1998) shows that the use of rainwater and greywater in combination can reduce the amount of drinking water used by up to 39%. Burkhard *et al.* agrees with Fewkes (1996) in the belief that the toilet is the greatest consumer of potable water, accounting for 30% of the overall amount used, so the benefits of such recycling systems can be seen in some context.

The literature review has established that there is a water shortage in the UK and its Government has identified that Building Regulations be changed to ensure newly constructed dwellings at design stage clearly prove by way of a water calculation water, that water usage is to be 125 litres per person per day. However doubts have been cast already on how this figure could be guaranteed to deliver the required water efficiency for dwellings using standard fixtures and fittings, so further water savings would potentially need to be made by providing water for non-potable uses through recycled rainwater and greywater initiatives.

3. The case study

In order to ascertain whether the Building Regulations would deliver water usage on new dwellings to the specified level, a case study approach was adopted, as it is particularly suited to this type of investigation with its in-depth analysis of a specific problem (Naoum, 2007). In this case the specific problem is to establish what the water usage level of per person per day will be, specifically will it be the new required level of 125 litres per person per day or will it be at the current ‘average’ consumption level of 150 litres per person per day?

The per person per day figure has to be calculated using the UK Government’s specified tool, the Water Efficiency Calculator for New Dwellings. The calculator lists all of the fittings and appliances that are likely to be found in a new dwelling and assigns to each one a numerical 'use factor' to signify how regularly that fitting or appliance is used and consequently what its effect is on the total water consumption on the dwelling, consumption figures are to be provided from manufacturers’ product details.

The case study was applied to reflect a new housing scheme which was at the design stage. The design specification and the available technologies specified will be the same as if a major housing developer were actually using the water efficiency calculator so this study will be a realistic reflection of the procedures that constructors and housing developers would face in reality.

The authors used proposed specification details, supported by relevant manufacturers' data for a three bedroomed house and followed the protocols defined in the Water Efficiency Calculator for New Dwellings, and applied the tool for water usage of WCs, taps, bath, shower, washing machine, dishwasher, waste disposal unit and water softener unit within the unit.

The results indicated that, after a normalization factor had been applied (this adjustment factor aligns predicted average and actual average usage) the proposed three bedroom house was consuming water at a rate of 132.8 litres per person per day. If the water calculator is accurate then this dwelling is consuming 17.2 litres of water per person per day less than the expected government estimate of 150 litres of water per person per day, yet more than the new level of consumption of 125 litres per person per day.

The same calculation was then undertaken for a second case study based on a one bedroomed apartment, and carried out on the same basis as for the three bedroomed dwelling. The calculation results for water usage in a new build one bed apartment produced exactly the same result as for the three bedroomed dwelling that of 132.8 litres of water consumed per person per day.

Upon consideration, there are two possible explanations for these results. Firstly, that the pre-established government figures rate of 150 litres per person per day are inaccurate or secondly that the calculator is inaccurate. At the moment the latter seems to be more likely, as the literature review did not find any evidence of disagreement with the government's 150 litres per person per day figures. This leads to the probability that there is a flaw in the way in which the Water Efficiency Calculator for New Dwellings specifically considers human behaviour or the 'lived experiences' of people in the unit, as per Gilg and Bark, 2006.

There is also possible third explanation for the water consumption in the two case studies producing results which are below the established UK average and that is that newer homes design already achieve water efficiency by incorporating more effective modern fittings and appliances and hence it is the older housing stock which is pushing up the national average consumption figure.

To attempt to establish whether this was an accurate explanation, a third case study was carried out using a 1930s semi-detached house as the case study. However it was difficult to pin-point exactly what makes a 'typical' example of the older housing stock as there can be such a wide variation in the type of fittings and appliances that are used, but the example chosen did not appear to be exceptional in terms of its water consumption and was therefore considered to be a valid choice.

If it was the poor water efficiency of older dwellings which was so significantly affecting the national average for water consumption in the UK, it was expected that this case study should return results towards the higher end of the UK Government's 150-165 litres per person per day figure. Following the same case study approach as before, it therefore came as some surprise then when the older dwelling performed even more efficiently than the new-build when using the Water Efficiency Calculator for New Dwellings. The case study for the older housing stock returned a consumption figure of 111.6 litres per person per day. This is 21.2 litres less than the new build dwellings and 38.4 litres less than the national average. The evidence continues therefore to suggest that the Water Efficiency Calculator for New Dwellings does not accurately reflect the way in which water is used in domestic properties.

If we move on from examining the validity of the calculator and look specifically at the results returned, the new dwellings investigated record a usage of 132.8 litres of water per person per day and therefore do not meet the required legal requirements, using 7.2 litres of water per person per day more than the regulations allow.

Further examination of the various appliances used in the new build case studies demonstrated that it was quite straightforward to reduce the usage total by 7.2 litres and hence comply with the legal requirements. This was easily done by removing the power shower that runs at 12 litres per minute and replacing it with one that runs at 9.5 litres per minute. This is still a relatively powerful shower and is much more powerful than the electric showers which are retrofitted into many older properties, which generally run at around 3.5-4.7 litres per minute. This amendment in specification achieved the stated usage per person per day with this relatively minor change.

The striking thing about the ease with which the 125 litres per person per day total can be achieved is that it would remove the need to incorporate rainwater and greywater recycling systems into the design of new housing schemes. The introduction of such technology was considered to be a significant event in terms of future water efficiency, reduced consumption and saving water, but it now seems that the use of these recycling systems will not be needed to meet legal consumption limits.

What is apparent is the ease in which the recommended usage levels have been met, which poses the question as to whether the prescribed UK Government limits are actually stringent enough to solve, what all experts agree, is an imminent water shortage?

The fact that it would be generally unnecessary to use rainwater and greywater recycling in new dwellings (the fittings and appliances used in the case study were at the high end of water usage and compliance was still easily achieved) could be considered to be something of a surprise in one respect. There is a belief in some quarters that for a sustainable water supply to be achieved then new sources of domestic water supply, such a greywater and rainwater recycling, must be used (Wood, 2003) but the revisions to the Building Regulations do not seem to encourage such innovations presently. Similarly Mussett (2009) states that these new Building Regulations are specifically intended to promote the reuse of rainwater and greywater but the results of the case studies suggest otherwise.

The Water Calculator for New Dwellings does allow the designer to offset recycled water against potable water use. For example, if the calculator showed that a dwelling as designed was using 135 litres per person per day the designer could incorporate a rainwater recycling system which returns ten litres of water per person per day back in the system and the two would balance out to give an overall water consumption of 125 litres per person per day.

The UK Government believes that allowing for the use of rainwater and greywater systems in the design of new houses will give greater flexibility for the designers to work within (Department of Communities and Local Government, 2008) but the ease with which the regulations can be satisfied without the use of such systems suggests that this flexibility will not be embraced by the house building sector as they look to meet the regulations at minimum cost at the design stage and maximum profit at the selling phase.

Although it is not intended to paint the house building industry as the guilty party in this debate they exist to make a profit and as such it seems unlikely that they will take on additional water recycling measures unless legislation is passed to say that they have to, for example the set-up costs for rainwater recycling has been estimated (Blackwood, 2008) to add a further US$3000 per dwelling. As this cost is likely to be passed onto the potential buyers of these new properties and in these times of economic recession would the UK Government be penalising homebuyers for a lack of innovation on the part of

the house building industry? Perhaps a viable alternative would be to educate people as to how to use water more efficiently, especially as the case studies indicated that there are serious doubts over the ability of the Water Efficiency Calculator for New Dwellings to take account of human behaviour when calculating water usage.

At first glance the measures undertaken in the case study to ensure compliance with the new regulations appear to be sound in terms of water efficiency as the designer has to look at using more efficient fittings or appliances to achieve the water usage targets. However as the usage figures were easily met, there is no reason for designers to move beyond this aspect of design and they can easily ignore the inclusion of rainwater and greywater recycling systems, albeit their inclusion would have greater permanency and an effect which would result in greater overall water reductions in the long term.

4. Concluding remarks

The literature review established that the UK has a future water provision problem, with water shortages inevitable unless consumption falls.

The UK Government introduced legislation to limit water consumption and expects house designs to use a Water Efficiency Calculator for New Dwellings to ensure water usage is at a stipulated level before house construction can legally commence. The case studies identified that the Water Efficiency Calculator for New Dwellings does not accurately reflect water usage, as there appears to be a flaw in the way in which the calculator ignores the human factor when using appliances and as a result the calculator will not in itself be able to drive the reductions needed in water usage.

Further the case studies have shown that the requirements of the revised Building Regulations' legislation are relatively straightforward to achieve and that new dwellings can easily be designed to meet Government requirements with minimal alterations to current practises and as a result will offer only very limited reductions in water consumption from current levels. In this respect the new legislation should be considered a failure as house builders will continue with current practises without embracing the new technologies of rainwater and greywater systems, whose use would decrease the amount of clean water consumed.

In conclusion these new regulations and the associated use of the water efficiency calculators are not sufficiently stringent to reduce UK water consumption nor, as a result, ensure the continuity of the future water supply as was the UK Government's intention. As it stands therefore, current UK Government water usage measures will not influence construction specification, design and the adoption of construction technologies such as rainwater and greywater recycling systems in housing schemes, so as a result future potable water sustainability has not been ensured.

5. References

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