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Contents

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Editorial - Dr Harold Harvey and Dr Paul Fleming

With this Issue, JEHR enters a new phase of development. A revised and enhanced Editorial Team has been recruited to provide even greater breadth and depth in the expertise available to take the Journal forward over the next five years. We are joined by Miss Julie Barratt, Professor Ian Blair, Dr Gai Murphy and Mr David Statham whose brief profiles appear on page 59.

We are also pleased to welcome Mr Bernard Forteath, President of` the Royal Environmental Institute of Scotland, who joins our growing list of distinguished guests who have written guest editorials; Bernard's first editorial introduces this Issue. From the range of papers awaiting publication we have made a selection which we hope will be of interest and value to practitioners, academics and scientists. Our aim is to provide a variety of topics, to balance practical and academic issues and to recognise geographical diversity thus providing an eclectic appeal to those with an interest in environmental health. Let us know if we have achieved this to your satisfaction!

To provide convenient access to the papers we will continue to publish in three formats; 'Full Printed' version, 'Printed Abstracts' - which is distributed to all CIEH members - and an 'On-line' version. The on-line version provides open access and is listed in the Directory of Open Access Journals (www.doaj.org) alongside 2500 other quality-controlled scientific and scholarly journals.

The falling plate method: Evaluating the risk of aquaplaning on wet floors - Dr François Quirion1 and Patrice Poirier1

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Abstract

Many slip and fall accidents occur on wet flooring. As the foot hits the wet floor, a liquid film may become trapped between the heel or the sole and the floor. If the threads on the heel or sole and the roughness and texture of the flooring allow the liquid to be evacuated rapidly, then there is a shoe-floor contact and friction dominates. If, however, the liquid cannot be evacuated rapidly, then the shoe slides over the squeezed liquid film without contact between the sole and the floor. This phenomenon is very similar to aquaplaning and its occurrence depends on the texture of the heel and sole material, the texture of the flooring and the thickness and viscosity of the liquid forming the squeezed film. We report a simple approach, the falling plate method, for the investigation of the slip resistance of wet flooring. A plate standing perpendicular to the wet flooring falls freely on it. As it hits the wet flooring, the plate slides over a distance that depends on the ability of the flooring to evacuate squeezed water. The minimum amount of water necessary for the plate to slide over a liquid film, t*, is called the aquaplaning threshold. It was determined by measuring the sliding distance of a smooth stainless steel plate as a function of the amount of water for nine floorings having a roughness, Ra, in the range 0.8μm < Ra < 11μm. We find that t* increases linearly with Ra being around 20μm for flooring with a Ra~1μm and increasing up to 63μm when Ra reaches 11μm. The aquaplaning threshold also correlates well with the wet friction determined with a Brungraber Mark II. These results suggest that the aquaplaning threshold provides valuable information on the slip resistance of wet flooring.

Key words: Aquaplaning; environmental health; falling plate; friction; slips, trips, falls; slip resistance; squeezed film; wet floor.

Introduction

It is well accepted that many slip and fall accidents occur on wet floors (Leclercq, 1999) and that slipping occurs mostly when the heel strikes the floor (Strandberg and Lanshammar, 1981). It is often suggested that during the slide, the heel is supported by a thin layer of water that allows little or even no contact with the flooring (Grönqvist et al, 2003). This raises the question of how much water is needed for the formation of a squeezed liquid film between a shoe heel or sole and the flooring. Intuitively, there should be a critical amount of liquid on a flooring under which the liquid film does not form and over which it forms and causes slipping. But what is that threshold and how does it vary from one flooring to another? Tribology (Rabinowicz, 1994) tells us that the apparent friction between two lubricated surfaces depends on many parameters including the relative velocity and the roughness of the two surfaces as well as the thickness and viscosity of the lubricant layer. It thus seems reasonable to assume that the threshold amount of water will depend on the heel material and its roughness, the flooring material and its roughness and the amount of water on the flooring.

Surprisingly, the investigation of the slip resistance of wet flooring seems to pay little attention to the amount and nature of the liquids used for the tests. The slipperiness of wet flooring is expressed as the friction coefficient measured with the same apparatus used for the determination of dry friction. Wet samples are often tested using an excess amount (Leclercq et al, 1994) or a fix amount (Chang, 1998) of liquid contaminant. It can be water, a detergent solution, mineral oil or a mixture of glycerol and water. For a review of these experimental methods, please see Chang et al (2001) and Cholet et al (2000).

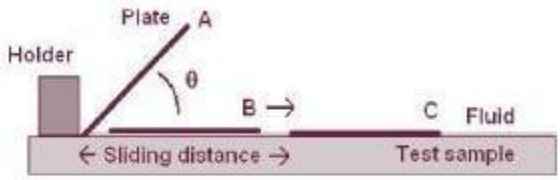
In order to investigate the slipperiness caused by a squeezed film, the experimental method must be able to generate that filmby hitting the wet flooring with a rather flat object simulating the shoe heel or sole. One very simple approach consists in letting a flat plate fall and hit a wet flooring. Interestingly, the movement of the plate, as it falls to the floor, is quite similar to the movement of the foot simulated by Liu and Lockhart (2006) for typical slipping events. As for a slipping event, the sliding distance will be longer if there is a squeezed liquid film formed between the plate and the flooring.

We (Quirion and Poirier, 2005 and 2006) presented preliminary results using the falling plate method to identify the aquaplaning threshold of various flooring. The purpose of this investigation is to present the method in more detail and to confirm that the aquaplaning threshold gives valuable information on the slip resistance of various flooring in wet conditions.

The falling plate method

The falling plate method measures the sliding distance of a plate as a function of the amount of water on the flooring. Experimentally (see Figure 1.0), the base of a thin rectangular plate is placed against a holder while its length forms an angle _ with the flooring.

Figure 1.0 In the falling plate method, a plate, leaning on a holder, stands at an angle with the flooring (A). When released, it falls flat on the flooring and slides (B) until it stops (C). The sliding distance is measured and analysed in term of the apparent friction of the plate on the flooring.



When the plate strikes the wet flooring, it is projected forward and parallel to the flooring. The sliding distance, *d*, depends on its horizontal kinetic energy and the amplitude of the forces acting against it. This approach was used for many years to determine the speed of cars from the length of the skidmarks (Adamson, 1976) assuming that the friction coefficient was known. In this investigation, we use the sliding distance to evaluate the friction of a plate on a flooring.

As the plate falls, its potential energy, *EP*, is transformed into kinetic energy. Upon impact with the flooring, a fraction, _, of that energy is transformed into horizontal kinetic energy, *EK,H*, so that the plate has an initial horizontal velocity, *vH* (Equations 1 and 2). The horizontal kinetic energy is dissipated into friction energy, *EF*, where *g* is the gravitational acceleration and *m* the mass of the plate (Equation 3). For simplicity, it is assumed that all the forces acting against the horizontal motion generate an apparent dynamic friction coefficient, *μK,app* (Equation 4).

$$(1)\quad E_{K,H} = \Phi \cdot E_P = \frac{m \cdot v_H^2}{2} = \Phi \cdot m \cdot g \cdot \left(\frac{L \cdot \sin(\theta)}{2}\right)$$

$$(2)\quad v_H = \left(\Phi \cdot g \cdot L \cdot \sin(\theta)\right)^{1/2}$$

$$(3)\quad E_{K,H} = E_F = \mu_{K,app} \cdot m \cdot g \cdot d$$

$$(4)\quad \mu_{K,app} = \frac{\Phi \cdot L \cdot \sin(\theta)}{2 \cdot d}$$

The apparent dynamic friction coefficient increases with the reciprocal of the sliding distance of the plate on the flooring. However, to obtain the absolute value of the apparent dynamic friction coefficient, one must determine the parameter _. In order to keep the method as simple as possible, we chose to eliminate _ by expressing the apparent dynamic friction coefficient of the wet flooring, *μK,app,wet*, relative to that of the dry flooring, *μK,app,dry*. It is also assumed that _wet = _dry. The friction ratio, *μR*, becomes a very simple function of the sliding distance under dry, *ddry*, and wet, *dwet*, conditions (Equation 5).

$$(5)\quad \mu_R = \frac{\mu_{K,app,wet}}{\mu_{K,app,dry}} = \left(\frac{\Phi_{wet}}{\Phi_{dry}}\right) \cdot \left(\frac{d_{dry}}{d_{wet}}\right) \approx \left(\frac{d_{dry}}{d_{wet}}\right)$$

When the sliding distance of a given plate-flooring combination is measured as a function of the amount of water, then ddry is a constant and the trend of the friction ratio is that of the apparent dynamic friction coefficient of the plate on the wet flooring. If the amount of water on the flooring is too low to form a liquid film between the plate and the flooring, then the sliding distance is rather small with a friction ratio close to one. Conversely, when the amount of water is large enough to form a liquid film under the plate, the sliding distance is high with a low friction ratio.

The critical amount of water necessary to form a liquid film between the plate and the flooring can be determined through the analysis of the sliding distance of the plate as a function of the amount of water on the flooring. We chose to express the amount of water in termof the apparent water thickness, t, using the volume of water, VW, spread on the geometrical area of the flooring, AW (Equation 6). For instance, an apparent thickness of 100µmof water corresponds to 100millilitre of water per square metre of flooring.

$$(6)\quad t\left(\mu m = \frac{ml_{Water}}{m^2}\right) = 10^6 \cdot \frac{V_W\left(m^3\right)}{A_W\left(m^2\right)}$$

A typical example is shown in Figure 2.0 for a smooth stainless steel plate sliding on a finished vinyl composition tile. The sliding distance remains almost constant until the apparent water thickness is around 30µm. At higher water thickness, the sliding distance increases steeply and finally reaches a plateau. Using Equation 5, the sliding distances were converted into a *μR vs. t* data set. The friction ratio, which reflects the apparent dynamic friction coefficient of the wet flooring, drops steeply at a thickness of water around 30µm.

To eliminate the subjectivity of a graphical interpretation, all the *μR vs. t* data sets were fitted to the same empirical model (Equation 7) with *μR,i* and *μR,f* the initial and final friction ratio, *t**, the aquaplaning threshold and *a*, the steepness of the friction drop. For most data sets, *μR,i* = 1 and *μR,f* is the friction ratio at high values of *t*. The data can then be fitted with only two variables, *a* and *t**.

$$(7)\quad \mu_R = \mu_{R,F} + \left(\mu_{R,i} - \mu_{R,F}\right)\cdot \exp-\left(\frac{t}{t^*}\right)^a$$

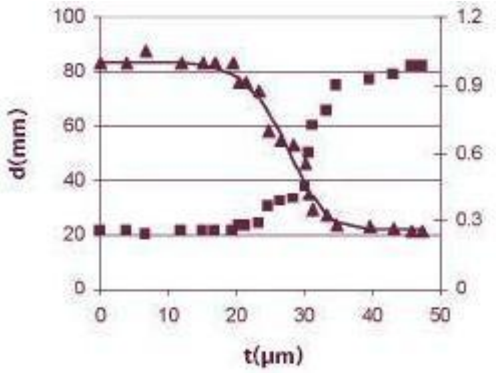
For example, fitting the *μR vs. t* data presented in Figure 2.0 with Equation 7 gave *μR,i* = 1.0 (fixed), *μR,F* = 0.26 (from experimental data), *a* = 6.5 and *t** = 29μm. The rather high value of the exponent a indicates a steep change in the friction of the wet flooring relative to the dry flooring. The change occurs at the aquaplaning threshold, *t**, and the model imposes that the friction ratio at the threshold is *μR** (Equation 8).

$$(8)\quad \mu_R^* = \mu_{R,F} + \frac{\left(\mu_{R,i} - \mu_{R,F}\right)}{e}$$

In the example of Figure 2.0, the threshold friction ratio corresponds to _*R*0.53, i.e. that the risk of aquaplaning would increase when the apparent friction drops suddenly to 53% of the dry friction. This is an empirical definition of the aquaplaning threshold and it only has the advantage of being objective. Our concern is not to determine the absolute value of the aquaplaning threshold and of the threshold friction ratio. We are mostly interested in their evolution for different types of flooring.

In this investigation, we wish to emphasise the contribution of the flooring to slip resistance in wet conditions. To do so, we used a smooth stainless steel plate as the slider. It is known that hard materials with little roughness are very slippery in wet conditions. For instance, the evaluation of the slip resistance of whole shoes is sometimes performed on smooth stainless steel plates (Leclercq *et al*, 1995) to emphasise the intrinsic contribution of the shoe to slip resistance. The reverse should also be valid, i.e. using a smooth stainless steel plate as the heel (sole) material in order to emphasise the contribution of the flooring to slip resistance in wet conditions.

Figure 2.0 Typical data set for the sliding distance, *d*, and the friction ratio, *μR*, of a stainless steel plate (mass = 76g, width = 41mm and length = 64mm) on a finished vinyl composition tile (VCTF) against the apparent water thickness (t). Solid line is the best fit using Equation 7 with μR,i = 1.0, μR,F = 0.26, a = 6.5 and t* = 29μm.



Note that the falling plate method is not limited to stainless steel and to smooth plates. We have also obtained good results using a Neolite slider (Quirion and Poirier, 2005). Rougher or even patterned plates could be used as well as rougher and patterned flooring materials.

Methodology

This section describes briefly the experimental procedures that were used to obtain the sliding distance, the average roughness and the wet friction of the flooring. The flooring tested consisted of commercial flooring cut to a width of 75mm and a length between 150 and 200mm.

Sliding distance, friction ratio and aquaplaning threshold

This investigation presents μR vs. t data sets obtained with a stainless steel plate of width 41mm and length 64mm weighing 76g. Before each series of measurements on a given flooring (typically 15 to 20 measurements), the plate was sanded (orbital sander) with 220 grit paper and cleaned with acetone. The average roughness, Ra, of the stainless steel was 0.15μm.

The sliding distance was always measured in the same way. As shown in Figure 1.0, the plate was placed against the holder. Unless otherwise specified, the drop angle was 90° so that the plate initially stood perpendicular to the flooring. The fall was initiated by pushing the top of the plate very slowly until it fell freely under the action of gravity. When the plate reached a stop, the sliding distance was measured. In this investigation, the maximum sliding distance is limited by the length of the flooring sample (either 150 or 200mm), the length of the sliding plate (64mm) and the thickness of the holder (12mm). It is thus either 82 or 124mm depending on the length of the flooring sample. In some conditions, the plate slid past the edge of the flooring sample. These data were rejected because there is no way to find out just how far it would have gone.

The sliding distance on the dry flooring, *ddry*, can be obtained at any moment. The only requirement being that the flooring is completely dry. The sliding distance on the wet flooring, *dwet,* was determined by spraying water homogeneously over the tile using an airbrush applicator. After weighing the mass of water on the tile, the sliding distance was measured as described above. After each measurement, water was wiped off from the flooring and the procedure was repeated for the determination of the sliding distance at a new water thickness. The sliding distances on the wet and dry flooring were used to calculate the *μR vs. t* data sets with Equation 5 and the aquaplaning threshold, *t**, was obtained by fitting the *μR vs. t* data sets with Equation 7.

Average roughness (Ra)

The average roughness of the flooring was determined at the beginning of the investigation using a DekTak 3030 (radius of curvature of the tip = 12μm, Force = 0.05 N, scan length = 5mm). Each scan provided a value for the average roughness, *Ra*, and the values reported in this investigation are the average of at least four scans at different locations of the flooring.

Dry friction (μK,dry)

The friction experienced by the plate as it slides on the Dr François Quirion and Patrice Poirier dry flooring is very similar to the friction obtained by a horizontal pullmethod. In this investigation, the dynamic friction coefficient was measured by pulling the stainless steel plate at a velocity of 25 mm.sec -1 on the dry flooring. For each run, the pulling force was sampled (Shimpo, FGV-1 force gauge) at 10 hertz for two seconds after the initial movement of the plate. The dynamic friction coefficient on the dry plates was then calculated by dividing the average pulling force by the weight of the plate. In this investigation, the values of *μK,dry* correspond to the average of at least 4 runs. The standard deviation on *μK,dry* was always between 1 and 2 % except for the *QTM* where it was 10%.

Wet friction (μK,wet)

The wet friction of the flooring was determined using a Brungraber Mark II apparatus. Instead of using the recommended Neolite or leather skates, we fitted the stainless steel plate used for the falling plate experiments to the Mark II holder. Before each drop, the back of the slidere was tilted so that it touches the flooring. Measurements were made on wet flooring at a water thickness around 100μm (100 ml.m-2).

Results and discussion

The flooring tested in this investigation were cut from commercial flooring having no definite patterns and a relatively low average roughness (*Ra*). Their origin and *Ra* are reported in Table 1. Sample *QTF* was prepared from a new *QTM* tile that was worn and fouled with fat according to a procedure developed in our laboratory (Massicotte and Quirion, 2002).

Table 1.0 Origin, average roughness, dry friction, fraction of potential energy converted into kinetic energy, sliding distance and critical water thickness of the nine floorings tested.

Description of the flooring	Abbreviation	<*Ra*> (μm)	$<\mu_{K,dry}>$	$<\phi_{dry}>$	$<d_{dry}>$ (mm)	$<t^{*}>$ (μm)
Quarry tile, CIPA GRES, Worn and Fouled	QTF	0.8 ± 0.1	0.190	0.107	18	20 ± 3
Glazed ceramic tile, Cecrisa, New	CER	0.9 ± 0.1	0.262	0.098	12	27 ± 5
Vinyl composition tile, Tarkett, Finished	VCTF	2.1 ± 0.2	0.244	0.168	22	29 ± 2
Porcelain tile,Megagres, New	POR	2.7 ± 0.2	0.253	0.087	11	22 ± 4
Vinyl composition tile, Tarkett, Stripped	VCT	2.7 ± 0.3	0.324	0.162	16	22 ± 4
Quarry tile, CIPA GRES, New	QTM	5.4 ± 0.8	0.236	0.066	9	43 ± 1
Quarry tile, American Olean,New	Q01	5.7 ± 0.9	0.212	0.066	10	39 ± 6
Vinyl floor covering, Forbo 7727, New	F77	6.7 ± 1.8	0.228	0.064	9	50 ± 1
Vinyl floor covering, Forbo 7527, New	F75	11.0 ± 3.3	0.338	0.084	8	63 ± 6

The resulting *QTF* is very similar to the tiles found in many commercial (Underwood, 1992) and institutional kitchens (Massicotte and Quirion, 2002). *VCTF* is the same vinyl composition tile as *VCT* with two coats of acrylic finish (ShureShine, Tarkett).

The average roughness of the stainless steel slider was 0.15 μm, i.e. much less than any of the floorings tested. The average roughness of the flooring tested did not change by more than 10% from the beginning to the end of the investigation.

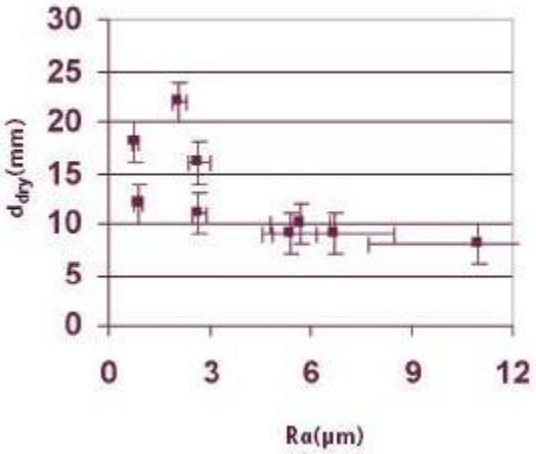
Sliding distance on dry flooring (ddry)

The sliding distance, *ddry*, and the dynamic friction coefficient, *μK,dry*, of the stainless steel plate over the nine flooring tested are reported in Table 1. There seems to be no correlation between either *ddry* and *μK,dry*. However, Figure 3.0 shows that *ddry* is higher for the smoother tiles and decreases to a plateau value as *Ra* increases.

The longer sliding distances on the smoother tiles could be the result of the formation of an air cushion between the plate and the tile. This is similar to a paper sheet sliding over a smooth table top or a wood panel sliding over long distances on a smooth concrete floor. In such conditions, the apparent friction on the dry flooring would be lower than the real friction, *μK,app, dry* < *μK,dry* and Equation 4 tells us that the d*dry* would be longer than expected. Equation 4 also tells us that the longer sliding distance could be the result of a higher energy transfer to the plate, _*dry*, for smoother flooring. At this point, it is difficult to discriminate between the two effects (lower apparent friction and higher energy transfer). Using

Equation 4, the value of _*dry* was calculated with by replacing *μK,app, dry* with *μK,dry* and it is reported in Table 1.

Figure 3.0 Evolution of the sliding distance, *ddry*, of a stainless steel slider (width = 41mm, length = 64mm) as a function of the average roughness, *Ra*, of the dry floorings.



The assumption that *μK,app, dry ~ μK,dry* is realistic for the rougher flooring where the air cushion is less likely to form under the plate. For these flooring (*QTM, Q01, F75* and *F77*) the average roughness increases from 5 to 11μm with very little change in the value of _*dry* which remains almost constant at ~7%. If one assumes that the energy transfer is not correlated to the roughness, than the longer sliding distance for the smoother flooring would be the consequence of a low apparent friction coefficient, possibly due to the formation of an air cushion.

Testing the method on wet tiles

The simplicity of Equation 5 suggests that the friction ratio, *μR*, is not a function of the drop angle, _, so that the sliding distances obtained at different values of _ should all fall on a master curve when they are expressed in terms of their friction ratio, *μR*.

Figure 4.0 Impact of the drop angle (_ = 90° (*), 70° ( ), 60° ( ), 50° (Δ), 40° (X)) on a) the sliding distance, *d*, and b) the friction ratio, *μR*, for a stainless steel plate falling on wet ceramic tiles (*CER*). *t* is the apparent water thickness.

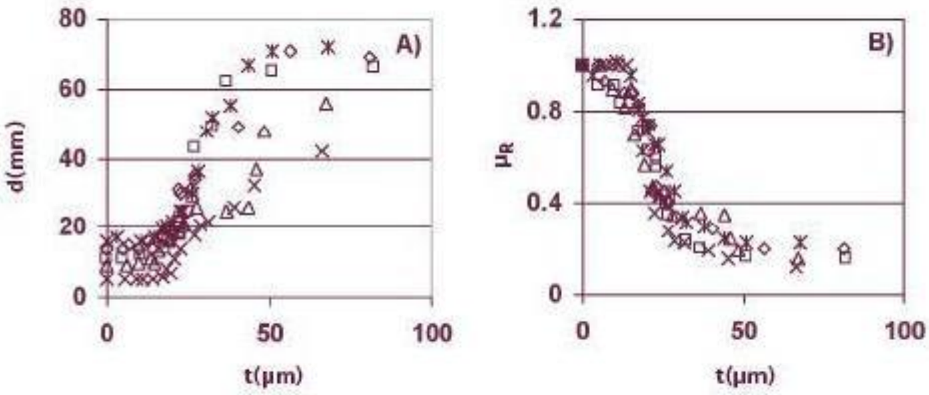
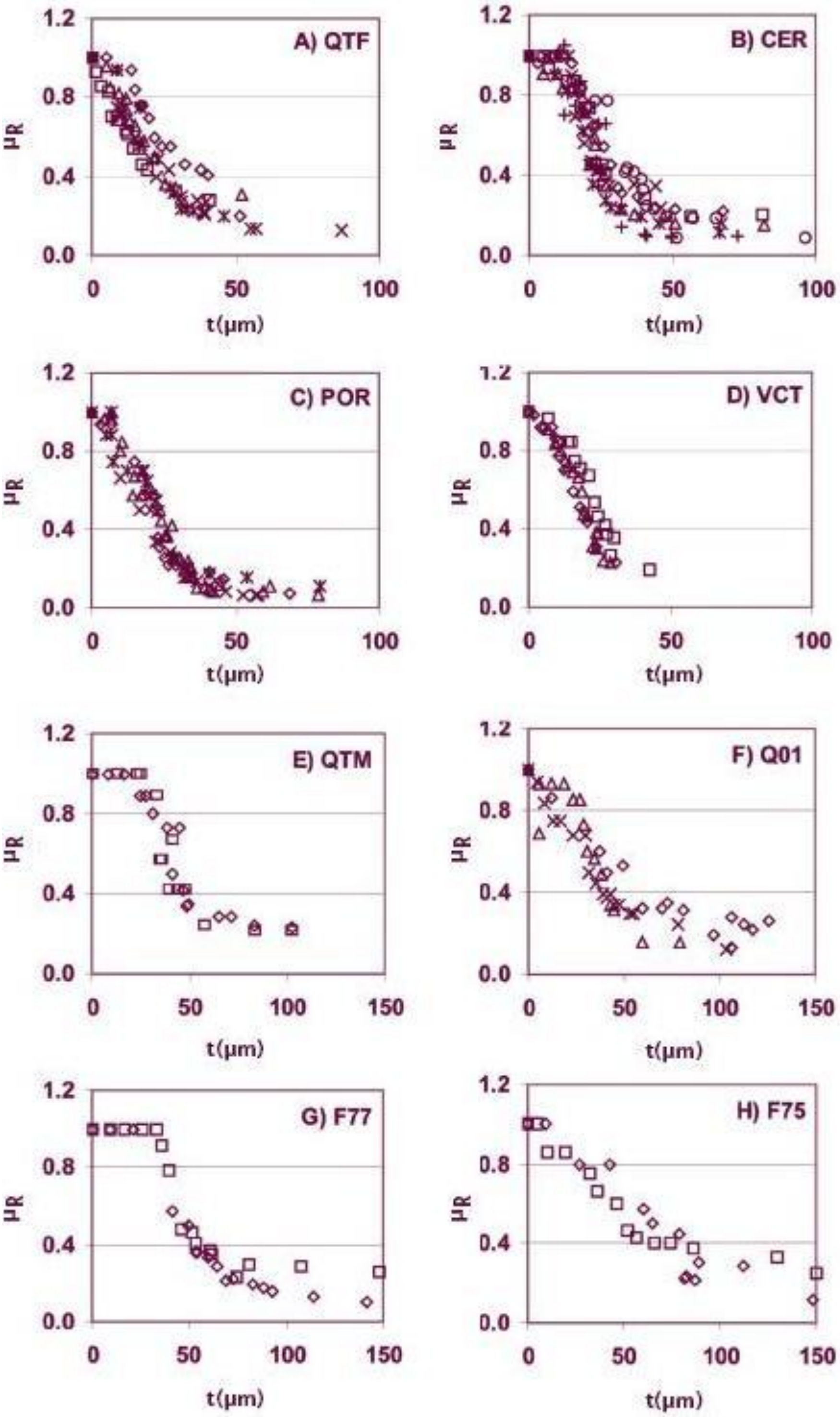


Figure 5.0 Evolution of the friction ratio, *μR*, of the stainless steel plate on eight different floorings as a function of the apparent water thickness, *t*. The different symbols represent different data sets.



This was checked by measuring the sliding distance, *d*, of the stainless steel slider on ceramic tiles (*CER*) as a function of the apparent water thickness, *t*, at five drop angles (_ = 90, 70, 60, 50 and 40°). Figure 4.0a shows that, on the dry ceramic tiles (*t* = 0), the sliding distance increases with the drop angle in accordance with Equation 4 (*ddry* _ sin(_)). This is also true at any given value of *t*, confirming that Equation 4 holds for both dry and wet conditions.

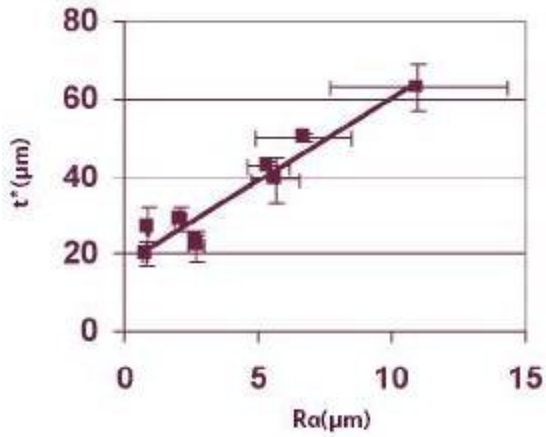
At a given drop angle, the sliding distance increases with the apparent water thickness and the trend is the same for the five drop angles tested. When the sliding distances obtained at a drop angle are reduced to the friction ratio, *μR*, with the corresponding sliding distances on the dry tiles, all *μR vs*. *t* data sets fall on a master curve (Figure 4.0b) in accordance with Equation 5.

The aquaplaning threshold (*t**)

When the plate hits the wet flooring, water has to be evacuated rapidly to prevent the formation of a squeezed liquid film that will reduce drastically the friction. If there is too much water, the plate will slide over the liquid film resulting in a low apparent friction coefficient, and a small friction ratio. As observed in Figure 4.0b, the friction ratio remains close to one at low water thickness and then decreases sharply when the apparent thickness reaches a threshold value. In this investigation, we refer to that transition as the aquaplaning threshold, *t**, and we define it as a critical thickness of liquid (in μm) over which the risk of aquaplaning becomes important.

Figure 5.0 presents the *μR vs. t* data sets obtained for eight of the nine floorings (for *VCTF* see Figure 2.0). All the data sets obtained on a given flooring are plotted together with different symbols to emphasise the good reproducibility. The trend of the *μR vs. t* data sets is not always the same from one flooring to another. Sometimes there is a small plateau at low apparent water thickness (*CER, F77* and *QTM*) and sometimes the friction ratio drops rapidly at very low water thickness (*POR, VCT, F75*). In most cases, the friction ratio reaches a plateau at high water thickness, suggesting that the addition of more water does not change the apparent friction of the plate with the flooring. This is in accordance with the formation of a liquid film between the plate and the flooring. Once the plate slides on the liquid film, adding more water should have little impact on the apparent friction.

Figure 6.0 Evolution of the critical water thickness, *t**, with the average roughness, *Ra*, of the floorings tested. The solid line is the best linear fit with slope = 4.24, ordinate = 17.2μm and r2 = 0.91.



All *μR vs. t* data sets were fitted independently to Equation 7 to get the aquaplaning threshold. The different values of *t** obtained for a given flooring were averaged and they are presented in Table 1.0 together with their standard deviation.

Intuitively, the ability of a plate-flooring combination to generate a squeezed liquid film should decrease as the roughness of the flooring increases. In other words, the aquaplaning threshold should increase with the average roughness of the flooring. This is shown in Figure 6.0 where the aquaplaning threshold, *t**, increases linearly with the average roughness, *Ra*, of the flooring tested. It has been suggested that the roughness of a flooring gives information on its slip resistance in wet conditions (Chang, 1999). So, the good correlation of the aquaplaning threshold with the average roughness of the flooring indicates that the aquaplaning threshold also gives valuable information on the slip resistance of these flooring under wet conditions.

Interestingly, t^* does not extrapolate to zero. This suggests that it would take a minimum amount of water to induce aquaplaning on a perfectly smooth flooring. This makes sense when we consider the empirical definition of the aquaplaning threshold imposed by Equation 7. Since, by definition, the risk of aquaplaning occurs when the friction ratio reaches the value of μR^* (Equation 8), then it seems reasonable to assume that it will take a minimum amount of liquid on the surface of any flooring for the friction to drop from 1 to μR^*.

Figure 7.0 Aquaplaning threshold, t^*, obtained with the falling plate method using a stainless slider as a function of the wet friction determined with the Brungraber Mark II. For these experiments, the Mark II was equipped with the stainless steel plate used for the falling plate method and the measurements were performed at a water thickness around 100μm (100 ml.m-2).

$$(7)\quad \mu_R = \mu_{R,F} + \left(\mu_{R,i} - \mu_{R,F}\right)\cdot \exp-\left(\frac{t}{t^*}\right)^a$$

The average value of μR^* for the 32 data sets analysed in this investigation was 0.48 ± 0.03. But is 17.2μm a reasonable value for the aquaplaning threshold of a perfectly smooth flooring? The value seems too high. Another contribution would be the roughness of the plate itself. Although it is very small, it can accommodate some water. We have considered that the plate and the flooring tested were perfectly flat. It is possible that both surfaces present small deformations that would allow some liquid to remain trapped, thus overestimating the aquaplaning threshold. But at this moment, it is not possible to quantify these contributions.

If, as suggested by Chang (1999), the roughness is correlated with the wet friction, and if the aquaplaning threshold is correlated with the roughness, than the aquaplaning threshold should be correlated with the wet friction. To check this, the wet friction of the stainless steel plate on the nine floorings tested was determined at an apparent water thickness of $t \sim$ 100μmwith a Brungraber Mark II. This experimental method allows water to be trapped under the plate as it hits the surface of the wet flooring. The aquaplaning threshold is plotted against the wet friction of the flooring tested in Figure 7.0.

There is indeed a good correlation between the two parameters. It is not clear if the aquaplaning threshold extrapolates to zero at very low wet friction or if it reaches a plateau. More experimental work is required to answer that question.

The results of this investigation strongly suggest that the aquaplaning threshold could be used to compare the risk of aquaplaning on different types of flooring. For example, the risk of aquaplaning would be similar for the smoother flooring (*QTF, CER, VCTF, POR* and *VCT*) with an average aquaplaning threshold of 24 ± 4μm. The new and rougher quarry tiles (*QTM, Q01*) would be able to accommodate about 70%more water than the smoother tiles before the risk of aquaplaning appears. This amount would increase to 100%for *F77* and 160%for *F75*.

The results of Table 1 also indicate that the aquaplaning threshold of newly installed flooring of quarry tiles (*QTM* = 43μm) would drop significantly as the tiles would wear and become fouled

(*QTF* = 20μm) in accordance with observations made during a field investigation (Massicotte and Quirion, 2002).

Conclusions

The falling plate method was developed to investigate the aquaplaning resistance of wet flooring. The experimental method is very simple to use and the theory behind it is quite easy to understand. A flat plate falls freely on a flooring covered with different amount of a liquid. The sliding distance on the wet and dry tiles are used to calculate the friction ratio between wet and dry conditions. The evolution of the friction with the apparent water thickness is then analysed with an empirical model to obtain the aquaplaning threshold for the plate on the flooring. This investigation confirms that: _ The falling plate method is easy to use and it generates reproducible data sets from which the aquaplaning threshold can be extracted.

- The theoretical background is respected, for instance that data obtained at different drop angle all provide the same results.
- The use of a smooth stainless steel plate emphasises the contribution of the flooring to the aquaplaning resistance.
- For flooring without texture and a relatively small average roughness ($0.8 < Ra < 11\mu m$), the aquaplaning threshold increases linearly with the average roughness.
- The aquaplaning threshold increases with the wet friction of flooring.

In this investigation, the falling plate was a rather light and smooth stainless steel plate but other types of plate could also be used to investigate the impact of the nature of heel or sole the material and texture on the resistance to aquaplaning. Although the results are promising, there is still much to do to come up with a method that would reproduce a typical heel(sole)-floor interaction. Nevertheless, the aquaplaning threshold can be used to compare the aquaplaning resistance of different flooring.

Table 2.0 List of symbols

Ra	Average roughness
t	Apparent thickness of the liquid layer between the plate and the flooring
L	Length of the plate
d	Sliding distance of the plate
d_{dry}	Sliding distance of the plate on a dry flooring
d_{wet}	Sliding distance of the plate on a wet flooring
m	Mass of the plate
g	Earth's gravitational acceleration = 9.81 ms^{-2}
E_P	Potential energy of the plate
E_{KH}	Horizontal kinetic energy of the sliding plate
v_H	Initial horizontal velocity of the sliding plate
θ	Drop angle between the plate and the flooring
Φ	Fraction of the potential energy transformed into horizontal kinetic energy
Φ_{dry}	Fraction of the potential energy transformed into horizontal kinetic energy when the plate hits a dry flooring
Φ_{wet}	Fraction of the potential energy transformed into horizontal kinetic energy when the plate hits a wet flooring
$\mu_{K,app}$	Apparent dynamic friction coefficient (wet or dry)
$\mu_{K,dry}$	Dynamic friction coefficient on a dry flooring
μ_R	Friction ratio between the apparent dynamic friction coefficient of a wet and dry flooring
$\mu_{K,app,wet}$	Apparent dynamic friction coefficient on a wet flooring
μ_{Ri}	Initial friction ratio
μ_{Rf}	Final friction ratio
a	Steepness of the friction drop
t^*	Aquaplaning threshold
μ_R^*	Threshold friction ratio corresponding to the friction ratio when $t = t^*$
A_W	Wet area of the flooring
V_W	Volume of water sprayed on the flooring
QTF	Worn and fouled quarry tile (Monogres)
QTM	Quarry tile (Monogres)
CER	Glazed ceramic tile (Cecrisa)
POR	Porcelain tile
F75	Vinyl sheeting, Traction step 7527 (Forbo)
F77	Vinyl sheeting, Traction step 7727 (Forbo)
VCT	Vinyl composition tile (Tarkett)
VCTF	Vinyl composition tile (Tarkett) coated with two layers SureShine acrylic finish (Tarkett)
Q01	Quarry tile (American Olean)

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Professional evaluation: Students supporting students – lessons learnt from an environmental health peer support scheme - Dr Esther Lockley1, Catherine Pritchard2 and Ed Foster3

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Abstract

Over the past eight years qualifying courses in Environmental Health have experienced problems of recruitment. In order to help address these issues it is important to understand the student experience and act to enable students to progress. Many students entering higher education find the transition a difficult one. Those entering directly from school or college may find the change in life style and study methods problematic whilst, mature students may experience problems with finances, family commitments and social isolation. These issues may increase the risk of students withdrawing from their course, particularly during the first few weeks of the programme. The peer support scheme was therefore designed as a mechanism to help new students with these transitions. The aim of the project was to provide informal peer support for students embarking on the BSc (Hons) Environmental Health programme at The Nottingham Trent University (TNTU) in 2003.

Students entering their second year of study in 2003 were invited to act as 'buddies' for the new student intake. It was envisaged that the buddies would support new students by sharing experiences, assisting with orientation and accessing university facilities, advising on the availability of student support services and providing social contact. After undergoing training, buddies communicated with new students via email or through informal "drop-in" sessions. After one term, the project was evaluated by means of a questionnaire survey. The project appears to have been very well received by new students, with 82 per cent of new mature students seeking support and advice from the buddies. The buddies were also positive about the scheme with all those participating indicating that they would have made use of the scheme had it been available during their first year.

Keywords Buddies, environmental health education, student peer support, widening participation.

Introduction

Higher education has changed dramatically over the past 40 years. In 1962, 6 per cent of the population entered higher education; now 43 per cent of 18-30 year olds are, or have, engaged in some form of higher education.

The Government's target is to further increase the size of the sector with 50 per cent of 18-30 year olds engaging in learning by 2010 (Department of Education and Skills, 2003). Whilst the overall student population has increased, the numbers of students' selecting courses in environmental health was declining up until 2003. The recent small increase in applications is still woefully insufficient to address the estimated shortfall of 1,000 new Environmental Health Practitioners needed by 2005 (Khanna, 2001).

As well as moving from a model of limited- to mass participation, the Government is keen to see the opportunity offered to all those who have the potential to benefit from a university education. Currently entry to university is still dominated by students from the top three social classes. However, strategies and objectives are now in place to draw in students from underrepresented groups. These widening participation groups include students with disabilities, students from families with no history of learning in higher education, or from areas with low levels of participation, students from under-represented ethnic minorities and, of most relevance to this project, mature students (Department of Education and Skills, 2000). The expansion of numbers in higher education and the increased heterogeneity of student population have created the potential for increased anxiety upon individual students. The diversification of the student population has the potential to leave individuals feeling isolated. It can be harder for students to feel that they belong and are supported if their course group is made up of students with backgrounds and experiences very different to their own. Student life has been associated with a number of stressors including financial pressures and examinations. For many students entry to higher education also marks the transition from home to independent living. For mature students there may be the added pressure of dealing with family and domestic responsibilities.

The net effect of all of these changes may result in an impact on student health. Stewart-Brown et al (2000) found that the health status of students is lower than that of the general population, particularly in relation to emotional problems. There is evidence that the number of students presenting with symptoms of mental ill health has increased in recent years (Royal College of Psychiatrists, 2003).

Several studies have looked at the proportion of students showing symptoms of mental ill health. A study by Webb et al 1996 indicated that 17 per cent of male and 25 per cent of female students had moderate to severe levels of anxiety. More recently, the University of Leicester's Psychological Health Project (Leicester University, 2002) surveyed more than 1000 students and suggested that 13 per cent of students were moderately distressed by feelings of depression. Transition into higher education therefore needs to be managed in order to enable students to engage in the learning experience and have a positive experience of the education system.

The BSc (Hons) Environmental Health has operated at The Nottingham Trent University since 1990. The course is managed via a course leader with a year tutor responsible for each cohort and in addition each student is allocated a personal tutor. The Environmental Health admissions tutor was approached by the Guidance and Progression Strategies for Widening Participation (GAP project) in 2001. The GAP project was particularly interested in developing access routes for mature students from further education into higher education. Links were established between the BSc (Hons) Environmental Health programme at The Nottingham Trent University (TNTU) and the access programmes of five local further education (FE) colleges. These links facilitated the development of targeted marketing material and direct access to students in the FE sector.

The work with this group contributed to maintaining recruitment levels. The numbers of students embarking on the BSc (Hons) Environmental Health programme following completion of an access programme increased significantly, as a result of this work, from 23 per cent in 1996 to 53 per cent in 2003. The age profile of the first year intake has also changed with mature students accounting for 48 per cent in 1996 to 63 per cent in 2003. The vocational nature of the programme and the accredited status make it attractive to mature students, particularly those seeking a career change.

Feedback from further education college tutors and students indicated that a support programme may be useful for new entrants. The peer support project aimed to provide informal support and advice to assist students embarking upon the BSc (Hons) Environmental Health programme in 2003 to settle into their new learning environment and to help reduce the risk of students withdrawing as a result of issues such as social isolation.

Recruitment and training of participants

Students entering their second year of study in 2003 were invited to act as buddies for the new student intake. Training was essential to ensure that buddies understood the aim of the project and their role within it. A half-day training session was devised and covered the following topics:

- Recalling the first term at university and identifying the problems and anxieties associated with this.
- Mature students and younger students – how does their experience differ?
- Listening skills.
- Case studies. Students were asked to suggest how they would respond to a number of different situations *e.g.* a first year student explains that they are thinking of leaving their course.
- Guidelines and principles of the project, especially establishing the boundaries of the buddy role, when students should be referred to another source of assistance or when academic staff should be alerted, and the importance of maintaining contact with the tutor overseeing the project.
- Appropriate ways in which buddies and new students should contact each other.

Methods

The aim of the research was to evaluate the effectiveness of the peer support system. To achieve this it was considered that a self-completed questionnaire would enable the largest number of students to be reached at relatively low cost. Two questionnaires were designed as the information collected from the first and second year students would be different. Demographic information related to age and highest qualifications achieved was obtained from both groups. In addition, both groups were asked about the amount of contact that was made with their buddy. The first year questionnaire included examples of situations that they may have found themselves in and the likelihood of contact with the course tutor, buddy, student support services or other students. These questions were based on work carried out in the Nottingham Business School related to mentoring in undergraduate business management programmes (Stewart and Knowles, 2003). The final question for both sets of students was an open question to provide comments and suggestions about the scheme.

Piloting was carried out with academic colleagues to ensure the face validity of the questionnaire. The questionnaires were distributed at the end of the first term to all new students and buddies. The data were inputted and analysed using the Statistical Package for the Social Sciences.

Results and discussion

Among new students 19 of the 23 (82 per cent) questionnaires distributed were returned. For second year buddies, 5 out of 6 (83 per cent) questionnaires were returned. Whilst the response rates are good it is important to consider the limitations of this size of sampling frame.

Demographic information

Of the 19 new student respondents 42 per cent (n=8) were from an A level background, 37 per cent (n=7) from access courses and 21 per cent (n=4) from had previous degrees or HND's. This demonstrates the change that has occurred in recruitment with 58 per cent (n=11) of the respondents being over the age of 21 and classified as mature students. This is a major difference from University wide figures for the period 2002-2003 where 16 per cent of full time undergraduate students at Nottingham Trent University were classified as mature students.

Although this project was primarily aimed at assisting mature students, it was felt that younger students (under 21) should not be excluded from seeking advice or assistance from the buddies should they wish to do so. Table 1.0 shows the numbers and age profile of first year students who made contact with a buddy. It is clear that a far greater proportion of mature students made contact with the buddies, than those in the under-21 age group

This may reflect the fact that the primary focus of the project was to assist mature students and that all of the buddies were themselves mature students. Indeed, an open comment from a student under the age of 21 years indicated that s/he would have felt more comfortable approaching someone of her/his own age. Of those students who did not make contact with a buddy, one student commented that they would have done so prior to enrolment if this had been possible. Another stated that although they had not contacted a buddy, they thought that the scheme was a good idea and felt reassured that there was someone to talk to 'just in case'.

Frequency of contact

Respondents were asked to estimate the number of times that they contacted a buddy (see Table 2.0).

The majority of respondents contacted a buddy on between one and five occasions. Approximately half of those who responded thought that the frequency of contact had changed between September and December and this change was generally a decrease in frequency.

However, it is worth noting that some students had reduced contact with their buddy due to a change in the first year timetable. The buddying model is based on the assumption that an individual first year student will speak to an individual buddy about their problems. In one instance, the student feedback indicated that the first year students approached their buddy about issues that were affecting the whole year group and then, having had their question answered, fed the information back to other first years. Therefore, advice from an individual buddy was often disseminated amongst the whole student group, thus reducing the total number of contacts occuring.

If new students were able to contact a buddy prior to enrolment, would they do so?

New students were asked to state whether they would have contacted a buddy prior to enrolment if one had been available *i.e.* they were introduced to a current student at an open day (Table 3.0). The majority of students indicated that they would welcome the idea of having contact with a named current student prior to enrolment. This response has resulted in the project being reformulated for the next intake of students.

Reason for contacting buddies

New students were asked to indicate how likely it would be that they would contact a number of different sources of help if they encountered a range of difficulties commonly faced by first year students. Figure 1.0 summarises how likely or very likely it would be that they would contact a buddy.

Figure 1.0 demonstrates that whilst students would be likely or very likely to contact course tutors regarding academic matters they would also be equally as likely to support each other in these areas. Access to their buddy appears to be most likely when having difficulty in accessing services although, with the exception of financial problems, between 20-30 per cent of students would consider contacting their buddy across the range of identified problems. Finally the role and importance of student support services as regards financial support and accessing facilities is important to note.

Conclusions

The development of the buddy scheme has provided a new form of support for students on the BSc (Hons) Environmental Health. Overall both first and second year students have found this development to be beneficial.

Whilst the buddy may not be the first point of contact for students, the fact that 68 per cent of first years made contact with them on at least one occasion, and 11 per cent had made contact on six or more occasions, demonstrates the value of this support scheme. In addition, there was a perception amongst lecturing staff that there had been a reduction in the number of queries from first year students about minor course matters, thus freeing up time for other pastoral duties.

The project also raises issues for the environmental health profession. Changes in student profiles have an impact on recruitment to environmental health. As mature students make up a significant number of recruits, locally based placements are essential to enable them to complete course and home commitments. While Olohan (2003) identified the need for advocacy support from lecturers for students with mental health problems it may be that students peer support may also prove to be helpful in tackling this issue. The evaluation, however, was not designed to consider this aspect.

Future changes to Higher Education with the advent of increased fees and widening participation may have a significant effect on the student population. This type of peer support may be one mechanism to ensure that students are enabled to engage and progress in higher education.

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The attitudes of bar staff to smoking in public houses in Wales – a predictor of compliance with the smoking ban? - Marc Adams Jones1 BSc (Hons) MCIEH, David Adams Jones2 MA MSc Dip Stat FSS, Colin Powell3 BSc (Tech) FHEA

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Abstract

The attitudes of bar staff to second-hand tobacco smoke and smoking controls in the workplace were investigated in 2001 bymeans of a questionnaire survey. At that time government policy favoured voluntary agreements with the hospitality industry. In 2006, when policy had changed and legislation was imminent, the same questionnaire was used to determine if any changes in attitudes had occurred over the five-year period.

The main findings were: bar staff had become significantly less tolerant of second-hand smoke between 2001 and 2006; bar staff who smoked had become significantly more supportive of the introduction of a smoking policy by 2006; the significant majority considering a smoking policy to be impractical in 2001 had disappeared by 2006; in 2006 it was still the majority view that smoking was an integral part of pub life and that smoking policies would interfere with customers enjoyment.

It is possible that while perceived feasibility and desirability of smoking policies has increased, there has not been a major shift in the positive view of bar staff towards smoking in pubs and it is argued that this may have implications for the implementation of smoking controls. Steps to accommodate clients who smoke may result in the migration of smoking to other areas of the premise and the growth of related nuisance issues such as noise and litter. Proprietors could consider steps to accommodate those who wish to use their facilities and smoke, whilst still ‘complying' with the legislation. For example beer gardens and courtyards could increasingly become the smoking areas of pubs during previously underused winter and autumn months resulting in noise and light nuisances. The modification of outdoor areas to provide weather protection could result in smoke accumulating. Previously family oriented beer gardens could now become the main smoking areas. This could increase children's exposure to second hand smoke as well as influencing their perception of the social acceptability of smoking.

Key words: Bar staff; environmental health, environmental tobacco smoke, ETS, pubs, smoking ban,Wales.

Introduction

Workers in the licensed trade have, despite policies on smoking in the workplace, been subjected to the effects of unwanted tobacco smoke whilst at work (Jarvis et al 1992).

Davis (1999) commented on "hell-hole conditions", whilst Francis et al (2000) highlighted the fact that many "bar workers" did not consider that there was any protection for them and that their health was being compromised with nothing being done to alleviate the problems of environmental tobacco smoke [ETS] in the workplace.

Over the years it has been accepted by employees in public houses that they worked in conditions throughout their working day where they were exposed to secondhand tobacco smoke. Adams Jones (2002) suggested that the prevalence of smokers amongst bar workers was higher than that found in the general population but even staff who were smokers commented that it would be nice to choose when, where and how often they smoked. Comments of those interviewed and recorded as part of the research in 2001 included;

"I'd like to choose how often I smoke, and the brand!"

"It's not so much the cigarette smoke I'm subjected to daily as much as the attitude that it's perfectly acceptable because it's a smokers choice. They don't consider that it's my place of work."

"It's part and parcel of working behind a bar, you just get on with it."

“If staff don’t like it, get another job, you don’t have to work in a pub, you can always get a job where people don’t smoke.”

Over the past 30 years restrictions on smoking have been put in place on public transport (trains and buses), theatres, cinemas and the London Underground. Airlines also began enforcing no smoking on planes. However, the bastion of support for the rights of the smoker, the licensed trade, did nothing, standing firm behind the fact that *“beer and fags go hand in hand”, “it’s part of the pub culture”.*

The hospitality industry, tobacco companies and prosmoking groups were prepared to stand toe to toe with anyone suggesting that smoking should be banned in pubs and restaurants despite evidence to suggest that there was a greater risk to employees in the hospitality industry, Jamorozik (2005) estimating that secondhand smoke causes one premature death a week among workers in the hospitality industries.

Despite Government offering the hospitality industry the opportunity to use the Public Places Charter to bring about change, the Department of Health noted that about half the pubs complying with the Charter requirements did so by allowing smoking throughout. (Parliamentary Office of Science and Technology, 2003). Heloma et al (2001) criticised voluntary agreements and concluded that legislation was more efficient than voluntary workplace-specific restrictions in reducing passive smoking and cigarette consumption. Reality really struck home when the Charter Group in a progress report in 2003 revealed that 46% of restaurants and pubs surveyed still allowed smoking throughout, with 22% having separate smoking and non-smoking areas and less than 1%banning smoking completely.

The Government, when deciding on legislative measures to deal with second-hand tobacco smoke in the workplace, stood by a number of exempted premises including members clubs and public houses not serving food when the Health Bill was published in late 2005. This would have created a two tier class of employee, those protected from the effects of second-hand tobacco smoke and those not protected. Public consultation however revealed overwhelming support for a comprehensive smoking ban and on 14 February 2006,MPs voted with a largemajority to remove these exemptions.

Scotland took the lead on 26th March 2006 with a ban on smoking in enclosed workplaces and Wales, despite being the first of the home nations to support a total ban on smoking in the workplace, had to wait until primary legislation through the Health Act 2006 came into force before being able to institute a ban on April 2nd 2007. Northern Ireland on 30th April 2007 came hot on the heels of Wales before England announced their ban, which came into force on July 1st 2007.

The initial research carried out between 2000-2001, and again in 2006 (Adams Jones et al 2007) points to there being a change in the attitudes of bar staff workers to their exposure to second hand tobacco smoke in the workplace between the time that legislation was first contemplated and when it actually became a reality. The study aimed to compare the attitudes of bar staff workers at two points in time; in 2001 when control was seen to be through voluntary agreements and an approved code of practice, and, in 2006 when control was seen to be imminently effected through legislation.

Methodology

In 2001 and 2006 questionnaires were distributed both to licensees/owners and to employees working behind the bar in pubs operating within the boundaries of the Vale of Glamorgan. Identification of premises was based upon data provided by the Local Authority Licensing Officer.

Personal questions relating to gender, age, hours of work etc. were set out in Part 1 of the questionnaire. This section also provided factual information about the establishments. Part 2 was designed to establish individual attitudes towards staff exposure to ETS in the workplace; it consisted of a Likert Scale using 29 attitude statements.

The 2006 study utilised Parts 1 and 2 of the 2001 questionnaire and a third section was added which focused on the issues surrounding the legislation coming into force on 2nd April 2007 in Wales. Questionnaires were distributed either via a special appointment with the manager or as part of a routine local authority visit to the premises.

Two questionnaires were to be completed at each establishment, one by the owner/licensee and the second by another member of staff. On a few occasions it was found that only a single staff member was present or that the pub was “family run” by the owners with no extra staff.

Twenty-nine Likert statements were designed to investigate four factors and were split into four groups to address four domains of perception; tolerance of the smoking habits of others; perception of passive smoking as a health risk; perception of the desirability of having a smoking policy in public houses; perception of the practicability of achieving a smoking policy in public houses by further legislation or any other means.

Results

In 2001 there was an 88 per cent response rate to the 92 questionnaires issued at 46 establishments. There was a similar response rate in 2006 to the 88 questionnaires issued at 44 establishments.

Table 1.0 Statements relating to the respondents tolerance of other people's smoking habits.

	2001		2006	
Statement	Percentage Agreeing	Percentage Disagreeing	Percentage Agreeing	Percentage Disagreeing
1. Smoking is a matter of individual choice	96.3	1.2	96.1	2.6
6. If a person wishes to smoke in a pub they should be allowed to do so	88.9	6.2	71.4	15.6
16. Smoking is an integral part of pub life.	88.9	7.4	67.5	15.6
18. Tobacco products should not be sold in a pub.	9.9	85.2	11.7	74.0
21. I personally do not mind smoking in pubs	85.2	13.6	79.2	14.3

During the initial research 95.7 per cent of the establishments sampled, in common with the majority of public houses had ash trays on the bar servery counter itself and allowed smoking directly at the bar. Figures indicated that in 2006 there was a statistically significant ($p<0.001$) increase in the percentage of establishments with a no smoking zone at the bar: 52.3 per cent compared with 4.3 per cent in 2001.

During the 5 years between the two studies, there was no overall difference in smoking prevalence but in both cases the level, at over 54 per cent, was more than double that of the prevalence in the general population.

The statistical analysis of the data was based on two standard tests: chi-squared tests were used for comments on establishment characteristics, prevalence and responses to individual questions whilst t-tests were used to comment on the differences between Likert scores (Tables 4.0 -6.0). For the size of the samples this test is sufficiently robust to accommodate a degree of non-normality in the underlying population.

Between 2001 and 2006 the main changes in perception detected in the surveys were;

- tolerance of second hand smoke has reduced significantly but remains towards the libertarian end of the scale;
- the high levels of awareness of the health risks associated with second hand smoke has not changed significantly;
- the majority in favour of a smoking policy has increased significantly mainly due to changes amongst smokers;
- the majority view in 2001 of the impracticality of legislation on smoking has disappeared by 2006.

In all four domains of perception there would therefore seem to be a trend towards more widespread acceptance of legal restrictions on smoking in the workplace. Particularly striking was the change in attitudes to the statement that smoking policies cannot work in a pub. In 2001 there was 54.3 per cent agreement with this negative view; by 2006 this position had been reversed with only 24.7 per cent now agreeing with the statement.

For each statement there was a large and statistically significant majority favouring the libertarian approach both in 2001 and in 2006. For two of the statements (6 & 16) there was a significant movement away from this end of the spectrum between 2001 and 2006.

In five of the six statements in this group there was a general consensus in favour of some type of smoking policy. The exception was statement 4 - that secondary tobacco smoke was “unacceptable”. This statement was opposed both in 2001 and in 2006. There was a significant increase in the support for statements 17 & 19 which both related to non-smoking areas within establishments.

Table 2.0 Statements relating to the desirability of some type of smoking policy

	2001		2006	
Statement	Percentage Agreeing	Percentage Disagreeing	Percentage Agreeing	Percentage Disagreeing
4. Secondary cigarette smoke is unacceptable in pubs	33.3	56.8	33.8	48.1
10. Bar staff should not have to accept exposure to tobacco smoke as part of their job.	59.3	35.8	54.5	29.9
12. Customers enjoy a smoky atmosphere.	81.5	4.9	72.7	7.8
17. All pubs should have non-smoking area	82.7	14.8	94.8	3.9
19. Smoking in pubs should only be allowed in a separate area well away from the bar.	60.4	32.1	75.3	14.3
20. Employers owe employees a duty of care.	88.9	2.5	84.4	3.9

In 2001 there was a statistically significant majority agreeing with the statements suggesting the impracticability of smoking legislation. By 2006 this majority had been reversed for statement 8 and apart from statement 15 the balance of opinion had shifted significantly towards the “practicability” end of the spectrum.

Before looking at an overall picture of respondents’ perceptions in the four domains it is necessary to validate the statements within each domain to ensure that they are all measuring the same perception or attitude. Correlating the individual responses within each domain does this. This procedure leads to the exclusion of several statements in the original study (Adams Jones 2002).

A likert score of 15 on the 5 implies balance between tolerance and intolerance with higher values for a more libertarian view. In both 2001 and 2006 respondents tended significantly to the libertarian view but the decrease in the score between 2001 and 2006 indicated that respondents in the later study were less supportive

Table 3.0 Statements relating to the impracticability of achieving a satisfactory smoking policy through legislative means.

	2001		2006	
Statement	Percentage Agreeing	Percentage Disagreeing	Percentage Agreeing	Percentage Disagreeing
8. Smoking policies cannot work in a pub.	54.3	28.4	24.7	51.9
13. Smoking is restricted enough without it being banned in pubs.	60.5	33.3	49.4	36.4
15. Smoking policies would interfere with a customers enjoyment.	72.8	19.8	59.7	23.4

Table 4.0 Likert scores relating to tolerance

	2001		2006	
Type of respondent	Number	Mean Likert score	Number	Mean Likert score
Smokers	44	21.22	42	19.88
Non- smokers	37	19.32	35	18.60
All respondents	81	20.37	77	19.30

Table 5.0 Likert scores relating to the desirability of a smoking policy

	2001		2006	
Type of respondent	Number	Mean Likert score	Number	Mean Likert score
Smokers	44	16.00	42	17.76
Non- smokers	37	19.00	35	18.91
All respondents	81	17.37	77	18.29

Table 6.0 Likert scores relating to the impracticability of a smoking policy.

	2001		2006	
Type of respondent	Number	Mean Likert score	Number	Mean Likert score
Smokers	44	17.81	42	16.07
Non- smokers	37	14.58	35	15.37
All respondents	81	16.36	77	15.75

of “people wishing to smoke in a pub being allowed to do so” ($p<0.05$) and less agreed with the statement that smoking is an integral part of pub life. ($p<0.05$) Despite respondents becoming less tolerant it is however still noticeable that a majority of people support smoking in the pub and view it as part of pub life.

A likert score of 15 on the 5 statements implies indifference to the introduction of a smoking policy. In both 2001 and 2006 respondents were significantly in favour of a smoking policy ($p<0.05$) and between 2001 and 2006 there was a statistically significant increase in this preference for smokers ($p<0.05$) with no significant change for non-smokers.

A likert score of 15 on the 5 statements implies a balanced view on the impracticability of a smoking policy. The mean score of 16.36 in 2001 is significantly towards the impractical persuasion ($p<0.05$). In 2006 the mean score of 15.75 is not significantly different fromthe balanced view. A significant ($p<0.05$) difference between smokers and non-smokers in 2001 has disappeared by 2006.

Discussion

This study aimed to consider bar staff attitudes towards smoking in pubs and aspects of smoking control. The significant change in the attitudes of employees to the statement that smoking policies cannot work in a pub is been by the reduction of agreement with the statement from 54.3 per cent to 24.7 per cent. This may be a reflection of the success of the implementation of voluntary restrictions over the years and linked to the publicity associated with the launch of legally enforced control in other countries.

The voluntary introduction of smoking policies in pubs and the perceived feasibility of controls may act as a predictor of compliance with new legislation in Wales as the results indicate that whilst tolerance of second hand tobacco smoke in the two studies has reduced significantly, it still remains towards the libertarian end of the scale.

This position is reinforced by the finding that the majority of the respondents supported the view that:

- smoking is an integral part of pub life
- a person wishing to smoke in a pub should be allowed to do so

- smoking policies would interfere with a customer's enjoyment
- customers enjoy a smoky atmosphere.

This potentially poses a challenge to the successful management of a ban on smoking in pubs. Bar staff are likely to be involved in the day to day operation of smoking restrictions and if they are not persuaded by the arguments for the new legislation they may not be fully committed to its enforcement.

A number of options are available to address this situation. Firstly the use of penalties for non-compliance administered by enforcement officers can andwill be used. The success of such an approach is however dependent upon bar staff's perception of the likelihood of detection of breaches of legislation and the size of the penalties. It would appear that there has not been a fundamental shift in bar staff view of the acceptability of smoking. This may have implications for the implementation of the ban on smoking in enclosedworkplaces. Staff may wish to support steps that would enable clients to continue what is perceived as a legitimate part of pub life.

In conversations with publicans they commonly indicated that the biggest problem would not be the actual physical change to smoke-free premises but the difficulty in persuading customers that the ban was primarily an essential tool in protecting the health of bar workers. Such protection is already given to workers in other industries dealing with dangerous substances e.g. lead and asbestos. It was suggested by publicans that more publicity should be given to this health aspect of the legislation with less emphasis on the punitive effects on smokers.

As most respondents appear to accept that controls are feasible and that there should be restrictions on smoking in pubs, it is anticipated that there would not be wholesale rejection of the legislation. However, there may be issues as to how the law is interpreted. This research clearly indicates that there are still positive attitudes towards smoking in pubs. As an industry geared to the provision of services to clients, there may be a tendency to comply with legislation whilst still meeting perceived customer preferences. As a consequence, legislation designed to protect the health and safety of employees may have negative consequences for the wider community. Proprietors could consider steps to accommodate those who wish to use their facilities and still smoke. For example beer gardens and courtyards could increasingly become the smoking areas of pubs during previously underused winter and autumn months resulting in noise nuisance and light nuisance. The modification of outdoor areas to provide weather protection could result in smoke accumulating. Beer gardens that may presently be family orientated could now become the main smoking areas. This could increase children's exposure to second hand smoke as well as the presence of increased numbers of smokers around children influencing their perception of the social acceptability of smoking.

Where provision is not made for smokers, clientsmay chose to step outside of premises to smoke; this may again impact on noise levels and increase litter in the street.

If proprietors take steps to accommodate smoking clients, there is a need to provide them with clear guidance as to what constitutes an appropriate environment. Whilst it is assumed that secondary tobacco smoke presentsmore of a health risk in enclosed spaces, there is a need tomonitor whether so called open spaces in pubs are appropriately designed to allow for the dispersion of smoke.

Conclusions

- There is an increase in the perception of the feasibility and desirability of restrictions on smoking in pubswhen the responses of bar staff in 2006 are compared with those in 2001
- The findings fromboth studies, however, imply that the majority of bar staff are supportive of people being able to smoke in pubs. In view of this, it is suggested that many pubswill take steps to support those wishing to smoke.
- Most respondents appear to accept that controls are feasible and that there should be restrictions on smoking of pubs; it is not, therefore, anticipated that there would be wholesale rejection of the legislation by pub staff, although there may be issues as to how thelaw is interpreted which could create challenges for those managing and enforcing the smoking ban legislation.
- Proprietors could consider steps to accommodate those who wish to use their facilities and smoke, whilst still 'complying'with the law. For example beer gardens and courtyards could increasingly become the smoking areas of pubs during previously underused winter and autumn months resulting in noise and light nuisances. The modification of outdoor areas to provide weather protection could result in smoke accumulating. Previously family oriented

beer gardens could now become the main smoking areas. This could increase children's exposure to second hand smoke as well as the presence of increased numbers of smokers around children influencing their perception of the social acceptability of smoking.

- Where provision is not made for smokers, clients may choose to step outside of premises to smoke; this may again impact on noise levels and increase litter in the street.
- In Wales the benefit of the ban starting in April was that smokers had the spring and summer months to acclimatise to the realities of the ban. Realistically, enforcement officers will have to wait until the darker, colder, wetter winter months to effectively assess the success of the ban in protecting bar staff employees from second-hand tobacco smoke.

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The use of imposex in Nucella lapillus to assess tributyltin pollution in Carlingford Lough - Mr Paul Mallon1 BSc (Hons) MCIEH and Dr Naran Manga2

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Abstract

The condition known as imposex in the female of the marine mollusc Nucella Lapillus is used widely as a biological indicator of tributyltin (TBT) contamination in the marine environment. TBT, an organic compound containing the metal tin, is an effective biocide used in antifouling paints applied to the underwater hull of large boats. It is banned from use on vessels less than 25 metres in length.

This paper provides a review of the literature and reports on a field study which focuses on Carlingford Lough, a cross-border water body, bounded by Counties Down and Armagh in Northern Ireland and County Louth in the Republic of Ireland. It is used by both smaller pleasure craft and large commercial ships.

Two hundred samples were taken from four sites (n = 50 at each site) and the female population of Nucella Lapillus examined. 100% of the female specimens showed the imposex phenomenon indicating various levels of TBT contamination. The intensity of imposex was higher on the Southern shore of the lough. The difference in average imposex values recorded between the Northern and Southern shores suggests that the Southern shore is more polluted with TBT. This may be partially explained by the way in which the tide flushes in the lough where material from the Northern shore may be lifted and deposited on the Southern shore.

This study shows that despite the partial ban on the use of TBT in antifouling coatings on ships the marine environment is still affected some 20 years on.

Carlingford Lough is used to cultivate oysters and there are mussel beds at various points along both the Northern and Southern shores. Shellfish which eat food contaminated with TBT, will result in TBT accumulation in the organism, and thus it will bio-accumulate in the food chain causing a potential food safety problem.

Key words: Carlingford Lough; Environmental health; Nucella Lapillus; Tributyltin (TBT); Imposex; Vas Deferens Sequence Index (VDSI).

Introduction

Tributyltin (TBT) is an organic compound containing the metal tin. It is used as a broad-spectrum killer of algae, fungi, insects and mites, and since the seventies TBT has been used as an effective biocide in antifouling paints. It is now the most commonly used antifouling agent used in paint for the underwater hull of large boats (Berge and Walday, 1999). Fouling is the unwanted growth of biological material e.g. barnacles, algae or molluscs on the water-immersed surface of the vessel. Alziue (1998) stated that fouling leads to problems such as loss of ship speed, excess fuel consumption, spreading of corrosion pits and increased weight of float structures.

Antifouling paint regulation is a genuine public policy concern because it increases the cost of maritime commercial shipping and thus influences the price that the public pays for vessel shipped common goods.

TBT is one of the most toxic substances that have been introduced to natural waters (Nicholson and Evans, 1997; Stewart and de Mora, 1990). During the last decade, organic tin compounds have received much attention because of their strong effects on marine organisms at low concentrations. Unintended environmental effects from TBT in antifouling paints were first found in Arcon Bay in France in the late 1970s in the Pacific oyster (Crassostrea gigas) (Nicholson and Evans, 1997). Since then, effects of organotin compounds have been reported for a variety of other marine species (fish, gastropods, crustaceans, echinoderms, microalgae) at concentrations thatmay be found in anthropogenically influenced areas (Walday et al., 1997).

The effects are particularly evident on neogastropod snails, where females develop male characteristics (penis and vas deferens), an irreversible phenomenon termed imposex (Gibbs and Bryan 1986; 1987, ten Hallers- Tjabbes et al., 1994; Skarphédinsdóttir et al., 1996; Walday et al., 1997; Berge et al., 1997; Svavarsson, 2000; Svavarsson et al., 2001). Several countries have banned the use of TBT for small boats, with France being the first to ban its use in 1985 followed closely by the UK in 1987, but international regulations still allow restricted use.

Tin organic compounds mainly result in pollution of water since the TBT compounds very easily bind themselves to particles and organic material in water thus accumulating in the sediments. TBT breaks down quickly in water with a half-life of only a few days, but can remain for a long time in sediments, especially in cold climates (Stewart and de Mora, 1990). Contaminated sediments are therefore potential environmental reservoirs for TBT, andmay continue to be a source long after the industrial use of TBT has been curtailed (AMAP, 1997 and 2002). Continued use of TBT on large ships is probably the main source for new TBT to aquatic environments.

Degradation of TBT

It is well established that TBT degrades by a stepwise debutylation pathway to less toxic breakdown products dibutyl-, monobutyl- and finally inorganic tin. Laboratory studies have shown that wide varieties of agents are capable of cleaving the tin-carbon bond. In aquatic environments, the most relevant processes are likely to be photochemical cleavage and biological cleavage by micro organisms. There are indications that TBT has a low persistence in the water column. However, as TBT shows a tendency to accumulate in sediments, TBT degradation processes in sediments are more likely to control the overall persistence of TBT in the environment (Stewart and de Mora, 1990).

TBT has a short residence time in natural waters, with a half-life in the range of several days to weeks as mentioned above. The rate of disappearance of TBT from the water column is the sum of physical removal processes, and chemical and biological degradation, as well as simple dilution due to water flow.

Biological processes are likely to be the most important mechanism for the decomposition of TBT in the marine environment. Photolysis by sunlight is not a major contributor to environmental TBT degradation (Stewart and de Mora, 1990). Temperature is another factor that affects the degradation rate in waters; TBT degradation proceeds more slowly at lower temperatures. It has been reported that TBT half-life at 5°C is around 60 days whereas at 20°C it is approximately 6 days. Stewart and de Mora (1990) have suggested that colder temperatures inhibit the growth of TBT-degradingmicroorganisms. TBT shows a tendency for both bioconcentration and sediment accumulation. Hence, the short residence time of TBT in the water column alone is unlikely to be an adequate indication of the environmental hazard posed by TBT (Stewart and de Mora, 1990).

In natural watercourses, TBT adheres to particles, then settles and accumulates in bottom sediments. It is effectively bound to organic and inorganic solids. Binding also occurs with organic substances dissolved in water.

As a rule, TBT is not present in a dissolved state in watercourses. Because of its binding tendency and limited dissolution, TBT and its degradation products (dibutyltin, DBT, and monobutyltin, MBT), in practice spread in waterways only when bound to solids.

Toxicity of TBT

TBT is toxic to a broad range of organisms and this is also the basis for its success as an antifouling agent. It is harmful especially to primitive maritime organisms, causing for example, disturbances in reproduction and growth. TBT is more harmful to younger than to older organisms.

The antifouling activity of all types of TBT coatings is based on the leaching of TBT to the water and the toxic/repulsive effect on foulers.

The problem with TBT is that the threshold for harmful effects (hormone disrupter) is extremely low in certain molluscs. Chronic effects in oysters, mussels and crustaceans are observed at exposure levels of less than 1 mg TBT/l while the most sensitive species (dogwhelk snails, e.g. Nucella Lapillus and Buccinum undatum) show sub-lethal effects at concentrations of only a few ng TBT/l or less (AMAP, 1997; Svavarsson, 2000; Jakobsen and Asmund, 2000). A “no-effect” concentration of TBT in water has not yet been quantified.

At these extremely low concentrations, dogwhelk snail's exhibit imposex that affects reproduction, and this phenomenon will be further discussed later on. Effects are observed in non-target organisms in non-target habitats worldwide (Svavarsson and Skarphédinsdóttir, 1995; Berge and Walday, 1999). Although effects have been observed most frequently along shores adjacent to obvious sources such as marinas or harbours and has been associated with both pleasure boats and commercial shipping, the problem has been defined as long-term and global (Svavarsson and Skarphédinsdóttir, 1995; AMAP, 1997 and 2002). TBT concentrations in natural waters are subject to high temporal and spatial variability, especially when tidal flushing is present (Stewart and de Mora, 1990).

TBT and imposex

The development of male primary sexual characteristics in female gastropods is known as imposex, also called pseudohermaphroditism. The phenomenon is caused by exposure to organotin compounds and results in accumulation of male hormone (testosterone) in the gastropods. TBT is fat-soluble, and therefore accumulates in organisms. Severe stages of imposex at higher TBT concentrations can lead to female sterilization and death (Mensink et al., 1996) and it is believed to account for the extinction and local disappearance of the dogwhelk in severely contaminated areas (Skarphédinsdóttir et al., 1995; Mensink et al., 1996). Imposex has most extensively been studied in the dogwhelk Nucella Lapillus, but effects of TBT have been observed in 70-100 species of gastropods worldwide (Svavarsson and Skarphédinsdóttir, 1995; Berge et al., 1997).

Since the introduction of restrictions on the use of organotin-based antifouling paints around the world, there has been much effort and need to assess the effectiveness of these restrictions (Evans et al., 1995). As there are many difficulties in chemically measuring organotins in the environment (Cleary, 1991; Foale, 1993), changes in imposex levels have been the main assessment tool used (Evans et al., 1995).

Sensitivity to changes in nutrient levels have been described by Gibbs et al. (1999) who reported a massive kill of N. Lapillus in Bude Bay, North Cornwall, and suggested that the mass mortalities may have been caused by eutrophication and summer algal blooms linked to a new sewage outfall in the area.

Occurrence and levels of TBT in the environment

Despite restrictions on the use of TBT in many countries in the late 1980s, occurrence of imposex is still extensive in most oceans and has increased in some areas (Svavarsson et al., 2001). The effects of organotins are mostly seen in areas with extensive shipping activity (harbours, shipyards, shipping lanes) (Svavarsson et al., 2001). Due to often slow degradation of TBT and its derivatives (dibutyltin (DBT) and monobutyltin (MBT)), these are accumulated in the sediments at the harbour and may be present for a long time.

It has been suggested that the high levels of imposex in dogwhelks aroundmarine European shipping and fishing ports are unlikely to decline until TBT is banned on all vessels (Minchin et al., 1995). Even then, there is the possibility of a continued contamination as TBT is persistent in sediments (Bryan & Gibbs, 1991; Hawkins et al., 1994).

It has been shown that TBT levels in sediments are closely related to the organic content because TBT adsorbs to organic material (Jacobsen and Asmund, 2000), but there seems not to be an obvious single factor responsible for the varying concentrations of TBT in the different harbour sediments. Factors like distance to shipyard and quays, shipping traffic intensities, water renewal, bottom current regime and sedimentation are together responsible for the highly variable concentrations (Berge et al., 1997; Green et al., 2001).

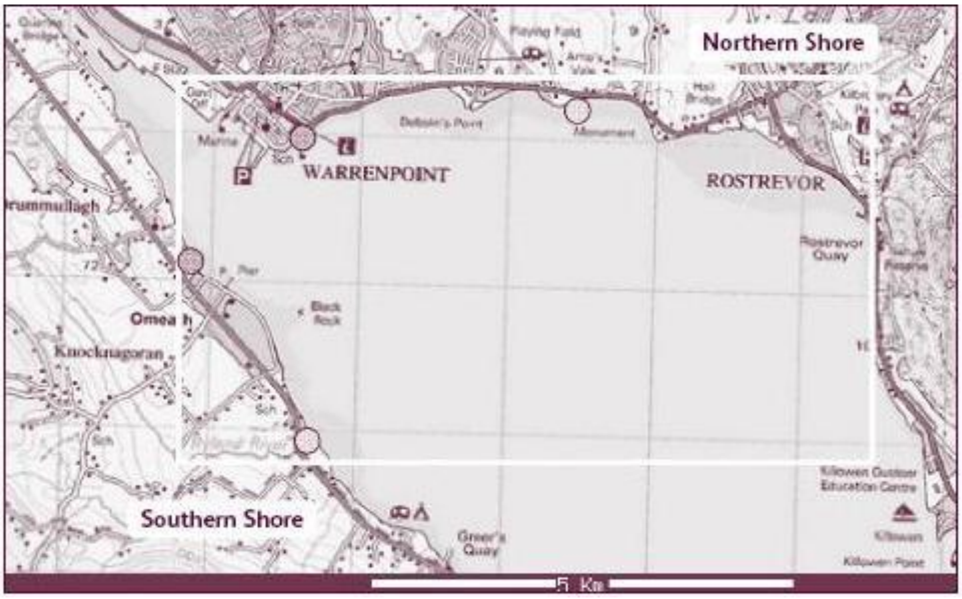
The first detailed survey of imposex was of the dogwhelk N. Lapillus in southwest England in the mid-1980s (Bryan et. al. 1986). The study found that the imposex condition and TBT contamination was severe in areas of high boating activity. In themost severe cases, there was female sterility and premature death. There was an absence of juveniles in some populations and in the worst affected areas, the species became locally extinct.

Smith, (1996) concluded that following restrictions in New Zealand, areas subject only to pleasure craft displayed a decline in the frequency of imposex. However, in harbours that were subject to both pleasure craft and commercial vessels, imposex frequency did not decrease, although the severity of imposex did.

A study of imposex in Thais Orbita (Neogastropoda) along the New South Wales (NSW) coast, Australia, found imposex was still widespread 10 years after a partial ban on TBT based antifouling paints (Gibson & Wilson, 2003). Transplant experiments carried out showed that imposex was induced in T. Orbita over a 9 week period in Sydney Harbour. A comparison of data collected shortly after the introduction of restrictions on TBT revealed a general decline in imposex frequency occurring at open sites, with the exception of one site located within harbour/bay areas, which did not display a decline in the severity of imposex.

TBT not only affects N. Lapillus, it is also known to affect other organisms (Svavarsson and Skarphédinsdóttir, 1995; Berge et al., 1997). As imposex is a phenomenon in the dogwhelk, intersex is a similar phenomenon known to affect the periwinkle (Littorina Littorea). Bauer et al. (1993) was the first to carry out work on intersex in Littorina Littorea and since this work, other studies have been conducted by Oehlmann et al. (1994) and Bauer et al. (1995).

Figure 1.0 Map showing the study area (enclosed in the rectangle) and the sampling sites at each shore. Key: Site 1 = [symbol] Site 2 = [symbol] Map adapted from: Northern Ireland Neighbourhood Information Service (NINIS) (2006)



Intersex in the periwinkle has been used in several surveys in Ireland, e.g. Cork Harbour, Killybegs Harbour, Richies Bay and Ballagan Shore by Minchin, et al., 1996, 1997 and also in Germany (Oehlmann et al., 1996; Bauer et al., 1997) and is now being considered, alongside the imposex response in Nucella Lapillus, for the biological TBT effect monitoring in coastal waters. Studies showed that the partial ban was less effective where the use of TBT based anti-foulants has continued on vessels over 25 metres in length.

Nogueira *et al*. (2003) conducted a study on the levels of TBT in sediments from selected stations located in the upper Tagus River from the Tagus Estuary Nature Reserve, Portugal. He found that the persistent TBT contamination observed in the sediments from this important European ecosystem was primarily related to shipping activities as well as the naval industrial complexes located downstream.

Aim of study

The overall aim of this study was to assess the relative effects of TBT pollution on *N. Lapillus* on the Northern and Southern shores of Carlingford Lough, Northern Ireland. This was to be assessed by measurement of imposex levels in *N. Lapillus* using the Vas Deferens Sequence Index (VDSI). The study aims to show that the site closest to the port will show a higher degree of imposex than that of sites further away from the port.

Methods

Approximately 200 specimens (n = 50 at each site) of *N. Lapillus* were collected by hand from the identified sites along the North & South shores, between February and March 2006 (Figure 1.0). Sampling was carried out whilst the tide was at low shore due to the *Nucella* binding to rocks further down the shoreline. They were placed in a container containing sea water and sealed for transit.

It should be noted that whilst sampling was undertaken, the specimens collected from the Southern shore were younger than those collected from the Northern shore. This assumption was made on observation of the shell size of the collected specimens. Generally for *Nucella*, the smaller the shell size the younger the organism.

Sites were located at varying distances from areas of boating traffic (harbours & marinas etc.). Following collection, specimens were transported to the laboratory for immediate analysis or stored in a refrigerator at approximately 4°C until analysis took place.

Site description

Carlingford Lough is the most southern of the five sea Loughs around the east coastline of Northern Ireland. It is a cross-border water body, bounded by County Down and County Armagh in Northern Ireland

and by County Louth in the Republic of Ireland. It is a narrow sea Lough surrounded by mountains. The northern shore lies in Northern Ireland and includes the most significant mudflats in the Lough and an area of saltmarsh. These provide important feeding areas for wintering the lightbellied Brent goose (*Branta bernicla hrota*) of the Canada/Ireland population. At the mouth of the lough are several small rock and shingle Islands which are of importance to breeding terns, which feed in the shallow waters of the lough.

Carlingford Lough supports a wide variety of aquaculture and fishing interests, including cultivation of oysters, mussels and clams as well as lobster and crab potting. To date, studies focusing on Carlingford Lough have largely centered around the use of the Lough as a major site for mariculture, and on sewage disposal activities in the lough.

The position chosen for the study is an ideal site as it rests on a shipping corridor to both the North and South of the island of Ireland. Extensive works were undertaken to the lough between the months of August and October 2005. This included dredging of the lough and sediment removal at the Warrenpoint Marina area. This INTERREG funded project was aimed at improving the water depths in the lough and expanding docking facilities at theWarrenpoint Port. With this information in mind, it is expected that imposex prevalence will be quite high.

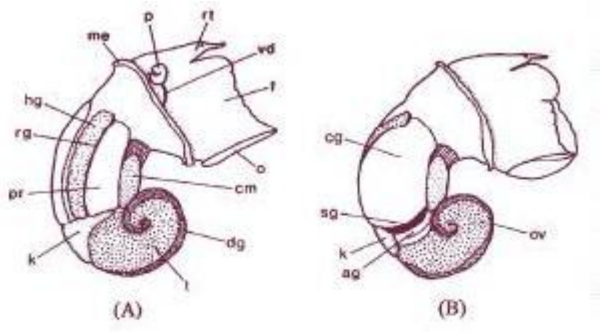
Dissection of *N. Lapillus*

As both male and imposexed female dogwhelks have a penis the removal of the outer shell is required to ascertain the sex of the animal. The technique adopted involved crushing the shell with a small vice secured to a bench and removing the tissue from within. The tissue was then placed under a dissection microscope in a Petri dish of seawater to prevent desiccation before sexing took place.

Recognition of the sexes

The dogwhelks were sexed solely on the presence of a spermingesting gland,which is only found in females. This brown/red band is situated at the posterior of female dogwhelks, immediately behind the capsule gland (Fig. 2). The degree of imposex is classified by either the Relative Penis Size Index (RPSI) or the Vas Deferens Sequence Index (VDSI). VDSI recognises the development of a vas deferens (sperm duct) in a female in 7 stages Figure 3.0 (Gibbs *et al*., 1987); stage 0= normal individuals, stage 1= proximal section of vas deferens is formed, stage 2= initiation of penis development and further development of vas deferens, stage 3= formation of a small penis and development of the distal section of the vas deferens, stage 4= involves mainly fusion of the vas deferens, stage 5= overgrowth of vas deferens on the genital papilla and hence female sterilely, and stage 6= aborted egg capsules can be seen in the capsule gland.

Figure 2.0 After Gibbs *et al.* (1987). *Nucella Lapillus*. External features of mature male (A) and mature female (B) after removal of the shell. Abbreviations: ag, albumen gland; cg, capsule gland; cm, columella muscle; dg, digestive gland; f, foot; hg, hypobranchial gland; k, kidney; me, mantle edge; o, operculum; ov, ovary; p, penis; pr, prostate; rg, rectal gland; rt, right tentacle; sg, sperm-ingesting gland; t, testis.



Individual snails with a VDSI of 5 or 6 are prevented from releasing egg capsules from their genital papilla and are sterile. Bennett, (2004) concluded that the VDSI is a more consistent method of measuring imposex in N. *Lapillus* than RSPI.

Figure 3.0 Nucella lapillus. Stages in the development of imposex based on Vas Deferens Sequence (VDSI). Abbreviations: a, anus; b, blister; gp, genital papilla; n, nodule; p, penis; v, vulva; vd, vas deferens. (After Gibbs and Bryan, 1986).

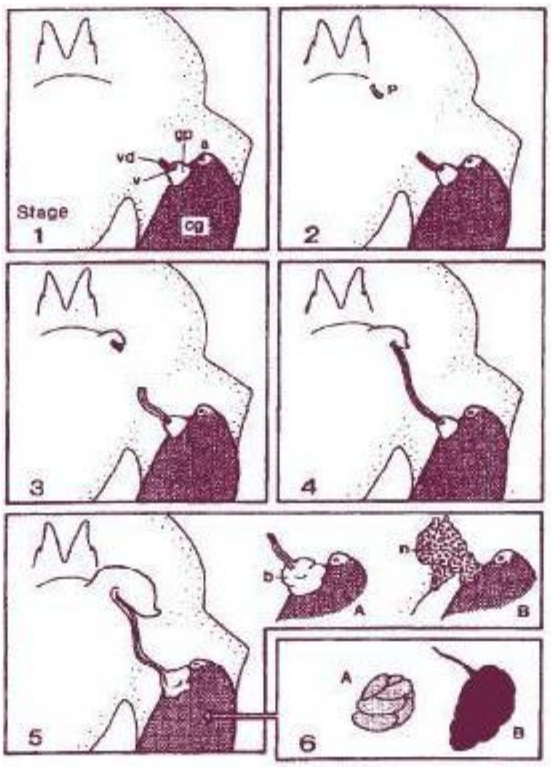


Table 1.0 Table showing the observed stages of imposex demonstrated by the female dogwhelks

	Number of females in imposex stage						
	0	1	2	3	4	5	6
Warrenpoint							
Site 1	0	0	1	1	12	3	0
Site 2	0	5	1	4	2	1	0
Omeath							
Site 1	0	0	0	2	5	6	4
Site 2	0	0	4	2	3	3	0

It does not depend on a penis but it measures the development of a vas deferens, which can indicate reproductive capability.

Results

Table 1.0 shows the varying degree of imposex stages observed at each site. Results obtained show that at each station, of the 50 specimens collected, 100% of the female dogwhelk population demonstrated the imposex phenomenon at varying stages.

The VDSI of individual *Nucella* ranged from 1 to 5. This shows that there were specimens, which were incapable of reproducing.

The average VDSI values for adults at Warrenpoint sites 1 and 2 were 4.00 and 2.46 respectively while at Omeath the values were 4.71 and 3.42. The average VDSI values for Warrenpoint and Omeath overall were 3.23 and 4.07 respectively. At each shore, site 1 (that closest to the harbour area), showed a higher average VDSI value than that of site 2 (further away from the harbour area).

Discussion

The fact that *Nucella Lapillus* demonstrated the imposex phenomenon means that TBT is present in Carlingford Lough. This would support other studies that TBT is still around some years after the partial banning of its use (e.g. Smith, 1996 and Walday, *et al*., 1997). Work carried out by Minchin *et al*. (1995) found that imposex in *N. Lapillus* was unlikely to decline until TBT was banned on all vessels. Vessels >25m in length can still use TBT based paints and since Warrenpoint is a busy port, large vessels use it. This may contribute to TBT levels around the Lough and subsequently imposex in *Nucella*.

The difference in average value of VDSI between Warrenpoint andOmeath 3.23 and 4.07 respectively would suggest that the Omeath site was more polluted with TBT. Thismay be partially explained by theway inwhich the tide flushes in the lough. A study of the nutrient inputs and trophic status of Carlingford Lough by Taylor *et al*., (1999), which found that the lough was not eutrophic, also suggested that the flushing pattern of the Lough is one which the tide enters the lough on the Northern shore and leaves the Lough on the Southern Shore. This is illustrated on Figure 4.0. The large arrow shows the current pattern generated by the flowpattern of the tide. This model would suggest thatmaterial fromthe Northern shore is lifted and deposited on the Southern shore. This reason may explain the higher VDSI value at the Omeath site. During dredging of the lough and sediment removal at the Warrenpoint marina, elevated levels of TBT from agitated sediment would have been carried round with the tide to the Southern shore. This may also support the observation made on sampling that the numbers of *Nucella* were extremely low at Omeath compared to those observed at Warrenpoint. Another important observation made was that no signs of breeding were present at Omeath whilst egg capsules were observed atWarrenpoint.

It may be hypothesised that the population of *N. Lapillus* at Omeath was wiped out or at least severely declined as a consequence of the works carried out on the Lough. Bryan *et al*. (1986) suggested that the percentage of females in a locality falls with increasing degree of imposex, which in turn puts additional pressure on the population. As noted in the method section the Omeath site specimens were younger and TBT is more harmful to the young. The high VDSI value at Omeath site 1 would support this statement as the high degree of imposex may account for the decline in numbers of *Nucella* due to increased pressure placed on breeding females.

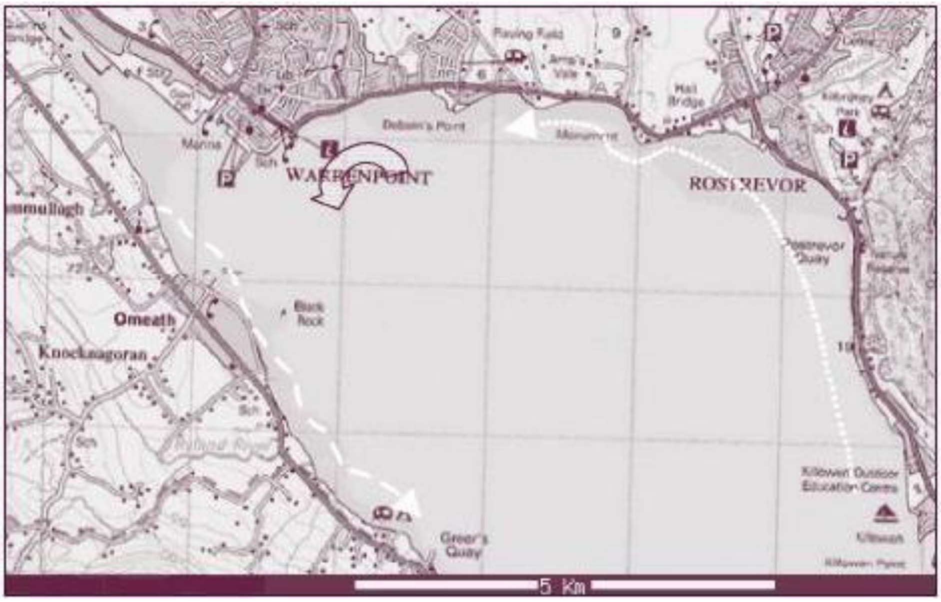


Figure 4.0 A diagrammatical representation of the flushing pattern in Carlingford Lough. (Key: •••••••• = tide – – – – = tide out). Map adapted from Northern Ireland Neighbourhood Information Service (2006)

Alzieu, (1991) and Dyrynda, (1992) blamed the near collapse of oyster farming in parts of western France and southern England during the 1980s on TBT in the aquatic environment. The first direct evidence of TBT contamination in Irish waters was detected byMinchin & Duggan, (1986). They discovered in the Owenboy Estuary, Cork that the pacific oyster (*Crassostrea gigas*) were found to have distorted shells and this was linked to TBT contamination.

The TBT contamination is greater in the sites nearer to most obvious sources. However, this differs slightly from the findings of Bryan *et al*. (1986) who found dogwhelks with high RPSI from coastal areas in the south of England (e.g. Plymouth) which indicated that levels of imposex were consistently high and remained elevated for distances of 5-10 kilometres along adjacent open coastlines.

As imposex is associated with the use of TBT in antifouling paints and, since TBT paints were banned in vessels less than 25min length in 1987, a decrease in the level of imposex would be expected in each subsequent year. Reports of imposex values (from UK and Ireland) for *N. Lapillus* following TBT restrictions have indicated that whelk populations have generally recovered from imposex, with only major ports remaining as imposex “hot spots” (Evans *et al*. 1991, Evans *et al*. 1996 & Miller *et al*. 1999).

As the samples collected from all sites but one had an average VDSI of less than 4, they could be assumed to be reproductive. Site 1 at Omeath showed an average VDSI of 4.71 which is closer to 5 and therefore gives cause for concern. The higher VDSI value would suggest that the population were perhaps not fully infertile, but nevertheless the elevated TBT concentrations may have had an impact on the reproductive capacity of the dogwhelks. This shows that there are elevated levels of TBT around this site. This may be explained again by the way, in which the tide flushes the lough as discussed earlier.

As already stated both these sites are close to a busy commercial port, which is used on a daily basis by a number of large vessels. TBT into the marine environment might therefore be fairly constant. The few pleasure craft launched locally in the spring and summer would have little effect at the sites.

It can be assumed from these findings that TBT in the water column is not the only factor influencing imposex at each site. The food source (e.g. barnacles andmussels) at each site can alter the uptake of TBT into the dogwhelk. Different food sources will accumulate different levels of heavy metals.

The study also suggests that both dumping and dredging, or the effects of tidal transport of re-suspended sediments, are likely the main sources for the TBT contamination observed in the upper estuary. Although the TBT contents found in the sediments studied are low relative to concentrations reported from other parts of the world, they appeared to represent a potential risk for some resident marine populations.

A review of the persistence of TBT in aquatic organisms by Maguire (2000) following the introduction of Canada’s Toxic Substances Management Policy showed that due to the long persistence of TBT in sediments there may be a “legacy problem” in sediments in some locations of Canada for perhaps 20 to 30 years after a total ban. This may help to explain why TBT is still impacting marine organisms in Carlingford Lough some 20 years after the partial ban.

Although effects of TBT on humans are not clear, several incidents of human exposure to the biocide have been reported. Underwear treated with TBT has caused severe skin irritation to its wearers. Shipyard workers exposed to TBT dust and vapours, while repairing a submarine, developed breathing problems, skin irritation, headaches, colds, flu, fatigue, dizziness, and stomach aches (US EPA, 1985). TBT exposure can also irritate the eyes and mucous membranes and prolonged exposure may cause liver and kidney damage.

Carlingford Lough is used to cultivate oysters and there are mussel beds at various points along both the Northern and Southern shores. Fish and shellfish which eat food that may be contaminated with TBT, will result in TBT accumulation in the organism, and thus it will bioaccumulate in the food chain (Kannan & Falandysz, 1997) causing a potential food safety problem.

A tolerable daily intake (TDI) of 15μg of TBT per person per day for a 60kg person has been set out, however there is no recognised TDI for total butyltins or other organotins. Concentrations of butyltin residues have been determined in muscle tissue of fish collected at local markets in Asian and Oceanian countries. This study found that the intake of butyltins by humans via consumption of fish in these countries was considerably less than that of the tolerable daily intake amount. Although this may suggest that there may be no need for concern about eating fish contaminated with TBT or other organotins, it must be stressed that as mentioned earlier in this study, TBT bioaccumultes in organisms and therefore there is no way of knowing if this accumulation is having an effect on public health in the long term.

Conclusions

- All of the female samples of *Nucella Lapillus* taken from Carlingford Lough showed evidence of the imposex phenomenon indicating TBT contamination.
- This supports the conclusions in other studies that TBT is still around several years after the partial banning of its use in anti-fouling paints for smaller vessels.
- The intensity (i.e. frequency and severity) of imposex was generally higher on the Southern shore of the lough. The difference in average values of VDSI recorded Northern shore (Warrenpoint = 3.23) and the Southern Shore (Omeath = 4.07) suggests that the Omeath site is more polluted with TBT. This may be partially explained by the way in which the tide flushes in the lough where material from the Northern shore may be lifted and deposited on the Southern shore.

- There were no signs of breeding within the *Nucella Lapillus* population at the Omeath sites whilst egg capsules were observed at the Warrenpoint sites indicating that breeding was taking place.
- TBT is still a widespread problem and is posing a threat to sensitive species, at least in coastal areas where shipping traffic intensities are high and in the vicinity of harbours.
- Shellfish and fish which eat food contaminated with TBT will result in TBT accumulation in the organism, and thus it will bio-accumulate in the food chain causing a potential food safety problem.
- A significant reduction in the overall occurrence and unintended effects of organotin compounds may only be achieved by extending regulations on the use of such compounds in anti-fouling paints to include a ban also on their use on large vessels in the United Kingdom and the Republic of Ireland.

Acknowledgments

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Book reviews

Books reviewed this issue are:

- Nanotechnology: Risk, Ethics and Law
- How to live a low-carbon life: the individual's guide to stopping climate change

Nanotechnology: Risk, Ethics and Law
Edited by Geoffrey Hunt and Michael Mehta, 2006, Earthscan

ISBN 978-1-84407-358-0 (Hardback)

This book brings together the views of a collection of well-know experts in nanotechnology and related disciplines. The book focuses on ethics, risk and the legal system associated with this fast developing topic. It is written for a non-scientist or early stage researcher who is generally familiar with the global research ethos. It may also be useful for an environmental health specialist as an insight and introduction to this fast-developing discipline.

The book begins by reviewing in general the current nanotechnology challenges and puts these into context against similar high publicity-based science topics. The introduction covers topics from history to the much argued definition; ethics to impact into society. This collection of chapters although short, is to the point and well referenced.

The next set of chapters illustrates the complexity and wide ranging nature of the subject. Included are the future of microsystems, nanoscience and the highly topical issues of nanotoxicology are presented. In fact a case is made for nanology, which can be interpreted as the down-sizing and convergence of all the sciences, medicine and engineering. The point is well made that the highly disciplinary nature of the subject is one of its greatest strengths.

Part two of the book reviews and provides an insight into the capabilities, strategies and developments in nanotechnology within Japan, USA, Europe, Canada. In particular these chapters provide a view on how the subject is being regionally adapted and accepted. Investments are highlighted and cross-referenced against various sectors with various degrees of success being highlighted. The third part of the book brings together a set of very important views on benefits and risks associated with the implementation of market led products. The question is asked “can we learn from all the difficulties that biotechnology has encountered” and “can regulatory agents play an important role in developing highly specific guidelines, labelling and risk & safety strategies”. These chapters all emphasise the issue of getting it right the first time and why government-led action is needed now. The key topic of nanoparticles is specifically dealt with by detailing the issues of size, shape, material type and how these properties relate to the mobility of penetration into the body.

The last two parts of the book deal with the ethics, public understanding and legal issues associated with research, development and commercialisation of nanodevices, nanoparticles and anything that involves the use of these size-related materials. Communication techniques on educating the public of the importance and applications of this new science are reviewed and some implantable health-related issues are highlighted with regards to ethics.

With regards to patenting this book focusses mainly on US patenting laws and in chapter 18 the author believes that although most of the work is currently science based and difficult to file, there will soon be an increase in filing rates as the technology matures. The novelty of nanoscience is also discussed with a belief that it will have to demonstrate high capability to be deemed patentable. As you would expect in a book dedicated to nanotechnogy research this text focusses on the broad range of applications within this area. Consequently, this is no light-weight read but rather is a reference text for those whose principal function is researching the peripherals of this new science. Overall this is a good general text book providing good quality analysis of the very broad range of nanotechnology topics. This book recognises that considerable volumes of research in nanotechnology are multidisciplinary. The text is aimed at researchers around the fringes of nanotechnology who may be studying environmental heath issues or benefits related to emerging technologies.

The individual chapters are informative and enable the reader to develop a concise understanding of the principles and pitfalls associated with each area. Detailed referencing is presented in the chapters and some on-line resources to augment the material included in the text. Sections of most relevance and interest to environmental health may well be the chapters on risk management, nanotoxicity, law and regulation. Yes, I would buy it – even though I am involved in the science of the subject, it is also important to be able to represent a wide range of societal-impact issues especially relating to ethical and risk matters.

Reviewed by Professor Jim McLaughlin, Director of the Nanotechnology & Advanced Materials Research Institute, University of Ulster

How to live a low-carbon life: the individual's guide to stopping climate change

By Chris Goodall 2007, Earthscan

ISBN 978-1-84407-426-6 (Paperback)

This ambitious text starts with the assertion that the UK can reduce its annual carbon dioxide output of 12.5 tonnes per capita down to three tonnes per person, with responsibility placed primarily on individuals, rather than governments or companies, for this ambitious reduction of greenhouse gases. While there is an expectation from the title and this assertion that the reader will be given a fullproof checklist for carbon reduction, the content goes further in a number of directions. Refreshingly, it concludes that some decisions are out of the hands of 'the man in the street', so that getting down to the three tonne target is not easy, but neither is it impossible. The need for behavioural change and personal environmental conscience lies at the heart of the arguments, with common sense solutions offered in many areas. Coverage of 'hot topics for carbon reduction' is comprehensive, as the author deals with 10 potential energy-reducing lifestyle-related areas, including heating, cooking, lighting, household appliances, car travel, public transport, air travel, food consumption, indirect greenhouse gas emissions and domestic use of renewable energy. A range of calculations is provided to justify the arguments, using a vast range of data, with more than 60 tables used to illuminate the arguments.

A fresh and stimulating read is maintained throughout the text by a non-standard approach to each area, but nevertheless, each chapter is introduced with a keynote statement of 'how to achieve carbon minimisation'. Lateral thinking points the reader to consider a 'cause and effect relationship' for personal activity and energy consumption. This thought-provoking attack is well demonstrated in the car travel chapter, when reduction of the steadily increasing body weight of English males could be addressed by a programme of walking exercise which contributes to improved health and reduces the carbon footprint through fewer short car journeys; however, the author concludes that the additional energy needed to produce food required after additional exercise would outweigh the car travel carbon reductions – a fine example of 'joined up' thinking! The practicalities of achieving energy reduction is complemented by valuable insights into methods for cancelling out emissions, such as use of green electricity tariffs, zero-emission power generation, tree planting and other offset schemes. While the author has not listed a specific references list, he has provided an impressive 279 notes, which cover formal texts, statistics, corporation reports and a myriad of press and web quotes.

The text is compelling reading for scientists, engineers, economists, academics, corporations and government decision-makers, even though it sets out to inform individuals. In a time of excessive public concern for and official statements on climate change, this book still stacks up as a source of vital information, primarily because of its fresh, stimulating and no-nonsense practical approach, concluding with a list of four steps for cutting direct emissions and eight steps for indirect emission reduction.

Reviewed by W Alan Strong, Senior Lecturer in Sustainable Development, School of the Built Environment, University of Ulster