THE SELECTION OF HEALTHY AND ENVIRONMENTAL RESPONSIBLE MATERIALS

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ABSTRACT

To select the construction materials which are safe to use, do not affect the building user's health, have minimal impact on the environment and yet are cost effective and technically sound is a complex process due to the different sources of information. The work described in this paper is a suggested process to be used to develop application and generic materials sheets incorporating all these issues that gives the specifier the possibility of applying their own perception to the problem when selecting a material.

Introduction

The last half-century has seen a revolution in science and medicine leading to a much clearer understanding of nature and of the human condition and of the natural environmental systems. Now the effects of environmental factors on human life and of human actions on the environment as well as the relationship to health and well-being are much more clearly appreciated. This paper is concerned with the actions that building designers, specifiers and the others involved in decision making over the nature of buildings should take to protect the health of the users and occupants. This can be addressed directly by reducing hazards to the health of occupants of buildings and indirectly by reducing environmental impacts in the general environment. The latter can be seen in global and local terms. Global issues such as global warming affect the whole planet and are of importance to the health of the global community. Local issues such as the pollution of water courses and the atmosphere are of importance to individual nations or to the health of the local community.

Health issues

The main concern in the recent past has concentrated upon the occupational exposure of the workforce involved in manufacture and processing industries, which has led to a general improvement in the workplace. Concern shown over deleterious materials at the workplace has developed an increasing awareness of the problems over pollution in the environment from irresponsible disposal of waste products to a point where serious public and government concern is now evident. This has become particularly acute where passive low level exposure to deleterious materials over long periods in the normal living and working environment is suspected. The ultimate effect this may have on health remains difficult to assess.

The reasons for this are numerous, but two areas provide an insight. Firstly, medical and toxicological research. Where toxicological research is carried out, and it often isn't, it provides early indication of the possible health effects of new materials, but the relationship of such work to true environmental conditions is extremely difficult to interpret. Epidemiological research must of necessity lag behind material developments that inevitably means that the population's health may be at risk in the intervening period. Furthermore, this research is usually based upon workplace experience where exposure levels are generally higher than in the general environment. It is also difficult to separate the effects of a suspected material from the influence of a range of other environmental factors.

The second area involves the practical assessment of the applications within buildings. Here the difficulty is in assessing the dose or exposure an individual might receive. Figure 1. lists the interrelated factors effecting dose or exposure, which illustrates the problem quite vividly.

Figure 1. Factors influencing dose or exposure

Factors	Comments	
Form and condition of material	Is the material loose and friable – will it be a source of dust? Does it contain volatile elements – will it emit toxic fumes by "off-gassing"? Is it combustible – again will it omit toxic fumes? Does it contain naturally radioactive elements?	
Position within the building	Contact with the water supply? Contact with foodstuffs? Internal or external? Exposed or concealed? Is there any danger from physical contact?	
Means of degradation	Abrasion	- normal weathering - normal wear and tear - DIY activities (sanding)
	Chemical action	- corrosion - drying - gas emission - DIY (burning off)
Ventilation	Air change rate	- residual properties of dwelling - normal rates achieved by opening windows etc.
Lifestyle	Periods of occupation The time factor governing the period of exposure	
Maintenance cycles	May introduce toxic chemicals or increase dust resulting from maintenance	

Environmental Issues

The environmental impacts of building materials are also difficult to assess primarily due to the many different issues that have to be considered. Figure 1.2, whilst not an exhaustive list, notes the various factors that can impact on any assessment. To make matters worse there are often inadequate data available to make an accurate assessment and even if there were, the implications to the designer selecting materials for a building will be further complicated by the source of materials relative to the location of the completed building.

Figure 2 Key factors effecting environmental assessment of building materials

Process	Issues
Upstream – extraction and manufacturing	Energy involved in both extraction and manufacturing processes. Transportation from source to manufacturing plant Depletion of resources – how much reserves remain? The amount of despoliation caused by the material extraction process Quantity of waste generated at both extraction and manufacturing stages Quantity of pollutants generated during these processes Proportion of the product made from recycled material
Construction	Energy involved in the construction process The distance the material has to be transported to site How much waste is generated and how much is, or can be recycled? What pollutants are generated during the process?
Buildings in use	Durability of the material in specific application and effects on maintenance Life expectancy
Downstream-demolition disposal and recycling	Pollutants caused during demolition Pollution as a result of disposal The volume of waste to be disposed of The distance material has to be transported either to tip or recycling point What proportion is recyclable or reusable? Ease of disassembly

Scope and constraints

From the points itemised in Figures 1 and 2, the magnitude of the task may be appreciated. Clearly it is difficult for one individual to possess the interdisciplinary skills to develop these ideas to a logical conclusion, hence the necessity for a group of specialists covering the fields of building design and production, environment, health and safety and medicine.

Whilst a review of the health effects and environmental impacts of all materials available for the use of all building applications forms a desirable, but unrealistic objective, clearly some compromise has to be accepted to retain the scope of the study within reasonable resource constraints. The study, therefore, has been directed towards low-rise residential premises, the reasoning being that this forms a large percentage of all buildings both old and new and at the same time is a clearly identifiable area of building technology. Further, it has implications for all sectors of society since, to all intents and purposes, we all live in houses or flats. It has also been necessary to rely upon the current "state of the art", i.e. to base the study on current knowledge. No special research has been commissioned nor has any special testing been undertaken. So reliance has been placed upon general knowledge of the constituents of building materials and on information supplied by manufacturers regarding their individual formulations. Hopefully the current work being carried out by the Building Research Station will mean that these opinions can be more finely tuned. Since from time to time manufacturers alter the composition of their products from that studied it is not possible to produce a list of names of manufacturers whose products comply with the findings. So it is suggested that in specifying any product where the health or environmental issue is of importance, the manufacturer or supplier be contacted if there is any doubt concerning the contents of the product.

Factors effecting selection

In considering the overall objective, it became obvious that a number of questions would need to be resolved when selecting a material or component for a specific application:

1. What are the main generic materials used in the building?
2. Where is the application in the building?
3. What alternative materials are available for the application?
4. Will the technical performance and appearance of the alternatives be adequate?
5. What are the comparative health hazards for all the alternatives?
6. What is the environmental impact of using each alternative?
7. What are the comparative costs?
8. What action should be taken when deleterious material is discovered in an existing building?

It should be noted that in attempting to provide answers to the above questions, the study was restricted to the materials that form part of the building fabric, services and fittings. Furnishings and loose furniture would require a further study. The one exception to this being carpets as these are often provided as part of the completed building.

Whilst questions 1 and 2 above are relatively easy to resolve the remaining ones are the most pertinent for the designer. Final selection will require them to make health, cost, environmental and technical comparisons between the alternatives. Questions 4 and 6 also relate to life cycle analysis, which is another consideration, the designer increasing needs to take account of.

Assessment – health and environment

If the building designer is to select appropriate materials to reduce hazards to health and the impact on the environment, in order to answer the questions posed in factors effecting selection, it is necessary to make a sensible comparative assessment of the alternative materials available for the application in question. Thus assessment forms the crux issue and a great deal time was devoted to establishing a workable system, because without this, the study could not have proceeded satisfactorily. The debate at the time revolved around whether or not an absolute categorisation ('safe' or 'unsafe') or a relative scale of hazard would be most appropriate.

An absolute scale would have been ideal, but it became obvious that this would be impractical for two main reasons. Firstly the lack of complete and conclusive toxicological and medical evidence on many of the materials was such that subjective judgements, or at the very least extrapolation from applications from other industries or from occupational requirements, would be necessary. Secondly the matter was further confused by the need to take into account the position in the building and relate this to other factors such as the rate of ventilation, in order to estimate the possible "dose" or exposure to the hazardous material. The problems of achieving this with any degree of confidence have already been identified in Figure 1. It would have been extremely difficult to establish the risk on an absolute basis, without undertaking exhaustive tests and trials. Little has changed from this perspective since the writing of the first edition.

A similar debate ensued over assessing environmental impact. As the work continued, it became clear that there were many gaps in the scientific knowledge needed to support all the decisions. This deficiency was accepted and the impact it may have had on the conclusions. Therefore, as with assessing health hazards, an absolute scale was impractical and a relative scale unavoidable. Hence the same system was selected for environmental assessment as with that of health. This was:
A hazard scale of 0 – 3, identified as:

- 0 – none reasonably foreseen
- 1 – slight/not yet qualified by research
- 2 – moderate

3 – unacceptable

In the context of health hazard assessment, the scale is applied to two different categories. These are defined as:

(A) The potential health hazard to the occupant when the material is in position in the building.
(B) The potential health hazard to the occupant when a reasonably foreseeable disturbance of the material could occur due to maintenance, repair, replacement or fire.

So, for example, asbestos cement slate on the A/B scale would rate 1/3. Category 1 because when it is fixed on a pitched roof of a building, asbestos fibre release will be of a low order in early years, and category three, because the risk of release on cleaning, maintenance or fire is unacceptable.

Whilst this provides a workable system, it should not be forgotten that very few normal activities are totally devoid of risk to health. Allergic reactions in susceptible individuals, such as hay fever and asthma, elicited by pollen, spores, house mites or certain types of food are well known. Perhaps less well known are those risks, which are associated with more serious diseases such as cancer. Such everyday processes as frying and grilling food produce traces of materials which in sufficient amounts have been shown to cause cancer, though the risks in the stated example are very small. Similarly some materials used in buildings have been shown to cause cancer under certain conditions. In assessing the safety in use of these materials, a judgement had to be made as to whether the risk from the intended use was significantly greater than that encountered in normal everyday use. If in their judgement it was not, then it scored "none reasonably foreseen". However, because many people would prefer to avoid this risk, even, though it is very small, where it occurs, its existence has been recorded.

The problem of the type and nature of the health information has been already mentioned. As there are insufficient toxicological and medical data available on many of the materials currently in regular use and in particular the substitutes for materials this often means that clear-cut advice cannot be given. So the authors have taken a possible optimistic view using factor 1 on the risk assessment scale for materials where the risk is still not determined. However, to penalise a material which may prove perfectly safe causes an equal dilemma.

It is accepted that the use of these somewhat subjective judgements in coming to conclusions is not completely satisfactory.

If the risk of fire involving a material in a given situation has been significantly modified by the choice of an alternative material, then this itself will obviously have an influence on the overall risk to health of the occupant associated with the choice of material, particularly if there is some significant health hazard associated with the degradation of the material by fire. This has been taken account of in the risk assessment when deciding the hazard rating for category B of the risk assessment.

Similarly ventilation has been considered when appropriate and, like fire considerations, is not simply a problem of material selection, but is also influenced by the general building design and layout. Equally changing life styles can affect both relative humidity levels and ventilation rates. However very low ventilation rates (below 0.5ach) can be, in themselves, a health hazard so it is important to appreciate the interaction between a possible pollutant and the normal ventilation expected in buildings.

In the case of environment hazards the same 0 – 3 scale is applied to four main categories:

(A) The environmental impact upstream, that is to say the extraction and manufacturing processes.
(B) The environmental impact during the construction process.
(C) The environmental impact during the life of the building
(D) The environmental impact downstream, that is to say on demolition either as waste or in recycling.

In assessing the impacts, the hazard scale is applied to secondary issues as identified in Figure 2. These assessments were made based on published environmental data on materials from research carried out elsewhere or experience. Assessments were made for all the alternative materials under categories A, B, C and D whereupon a subjective judgement was made as to which point on the hazard scale should be selected. Again, it is accepted that this is not entirely satisfactory. A more scientifically based life cycle assessment approach is possible but requires much more extensive research and for various reasons, is problematical in itself. It is important to note that the environmental impact grading is a relative assessment between the alternatives materials identified for a particular application and not between applications. Therefore cross comparisons of gradings between applications should not be made.

The transport of materials from place of extraction to the manufacturing and construction processes, or direct to the construction site, is problematic in fully considering the environmental impact. It is concluded that it was impractical to give any definite answer and the user would have to consider and judge transport implications themselves when selecting a material where it was appropriate so to do. For example, there are well known cases where the extracted material was transported long distances to the place of manufacture only to be hauled back to the construction site close to the place of extraction.

An example of how technology and life style changes influence the internal environment of buildings.

In the early seventies, the oil producing states of the Middle East commenced an oil embargo. One of the effects of this action was a wider awareness that a considerable amount of energy was being wasted in the operation of buildings. Resulting from this several actions were taken, including improving insulation performance, reducing the number of air changes and increasing the air-tightness of the building. The later was achieved by a variety of measures including designing new houses without chimney flues, sealing flues in existing buildings, improving the air-tightness of windows and doors either in their design or by using draught exclusion products, and the development of the double and secondary glazing markets.

At approximately the same time there was a revolution in the availability of new building products, notably with the development of the petrochemical industries. Plastic products, new adhesives, solvents, fungicides and other chemicals were being used increasingly in the construction or furnishings of buildings. The majority of these, if not all, had had little or no scientific analysis carried out to determine the effects on the occupants of the building of their use or indeed any problems associated with the combination of such materials.

Resulting from these situations were room spaces within dwellings with possibly less ventilation, but including a likely increase in the number of pollutants.

One also must consider the changes in lifestyle that have occurred over the last fifty years. In the immediate post war period, the majority of householders lived without central heating and with either a polished or varnished timber floor perhaps with an occasional rug or linoleum with an occasional rug. As society became more affluent, linoleum gave way to carpet and by the late sixties, cheap foam-backed broadloom carpets were readily available. At this time central heating was becoming the norm in new housing and retrofit was also occurring on a substantial scale. During the seventies and onwards, the double-glazing market expanded dramatically to such an extent that it is now the norm to automatically install it in new buildings.

The life style changes affected the relative humidity in buildings. Prior to central heating, levels would generally be higher. The advent of central heating reduced the levels and increased again with the installation of double-glazing. Add to this the reduction in air change rates mentioned previously and the question should be posed whether or not there is any correlation between the increased incidences of ill health in terms of allergy and asthma. The house mite infestation implicated in the epidemic of asthma in the UK may be a symptom of changes in life style which have occurred over the last half century. The long-term effect of reduced ventilation rates and such other changes on the health of the occupants is still not fully understood.

Technical Assessment

For each application the materials have been compared against a performance specification which may exceed the minimum laid down by the UK Building Regulations, but is generally related to normal building design and practice.

The assessment used for the technical and aesthetic performance is a relative scale of 1 –10. A simpler scale is adopted, as the problems associated with investigating the comparative performance are less severe, as designers regularly carry out this type of technical comparison. This scale is provided to assist, but it is anticipated that it does not cover every conceivable use of the materials. Designers must, therefore, use their own judgement in individual circumstances.

On the scale of 1 – 10, 1 represents the best material available, i.e. that considered from a technical point of view, and 10 to be generally unsuitable for the application under consideration or having poor life expectancy. In all cases the grading is a compromise considering all function and performance factors, durability and buildability, i.e. the ease of construction. It could be argued that the latter factor is of lesser importance, but this does effect the contractor's perception of the best material to use.

Aesthetic assessment

On the whole aesthetic judgements have not been an issue in the assessment made in the application sheets. This parameter is, quite rightly, left to the individual designer's preference. However, where it is judged an alternative presents a significantly inferior appearance, comment is made.

Building costs

The cost ranking figures provide a comparative guide for each separate application. The material having the lowest unit cost is allocated a base rank of 100 and all other material costs are compared with this. This is only used as an indicator' as it is not always possible to compare like with like. For example, some materials are produced in fixed modular sizes whereas others provide greater flexibility. In the case of the example shown, the cost ranking information has been omitted, as costs of materials will vary considerably in different parts of the world.

Use of the application sheets

In an effort to provide precise and useful information for those involved in the design process, the detailed results of the technical, health, environment and cost comparisons are shown in a concise manner in each application sheets See Fig 3. Each sheet also provides overall guidance on the selection for new buildings as well as comments on the possible problems encountered with each application in existing buildings.

However designers and specifiers should resist the temptation to solely rely upon the information provided in the application sheets. In order to appreciate the detailed health risk assessments and environmental impact shown on the application sheets, it is necessary to have a broader understanding of the recognised health and environmental hazards posed by building materials, respectively. The importance of this general understanding cannot be overstated. Although architects and other designers may feel that this is another imposition on their already short design time, and perhaps even on their design freedom, it has become obvious that, in particular, the health and environmental issues must be given more consideration as subsequent remedial or removal measures resulting from unwise selection may ultimately result in claims for negligence.

Fig 3
APPLICATION
RAINWATER PIPES AND GUTTERS

Alternatives	**Technical Comment**	**Rank**	**Health Comment**	**Rank**	**Environment Comments**	**Rank**	**Cost Rank**
Cast Iron	Durable but brittle material. Will support loads from ladder. Needs regular painting	2	No significant risk foreseen to occupants	0/0	Raw materials source is critical, eg. pig iron is smelted with charcoal in some parts of Brazil. See technical comment on maintenance for good durability	2/0/0/0	
PVCu	Lightweight easily worked material. Wide range of propriety systems now available. Improved products now offer adequate durability. Painting not required.	1	No significant risk foreseen to occupants	0/0	Problems with pollution from manufacture but situation is improving. Problems at disposal	2/0/1/2	
Aluminium	Durable lightweight material. Normally available only through specialist fixers. Seamless pattern. Painting not required.	1	No significant risk foreseen to occupants	0/0	High embodied energy. Pollution from manufacturing. High recycled content.	2/0/0/0	
Timber (Gutters only)	Regular Painting required to ensure durability. Timber needs to be vacuum impregnated with preservative for long term durability. Will support loads from ladder	3	No significant risk foreseen to occupants	0/0	Life expectancy related to maintenance and preservative treatment. Disposal by combustion causes atmospheric pollution	1/0/1/0	
PVA Cement	Needs regular painting to give good appearance. Lighter weight than cast iron. Durability comparable with asbestos cement, impact resistance slightly improved.	3	The status of PVA fibres is uncertain. Weathering, cutting and attrition will release fibres. If maintenance workers and DIY occupants are exposed to inhalable fibre, a small health risk will result	0/1	Polymers involve high energy processing	2/0/1/1	
Asbestos Cement	No longer used in new work. Had limited application in house building	3	Fibre release on aging and maintenance in old material will expose maintenance workers and DIY occupants, construction and demolition operatives to an inhalation risk	1/3	Asbestos is a hazardous waste and needs to be disposed of properly. Asbestos In existing buildings needs to be identified, recorded, assessed for comparative risks and removed or perhaps treated or encased and managed as appropriate. The (-) classification refers to lack of availability/no longer used	-/-/-/3	

Fig 3 is an example of an application sheet for rainwater pipes and gutters. The alternatives are those commonly used in the UK. for low rise residential construction. Asbestos, whilst not specified is included as this material is still in use in some existing properties and will be maintained or eventually disposed of.

The technical requirements against which the materials were compared is as follows:
"*Durable and impervious gutter and down pipes. Must span recommended bracket spacing, provide easy jointing and cutting and permit decoration if required. Jointing system must cope with thermal*

movements. Ability to support ladder during maintenance an advantage, as is resistance to impact at base of down pipe. Must be compatible with most building materials."

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