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Edited by: Howard, B.J. & Beresford, N.A.

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PROJECT CO-ORDINATOR : B J Howard

PARTNERS :

Centre for Ecology and Hydrology – NERC	**UK**
Risø National Laboratory	**DK**
National Radiological Protection Board	**UK**
Norwegian Radiation Protection Authority	**NO**
Agricultural University of Norway	**NO**
The University of Nottingham	**UK**
Diputacion General de Aragon	**ES**
GSF-Forschungszentrum fuer Umwelt und Gesundheit	**DE**
Lancaster University	**UK**

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Part 1: Publishable Final Report

1.1. Executive publishable summary

Following a large-scale release of radioactivity into the environment, food production systems and inhabited areas may be contaminated for many years. Accident response throughout Europe has tended to focus on the early phase. To sustain acceptable living and working conditions in contaminated areas we need practicable restoration strategies that address the different types of environment, land use and ways of life. The STRATEGY project (Sustainable Restoration and Long-Term Management of Contaminated Rural, Urban and Industrial Ecosystems; www.strategy-ec.org.uk) has established a holistic framework for the selection of optimal remediation strategies for long-term sustainable management of contaminated areas. A requirement of this framework was the development of databases containing state-of-the-art information on individual countermeasures. A datasheet template was designed incorporating all criteria that decision-makers might consider when evaluating different countermeasures. These included a short description of the countermeasure, its key attributes, constraints, effectiveness, feasibility, waste generated, doses incurred through implementation, costs, side effects, stakeholder opinion and practical experience. A compendium, comprising datasheets for 101 countermeasures was produced. For some criteria, the inclusion of more detailed guidance was made possible by adopting a CD-Rom format with hyperlinks to underlying documents. The compendium has been well received by national and international bodies and plans are currently being made for its further development under the direction of the IAEA/FAO and the EC.

A spatially implemented model to identify optimal medium to long term countermeasure strategies for radioactively contaminated regions has been developed. Collective and individual doses within the affected area are estimated for internal and external exposures; exported ingestion doses are also estimated. Countermeasures aimed at reducing ingestion doses and external doses are incorporated within the model. Waste disposal options and environmental restrictions have also been included. The model evaluates the effectiveness of a combination of countermeasures through a cost function which balances the benefit obtained through the reduction in dose with the cost of implementation and the side effect costs. The optimal countermeasure strategy is the combination (of individual countermeasures and when and where they are implemented) which gives the lowest possible cost function value. The model has been successfully applied to hypothetical scenarios in the UK and Spain. The model outputs should not be considered as definitive solutions, rather they present a useful (and interactive) input to the decision making process.

Socially related objectives related to the implementation of countermeasures need to be given due weight and not subsumed by issues connected to dose reduction. Whilst early involvement of the local and wider community of stakeholders within participatory decision making would be beneficial, mechanisms for doing so need to be identified. Within STRATEGY, we have considered the ethical aspects of restoration strategies and suggested a practical means by which these can be taken into account in the decision making process, introducing the use of a value matrix. Combined with stakeholder participation, the matrix is a method of ensuring transparent and systematic consideration of social values in selection of a restoration strategy.

Part 2: Detailed Final Report

2.1. Objectives and strategic aspects

Following a large-scale release of radioactivity into the environment, different urban, industrial and rural areas may be contaminated for many years. Consequently, areas of industrial and agricultural production (with associated employment), residence and recreation may all need to be managed to mitigate the impact of contamination. Although responsible bodies throughout Europe conduct emergency planning, it is generally focused upon the short-term response (few days - weeks) addressing issues such as potential evacuation, requirements for restrictions being placed upon drinking water/food and immediate problems associated with ^{131}I such as the provision of stable iodine. Previously, there were limited systematic considerations of long-term management to ensure sustainability of areas contaminated by long-lived radionuclides. Over the long-term, most deposited radionuclides will remain in the surface soil and recycling of radionuclides will occur to differing extents in different ecosystems. External doses will result from exposure to deposited radionuclides in all types of systems. To sustain acceptable living and working conditions in such areas it is important to be able to construct robust, effective restoration strategies which address the many different types of environment, land use and ways of life. Furthermore, it is essential that long-term management is considered during the early phases of accident management, as actions conducted during this phase will impact upon the potential for, and mechanisms of, long-term restoration.

Many individual countermeasures have been developed, especially since the Chernobyl accident. However, in practice many of these have only been implemented within the former Soviet Union (fSU). The applicability of most measures to the European Union Member States has not been fully and critically assessed. Furthermore, countermeasure research has previously largely focused on the effectiveness of individual methods, although some attention has been given to cost benefit analyses (e.g. cost per averted unit of dose). There has been little previous consideration of how to combine these individual countermeasures within a sustainable restoration strategy for a contaminated area comprising urban, rural and industrial systems.

In designing restoration strategies to ensure the long-term sustainability of large and varied contaminated areas, there is a requirement to adopt a more holistic approach rather than simply selecting cost-effective countermeasures. Resources will be limited and must be used in the most appropriate manner, considering a range of different requirements to ensure sustainable use, including social and ethical aspects, environmental considerations and quality of life. In addition, public perceptions and communication of technical information has only recently become a major issue when defining policy, and although it is now the subject of a substantial field of research, it has been little integrated in a practical context. Countermeasures that are not only available to decisions makers but also at a self-help level to the public are likely to be important in fostering a more active response by the community in affected areas.

The potentially negative consequences of restoration must be fully considered. The implementation of a remediation strategy may lead to a reduced collective dose, but increased dose to those implementing the strategies. Thus, some measures will result in an imbalance in the distributions of dose and costs across different population groups. There is also a requirement that the radiological situation is fully explained and any remediation measures employed are transparent to affected populations. Psychological stresses associated with living within contaminated areas of the fSU and the consequences of some remediation measures have been shown to be more detrimental to health than the radiation risk itself within some populations.

In response to the issues described above, the overall objective of the STRATEGY project was to establish a decision framework to enable the selection of robust and practicable remediation strategies for Member States, which enable the long-term sustainable management of contaminated areas. To achieve the objective the following factors needed to be taken into account - (i) practicability, including technical feasibility and acceptability of individual measures; (ii) cost benefit; (iii) ethical and environmental considerations; (iv) requirements for effective public communication; (v) spatial variation in many of these factors and (vi) the contrasting needs of urban, rural and industrial environments.

Contribution to EC policy needs

STRATEGY directly addressed *Key Action 2: Nuclear Fission - Off-site emergency management*. The framework contributes to the enhancement of decision support tools. Evaluations of ethical criteria, communication requirements and mechanisms, and other social issues contribute towards a better exchange of information with affected populations in the event of an emergency.

Through a greater degree of public understanding of restoration procedures, radiological risk and an improved capability for long-term management of contaminated environments STRATEGY contributes to the overall objective of the Nuclear Energy Programme - *the maintenance of a sustainable nuclear industry within Europe*. The overall ability of the regulatory authorities to manage off-site radiological emergencies, especially the public communication dimensions, is significantly enhanced by this study's integrated, interdisciplinary output.

A novel and integral part of the STRATEGY approach has been to promote the inclusion of social and ethical issues, including public perceptions and communication, explicitly within the evaluation of restoration strategies. Combined with a consideration of aspects of public perception this contributes to a higher degree of public understanding and confidence in information given by authorities and in remedial measures applied in the event of a nuclear accident. Consequently the outputs of STRATEGY contribute to the objective of the Fifth Framework Programme - *Quality of life and management of living resources*.

2.2. Scientific and technical description of the results

Work Package 1: Practicability and cost of individual countermeasures

The overall objective of the work package was to critically evaluate individual countermeasures to be implemented after a nuclear accident affecting Europe.

Identification and description of countermeasures

A large number of potentially applicable countermeasures were critically evaluated; their potential suitability for application in European member states was identified. The final list of countermeasures comprised:

- 35 methods specific for urban/industrial environments,
- 29 methods specific for agricultural and semi-natural environments,
- 12 for rural waste disposal options
- 3 methods specific for forest environments,
- 7 methods specific for aquatic environments, and
- 15 methods based on social/human/communication issues.

Short descriptions were produced for these countermeasures. For detailed description of the countermeasures in a uniform format facilitating intercomparison of method features, a datasheet template was developed and applied to all countermeasures. The datasheet template format was discussed internally and externally, and incorporated comments from representatives of an 'end-user' community. This template contains the required information describing practicability and direct costs of each countermeasure (Table 1). In addition, averted doses and elements originating from other work packages, such as ethical, social, legal and communication concerns, and side effect costs have been included. This holistic approach, taking into account important factors that have not been considered in previous compiled countermeasure databases (e.g., Anderson K.G. & Roed, J. 1999; Anderson *et al.* 2000; Voigt *et al.* 2000; Salbu *et al.* 2001), is believed to greatly improve and facilitate decision-making.

Throughout the project period the descriptions have undergone an extensive development and quality assurance process, incorporating contributions and comments from various project partners. An external peer review was performed by end-users, partners in the SAMEN network and other independent experts and organisations.

The datasheets and associated documents were completed for all 101 countermeasures with all required information, including evaluations on wastes, doses, cost effectiveness, social/ethical/communication impact (from work packages 2 and 3) and side effects (from work package 4).

A total of 15 countermeasures were identified for which datasheets have not been completed because there was evidence that they are ineffective or they are inappropriate for long-term application. A further 6 might possibly be considered in the future, but require further investigations due to current lack of knowledge.

For some criteria, the inclusion of more detailed guidance was made possible by adopting a CD-Rom format with hyperlinks to underlying documents, where relevant (see following sections).

Table 1 Criteria used to describe countermeasures

Criteria	Issues
Key attributes	Objective, Other benefits Countermeasure description Target Target radionuclides Scale of application Contamination pathway Exposure pathway pre intervention Time of application
Constraints	Legal, Social, Environmental, Communication
Effectiveness	Countermeasure effectiveness Factors influencing effectiveness of procedure (Technical) Factors influencing effectiveness of procedure (Social)
Feasibility	Required specific equipment Required ancillary equipment Required utilities and infrastructure Required consumables Required skills Required safety precautions Other limitations
Waste	Amount and type Possible transport treatment and storage routes Factors influencing waste issues
Doses	Incremental averted doses Factors influencing incremental averted dose
Intervention Costs:	Equipment, Consumables. Operator time Factors influencing costs, Communication costs, Compensation costs, Waste costs Assumptions
Side effect evaluation	Ethical considerations, Environmental impact, Agricultural impact, Social impact Other side effects
Stakeholder opinion	
Practical experience	
Key references	
Comments	

Management strategies for countermeasure wastes

Some of the countermeasures that were identified as potentially suitable generate various types of waste that require handling in a safe and acceptable manner. This implied a number of considerations, which entered the decision matrix as an inherent part of the countermeasure evaluation process. Therefore, descriptions of strategies for countermeasure waste management must be available in connection with the countermeasure descriptions. Relevant documents for each type of countermeasure waste were produced for linking to the countermeasure description datasheets.

Agricultural wastes

An overview of the waste streams produced from the implementation of countermeasures in food production systems was produced. A total of 12 waste treatment and disposal routes were identified, which included ploughing in and composting for crops, land spreading and sea disposal for milk, rendering, burial and burning for animal carcasses. Datasheets, based on the template used to characterise countermeasure options, were completed for all 12 rural waste options. Few of these options had previously been considered in the context of restoration and none to the level of detail carried out here. The datasheets were included in Deliverables 1 and 2 and as such have undergone peer review.

Urban and industrial wastes

Options for the management of wastes generated from the implementation of countermeasures in urban and industrial areas have been identified. This has led to the description of 15 methods, ranging from techniques for disposal of contaminated urban soil and vegetation to sophisticated methods for volume reduction of wastes originating from clean-up in the industry. Information on the transport, storage and treatment/disposal of urban and industrial wastes is presented as a 'second layer' document on the CD-Rom.

Forest wastes and wastes from countermeasures for the aquatic environment.

Only one countermeasure was considered which would require the management of wastes arising from the implementation of countermeasures in forest areas, namely Restrictions on use of wood. The waste arising from this countermeasure can either be left in the forest or, if in the wood industry, be disposed of or treated according to the descriptions of biological waste from agricultural or urban implementation (e.g. as for tree pruning). For the aquatic environment, only one countermeasure produces waste, namely a limited volume of ion exchange resin that can be disposed of at a landfill site suitable for radioactive waste.

Dose redistribution due to countermeasure implementation

According to the ecological, biological and physical half-lives of the contaminants, doses to members of the public through consumption of contaminated foods and external exposure will naturally decrease, and countermeasures implemented will lead to reduction of dose according to their efficiency. However, the implementation of most types of remedial actions will lead to additional doses to those individuals implementing them, and to those affected by wastes generated. A series of calculations have been made to examine the redistribution in dose resulting from the implementation of countermeasures, for the public and for those implementing countermeasures.

Additional dose is an incremental dose that specifically excludes doses from contamination already present in the environment. Among these dose contributions were doses to drivers transporting contaminated materials and operatives working at processing facilities. These doses were estimated using the NRPB MICROSHIELD shielding code. Dose coefficients for external exposure from a plane of contaminated land, e.g., in connection with land treatments, were calculated using another NRPB GRANIS model. A detailed account of the methodologies is currently being prepared as an NRPB report. A shorter report giving incremental doses at an hourly rate for ^{131}I, ^{134}Cs, ^{137}Cs, ^{89}Sr and ^{90}Sr for those countermeasures incurring an incremental dose is presented as a 'second layer' document on the CD-Rom. A breakdown of these incremental doses into their principal exposure pathways is also provided, with an example calculation.

For the urban/industrial environment kerma rates in air were calculated for various representative locations indoors or outdoors in selected urban and newly characterised industrial environments. The calculations were carried out using dose coefficients obtained with the MCNP standard photon transport model from Los Alamos National Laboratory, USA, and taking into account state-of-the-art knowledge on deposition and migration of radionuclides in the urban/industrial environment. Descriptions of the external dose calculation method in urban and industrial environments including a sensitivity analysis to identify the correlations between doses and the different model input parameters have been presented in a GSF report.

Criteria determining cost-effectiveness

A generic method has been described for calculating cost-effectiveness of countermeasure implementation on the basis of the STRATEGY countermeasure descriptions. The parameters to be considered in the calculations were outlined and all STRATEGY countermeasures were attributed suitable equations for calculating averted dose and monetary costs where possible. In any real situation the calculations will of course depend on site-specific data. A simplified example is given to demonstrate how site-specific predictions can be made on the basis of the STRATEGY model. Similar predictions can be performed for other countermeasures and other types of sites or real accident situations. A short report on cost-effectiveness is presented as a 'second layer' document on the CD-Rom.

Ethical, legal and social issues and side effect costs

Documents have been prepared in connection with work packages 2 and 3, which further elaborate on the information given in the datasheets on ethical, legal and social issues (CD-Rom second layer information). Here, useful definitions of terms applied in the datasheet are given together with a more thorough account of some of these issues than was possible to include directly in the datasheets. Generic text was provided on potential legal issues and communication costs associated with countermeasure implementation.

A further associated document has been provided (from work package 4), which summarises a number of techniques for valuation of indirect costs associated with side effects of the countermeasure implementation.

Stakeholder activity

The STRATEGY work has been further reviewed by involving groups of 'stakeholders' (representatives of individuals or organisations that would in some way be involved in, or affected by, the implementation of a countermeasure). This process is considered to be an important part of the project, as it ensures the incorporation of viewpoints of representatives affected by the countermeasure implementation.

The EC project FARMING has established a network of stakeholder groups in the UK, Belgium, Finland, France and Greece, involving more than 100 individual stakeholders. The network specifically considers restoration options for food and agricultural systems following a nuclear accident. The STRATEGY compendium of agricultural countermeasures and rural waste disposal options were the main focus of discussion at the 2002 meetings of national stakeholder panels in UK, Finland, Belgium, Greece and France. Due to constraints in time and resources not all of the 41 options could be evaluated by each national group. The greater maturity of the groups in UK and Finland and their familiarity with many of the countermeasure options enabled all 41 options to be evaluated. In all but the UK, the feedback was considered as preliminary, as discussions with stakeholders are continuing.. However, a more general overview of stakeholder opinion from across Europe was presented at the WISDOM workshop

For the urban/industrial environments a stakeholder network did not exist outside the project and consequently stakeholder groups were formed with numerous representatives, and stakeholder meetings took place in the autumn of 2001 in Denmark and Germany. The outcome of the activities has been reported, and was incorporated into the project database as appropriate.

For the forest and aquatic environments a stakeholder group was set up in Finland in February 2003. The feedback from this group has been incorporated in the datasheets.

Work Package 2: Social and ethical considerations of countermeasures and restoration strategies

The work carried out in work package 2 can be best summarised according to the three main objectives of the original work plan: 1) to evaluate social and ethical considerations for individual countermeasures; 2) to identify and evaluate relevant criteria for communication and compensation strategies; and 3) to develop decision tools for the evaluation and selection of holistic restoration strategies.

<u>Social and ethical aspects of individual countermeasures</u>

The three main activities associated with this objective were: a) identification of relevant ethical considerations for inclusion in the countermeasure database spreadsheets; b) evaluation of individual countermeasures according to the selected criteria; and c) collation of information on legal aspects and regulations affecting countermeasures. The main change from the original work plan was inclusion of datasheets specifically on “social” countermeasures for work package 1.

a) Identification of relevant ethical considerations

There are a number of ethical issues that will be relevant for any risk assessment, including questions such as whether: (i) the distribution of cost and benefits are equitable; (ii) the risks are imposed or voluntary; (iii) stakeholders have been involved in the decision-making process; and (iv) the action carries a risk of serious environmental damage. Within STRATEGY, these have been extended and revised to be specifically relevant to countermeasure implementation and to provide an overview of the main types of questions and ethical criteria against which each individual countermeasure can be evaluated. The concepts themselves, and examples related to countermeasure applications are summarised in the background documentation to the datasheets. A more philosophical discussion on their relationship to fundamental values and ethical principles can be found in Deliverable 4. The relevant ethical issues considered include:

- Self-help/Disruptive
- Free informed consent of workers (to risks of radiation exposure and/or chemical exposure) and consent of private owners for access to property.

- Informed consent regarding consumption of foodstuffs
- Liability and or compensation for unforeseen health or property effects
- Change in public perception or use of an amenity
- Distribution of dose, costs and benefits
- Animal welfare issues
- Environmental risk from ecosystem changes, groundwater contamination, etc.
- Environmental consequences of waste generation and treatment (chemical and radioactive)
- *In situ* treatment of waste
- Uncertainty

b) Evaluation of individual countermeasures against above criteria

Evaluation of individual countermeasures has been carried out in close collaboration with work package 3. Brief descriptions of the most important ethical considerations have been inserted in the datasheets. Obviously the descriptions in the datasheets are rather general, since the actual issues will be site and context specific, but the information gives decision-makers an insight in to some of the main questions that should be considered in evaluation of countermeasures. The ethical dimensions used in evaluation of individual countermeasures have been further developed for links with the ethical matrix (see objective 3), and a brief summary document collating information of the various ethical, legal and social aspects of the individual countermeasures has been prepared as a second layer to the countermeasure datasheets. This included a review of legal and regulatory issues, specifically focusing on international environmental legislation. Information has been gathered on more than 30 international treaties, conventions and laws (e.g., on conservation, water pollution, endangered species, waste treatment and disposal), including UN, EU and IAEA, and an overview of table of websites provided.

c) Social countermeasure datasheets

Together with work package 3, 15 social countermeasures have been identified and countermeasure datasheets completed and subjected to peer-review.

<u>Identification of relevant ethical criteria for information strategies</u>

This activity formed the basis for Deliverable 3 "Ethical considerations for communication strategies" which identifies a number of ethical criteria that are important for evaluation of communication strategies. In addition to a general requirement to provide honest and open information to the public, it is argued that authorities have a particular obligation over those groups for which exposure to radiation and/or remediation actions to reduce that exposure can impose a risk of harm. The report suggests that the ability of affected persons to consent to the imposition of such risks can provide guidelines for the evaluation of communication strategies. Medical ethics has identified four conditions which are necessary to satisfy the requirements for free informed consent: *disclosure*, *understanding*, *voluntariness* and *competence*. These conditions can be adapted to provide criteria for communication in radiation protection. Affected persons need clear, relevant information about possible risks and benefits together with available alternatives (i.e. *disclosure* and *understanding*), and authorities should pay due attention to the skills and knowledge of persons affected by, and involved in, countermeasure implementation (*competence)*. The criterion of *voluntariness* highlights the significance of communication strategies that enhance personal choice and control over the situation, and that people may refuse to consent to risk without some form of compensation. Likewise, the promotion of self-help strategies is an important ethical factor in evaluation of individual countermeasures. Finally, it is important that communication is seen as a two way process, involving exchange of information between parties and not a simple one way expert-to-public flow of information.

The need for informed consent, as well as political human rights and the principles of autonomy, equality and democracy, stress the need to include affected parties in decision-making. Stakeholder participation also recognises an important public dimension in societal policy-making and can enhance public acceptability of decisions.

<u>Development of decision tools for the holistic selection and evaluation of restoration strategies</u>

Any decision on countermeasure implementation will have to take into account a large amount of information on the benefits, risks and costs of the restoration strategy and its alternatives. The actual selection of a strategy will require trade-offs and value judgements, and almost certainly some lack of agreement within society on what is practical or acceptable. If such a selection is going to be ethically defendable, decision-makers require advice on what criteria are important to consider and why, and also a methodology to ensure a transparent and publicly justifiable procedure for balancing these criteria. As a procedure for ensuring a systematic consideration of ethical issues, and as guidance for stakeholder participation processes, the work carried out in work package 2 has focused on the development and application of a *value* or *ethical matrix*. This has been carried out in close collaboration with researchers from the Norwegian Ethics Committee on Science and Technology (NENT), who were identified as sub-contractors in the original contract, and is summarised in a number of articles and reports (Forsberg and Kaiser 2002; Oughton 2004), including the associated Deliverable 4.

A value matrix is a tool to ensure that all relevant concerns are being taken into consideration and to clarify the ethical basis upon which eventual decisions are made. The matrix approach proposed in STRATEGY takes its starting point in three fundamental principles, namely:

1. To promote **well-being** and minimise health risks, welfare burdens and other detriments to affected stakeholders
2. To respect the **integrity** or **dignity** of affected stakeholders
3. To recognise the norm of **justice** and aim to treat everybody fairly and ensure an equitable distribution of goods among affected stakeholders.

In practice, a matrix can aid a decision-making group by giving an overall picture of the issue at stake, thereby making the ethical dimension of decision-making more transparent. Different countermeasures can affect different groups in different ways, and the matrix can be used to help identify the relevant information required for decision-making (i.e., the facts, values and stakeholders affected). In this way, a bias towards certain kinds of values may be avoided, and the matrix can be used to address conflicts between values in a systematic way, without, necessarily, having to invoke full-fledged theories. It is important to stress that the matrix is not a substitute for public and/or stakeholder participation, it is a tool that might be used on connection with other possible communication and consultation procedures (see Deliverable 6). However, a further advantage of the matrix is that it is well suited to use within a participatory process with appropriate stakeholder representatives of affected parties.

The matrix developed in STRATEGY has been tested with the end-user group as part of a case study exercise. The exercise demonstrated that the matrix was useful in mapping the concerns of various stakeholders and helpful in weighting the importance of those values. The exercise itself is described in more detail in Deliverable 9. Although the primary objective of the end-user exercise was to test the value matrix as a decision-making aid, the matrix approach in STRATEGY was specifically designed for use in conjunction with the other STRATEGY outputs. Thus the exercise also provided a limited opportunity to explore the other tools (in this case, the model and countermeasure datasheets) and, specifically, a demonstration of the practical benefits of the interaction between the model and the value matrix in decision-making. On the whole, the group evaluated the exercise positively, thought it would be worthwhile for decision-makers to be trained in this kind of method, and expressed a wish for further demonstration of the matrix approach.

Table 2. Illustration of a tentative value matrix developed for use in a radiation accident situation.

Stakeholder	Examples	Well-being	Integrity	Justice/ distribution
		Example: Health and economic welfare	Example: Choice/consent /(legal) rights	Is any sub-group of stakeholders worst-off?
Owners/ Employers	Government Farmer House dweller Land owner Hotel owner Shop owner Business proprietor Factory owner Local authority	Doses to humans Loss/gain in income Loss of property Damage to, or reduction in value of, property Loss of taxes Compensation	Self-help Consent Property rights Being allowed to pay their duties Contract fulfilment No disruption No insecurity Liberty	Possibility for conflict between different industries or projects
Workers/ Employees	Tennant farmer Farm workers Factory workers Contractors Count.meas workers Immigrant workers Other employees	Doses to humans Fear of job loss Gain/loss of income Insecurity Family relationships Compensation	Traditional skills and practices Trust and loyalty to local farmers Consent Training	Possibility for disputes and social inequity
Users/ Community	Neighbours Recreational Tourists Public amenity (library, town hall, playground, park) Local community	Access Aesthetic value Empathy Isolation Community values Tourism Compensation	Respect for public heritage and footpaths Community sense Personal control Self-help Liberty	Potential conflict of age/sex/ cultural minorities Availability of alternative amenities
Consumers	Consumers Secondary food producers Other secondary producers (e.g. timber)	Doses to humans More expensive goods Loss of jobs Insecurity	Information Choice Self-help Intervention limits	Potential conflict between different income groups concerning diet and possibility of self gathering
Future gen.	Future food production Future clean air and water Future users of recreational areas, etc	Loss of opportunities to use areas, resources, common goods, etc	Respect for the right to keep living according to basic human values	No one future group be sacrificed for the presumed good of other future groups
Environment	Farm animals Wild animals Pets Other biota Ecosystems	Dose to biota Other toxic/health effects Compensation	Endangered species Loss of habitat Right to life consistent with their nature	Potential conflict between farm and wild animals, between ecosystems
Waste location stakeholders (if different from accident location)	Including all the above stakeholders connected to the waste site.	Uncertainty/risk estimates: Possibilities for monitoring, retrieval and treatment must be known Compensation	Consent Self-help Information etc	Potential conflict between stakeholders close to disposal site

Work Package 3: Public interaction and Communication

The focus of this work package has been to (i) identify the social assumptions in remediation strategies (Deliverable 5) and (ii) provide guidance on consultative communication approaches for use in radiological remediation (Deliverable 6). In addition together with work package 3 participants 15 countermeasure datasheets for ‘social countermeasures’ such as, advice and information to the public, restricting activities and participatory dialogue approaches, were produced (see work package 1 report). The production of these datasheets represented a change from the original work programme.

Social assumptions

Any countermeasure or set of countermeasures contain within them a variety of social assumptions, those ‘taken-for-granted’ expectations about the ways in which people will behave and what is meaningful, valuable, credible and possible for them. These assumptions are often unspoken, and maybe implicitly built into other inputs such as information provision and decision-making practices. If these assumptions do not accurately reflect social reality, then the effectiveness of any remediation strategy is likely to be reduced. The negative effects of false assumptions in one measure may well spread across the whole institutional programme of remediation *per se*. If one can identify, assess, and where appropriate change these assumptions, better remediation choices are likely, leading to more effective remediation.

Deliverable 5 considered several dimensions of social assumptions and used particular countermeasures to exemplify these. Both embedded assumptions implicit in risk assessment and assumptions about behaviour, confidence, institutional capabilities, social and cultural feasibility and compliance were addressed.

Despite extensive literature searching, very few studies with sufficient socio-cultural depth to enable the detailed examination of social assumptions in relation to remediation activities in the post-Chernobyl context were found. The relatively comprehensive studies made of the Saami reindeer herders, village populations in some parts of the former Soviet Union (fSU) and Cumbrian sheep farmers, are not reproduced in comparative studies of other populations. Furthermore even in these detailed studies, which report sociological data, analysis has not generally been conducted sociologically. However, there have been relatively extensive studies in related areas, for example, relocation has been studied in relation to large infrastructure projects such as dams. It has therefore been necessary to draw from the wider literature on risk and hazard and apply the findings to the situation of large-scale radioactive contamination. This must, however, carry the caveat that the case of a large-scale nuclear accident giving rise to extensive contamination is a particular one, and the ways in which it may be understood and responded to are unlikely to be fully analogous to other risk situations.

Our recommendations were that social assumptions inherent in countermeasures and remediation strategies need to be recognised, and their validity assessed in the socially and culturally variable range of contexts in which countermeasure strategies may be implemented. Social assumptions need to be monitored subsequent to implementation to identify and address unforeseen consequences. To do this involves a greater degree of local knowledge, and of local participation, than has hitherto been the case. Yet, to enable effective implementation, it is necessary to have knowledge of the local conditions which will affect that effectiveness. Multi-sided and inclusive communicative and deliberative processes enable both the collation of local knowledge, more learning, and representation of the differing preferences of particular communities. In general, participation in decision making enables greater compliance and acceptability, leading to more appropriate choices in strategies and greater effectiveness in the dimensions which are of primary importance to affected groups.

Consultative communication approaches

A coherent programme of consultation and communication will be essential to the effective development and delivery of a remediation strategy, to determine people's preferences, to develop understanding of the social and ethical dimensions, to access socio-cultural information and knowledge, and to meet the rising expectations of participation. With regard to consultative communication Deliverable 6 discussed principles of good practice, information needs, roles and participation, consultative communication methods, and presents a consultation and communication protocol for remediation strategies.

Principles of good practice

A number of principles of good practice in communication and consultation have started to become established and provide a framework to enable the legitimacy and credibility of the consultation (and hence remediation strategy). Not all principles may be relevant, depending on the aims of the consultation. In summary these principles are:

Transparency – the clear purpose and aim of consultation must be explicit;

Openness – information must be assessable, available and understandable to recipients;

Uncertainty – the limitations and uncertainties of information must be explicit;

Inclusion – the participation of appropriate people needs to be enabled;

Responsiveness – decision making must be genuinely open to influence from consultation (decisions must not be made in advance);

Justification – decisions need to be explicitly justified in relation to consultation input;

Adaptability – the consultation should be adaptable to the emerging needs of participants.

Information needs

Information benefits for decision makers of the consultative approach fall into a number of areas:

- Improved data on people's behaviour, food consumption, etc., enabling more accurate modelling of radiological and other effects of particular countermeasure strategies;
- Better understanding of the wider range of social factors (such as the extent to which scientific pronouncements carry authority or the degree of trust in particular institutions, including government) which influence and frame countermeasure strategies (for example, a dietary advice programme is more likely to be successful if the organisation(s) providing and distributing advice have public credibility);
- Potential for identification of social and cultural constraints, and side effects, which are otherwise hard, if not impossible, to identify (for example, a change in land use is likely to impact on local economies and on patterns of agricultural and related activity; whilst primary impacts might be relatively

easy to identify, secondary impacts require a more detailed input from affected communities);

- Access to the ethical judgements and preferences of the wider community (for example, in the decision whether to prioritise protection for particular groups e.g. by cleaning school buildings and other areas where children spend more time when carrying out urban cleaning measures)

Clearly, decision makers have extensive information needs. However, it is only more recently that the need for better understanding of social and ethical factors has begun to be recognised. The need for, and provision of, 'social and ethical intelligence' is important:

Social intelligence – An understanding of, and information about, the social dimensions of a decision, including social impacts (economic, cultural, behavioural, etc.). Questions such as who is believed to provide trustworthy information, how disruptive of daily life patterns an intervention might be, and what the potential and scale of non-compliance are likely to be, need answering.

Ethical intelligence - An understanding of, and information about, the ethical dimensions, preferences and judgements embodied in a decision. The use of a value matrix (see work package 2) allows a structured approach to identifying the ethical aspects of a decision, but leaves unanswered the (itself ethical) question of who should be making the judgements as to, for example, the relative weight to be placed on reducing a small number of high exposures or a large number of low exposures.

Public information needs have been identified from information in relation to other nuclear issues and environmental hazards. Generic information, which needs to be included at the national level, includes:

- Explanations of radioactivity – what is it, how it affects biological organisms; associated health risks;
- Exposure pathways;
- Levels of contamination in food, water, and external exposure rates, and details of monitoring regimes;
- Self-help measures;
- Measures being considered and implemented, and the justification of these choices;
- Aspects of decisions – scientific inputs, economic considerations, ethical judgements;
- Social impacts (reflecting information gained in the first phase of deliberation);
- Who is responsible for action, and how decisions are being made;
- The routes through which people can input to decisions.

Roles and participation

The term 'stakeholder' is one that is used with a range of meanings. Within STRATEGY we use the term to describe those individuals who are representing or primarily associated with particular institutions or organisations. Stakeholders are considered here in two respects: as sources of informational inputs in stakeholder networks; and as political/decision making actors in stakeholder dialogue. Two important caveats need to be made at this point. Firstly, stakeholders do not, and cannot, properly represent the wider public, and stakeholder views and assertions should not be taken as representative, particularly when they include assertions about what the public do and do not think. Access to public views needs to be direct, rather than mediated and distorted through stakeholder representations. Secondly, stakeholders have particular ‘framings’ of the issues – that is, they understand the issue to be about certain things, and define the problem(s) in particular ways.

Brain-storming and snowballing are satisfactory in identifying existing and known stakeholders as perceived by the initial group, but has the problem that ‘outsiders’ can remain outside the eventual network. Therefore, thought needs to be given to who else might be appropriately included, the lay public generally have ideas, too, about who should be involved. In addition, the regional and local actors need to be included (which can only be done after a deposition event). As a remediation strategy evolves, there will be clear cases where input from particular groups is necessary – local businesses dependent on tourism in relation to measures involving restrictions of access to the countryside, for example, will be able to make valuable inputs both on the nature and extent of social and economic side effects, and possibly suggestions for the amelioration of these impacts, such as the clean-up of particular amenities, or changes in land use.

Communication and consultation methods

A range of deliberative consultation methods have been developed which enable participants to define, discuss and consider the issues, input their own information and

ethical judgements, and reach conclusions. Descriptions and comment on a range of these can be found in Deliverable 6.

Consultation and Communication Protocol for a Remediation Strategy

It is useful to think of a consultation process in terms of the following questions:

- ✓ ***What*** – is the purpose, is required as outputs, is the topic or topics;
- ✓ ***Who*** – should be consulted and communicated with;
- ✓ ***How*** – should the consultation and communication take place in the light of the above.

The answers to these questions will vary through the lifetime of developing and implementing a remediation strategy, and a process such as that outlined in Deliverable 6 will need revision and additions in the light of the specific contexts in which remediation is taking place. It should be borne in mind that an integrated consultative communication protocol requires time – for planning, for carrying out consultation, and for analysing results and incorporating them into decisions. In the first few weeks following an accident, time is clearly limited and the opportunities for consultation are likewise restricted. The protocol presented in Deliverable 6 is relevant to longer term (months/years) remediation strategies, where more time is available to make participatory decisions.

Work Package 4: Economics of restoration strategies

The objective for work package 4 was: to assess methods for quantifying indirect costs and benefits associated with restoration strategies. This was implemented through the production of i) a Deliverable (D7) with a review of all the methods available for valuation of non market costs and ii) the design of an example of application of the recommended approach through an empirical application.

<u>Review of all the methods available for valuation of non market costs (Deliverable 7)</u>

A literature review highlighted the lack of economic valuations of non-marketed impacts derived from radiological countermeasures application. As a result, a description and relevant main characteristics of all available methods was produced in D7. The Deliverable was structured in two main sections. In the first section, a definition of non-market goods and side effect costs was included. In the second, main methods for quantifying non-market costs and benefits are reviewed.

Any countermeasure could potentially generate some unintended consequences which could be positive or negative (namely benefits or costs), as thus improve or worsen the welfare of the affected population. Such effects are termed "externalities" or, as agreed within STRATEGY, side effect costs (such as changes in the number and variety of endangered species, quality of landscape, and human health). The monetary value of many side effect costs can be estimated. Some of them have a monetary countervalue and can be calculated via market prices (e.g. loss of tourism and agricultural production). However, goods or services not traded on markets (e.g. biodiversity) need to be quantified through non-market valuation methods which was the main objective of the second section of Deliverable 7.

Methods for quantifying non-market costs and benefits have in common that, in one way or another, the individual's utility is affected. In this context, "individual" could be a single person or a group (including manufacturers or farmers), so we can take into account personal and societal welfare changes coming from both individual people and groups.

The methodologies can be categorized into three groups:

- Revealed preference methods
- Stated preference methods
- Production function approaches

Among stated preference methods, we have highlighted and justified the choice modelling approach as being the most useful for the valuation of the side effect costs of countermeasures. Choice modelling takes into account the multiple trade-offs between different decisions the individual makes when choosing. So instead of assessing just one feature at a time (as in the case of contingent valuation) the method can consider several impacts simultaneously (improvements and deteriorations), and is consequently a more realistic approach.

As a complement for the D7, summarized descriptions giving the main characteristics of the different methods have been included as a second layer of complementary information within the countermeasure datasheets. The main purpose of including a summarized description of methods for valuing external effects of countermeasures implementation was to illustrate the possible approaches of valuing side effect costs within the decision making process.

Two case studies of the choice modelling approach were designed, one in Cumbria (UK) and the other in Zaragoza (Spain), to assess the impact of a remediation strategy. The first step in this method to elicit a valuation is the use of specific surveys which require the elaboration and testing of questionnaires.

Specifically, questionnaires for choice modeling need to determine main attributes (effects in our case) and levels of side effects. Two matrices were designed with GSF for urban/industrial and for agricultural countermeasures side effects (only main and measurable effects). Side effects were specified for the case study once the deposition scenario was decided (work package 5) with the collaboration of CEH and NU.

Once the final questionnaire was designed, two citizens' groups was arranged, one for Cumbria and another for Zaragoza. Between 20 and 30 potential participants were contacted to allow for possible lack of attendance. Each group attended two meetings. In each one they received some information, discussed it among themselves and completed a questionnaire. They were advised to comment and discuss the different aspects with their relatives/friends. After completing the questionnaire during the second meeting, they had to make collective choices as a group and avoid personal strategic behavior, so that the output from that session could be used as an input to design remediation policies in a European context (within the work package 5 case study scenarios).

The questionnaires had three differenced parts: (i) attitudes and perceptions towards general issues and radioactivity, (ii) choice experiment and (iii) socio-economic characteristics of participants. In the following, we will describe the main results obtained. Table 3 shows, for both groups, a ranking of participants' main concerns whilst Table 4 shows the ranks built with the scores to the question *How do you think radioactivity affects the following…?*

As can be observed, a certain altruistic and generous behaviour seems to exist in completing the questionnaires. In Zaragoza, participants were asked similar questions to those in Cumbria, but an extra concern was introduced (control on immigration) to better reflect actual problems in daily life. In general terms, no big differences between the two groups were found in relation to the importance of individuals' main concerns. The most noticeable difference is that due to a younger age composition of the Zaragoza group where education and employment levels are of major concern. On the other hand, some differences were found with respect to the perceived potential effects of radioactivity.

Table 3. Ranking of individuals' concerns for both groups.

Cumbria		***Zaragoza***	
Rank	*Concerns*	*Rank*	*Concerns*
1	Clean environment	1	Good state education system
2	Good state education system	2	Low unemployment levels
3	High quality National Health Service	3	High quality National Health Service
4	Low levels of criminality	4	Clean environment
5	Good old age pension	5	Low levels of criminality
6	Moderated cost of living	6	Good old age pension
7	Low unemployment levels	7	Immigration control
		8	Moderated cost of living

Table 4. Beliefs on how radioactivity affects life (in order of importance)

Cumbria		***Zaragoza***	
Rank	*Effects on:*	*Rank*	*Effects on:*
1	Future Generations	1	Health of fish in the sea, lakes, etc
2	Economy and health of fish in the sea, lakes, etc.	2	Future Generations
3	Farming	3	People's health
4	People's health	4	Local wildlife
5	Local wildlife	5	Farming
6	Scenic quality of the landscape	6	Scenic quality of the landscape
		7	Economy

General and specific attitudes towards radioactivity were measured by tested scales, requiring participants to evaluate and assign a valuation (from 1 to 5) giving their degree of agreement with different statements. Results are shown in Table 5. Comparisons between groups, in this case, is not possible as statements included in the respective questionnaires differed as Zaragoza's participants were not familiar with radioactivity since no nuclear plants are located in the surroundings and there have not been recent events involving other health hazards.

In general, for the Cumbria group there seemed to be a higher demand for information, maybe due to the lack of confidence in consumption products. On the other hand, it seems that, as a citizens group, they did not have preformed opinions on consequences and actions to apply in case of radioactivite contamination. The Zaragoza's citizens group has several similarities with the Cumbria's group, despite the questions being different, such as the demand for better information and the rejection of certain kind of products which are controversial in relation to the consequences for human health (e.g.GMO). This group shows a tendency to an altruistic behaviour and have strong opinions on nuclear power production (against). The altruistic pattern may be due to the age composition of the group, ie young people with small children.

Table 5. Attitudes towards general and radioactivity issues: Cumbria and Zaragoza

Cumbria		***Zaragoza***	
Rank	***Attitudes***	***Rank***	***Attitudes***
A	In case of local radioactive contamination I would prefer to eat imported food from another region or country free of radioactivity	A	All products in the stores should be labelled, stating clearly the amount of GMO they contain and where they are from
A	All products in the stores should be labeled, stating clearly the amount of radioactivity they contain	A	There is not enough understandable information about pollutants on our surrounding environment for ordinary citizens
A	There is not enough understandable information about radioactive pollution for ordinary people	A	Today's young and children will inherit a higher degraded environment than that my generation have enjoyed.
A	All products in the stores should be labeled, stating clearly if they come from an area that has been affected by radioactivity	A	I would be willing to accept a payment to remediate consequences of a pollutant after an accident
A	The consumers in Great Britain were given too little information about how to act after the Chernobyl accident	I	I buy green products because they are healthier despite they are more expensive
I	I would be willing to accept a payment to remediate consequences of removing radioactivity after an accident	I	I think that recent environmental policy has improved the precedent situation substantially
I	I believe that the benefits to humanity from nuclear energy are greater than the disadvantages	D	My family and I are willing to consume GM products
I	The health risk associated with radioactivity is considerably exaggerated	D	Before helping developing countries we should solve our own domestic problems
D	I would allow my family, and myself, to eat products that are said to be safe by the experts, but have some radioactive contamination	D	I believe that the benefits to humanity from nuclear energy are greater than the disadvantages
D	I don't mind if my family and I eat food which has been treated to remove all or most of the radioactive contamination	D	The health risk associated with radioactivity is considerably exaggerated
D	The authorities should withhold information about areas that could be severely affected by radioactivity after an accident to avoid scaring the population	D	Authorities spend too much to protect and preserve the natural environment

Note: A - agreement; I - indifference, so not agreement nor disagreement, maybe due to a lack of formed preferences towards the issue posed; D- disagreement.

The second part of the questionnaire was devoted to the choice modeling exercise. Initially, respondents ranked which were the most important side effects. Similar rankings were found for both groups (Table 6).

Table 6. Ranking of possible side effects of a remediation strategy. 1 is most important

	Rank Cumbria	***Rank Zaragoza***
Water Pollution	1	1
Disruption of daily life	2	2
Loss of scenic landscape and biodiversity	3	3
Animal welfare	4	4
Spend money	5	6
Cultural heritage	6	5

Finally, the choice experiment was carried out (detailed information about the procedure is described in D7) and the main results obtained are given in Table 7. The most valued aspect of those presented to participants in Cumbria was the scenic landscape, which involves not only the beauty of nature, but the biodiversity and degree of environmental 'health', followed by animal welfare. It seemed that the restoration of cultural heritage had no importance for the participants. This does not mean that they do not value their cultural worth but that other things were so important for them that when they had to choose, heritage was relatively less important. In other words, heritage was not an issue in their decision-making process taking into account that some or all of the other factors were more determinant for them.

Water appears in third and fourth position, which is consistent with previous answers, where they were asked about water pollution. Under the side effect valuation, the water pollution effect was restricted to the effects on recreation, that is, they valued the restrictions on water activities such as fishing, canoeing, yachting, etc.

Table 7. Valuation of side effects

	Cumbria £ (€*)	**Zaragoza (€)**
Scenic landscape	34.5 (50.0 €)	47.5
Animal welfare	26.08 (37.8 €)	No value can be inferred
Water	13.3 (19.3 €)	23.73
Disruption	15.7 (22.8 €)	21.04
Heritage	No value can be inferred	No value can be inferred

* £ were converted to Euros using a value of 1.45

Initially table 6 and 7 look contradictory, but this is not the case. In table 6 respondents answered in the context of a general assessment of different aspects. In table 7, monetary results relied on specific examples described to the participants. In this case, it is possible that the examples did not fit with respondents initial perceptions of what each side effect was.

As for Cumbria, Zaragoza's group most highly valued scenic landscape and biodiversity, but did not show an affinity to guarantee animal welfare or heritage. Water recreation activities were the second most important side effect to avoid. This may be due to the collective conscience in Spain to protect and preserve all water assets, no matter what it is used for, as a consequence of very strong cyclic droughts.

Both experiments were successful since participants collaborated and answered consistently (several tests for consistency have been performed). As expected, valuation of side effects reflect the tradition in each of the communities, for example, the lack of tradition on animal protection in Spain is shown in the absence of a valid value for avoiding this damage.

Both groups were, in general, very active participants and generous with their time, giving their views in what they were really worried about. We consider that the use of citizen's juries together with choice modelling is a very useful and realistic tool for elicitation of community values and, consequently, it would be of help to elaborate policies for restoration.

Work Package 5: Selection of restoration strategies

The model based methodology for the selection of restoration strategies uses a spatially distributed approach in which the affected area is divided into an array of grid squares, each with an associated dataset (e.g. soil characteristics, land use, and human and animal population numbers, agricultural management practices, food production data, types of buildings).

<u>Estimation of internal dose</u>

The model uses existing radionuclide plant-uptake models to predict the transfer of four long-lived radionuclides (^{137}Cs, ^{90}Sr, ^{241}Am, ^{239}Pu) through the food chain and to estimate the resulting ingestion dose. The model used to estimate the transfer of radiocaesium through the food-chain is an updated version of the SAVE model (Gillett *et al*. 2001), which takes into account relevant soil properties such as pH and the percentage of clay in soil. To estimate the transfer of the other radionuclides through the food-chain, a hybridised model of the SAVE system and the ECOSYS-87 (Mueller and Pröhl 1993) system has been developed.

To estimate the ingestion dose, the human population is divided into various sub-populations that are assumed to exist within every grid square in the affected area. These sub-populations can be user defined, allowing the investigation of the effects on a particular section of the population (e.g. the 'critical group'), or they can be generated automatically by Monte Carlo simulation to generate an overall human population using defined statistical characteristics.

Each population has a diet attribute, and within that attribute the consumption levels of twenty-seven food products are defined. Also, the geographical origins of groups of food products (i.e. dairy, meat, fruit and vegetables, semi-natural, cereals) can be defined for a sub-population. These food products can be sourced from three locations:

1. Local: Food produced from within the grid square where the sub-population resides. In the case of vegetables an additional sub-category ('home') is available to represent production of vegetables outside the normal traded market (i.e. home grown vegetables).
2. Regional: Food produced from within the region that the sub-population resides. The activity concentration of regionally produced food products is taken as a production weighted mean of all of the grid squares within that region.
3. External: Food produced from outside the affected area. The activity concentration of externally produced food products is, at present user defined (typically zero).

The Monte Carlo simulations generate an overall population by randomly selecting consumption levels from within statistically defined population characteristics. This is performed for each food product, to generate an overall diet for each Monte Carlo sample.

<u>Estimation of External Dose</u>

The external dose to humans is calculated using air kerma rates (Gy s^{-1}) calculated using the model developed by Meckbach, Jacob & Paretzke (1988) and Kis *et al*. (2003) for a range of surfaces at different locations within standard building types. This takes into account radionuclide interception, fixation, and weathering processes. This model is combined with user supplied data for the time an individual spends at each location to estimate the resulting dose from external sources. This data is defined as statistical distributions for the population and Monte Carlo simulated sub-populations.

Two environments are considered within each grid square: domestic (i.e. where people live) and industrial (i.e. where people work).

In the domestic environment, three building types are considered:

1. Semi-detached houses. Standard brick type construction with gardens and trees surrounding them.
2. Terraced houses. Standard brick type construction with gardens and trees surrounding them.
3. Apartments. Standard five storey brick and concrete constructions with a courtyard within the centre.

In the industrial environment, two typical building types are considered:

1. Factory/Supermarket. Standard concrete construction with steel roof.
2. Offices. Assumed to have the same properties as apartments (above).

Countermeasures

The model allows the user to select from a number of countermeasures:

- Normal ploughing of pasture.
- Deep ploughing of pasture, edible crops[a], and silage crops[a].
- Skim and burial ploughing of pasture, edible crops, and silage crops.
- Addition of potassium fertilisers to pasture, edible crops, and silage crops.
- Addition of lime to pasture, edible crops, and silage crops.
- Administration of AFCF to livestock animals as either boli or concentrates.
- Food bans
- Clean feeding of livestock animals.
- Cleaning of walls
- Cleaning of roof surfaces
- Street sweeping/vacuum cleaning
- Pruning of urban trees/shrubs
- Mowing of urban grass areas
- Triple digging of urban soil
- Removal (by bobcat) of urban soil

[a] Crops are grouped into either edible crops (fruit, root vegetables, leafy vegetables, cereals, potatoes) or silage crops (grass silage, maize silage, wheat silage) in order to reduce the number of intervention limits required and hence reduce time required for computation.

Each countermeasure has an implementation threshold and a target variable. If the target variable in a grid square exceeds the implementation threshold then the countermeasure is activated in that grid square. For example, when considering administering AFCF to dairy cows, the target variable is the activity concentration in milk. If the activity concentration of the milk in a grid square is predicted to be above the implementation threshold, then AFCF will be administered to the dairy cows within that grid square.

Implementation thresholds can either be set manually, at a constant value to simulate policies and rules set by the relevant authorities (e.g. Council Food Intervention Levels (CFILs)), or can be optimised to find the optimal combination of countermeasures under consideration.

Estimation of Side Effect Cost

To enable the influence of countermeasure side effects to be incorporated into countermeasure selection the model estimates the cost of specific side effects. Due to the constraints of the project the range of side effects considered is not exhaustive, but nevertheless represent a useful first attempt at including this important consideration in such a model.

This is accomplished by assigning a relative level of impact for each unit of implementation of a countermeasure for a given side effect. For example, the impact of normal ploughing of pasture on the scenic landscape could be high per unit of implementation, however it's impact upon animal welfare may be low. The total impact of a particular side effect can then be calculated as the product of the number of units of implementation (e.g. hectares) and the impact level per unit implementation. The 'cost' of the side effects, S (€), arising from a countermeasure strategy can be estimated as the sum, over all individuals, *i*, of the product of the total impact, *I*, of each side effect, *e*, and the value that an individual places upon the aspect that the side effect refers to, *V* (€).

$$S = \sum_{e,i} I_e V_{e,i}$$

The estimation of $V_{e,i}$ has been undertaken by work package 4 for each specific case study region. The values of I_e were estimated by expert judgement. based on an assessment of the impact relative to those presented during the studies conducted under work package 4.

Optimisation

To select the most appropriate countermeasure strategy for a specific scenario a minimisation cost function, C(€), is defined as:

$$C = -\sum_{\substack{regional \\ population}} \Delta_i \alpha_{d_i} - D\alpha_{base} + I$$

where: I is the cost of countermeasure implementation (€)

D is the averted exported dose from the region (i.e. ingestion of contaminated food by people outside the study area)

D_i (Sv) is the averted dose for the *i*th sub-population in the affected area which summed to the regional population

α_{d_i} (€Sv^{-1}) is a variable which converts dose to monetary value and can take a number of forms (e.g. constant, or dependent on individual dose (e.g. Leblanc *et al*. (1993)).

The averted dose is calculated for people living within the affected area and outside. Within the affected area this is calculated by aggregating the averted doses estimated for each grid square. Outside the affected area the averted dose is calculated as a collective dose assuming that all the produce is consumed.

I (€) is the cost of the countermeasures, which can include not only the direct costs associated with implementation and waste disposal, but also the 'cost', in monetary units, of countermeasure side effects, such as environmental damage or loss in aesthetic value.

The optimal countermeasure strategy is that combination of countermeasures which gives the lowest value of C. To locate this a standard numerical minimisation procedure has been used (Powell's conjugate vector method). Such methods can be computationally demanding and may not distinguish between a 'global' minimum (i.e. the lowest possible value of C) and 'local' minima (i.e. plausible, but sub-optimal combinations of countermeasures). Therefore the method has been adapted to take into account the characteristics of the cost function surface, nevertheless, the use of countermeasure optimisation needs to be undertaken cautiously.

Case-study Application

The two sites chosen for the case studies were the county of Cumbria in the UK, and the province of Zaragoza in Spain. Simple deposition patterns were created for each site, and a database was constructed of spatially distributed data (e.g. soil characteristics, population numbers, and land use), at a resolution of 5x5 km, and agricultural management practices and food production rates. The dietary and activity habits of the human populations in each region, were simulated by the creation of numerous distinct individual types, using Monte-Carlo sampling of the defined statistical attributes of the population. In addition, the value that each individual type placed upon a limited number of environmental attributes (e.g. landscape, water quality, and animal welfare) was also defined, according to the values derived from a questionnaire, produced by work package 4. The system was then used to investigate the effects of various restoration strategies for each scenario over a ten year period.

In the Cumbrian scenario, the model estimates that the major source of dose to the residents of Cumbria is exposure to external radiation, which contributes almost three times as much collective dose as that arising from internal radiation.

The model calculates that the food products contributing most to the local collective ingestion dose are potatoes, lamb, milk, beef, cereals, and fruit. If food restrictions, at the recommended CFILs, are the only countermeasure implemented, the model predicts that this strategy would cost over £2000 million and avert almost 33,000 Man-Sv. The majority of the expenditure for this strategy would be due to the restrictions placed upon the sale of lamb and beef food products. The results imply that, according to ICRP principles, this countermeasure strategy is unjustified. With food restrictions maintained at CFIL levels, the implementation thresholds of pre-selected countermeasures were optimised automatically. This was performed both with, and without, the social costs of environmental side effects considered. When the social costs of side effects were not considered during optimisation, the model proposed a more cost effective countermeasure strategy when compared to only using food restrictions. In addition to reducing the local collective ingestion dose by a factor of three, and nearly halving the local collective external dose, the strategy drastically reduces the expenditure on the restriction of lamb and beef food products. Including the social cost of countermeasure side effects during optimisation has little effect upon the output from the optimisation process. Almost exactly the same set of countermeasures are selected, and at similar implementation levels. There is only a slight reduction in the level of AFCF administration to beef cows, and of clean feeding beef cows and sheep. The level of implementation of the ploughing countermeasures suggested, which have a large impact upon the side effect attributes considered, are the same in both optimised strategies. In both optimised strategies the only urban countermeasure that was found to be of benefit was lawn mowing. However, it is debatable whether this countermeasure could be fully implemented before weathering processes rendered it ineffective.

In the Zaragoza scenario, the model predicts that the major source of dose to the local population is via ingested radiation. The food product which contributes the most to this dose would be fruit. This is because the population has a relatively high fruit consumption rate, and because it is a food product that is often home-grown or sourced from within the region. Therefore, a large proportion of the fruit consumed by the local population is from contaminated areas. A compounding factor is that the first harvest is assumed to take place only two months after the deposition event, when the plants' activity concentrations would still be considerable.

With food restrictions implemented at CFILs, in Zaragoza the model predicts that this strategy would cost €187m and avert almost 10,000 Man-Sv. In contrast to the Cumbrian case study, the results suggest that this strategy would be justified according to ICRP principles. However, again countermeasure optimisation results in a more cost effective strategy. By implementing other countermeasures, not only is the collective dose to the local population reduced further, but the expenditure on food restrictions is also reduced. As for the Cumbrian case study, the only urban countermeasure suggested by the system is lawn mowing, and again it is debatable whether this could be fully implemented before it was rendered ineffective by weathering processes. In this scenario, the inclusion of the social costs of countermeasure side effects has almost no effect upon the strategy suggested by the optimisation process.

Use of the Model in Decision Making Processes

While some social dimensions of countermeasure implementation can be estimated through the model (for example uneven dose distribution) in many cases this is not the case and management through interaction with affected communities will be required. Although economic and demographic data is generally available, data on social relationships (such as trust, authority and confidence), on the particular understandings and priorities in relevant communities, and on the significance and implications of countermeasures (and their side effects) at the local level, is not available. Furthermore, it is liable to be affected by an event giving rise to large scale contamination, and by the actions taken in the immediate aftermath of such an event. Additionally, even where such data is or could be available, there are arenas where a) explicit judgement is required, and b) where the indeterminacies and potential socio-cultural feedbacks are impossible to model, given both the dynamic nature of many social processes, and the complexity of the relationships between social 'components'. For these reasons, the model outputs should be used as inputs into decision-making, rather than a substitute for (explicit and inclusive) decision-making. Inclusive decision-making requires two-way communication, which then enables both the collection of local and stakeholder knowledge as an input into decisions, and a more democratic process. Further, local and stakeholder inclusion generates more widely acceptable decisions. The model outputs therefore need to be incorporated into an inclusive decision-making process such as those outlined in Deliverables 4 and 6.

2.3. Assessment of Results and Conclusions

Key criteria considered when assessing the STRATEGY output are: novelty of the output, efficient dissemination of information on the project, feedback on outputs during and after the project, and discussion of possible future uses of the output. The three main outputs from the project were the datasheets compendium, the optimisation methodology and the value matrix.

The datasheets compendium give the first thorough description of the most important issues related to long term restoration, including not only technical but also social, ethical, economic and side effect issues. The input in the datasheets have been incorporated in the STRATEGY decision support model which can predict activity concentrations in foodstuffs, doses to humans, and perform an optimisation of proposed countermeasures in a given scenario which takes account of the cost of countermeasure implementation and waste disposal. The value matrix is a new approach within nuclear emergency management that can help decision makers to take actions that are broadly acceptable to stakeholders and the public.

Assessment of results

The datasheets compendium has advantages over prior countermeasure databases (e.g. NKS and IUR) in that they include a wider perspective like legal, ethical and environmental constraints and describe countermeasures for all environments including the industrial and social sector. The information in the datasheets was intended to be general as they are planned for use in different European countries. Nevertheless, for some information there is a bias towards the home country of the originators or the regions in which methods have been tested. Furthermore, countermeasures for foodstuffs from Mediterranean countries were not covered as well as those for northern conditions. It is an important aspect of the datasheets that they are freely available to be made 'country specific' both in terms of the information they contain and the language they are published in.

The STRATEGY end users felt that although the methods of publication of the datasheets compendium (i.e. CD-Rom, accompanying report and free availability on the STRATEGY web site) are acceptable they could be improved with publication of a paper copy. From a wider perspective, they felt that the range of countermeasures covered could easily be extended to include many other pollution scenarios and that the datasheets would be a good tool for further education and training of a wide range of people involved in emergency preparedness (they have been used successfully in Nordic and IAEA training courses). It was felt that the lay user would feel comfortable using the datasheets. Overall, the end users felt that the datasheets were a valuable resource which they all intended to use.

To our knowledge the STRATEGY model is the first to successfully implement a countermeasure strategy optimisation within spatially predictive models. In the context of possible application, this is important as decision makers will face choices on both when and where to apply countermeasures. Given the spatially distributed nature of deposition, agricultural land use and production, residential and industrial areas approaches that do not explicitly address spatial variation are intrinsically less useful to decision makers.

As far as we are aware, the STRATEGY model is also the first to combine a large number of practicable countermeasure options within a single framework. Previous attempts (e.g. Papamichail and French, 2000) have only considered a very narrow range of countermeasures.

The inclusion of side effects as an additional cost within the model is novel. In the case study applications side effects have had a limited effect, however, this would not necessarily be the case in all situations (e.g. under lower deposition). This work is a first step. More exhaustive inclusion of side effect costs would need to be undertaken before the model could be considered truly applicable in this respect.

The major limitations to the model are that, at present, of the 101 countermeasures considered for the countermeasure datasheets only 22 are simulated, and only a small number of countermeasure side-effects are considered.

The end users felt that the underlying assumptions behind the model, and their implementation were acceptable. The available resources within STRATEGY were adequate to develop a more user friendly "front end" which the end users felt would be useful especially if it was to be demonstrated to and/or used by non specialists. For some countries, there may be a lack of underlying data but the model can take account of this and will adapt to handle further information if it becomes available. The end users thought the model would be used as a starting point within an emergency situation thus providing focus and then, at a later stage, to confirm or refine a previous decision and to inform on aspects such as compensation levels. The end users considered that demonstrations of what the model is capable of would be required so that they would know what to ask for from an expert elsewhere who would run it and provide feedback (they felt that they would not use the model, as currently constructed, themselves).

The STRATEGY model and countermeasure datasheets CD-Rom were used in a UK off-site emergency exercise (OSCAR 7) recently. The exercise helped to identify a number of areas where the application and implementation of the model could be improved. In particular, the small scale nature of the ground deposition (a common characteristic of emergency exercise scenarios) revealed some issues surrounding the time and temporal resolution of the models. While the model could be used to generate useful outputs at small scales it has been set up with large scale accidents in mind. This is something we would hope to address in any future work. Feedback on the usefulness of the STRATEGY outputs (and some of the input data) was that these were valuable to the UK Food Standards Agency, and to a slightly lesser extent the UK Environment Agency. This exercise incorporated, for the first time, a stakeholder representation (including local elected officials, farming and business representatives, and the tourist board) as a result of the exercise organiser being a STRATEGY end user group member. The inclusion of stakeholders was generally taken to have been useful by all participants. The model (and other outputs) would benefit from application in further emergency exercises, and discussion and evaluation in the wider emergency response community. The advantages of the approach used need to be compared with other systems and consideration given to incorporating those elements from the STRATEGY approach which signify an advance in modelling approaches which can be used to assist decision making after accidents.

The value matrix has been tested with the STRATEGY end user group as part of a case study exercise, specifically designed to test the matrix in conjunction with the model and countermeasure datasheets. Thus, the exercise provided a limited opportunity to explore the practical benefits of the interaction between these two outputs and the value matrix in decision making. The exercise demonstrated that the matrix was useful in mapping the concerns of various stakeholders and helpful in weighting the importance of those values. In general, the group evaluated the exercise positively, thought it would be worthwhile as decision-makers to be trained in this kind of method, and expressed a wish for further demonstration of the matrix approach.

Conclusions

We conclude that the project has, overall, provided useful input into the process of making decisions for off-site remediation. In part, this is due to the inclusion of a variety of expertise from different disciplines to address the wide range of relevant issues, and to the liaison with potential end users. For a holistic, integrated approach to decision making regarding off-site remediation after accidents, the importance of considering a wide range of issues, and integrating technical information and approaches with social issues is clear. The mechanisms by which such integration can be achieved need careful consideration. Socially related objectives need to be given due weight and not subsumed by issues connected to dose reduction. Whilst early involvement of the local and wider community of stakeholders within participatory decision making would be beneficial, the mechanism for doing so needs to be carefully discussed. The best mechanism for using the two “technically based” outputs from STRATEGY, the datasheets and the model, needs careful consideration and the value matrix approach developed in STRATEGY is one means of doing this.

2.4. Acknowledgements

The participants in STRATEGY would particularly like to thank the end users who have attended various STRATEGY meetings and provided valuable input and evaluation as the project has progressed. The end users were Dr Katherine Mondon, Dr. Kathy Alexander, Dr Paul Bonnner and Dr Victoria Campbell of the Food Standards Agency, UK, Mr David Humphreys, the Cumbrian Emergency Planning Unit, UK, Prof. Dr. Anton Bayer of the Bundesamt fuer Strahlenschutz, Institut fuer Strahlenhygiene, Germany, Dr Lisbeth Brynildsen of the Norwegian Ministry of Agriculture, Jon Barikmo of the Directorate for Nature Management, Norway and Dr Ole Harbitz of the Norwegian Radiation Protection Authority.

We would also like to thank the members of the FARMING network for their valuable comments. The project benefited from being part of the SAMEN cluster, co-ordinated by Carlos Rojas Palma in that it provided an opportunity to discuss STRATEGY in the context of other relevant projects in the fifth framework and to identify fruitful links with other projects.

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3.1. List of Deliverables

Expected and actual delivery dates specified below refer to those agreed on the most recently revised management plan in the last 6 monthly report.

Deliverable 1: Countermeasure databases (restricted)
Authors: All partners
Expected delivery: M 21
Actual delivery: M 21

Deliverable 2: Report/CD-Rom on practicability of individual countermeasures for rural and urban (including industrial) environments taking into account waste, doses and stakeholder opinion.
Authors: All partners
Expected delivery M 35
Actual delivery: M 36

Deliverable 3: Ethical Considerations for Communication Strategies.
Authors: Oughton, D. & Bay, I.
Expected delivery: M 15
Actual delivery: M 18

Deliverable 4: Social and ethical aspects of countermeasure evaluation and selection - using an ethical matrix in participatory decision making.
Authors: Oughton, D.H., Bay, I., Forsberg, E-M., Hunt, J., Kaiser, M. & Littlewood, D.
Expected delivery: M 27
Actual delivery: M 30

Deliverable 5: Social Assumptions in Remediation Strategies.
Authors: Hunt, J. & Wynne, B.
Expected delivery: M 24
Actual delivery: M 25

Deliverable 6: Criteria and recommendations for communications strategies.
Author: Hunt, J.
Expected delivery: M 36
Actual delivery: M 37

Deliverable 7: Valuing side effects associated with countermeasures for radioactive contamination.
Authors: Álverez-Farizo, B. & Gil, J.M.
Expected delivery M 28
Actual delivery: M 30

Deliverable 8: A methodology for the selection and optimisation of countermeasure strategies.
Authors: Cox, G.M. & Crout, N.M.J.
Expected delivery: M 32
Actual delivery: M 33

Deliverable 9: Report of case studies.
Authors: Cox, G.M. & Crout, N.M.J., Howard, B., Beresford, N., Wright, S., Oughton, D., Bay, I., Forsberg, E.M., Álverez-Farizo, B. & Gil, J.M.
Expected delivery: M 36
Actual delivery: M 38

3.2. Comparison of initially planned activities and work actually accomplished.

There have been no major deviations in the project from the work content of the original Description of Work. The major alteration in effort was that more time was needed than originally anticipated by many participants in work package 1 to compile the countermeasure compendia. In particular, some effort in work package 2 and 3 was transferred to allow the production of 15 social/communication datasheets.

3.3. Management and co-ordination aspects

In general, the motivation to carry out the objectives to the best of each partners abilities has been impressively high with a significant input by each group. The interaction between consortium partners has been very important and much discussion has been focused on the various dimensions of the project, in particular on the integration of the social aspects into the decision making process.

STRATEGY has had a large number of different types of meetings (see Table below). In general, the timing and type of meeting has been consistent with that originally specified, supplemented by additional bilateral contacts as and when appropriate.

Meetings	Venue and dates	Participants	Purpose
Pre-contract meeting	CEH Merlewood 24^{th} – 26^{th} July 2000	All partners	To discuss anticipated project
Work Package 1	RISØ 21^{st} – 22^{nd} November 2000	NRPB, RISØ, NRPA, ULANC, CEH, GSF	Discuss approaches, responsibilities and timescales
Work Package 2/3	ULANC 27^{th} -28^{th} November 2001	ULANC, AUN, CEH	Discuss work package objectives and implementation and input into work package 1 templates
Work Package 3/5	ULANC 18^{th} January 2001	ULANC, NU CEH,	Discuss approaches for model development
Work Package 1 & full consortium	CEH Merlewood 4^{th} – 7^{th} February 2001	All partners and end users	Finalise template for countermeasure datasheets
Work Package 5	NU 5^{th} April 2001	NU, CEH	Discuss model development
Work Package 5	NU 2^{nd} May 2001	NU, CEH	Discuss model development
Work Package 5	CEH Merlewood 20^{th} July 2001	NU, CEH	Discuss model development
Work Package 4/5	DGA Zaragoza 23^{rd} -25^{th} July 2001	DGA, NU, CEH, GSF, NRPA	To discuss indirect cost issues and interaction between work package 4 and 5
Work Package 1	NRPA, Oslo December 2001	NRPA (2) NRPB (2) RISO (2) ULANC (1) AUN (3) CEH (1) DGA (1) GSF (2)	Discussion of data sheet progress, presentation and discussion of dose calculations, cost-effectiveness, waste options and ethical inputs to datasheets.

Meetings	Venue and dates	Participants	Purpose
Work Package 2/3	ULANC, Lancaster January 2002	ULANC (1), AUN, (2)	Social and ethics inputs to countermeasures and revision and completion of social countermeasures
Mid Term & Full Consortium.	DGA, Zaragoza 3rd – 8th February 2002	NRPA (2) NRPB (2) RISO (2) AUN (3) CEH (1) DGA (1) NU (1) GSF (2)	Review of mid term report; discussion of project progress, interaction with end users
Samen Meeting,	Manchester Business School, Manchester 17th-18th March 2002	CEH (2) NRPB (1) NU (1) Riso (1) GSF (1)	Cluster meeting to discuss interaction between projects
Work Package 5	CEH, Merlewood 30th May 2002	CEH (1) NU (2)	To discuss case study
Work Package 1	NRPB 25th-27th Nov 2002	NRPB (2), CEH (1), RISO (2), NRPA (2), GSF(2), AUN (2), ULANC (1), UNOTT (1- part)	To review progress To discuss ideas for presentation of D2, including inclusion of 2nd layer information
Work package 4	CEH, Merlewood 21-22nd Jan 2003	DGA (1) CEH (2)	To discuss side effect definitions for jury choice experiment
Work package 4	CEH, Merlewood 24th – 27th March	DGA (2) CEH (2)	Jury choice experiment Cumbria
Work Package 4/5	NU, Nottingham 9th -10th May 2003	NU (2) ULANC (2) AUN (1) CEH (2) DGA (2)	To discuss case study
Work Package 5	NU, Nottingham 15th May 2003	CEH (1) NU (1) NRPB (1)	To discuss service costs and waste disposal options within modelling for the case study
Work Package 5	NU, Nottingham 17th July 2003	CEH (1) NU (2)	Discuss provisional case study outputs
All Work Packages	Cumbria Emergency Planning office, Carlisle 23rd May & 27th Aug 2003	CEH (1)	Discuss STRATEGY participation in OSCAR emergency exercise
Work Package 1	MRC, London 10th July 2003	NRPB (2) CEH (2) RISO (1)	Identify remaining actions for the datasheets and 2nd layer documents.
Work Package 5	NU, Nottingham 24th July 2003	CEH (1) NU (2)	Discuss revision of case study outputs
Work package 2/3	Lancaster 28-29th July 2003	AUN (1) ULANC (1)	Discuss work package reports and finalise end-user exercise
Final meeting. Full consortium.	CEH Merlewood 30th July – 1st Aug 2003.	NRPA (3) NRPB (2) RISO (2) AUN (3) CEH (4) DGA (1) NU (2) GSF (1) ULANC (1) and End users (5)	Discuss model outputs Discuss final outputs from work packages Discuss final report and TIP Perform Ethical evaluation exercise with 'end users'
All Work Packages	BNFL Summergrove House 24th & 30th September 2003	CEH (1) NU (1)	Participate in OSCAR 7 emergency exercise (outside contract period)

The end users were present at each of the full consortium/mid term meetings. Additionally, D. Humphreys, Cathy Alexander (FSA), Lisbeth Brynildsen (Ministry of Agriculture) and Anne-Barbro Vatle (Municipality local food control authority) also assisted in the model development by participating in work package 5 meetings.

Discussion with the end users has been invaluable and we consider their participation greatly enhanced the consideration of the various outputs of the project.

The original Deliverable list was adhered to, although production of the reports was sometimes delayed. Deliverables 1, 4, 5, 7 and 8 were all delivered with 3 months of the originally intended dates. In general drafts of each of these Deliverables had been prepared within the time specified and the additional time was used for peer review internal (partners and end users) and external to the project.

Deliverable 2 was rescheduled from month 27 to month 35 for a number of reasons. To maximise the usefulness of this Deliverable it was decided in November 2002 to produce a CD-Rom in addition to a report. The CD-Rom contained updated versions of the previously published countermeasure datasheets with hyperlinks to more in depth 'second layer' information on doses, stakeholder opinion, cost-effectiveness, ethical, legal and social issues. This additional commitment required more time. In addition, there was some necessary delay due to the timing of feedback from FARMING stakeholders on acceptability of countermeasures.

The other two Deliverables for which there were significant delays were Deliverable 3 (6 months) and Deliverable 6 (5 months). In both cases the delay was due to extended ill health of a major contributor and the EC was informed of the delay and agreed to it.

Contact details for follow-up of the Project:

1. NERC-CEH
Brenda Howard, *Co-ordinator*
Centre for Ecology & Hydrology,
Lancaster Environment Centre,
Library Avenue, Bailrigg
Lancaster, LA1 4AP
+44 1524 595855
+44 1524 61536
E-mail: bjho@ceh.ac.uk

2. Riso.nsr
Kasper Anderson, *joint work package 1 leader*
Risø National Laboratory
Radiation Research Department
P.O. Box 49, NUK-201
Frederiksborgvej
DK-4000
Roskilde, Denmark
Tel: +45 467 74173 / 74186
Fax: +45 467 74959
E-mail: kasper.andersson@risoe.dk

3. NRPB.ead
Anne Nisbet, *joint work package 1 leader*
National Radiological Protection Board
Chilton
Didcot
Oxon
OX11 0RQ, UK
Tel: +44 1235 822761
Fax: +44 1235 833891
E-mail: anne.nisbet@nrpg.org

4. NRPA
Astrid Liland,
Department for emergency preparedness
and environmental radioactivity,
Norwegian Radiation Protection Authority,
P.O.Box 55,
N-1332 Østerås, Norway
Tel: +47 67 162538
Fax: +4767 147407
E-mail: astrid.liland@nrpa.no

5. AUN.dcb
Deborah Oughton, *work package 2 leader*
Department of Plant and Environmental
Science, P.O. Box 5003
Agricultural University of Norway
1432 Ås, Norway
Tel: +47 64948250;
Oslo Univ +47 22958311
Fax: +47 64948359
E-mail: ijvfdo@bukk.nlh.no

6. UNOTT.sles
Neil Crout, *work package 5 leader*
School of Life and Environmental Science
University of Nottingham
Nottingham
NG7 5RD, UK
Tel: +44 115 9516253 NC
Fax: +44 115 9516267
E-mail: neil.crout@nottingham.ac.uk

7. DGA.sia.ue
Jose Gil, *work package 4 leader*
Previously: Unidad de Economia Agaria
Servicio de Investigacion Agroalimentaria –
DGA APDO 727
Carretera de Montañana, 930
50080 Zaragoza, Spain
Current address:
ESAB
Universidad Politécnica de Cataluña
Comte d'Urgell, 187
08036-Barcelona
Tel no: ++34-934137523
Fax: ++34-934137444
E-mail: Chema.Gil@upc.es

8. GSF.is
Gabi Voigt,
Previously: GSF-Forschungszentrum für
Umwelt und Gesundheit
Ingolstaedter landstrasse 1,
D-85764 Nueherberg, Germany
Current address:
Agency's Laboratories Seibersdorf
IAEA
Wagramerstrasse 5
P O Box 200
A-1400 Vienna, Austria
Tel: +43 1 2600 28248
E-mail: G.Voigt@iaea.org

9.ULANC.csec
Brian Wynne, *work package 3 leader*
Centre for the Study of Environmental Change
Institute for Environment, Philosophy and
Public Policy
Furness College
Lancaster University
Lancaster
LA1 4YT, UK
Tel: +44 1524 592653 BW
Fax: +44 1524 846339
E-mail: b.wynne@lancaster.ac.uk

Part 4: Summary of Final Report

Urban (including industrial), agricultural and semi-natural environments may be contaminated for many years following a nuclear accident. To sustain acceptable living and working conditions, a capability to implement robust and effective restoration strategies is required. Experience after the Chernobyl accident has shown that remediation strategies need to consider a wide range of different issues to ensure the long-term sustainability of radioactively contaminated areas.

4.1 Objectives

The STRATEGY project (www.strategy-ec.org.uk) had the overall objective of establishing a holistic decision framework for the selection of optimal remediation strategies for long-term sustainable management of contaminated areas in member states. In optimising restoration strategies, decision makers should aim to achieve a wide range of objectives. Clearly, objectives relevant to radiation protection such as reducing individual and/or collective dose while minimising other health risk factors, meeting legal limitations regarding environmental protection, dose limits and Council Food Intervention Limits, distribution of dose and optimising cost effectiveness are important. In addition, for sustainable use, we need to consider other objectives from a social perspective such as providing public reassurance and maintaining a sense of well being, minimising social and cultural disruption and environmental damage and maintaining and/or creating economic activity. Decision making criteria therefore need to be established to balance radiation protection objectives with social, ethical and environmental considerations.

4.2 Research performed and methods/approach adopted

Datasheets on countermeasures for mid-long term restoration

Countermeasures which can be used in the mid-long term after an accident in rural and urban/industrial areas have been critically evaluated. The approach adopted has been to extend the criteria against which countermeasures are evaluated from simply effectiveness and radiological protection criteria to a more integrated, holistic approach which addresses the wider range of objectives listed above. Specifically, the aspects used to assess available countermeasures were: (i) can measures be practically applied (e.g. are the required resources likely to exist or do some environmental characteristics limit the applicability of the measure); (ii) do they incur considerable direct or indirect (side effect) costs; (iii) do they have significant environmental effects; (iv) are wastes generated as a consequence of the measure and if so what are the appropriate methods to dispose of these; (v) what doses will be received by people implementing the countermeasure. To achieve this, a critical evaluation was carried out on a range of countermeasures and waste disposal options. A template was devised which provided a means of carrying out a comprehensive and wide ranging evaluation of different countermeasures. A review of possible countermeasures which might be used in the mid-long term after an accident was carried out and countermeasures were divided into those considered worth evaluating, those which were rejected as being unlikely to be of use, and those with potential but requiring further development. For those measures fully evaluated, a datasheet based on the template was completed and subsequently peer reviewed.

Decision support model

A model based methodology to identify optimal medium to long term countermeasure strategies for radioactively contaminated regions has been successfully developed and parameterised for Cs, Sr, Pu and Am. In the model, collective and individual ingestion doses of the region's population are estimated using a spatially variable radionuclide transfer model and a combination of dietary data and information on the geographical sources of foods. External doses are derived from kerma rates for a number of surfaces (e.g. walls, roofs, streets etc.) per unit deposition. These are combined with data describing the distribution of daily activity for the population (e.g. time spent indoors, outdoors etc).

A restricted range of countermeasures are considered within the model: restrictions on the sale of contaminated foods; shallow ploughing of pastures; deep ploughing of pastures, and edible crops; skim and burial ploughing of pastures, edible and silage crops; application of potassium fertilisers and/or lime to pastures and crops; administration of AFCF to animals; clean feeding of animals; washing of roofs, walls and streets; urban topsoil removal; triple digging of gardens; mowing of lawns; pruning of trees in urban areas; and dietary advice. Any combination of these countermeasures can be activated within each grid square and the combined effect on dose simulated. Waste disposal options and environmental (physical and 'legal') restrictions have been included within the implementation of countermeasures as appropriate.

Social issues and stakeholder participation

Work on social issues and stakeholder participation has been an important part of the STRATEGY project as a whole, with various end-user interactions as well as specific activities taking place in all work packages. For example, engaging stakeholder groups in evaluation of datasheets, use of focus groups within environmental evaluation, and involvement of end-users in case-study exercises.

Theoretical evaluation of social and ethical issues has involved state-of the art reviews of the social impact of countermeasures, communication and consultancy practice, and ethical aspects of communication and decision-making in selection of restoration strategies. This work has formed the basis of inputs onto countermeasure templates, as well as recommendations for communication and decision-making processes. As a procedure for ensuring a systematic and transparent consideration of social and ethical aspects of restoration strategies, we introduced the use of a value matrix as practical means by which these can be taken into account in the decision making process. A template matrix was developed for and the application of the methodology demonstrated with end-users within a case-study exercise.

<u>SAMEN-MOSES cluster</u>

The STRATEGY project approaches and output has been discussed within the SAMEN/MOSES cluster (http://www.sckcen.be/samen). This provided a good opportunity to discuss STRATEGY in the context of other EC projects on off-site remediation. Within this co-operation, cluster projects had access to the datasheets prior to their publication. Some SAMEN cluster members provided valuable feedback on the content of some of the datasheets. Stakeholder participation is an important mechanism to explore these additional benefits or disadvantages to the use of countermeasures, and is an essential step in developing a decision framework which avoids problems previously experienced in emergency management. Close liaison with the FARMING stakeholder network facilitated evaluation of countermeasure datasheets for rural ecosystems whilst for other datasheets stakeholders were consulted in small groups or individually. Stakeholder opinion suggested that some countermeasures were as likely to be rejected on socio-ethical grounds as technical and economic grounds. Rejection of specific countermeasures can be expected to show site, context and national differences. A paper summarising stakeholder feedback from across Europe was presented at the WISDOM workshop (http://www.ec-farming.net/wisdom.html).

4.3 Main achievements

The project has achieved all of the objectives it set out to meet. The discussion here will focus on the project's three major outputs; other outputs can be found on www.strategy-ec.org.uk, including Deliverables on the evaluation of indirect costs and communication strategies, and a number of refereed and conference papers.

Datasheets on countermeasures for mid-long term restoration

For those measures fully evaluated, a datasheet based on the template was completed. Overall, datasheets were produced for 101 countermeasures, comprising 35 methods for urban/industrial environments, 29 methods for agricultural and semi-natural environments plus 12 waste disposal options, 3 methods for forest environments, 7 methods for aquatic environments and 15 methods on social/human/communication issues. A main output was thus a comprehensive, documented, critical evaluation of countermeasures that would be relevant for off-site nuclear emergency management in the mid to long term. The datasheets were peer reviewed by independent experts and are available as a CD-Rom and on www.strategy-ec.org.uk. Documents on a range of issues including social and legal aspects, dose estimation methodologies and cost effectiveness are hyper-linked to the datasheets.

Population of the datasheets was dependent on relevant information being available. In some cases this required the derivation of novel data, for instance, implementation doses to operatives carrying out the measures (completed for the rural datasheets). For some aspects considered, there was a heavy dependence on the particular scenarios and area affected so only general statements could be made.

Decision support model

The model evaluates the effectiveness of a given combination of countermeasures through a cost function which balances the benefit obtained through the reduction in dose with the cost of implementing countermeasures. The optimal countermeasure strategy is the combination (of individual countermeasures and when and where they are implemented) which gives the lowest possible value of the cost function. Outputs allow an evaluation of resources required and hence present a starting point for discussion of practicability of suggested remediation strategies. Of the 101 countermeasures for which datasheets were generated, 22 are simulated on the basis of their probable use, and only a small number of countermeasure side effects are considered.

In addition to the economic and health implications of a restoration strategy, the model allows the indirect side effects of countermeasure implementation to be assessed, which leads to a more holistic approach to the decision making process; some additional social dimensions of countermeasure implementation can also be estimated through the model (for example uneven dose distribution). However, whilst there was an initial intention to put numeric values to more social factors to enable their incorporation within the model it soon became obvious that interaction with affected stakeholders would be required. Therefore, it was decided that further inclusion of social parameters into the model was inappropriate. The model outputs should be used as inputs into decision-making, rather than a substitute for explicit and inclusive decision-making. Case study outputs of the model have been used interactively as part of the decision making process.

Social issues and stakeholder participation

Within STRATEGY there has been an emphasis that the social aspects of countermeasure implementation need to be given due weight and not subsumed by dose reduction within restoration strategies. Likewise there has been a commitment to the involvement of the local and wider community of stakeholders within participatory decision making. As a possible aid to these goals, the value matrix has been developed as a tool to ensure that all relevant concerns are being taken into consideration and to clarify the ethical basis upon which eventual decisions are made.

In practice, a matrix can aid a decision-making group by giving an overall picture of the issue at stake, thereby making the ethical dimension of decision-making more transparent. Different countermeasures can affect different groups in different ways, and the matrix can be used to help identify the relevant information required for decision-making (i.e., the facts, values and stakeholders affected). In this way, a bias towards certain kinds of values may be avoided, and the matrix can be used to address conflicts between values in a systematic way, without, necessarily, having to invoke full-fledged theories. It should be stressed, that the matrix is not a substitute for public and/or stakeholder participation, neither is it a substitute for ethical evaluation. But it is a tool that is well suited for use within communication or participatory processes.

4.4 Exploitation and dissemination

Exploitation

The STRATEGY members have agreed that the datasheets should be freely available to any interested parties. Organisations are free to modify them for their own particular needs such as into mother tongues – the datasheets are being translated into German – or regional agricultural or climatic conditions. The decision to provide free access has greatly enhanced interest in the datasheets and increased the probability of them being used in many different countries.

Currently, the rural and waste datasheets are being taken forward by the joint FAO/IAEA division to be adapted to other climate conditions (e.g. tropical) and to update Handbook 363. A meeting arranged by FAO/IAEA was held in Sep 03 to discuss possible use of STRATEGY output attended by c. 40 people. There was strong support for the project and numerous expressions of interest to have access to the outputs, in particular the datasheets and the optimisation model. FAO and IAEA are currently discussing possible ways forward with STRATEGY participants.

Plans to expand the compendium in a new Integrated Project (EURANOS) are being negotiated under the auspices of the EC Framework Sixth Programme. Countermeasures applicable to the pre-release and early phase will be identified and new datasheets compiled. Existing datasheets will be extended to cover radionuclides of importance in the early phase, as well as those from potential terrorist devices. Updated versions of the CD-Rom, for both food production systems and inhabited areas, are expected by the end of 2005. These revised countermeasures compendia will form the main input to recovery handbooks being developed in collaboration with stakeholders for future use in Europe

The STRATEGY model and countermeasure datasheets CD-Rom were used in a UK off-site emergency exercise (OSCAR 7) recently which helped to identify a number of areas for improvement. In particular, the small scale nature of the ground deposition (a common characteristic of emergency exercise scenarios) revealed some issues surrounding the time and temporal resolution of the models. While the model could be used to generate useful outputs at small scales it has been set up with large scale accidents in mind this could be addressed in any future work. Feedback on the usefulness of the STRATEGY outputs (and some of the input data) were that these were valuable to the UK Food Standards Agency, and to a lesser extent the UK Environment Agency. This exercise incorporated, for the first time, a stakeholder representation (including local elected officials, farming and business representatives, and the tourist board) as a result of the exercise organiser being a STRATEGY end user group member. The inclusion of stakeholders was generally taken to have been useful by all participants. The model (and other outputs) would benefit from application in further emergency exercises, and discussion and evaluation in the wider emergency response community. The advantages of the approach used need to be compared with other systems and consideration given to incorporating elements of the STRATEGY approach into operational models. The NRPA would like to adopt the model and make it functional on a municipality level in Norway. The goal is to make the model fully operational for use in exercises and possible future radiological accidents.

Work on further development, application and demonstration of the value matrix in radiation protection is expected to form an important follow on to the STRATEGY project. The method itself is under development within other areas of technology assessment (including biotechnology and agriculture) and, as such, represents a state-of-the-art area of research in applied and practical ethics. Various end-users and decision-makers have expressed an interest in learning more about the approach and in training and demonstration exercises. There needs to be further testing of the methods in stakeholder consultation and decision-making activities.

Dissemination

An essential part of ensuring that the project output is publicised is to disseminate information about the approach and outputs at conferences, in refereed literature and in institute reports, and at other national and international fora. A considerable effort has been made to do this, and a list of such output is provided on the web site. Currently, we have produced 7 papers in refereed journals, 23 conference papers and posters and 4 institute reports by participants.

In addition, STRATEGY reports and Deliverables are freely available on the web site. They have also been distributed as hard copies on request and at international meetings and through the FARMING network. A workshop WISDOM (Workshop to extend the Involvement of Stakeholders in Decisions On restoration Management) to disseminate FARMING and STRATEGY outputs was held in Oxford in September 2003. In addition to an overview presentation, papers on several of the key aspects of the STRATEGY project were given, including ethical considerations, communication strategies and case-studies

Depending on funding opportunities, there would be considerable value in producing “handbooks” based on STRATEGY outputs and the development of training courses on practical remediation strategies.