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Scientific reassurance as public policy; the logic of the Black Report.

S M Macgill, J R Ravetz, S O Funtowicz

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Abstract

Science is increasingly involved in public policy issues, including the investigation of local environmental pollution controversies. In such contexts it can lose the sharp edge of clarity and criticism expected from research communities, and instead display some quite different complexities and peculiarities. The Black Inquiry into the excess of child leukaemia in the vicinity of nuclear fuel reprocessing operations at Sellafield in Cumbria was a particularly significant and difficult case. In this article we suggest terms in which its nature might be understood.

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The authors are at the University of Leeds, School of Geography (Macgill) and Department of Philosophy (Ravetz and Funtowicz).

Introduction

Current controversies over feared pollution in local environments present important new policy-related problems. The reassurance of the public, the framing of appropriate remedies and the possible assignment of legal responsibility are all expected to be achieved, even in cases of real uncertainty over the physical causes of the perceived pollution effects. Increasing use is made of special tribunals to assess and advise on such situations, headed by public figures whose personal authority alone might seem sufficient to guarantee the favourable reception of their eventual judgements and recommendations. Of all such tribunals, one of the most important in recent years in the United Kingdom was that chaired by Sir Douglas Black, MD FRCP.

Black's committee of Inquiry was commissioned in November 1983, in the wake of a highly controversial television documentary (Windscale; the nuclear laundry, Yorkshire Television) containing hitherto unacknowledged observations about child leukaemias in the vicinity of a spent nuclear fuel reprocessing plant. The programme made public the finding that the incidence of leukaemia among under fifteen-year olds in Seascale, the nearest village to the plant of British Nuclear Fuels Ltd at Sellafield (commonly known as Windscale), was practically ten times the national average. The speed of government response to this programme in setting up the high level inquiry under the distinguished medical scientist, Sir

Douglas Black, bears witness to the sensitivity of the issues that had been highlighted. Viewers had been left to draw their own conclusions as to the cause of the excess leukaemias from the programme's disclosures that: (i) radiation is the only established environmental cause of leukaemia in children (within the limits of present knowledge), and that (ii) the nearby British Nuclear Fuels (BNF) operations discharge greater quantities of radioactivity into the environment than any other installation in the U.K.

The drama surrounding the Black inquiry was heightened with the occurrence of an unplanned discharge from Sellafield of a sea-tank of radioactive effluent which should have been held for further reprocessing. The incident led to the contamination of a 20 mile stretch of local coastline, and subsequent government investigations into the circumstances of the incident led to the successful criminal prosecution of BNF in July 1985. The discharge itself was first made public by Greenpeace who, as part of a longer running campaign against the build-up of man-made radioactivity in the environment, were engaged in protest action at the time - trying to block the outlet of the effluent pipeline in the Irish Sea.

Partly because of the importance of the issues around which Sir Douglas Black's inquiry was convened, and partly also because of its length, articulation and weight, we shall use 'Black' (standing both for the inquiry and for its report [1]) as a most important case study of its

kind. In spite of its outward appearance as an authoritative scientific study, on closer analysis it displays some quite paradoxical features. The most visible of these is the great variety of interpretations of its message. As described and evaluated in reports of further research by one of the authors (see below), the press could and did portray it as doing everything from vindicating to condemning BNF, and local opinion near Sellafield retained much the same complex divisions after the publication of the report as it had before. Further, in spite of widely recognised room for improvement in work practices and safety procedures at BNF, Black maintained a strict separation between those aspects of the situation and his own reflections on the origins and effects of the local radioactive emissions.

Some particularly paradoxical features of Black emerge from a close scrutiny of the written report. In policy terms it explicitly offers a 'reassurance' to people who are concerned about the supposed health hazards of the ambient radiation; but the reassurance is so heavily qualified, because of inherent deficiencies in the empirical evidence on which it could draw (we examine these more fully below, though are more concerned about related methodological aspects), that one can in effect be as comforted or as worried as one chooses. Thus the classic model of a tribunal of inquiry, where the chairman and panel ascertain the relevant facts, interrogate the appropriate witnesses, and thereby draw clear conclusions and make firm policy recommendations, does not fit Black as

closely as might be assumed. Instead we are led to reflect upon what might be called the ritual aspects of inquiries, where it is the deemed credibility and legitimacy of the proceedings in the public eye, rather than hard substantive content, through which meaning (and in the present case reassurance) is or is not attained. A study by Wynne [2] tellingly portrays an earlier inquiry into aspects of the Windscale operations in such respects as these.

Below we shall analyze Black in terms of three aspects, which we call the 'scientific', the 'forensic' and the 'policy'. In these terms, we can hope to understand its peculiar difficulties, and explain further paradoxical features of its argument. These are of importance because they can affect any epidemiological inquiry where (as is usual) the basic evidence is insufficiently strong for the ascertainment of the causes of the supposed effects. In such situations, explicit distinctions between the different aspects of the inquiry are essential if a truly rigorous investigation is to be achieved; but (paradoxically again) as in the case of Black, such distinctions are most difficult to maintain when a goal of scientific reassurance is accepted for the inquiry.

In this study we shall concentrate on elucidating a logic in the Black report. Our concern is not to enter into the scientific question of the causes of the excess leukaemias at Seascale, but rather to unfold the [illegible] of the (rather hidden) science methodology [illegible]

forensic and policy characteristics of the Black Report. We can thereby elucidate some of the peculiar properties of the inquiry and also of its conclusions.

Which sort of inquiry?

At the outset we can clarify our threefold distinction between the scientific, forensic and policy aspects of the Black inquiry and outline the general character of each.

Although the problem being investigated by Black can be stated in scientific terms (was there an excess in leukaemia deaths, and if so how might it be explained?), it does not admit of a straightforward scientific analysis. First, in spite of the dramatic ratio of local child leukaemias to the national average, the numbers involved are small (4.0 : 0.45), and there are consequently severe difficulties in legitimating any particular formal tests of significance that might be proposed. Second (as we shall see), the task of investigating possible causes, in terms of known emissions of radiation and their effects, is far from straightforward. The relative certainties of laboratory science are simply not available. Were it otherwise, if there were unambiguous scientific findings that fixed a cause and implied a remedy, then the other aspects of the inquiry

— the forensic and the policy — might be trivial; but in the present case they could not be so.

Moreover in distinguishing both scientific and forensic aspects of the inquiry, we would not suggest that these two aspects are separate from each other. On the contrary, the forensic aspects are embedded in and complicate the ostensibly scientific aspects, and these serve further to differentiate the inquiry's investigations from 'pure' science. The forensic aspects arise from the following two considerations. First, the testimony of individuals was necessary at various points, particularly on the question of possible previous unreported discharges of radioactivity from BNF. Second, since any excess of radioactivity in the area would naturally be associated with BNF rather than with natural causes, that organization and its management would have some responsibility in law, should BNF's emissions be demonstrated as having caused the excess leukaemias. Hence in respect of that institution and its employees, Black's investigations necessarily had 'forensic' character: interrogating vulnerable witnesses and dealing (however implicitly) with responsibility, liability, or guilt.

There is a great variety of forensic inquiries in operation, and a corresponding variety of procedures. These may be very informal (as in the present case); or highly stylized (as in law courts) with elaborate rules for assessing evidence and for reaching conclusions. A price is paid for

the formalised procedures, in experts' time and in the length of proceedings. But informality also has its price, in the blurring of distinctions that may be important in delicate cases. In particular, the choice of questions which are to be pursued (and of which are not), and the interpretation of testimony, can both be left in confusion unless some explicit consideration is given to them. We shall find these implicit procedures to be significant for our understanding of Black.

As to the 'policy' aspect, here Black had to proceed in the absence of conclusive arguments one way or the other. Therefore, considerations of general prudence could justifiably be allowed to operate; the dangers of unnecessary panic and loss of confidence in established institutions are inevitably balanced against those of a false reassurance.

Any particular recommendations that might be made would depend on quite complex judgements and estimates of the scientific situation. In general given evidence for a number of possible causal agencies involved in a situation, but proof for none, then before deciding on remedial measures a policy-maker would weigh carefully the costs and benefits of each policy option in relation to the likelihood of each supposed cause which it was designed to remedy. Thus taking acid rain - or more properly forest death - as a very prominent recent case, then if the cause is simply sulphur dioxide from power stations emissions, that entails one set of policy consequences localised on them. But if the cause is some synergistic

effect between such sulphuric acid and nitrates from automobile emissions, then the appropriate policy response would be very different. Indeed if the mix of the suspected causes is as yet undetermined, policy makers must decide on the wisest option of various regulations on power stations and on automobile engines, and on the timing of these in relation to the possible production of more definitive research results. Thus, when causes are unclear there is an interaction between the tentative scientific conclusions and their timing, and the appropriate policy recommendations.

The Black Committee

Sir Douglas Black's committee of inquiry consisted of six experts in relevant fields. There were two epidemiologists (with complementary experience), a medical statistician, a paediatrician, a radiobiologist and a radiation physicist. The secretary to the committee was a medical scientist from the DHSS. The inquiry's terms of reference were: 'To look into the recently published claims of an increased incidence of cancer in the vicinity of the Sellafield site: (1) examine the evidence concerning the alleged cluster of cancer cases in the village of Seascale; (2) consider the need for further research; (3) and make recommendations'

The group met frequently (usually in London) between November 1983 and July 1984 when the report was published; and in the intervening period they were sent written and took oral evidence from representatives of Government agencies and other interested organisations and individuals. Many of these also submitted written reports. At the request of the Committee, the National Radiological Protection Board prepared three specific reports, and others made available the results of then unpublished epidemiological studies. These specially produced scientific studies are a reminder of the novelty of the problems faced by Black. Black did not publish or release transcripts or written reports of many of the submissions he received; in this its procedure differed from that of many analogous tribunals. We shall comment more fully in this later.

The report itself is in six chapters; a short introduction; a chapter reviewing epidemiological evidence; a chapter describing some envionmental aspects of the Sellafield site, the nuclear power industry in the UK and other environmental factors in West Cumbria; a chapter reviewing radiation exposure of young people in Seascale (with an appendix on radiation and its biological effects); a chapter on risk perception and evaluation; and a chapter containing conclusions and recommendations.

The three aspects of the Black inquiry; a summary

We cannot expect that the Black inquiry itself or its terms of reference should explicitly make the distinctions that we draw in this paper between the scientific (the description of observable effects, the examination of possible causal links, or other explanations), the forensic (taking of evidence and assignment of responsibility), and the policy (recommendation of action) aspects of an inquiry. They are labels to help ourselves understand what was done.

The scientific component was of two sorts - epidemiological and radiobiological - and neither was conclusive. There was a survey of a selection of epidemiological evidence and the important conclusion that the four leukaemia deaths among children in the village of Seascale did appear to be a real abnormality in the incidence pattern of leukaemia for the nation as a whole. They were to be described as representing an "excess" - too long lived in their time-scale to be described merely as a cluster and suggestive of an effect of some regularly operating cause.

In this the report vindicated the findings of the Yorkshire Television programme. Whatever else is said about the Black Report it could be seen as giving scientific credence to the claim that there is an excess of at least one sort of cancer in the district in which the BNF plant is located. The credence was not unreserved, the excess being described as

"unusual but not unique" (to the area), and embedded in unresolved, perhaps unresolvable, debate over what the most appropriate indicator of excess in such cases should be.

The second part of the scientific component, the radiobiological, is also somewhat obscure. Briefly, from information on known emissions and discharges from BNF and from the report's models for the pathways and uptake of radiation that causes leukaemia, it is estimated that no more than 0.1 of a death from leukaemia would be expected from the discharges (accidental and planned) from Sellafield in the under 20 year old population of Seascale born between 1945-1975. It then compared the four actual deaths to the 0.1 predicted death according to its model and used the disparity, a factor of 40, as the basis for its policy conclusions.

Black was thus in the ambivalent situation of agreeing, more or less, that there was a serious phenomenon in terms of a leukaemia excess but unable to provide an explanation for it. Other possible causes in the local environment were examined (Annex to chapter 3) and rejected; and possible modifications to the explanatory argument were listed, but rejected as 'remote possibilities' (4.85). Hence as a scientific study Black was radically inconclusive.

For the implicit forensic aspect of Black, one could say that there was a prima facie case against BNF; it is after all the only major emitter of

radioactivity in the area of this admitted excess of leukaemias; and radiation is the only known cause of leukaemia within limits of present knowledge. Indeed in a subsequent comment [3], Sir Douglas did suggest that he saw his inquiry as a legal-forensic exercise.

> "The 'case against Windscale', if I may so dramatise it, rests on three propositions. (1) People in West Cumbria are exposed to high levels of radiation. (2) People in West Cumbria are more liable to cancer than people elsewhere. (3) The second is a consequence of the first." (p59).

The implicit prima facie case against BNF as responsible, was, thanks to the small number of predicted leukaemia deaths produced by the model, considered as 'not proven'. We can now see how the forensic aspect of the inquiry operates. Although not explicitly in the terms of reference of the inquiry, Black clearly took on board the matter of seeking to discover a cause for the leukaemias. From the way the conclusion was framed and the subsequent comments of Sir Douglas, BNF was indeed to some extent figuratively "in the dock"; when the case against it was not established then BNF was, as it were, 'let off'. This may seem obvious procedure, until it is asked whether it is legitimate, as was apparently favoured in this case, to interpret an absence of proof of a direct causal link between BNF's discharges and the local leukaemias as a proof of absence of the existence of such a link. An alternative question might have been 'what cause other than BNF's reported radioactive emissions can be imagined for those leukaemias?' It would then be up to Black, or anyone else investigating the problem, to find some plausible alternative cause.

In the absence of an alternative cause one might then say that there would remain a strong suspicion on BNF. However this alternative formulation of the problem was not pursued or even discussed; and so BNF enjoyed the 'presumption of innocence' characteristic of the 'adversarial' mode of inquiry common to Anglo-Saxon criminal law, with the burden of proof totally on the prosecution. (There is little reason to believe that the alternative 'Scottish law' interpretation of 'not proven' as 'open verdict' was intended, neither in the report nor in subsequent press statements.)

On the surface, the policy component in Black is fairly clear, in that it made recommendations for certain courses of action, and it was able to offer a reassurance to members of the public who are concerned about a possible health hazard in the vicinity of Sellafield. However, although the report fails to identify a cause in its scientific aspect, and accepts a 'not proven' interpretation in its forensic aspect, amongst its recommendations are measures designed to reduce potentially critical discharges from BNF (by installing filters, preventing discharges of solvent and building plant to remove speific radionuclides - measures for which there was additional pressure from the public and an impending court case). There are also recommendations for the improvement of monitoring and suggestions for further research designed to improve the information on whose basis future revisions could be made to models of the possible carcinogenic effects of ambient radiation. Thus any impression that, in

offering a reassurance Black was satisfied with the state of the community's health, must be duly revised in the light of the severe qualifications. We shall later discuss how such an ambivalent (and perhaps temporary) reassurance may be characteristic of inquiries such as this in their public function.

Black as a scientific study

At first sight the general style and tone of Black might appear to be that of a scientific study, and it is as such that it has been portrayed by Authority. Clearly, Sir Douglas himself is an eminent medical scientist, not a barrister or judge; and the bulk of the report is devoted to an examination of scientific materials on radiation and epidemiology. There is only one point at which there is mention of witnesses being questioned (para 4.75), but otherwise little suggestion that it is intended to be other than a scientific study. The report comprises a considerable mass of technical material, comprehensible only to experts. These are the sort of thing one expects to find when a puzzling phenomenon is to be scientifically investigated. Hence the 'reassurance' with which the report concludes is presumably based on scientific considerations rather than any others. Anyone would naturally infer that, having agreed about the prescence of an excess of leukaemias locally (along with the other cancers), Black had come up with some sort of scientific explanation of the phenomenon, and on that basis could issue his judgement and

recommendations.

Our expectation of a mature scientific study, then, would be for it to seek to provide an explanation of observed phenomena. Normal scientific practice is to build a model of the situation. A model is implicitly adopted in Black which includes possible causal agencies (in the various sorts of ambient radiation); the pathways by which they can move from their origins through the environment and then into and through the human body to known critical sites; their pathogenic effects; and the quantitative parameters describing the transmission and transformation of the agents along their various paths. In figure 1 we give a broad conceptual outline of this implicit model. (We will discuss later some severe uncertainties both within the model, and in terms of possible pathways excluded from it.)

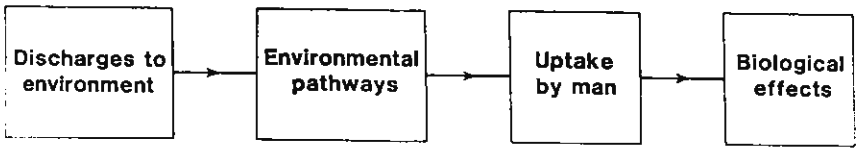

Figure 1 The transmission of possible radioactive contaminants

The implicit model is supplemented by two sorts of local studies: an estimate of the size or intensity of the possible causal agencies in the environment; and an analysis of the raw epidemiological data so as to determine that the phenomenon is a real one. All this will be found in chapters 3,4 and 2, respectively, of the report.

Normally, one would say that an explanation is complete, and conclusions can be drawn, when, (usually after a phase of trial-and-error and development of the model), the model yields numbers that fit sufficiently closely with the attested observations. Although all scientific work is corrigible, one can say then that one is reasonably certain to have explained the phenomenon through identifying its likely causes. On such a basis, policy recommendations can be made in the justified expectation of assent among the relevant communities.

However, such a satisfying scientific conclusion is not to be found in Black. The model, as worked out and calculated, yields an 'expected' value for leukaemias in Seascale only one-fortieth as large as the attested 'observed' value: 0.1 compared to 4. In that sense, the model has failed to provide an explanation of the leukaemias. Scientifically speaking, we are all as ignorant after Black, as we were before, of the (pathological) cause of the leukaemias. We consider in more detail each of the scientific components in turn.

Radiobiology

We recall that the key radiobiological finding from the Black Report (based on reported discharges from Sellafield, routine monitoring data, and models of the transmission and transformation of radiation, as broadly indicated in figure 1) was that at most 0.1 of a leukaemia death could have been caused by the Sellafield emissions since 1952. In the scientific studies supporting the report "worst case" assumptions were invoked in deriving this estimate, but these applied to what we might call 'inexactness' applying at the technical, simplest level of uncertainty - dealing with numbers having a known 'spread'. (Recent work by two of the authors [4] distinguishes such 'technical' from other levels of uncertainty.) Higher levels of uncertainty were alluded to on several occasions, but never explored, still less quantified. So, the calculations yielding the crucial 'worst case estimate' of 0.1 of a death depended both on data of admittedly inadequate quality, and on models generally of unknown fit to the physical situation. Thus there was an assumption of uniformity in diffusion and location of radioactive substances from emissions, in spite of known concentrations due to sedimentation and stray objects. Such non-uniformities could well have been taken as the signal for sensitivity-testing of the models, but this

was not done. Similarly explicit sensitivity testing of the gut transfer factors (the assumed rate of uptake of radionuclides through the wall of the gastro-intestinal tract) and of the model used to calculate the dose to the red bone marrow would be expected in a rigorous scientific study, but again are not to be found in Black. A further uncertainty arises over the question of whether children in Seascale are at exceptional risk (for example in terms of eating habits, the habit of pica, or the length of time spent on local beaches), and further still over the appropriateness of 'averaging' biological effects over whole populations rather than allowing for different susceptibilities in different people to possible radiation induced health effects. Another area of relative ignorance concerns the possibility of more critical radioactive elements and pathways than those explicitly modelled in the report. These would include inhalation of plutonium particles; and unrecorded contact with contaminated workers or stray objects. The preponderance of victims with close relatives who work at BNF has been noted, by Black as well as by others; Black's dismissal of this factor is based on what seems to him a truism, but which may yet be worthy of epidemiological analysis. A further uncertainty arises over the possibility of hitherto unreported discharges from Sellafield; we examine this point in more detail later.

The above uncertainties have been a source of considerable controversy among expert commentators following the publication of the Black Report. Communications have appeared, for example, in the 'Lancet', the 'British

Medical Journal', 'Nature' and 'The Guardian'; a useful review of the key points of controversy has been prepared by Crouch [5].

Given that different sources of uncertainty and ignorance can combine multiplicatively, not merely additively, Black's estimate of at most 0.1 'expected' leukaemia deaths as a result of discharges from Sellafield may be in need of revision by one or more orders of magnitude. As things stand we find Black interpreting the evidence in such a fashion that it becomes difficult to strengthen the scientific arguments for the ambient radiation as a cause of the leukaemias.

Epidemiology

The problem of explaining the excess leukaemias depends on the prior assumption that such an excess exists. With such small numbers, the matter cannot be straightforward and it beckons close scrutiny of Black's choice of measure for the assessment of the 'abnormality' of the incidence of leukaemias in the vicinity of Sellafield.

As explained elsewhere [6], with 4 cases of lymphoid malignancy in the under 15 population between 1968-1982 and (the same) 4 cases of cancer, Seascale (ward) ranks 6th in all wards in the Nortern Region in terms of its total cancer rate and third in terms of lymphoid malignancy per 1000 population. It ranks fifth and first, respectively, according to Poisson

probabilities. The rate per 1000 gives a direct measure of incidence over the period as a whole as a proportion of the 1981 (census) child population, but since most wards have only 0 or 1 cases, all that might be reflected in 'rate' figures is variability in ward size (varying by about a factor of 20, from 100 to 2000 children). Poisson probabilities, on the other hand, give the probability of occurence in a ward of a given number of cases on the assumption that the cases are randomly distributed and come from a population with a constant mean rate of incidence; as such they measure the chance of finding either the observed cancer rate, or even a higher one accounting for effects of different ward population size. The resulting probabilities are not in themselves tests of significance (though they are sometimes wrongly interpreted as such), only qualitative indicators of deviation.

Black took rates per 1000 rather than Poisson probabilities as the leading indicator of the degree to which the incidence at Seascale may or may not be excessive, and in this respect he may have understated the significance of the local excess. In particular, subsequent significance tests, on the same data find that, when compared with a set of Monte-Carlo simulations, the null hypothesis of 'no significant difference between the distributions' can be rejected at the 5% or 10% level (cancer or lymphoid malignancy). On the basis of these findings, Seascale is a real abnormality (Craft and Openshaw [6]).

Since child leukaemia is relatively rare, inference is necessarily based on relatively small numbers of cases, and each single case can be statistically very significant indeed - by whatever test or indicator is used. It is the smallness of the number of cases that is at the same time the cause of severe difficulties in epidemiological analysis and part of Black's justification for being able to offer a 'reassurance'. That leukaemia may be, by its nature, a clustering disease further confounds attempts to identify the ocurrence and assess the significance of possible local excesses.

Black's preference for 'rate' as opposed to 'Poisson' is a case where he selects an indicator that tends to minimize the problem he was asked to investigate. This in turn makes the credence given by his committee to the findings of the Yorkshire Television programme appear rather strongly hedged. In a recent article [7], Sir Douglas later justified this approach by stating a preference for the more concrete result of a count in order to yield an 'actual measure' of leukaemia incidence. However, the pitfalls of such 'counts' in small-sample epidemiology are well-known.

The accuracy of the data drawn upon in compiling any indicators is, of course, of profound importance. The choice of time period over which records were examined, the choice of spatial unit, the two cases diagnosed in Seascale after the Black Committee began to sit, the difficulty of tracking down those in and out migrants who should be counted amongst

known cases, the significance of cases in neighbouring wards, the losses in data handling through coding difficulties, and the question of whether cases should be counted on death or on diagnosis - each of these factors had an important bearing in determining the assessed significance of the local leukaemia excess in the vicinity of Sellafield. As it stood Black's case rested essentially on just 4 reported cases in Seascale. The consequent 'reassurance' was qualified not only in terms of its uncertain radiobiological aspects (as we have described above) but also in terms of its epidemiology. A recognition of the need for greater accuracy and detail in the analysis of cancer registry statistics than could be accomplished within the time-span of the Inquiry was recognised by Black. A crucial recommendation for further research in this area was accordingly made.

As again with uncertainties in its radiobiological component, Black could not pre-empt the disquiet that has subsequently arisen over the report's epidemiological findings. This results partly from the ease with which additional evidence has been identified which strengthens the impression of a more pronounced excess of cancer in the vicinity of Sellafield. The implicit contradiction between 'scientific reassurance - with severe qualifications' has been noticed by experts if not yet by the media and much of the wider public.

Beyond Black's science

The public's image of 'science' is generally that of accomplished, incotrovertible facts. A radically incomplete and inconclusive scientific study is not a familiar object of discussion or analysis. This may be why sections of Black's audience (and perhaps even Sir Douglas himself) could not cope with the paradoxes of a study which not merely was inconclusive, but which patently failed as an explanation of an important phenomenon.

We should recall that Black was operating under severe limitations of time, and perhaps of resources too. There was no opportunity to go through the lengthy procedures of peer-review and scientific criticism whereby new ideas could have been injected for a second round of exploration of the problem. This was doubtless one reason for the list of recommendations for further research, with which the report concluded. Also, near the end of the report there are traces of a concern for improving the scientific explanation. In para 4.85 there is a list of four possible reasons why the results of the key radiobiological model are so greatly at variance with observations. However, all these are dismissed as being only 'remotely possible', without any further analysis in the text. They are that:

a. there is an unusual concentration of unusually susceptible children in the Seascale area;

b. there have been undetected discharges that have given rise to doses to the public greatly different to those believed to have occurred;

c. ingestion, inhalation and/or absorption of high LET (linear energy transfer) emitters has been grossly under-estimated;

d. the model used to calculate red bone marrow doses is highly

inaccurate.

The latter three of the above four 'remote possibilities' would, if interpreted in greater strength, tend to revive the explanation of the leukaemias being caused by the ambient radiation. The first points in the opposite direction.

We have, then, a model whose predictions do not fit the observations, and a rejected set of possible alternatives and modifications and ignorance of the cause of the leukaemias. As we have observed, the outcome of Black as a scientific study is a failure of explanation (and, inconclusiveness).

It is important to stress this point because the text of the report does not remark explicitly on this failure. But in the two sections where a conclusion of sorts is reached, the areas of uncertainty and ignorance are clearly marked. Thus paragraph 4.88, in which the ratio 1/40 is mentioned, starts with the conditional 'if all these assumptions are correct....'.The evident strength of the 1/40 is supported only by the (doubtful) statement that the total (underlined) discharges from Sellafield would need to be 40 times larger than reported, with a similar error in monitoring and extrapolation of doses to the public. This crucial paragraph (4.88) is preceded by two on the extreme uncertainties in estimates of alpha radiation doses (4.84, 4.86), separated by the one on 'remote possibilities' (4.85), and which are followed by one remarking the model's 'worst case' assumptions (4.87). Such an ordering does not

convey an impression of inexorable logic.

The argument in the chapter on Conclusions and Recommendations is similarly free from overstatement. Paragraph 6.10. warns about possible undetected discharges and also on unsuspected routes (contrary to their dismissal in 4.85); paragraph 6.11 repeats the story of the radiation model, not mentioning the 1/40, but invoking instead the less striking figure '20% of the number expected from background radiation'. Paragraph 6.12 may be taken as the official verdict, and so should be quoted in full:

"These calculations do not support the view that the radiation released from Sellafield was responsible for the observed incidene of leukaemia in Seascale and its neighbourhood. However, it is important to stress the unavoidable uncertainties on dose in this situation, and the model we have used does not exclude other possibilities."

We are left, then, with a radically inconclusive scientific result, though stated in a form appropriate to the forensic aspect, and both conclusions are stated as negatives.

The policy conclusion that appears in the following paragraph, 6.13, is a little masterpiece of cautious exposition. In its second sentence we find the sole occurrence in the report of the key term - "reassurance": a term that was to be much stressed by Black during media interviews following the publication of the report [8]. But in the report, the 'reassurance' comes, weakened by the adjective "qualified", just before a series of no less than six caveats and criticisms.

But when all is said and done, the report, and Sir Douglas himself, found it justifiable to give the local and national publics a "reassurance". Why? Because the conclusion of the model, while failing to explain the phenomena and to indicate the real cause, did at least contain one negative implication. This was that the excess measured ambient radiation, deriving from the BNF operations (and measured by BNF's own monitoring procedures), was wholly insufficient to have caused the excess leukaemias in Seascale.

We have found, then, that scientifically speaking, we can draw one of two conclusions, not mutually contradictory but certainly strongly contrasting in their implications. One is that we have as yet a very rudimentary model, incapable of explaining the phenomena. The other is that the model does at least tend to exclude BNF's emissions as a cause of the leukaemias. But how can such a defective model be taken as entailing the exclusion or inclusion of anything? Certainly, in an ordinary scientific research paper, a model which was such a notable failure as an explanation and laden with such severe uncertainties, would hardly be accepted by a research community as the basis for any conclusion about the phenomena to be explained. We suggest that a way out of this paradox can be found in the 'forensic' aspects of Black's task.

Black as a forensic study

We recall that the legal aspect of the panic evoking the Black inquiry was well recognised. If nothing else, BNF was eventually brougnt to court by the DPP on criminal charges arising out of an 'unplanned' discharge in November 1983, shortly after Black began to work. Its image thus tarnished, its management discredited, and known to be a regular emitter of radioactive substances, BNF can be fairly said to have a prima facie case against it, as the institution ultimately responsible for the leukaemia deaths.

In these circumstances, any explanation of the leukaemias made by Black would inevitably be interpreted in terms of the actions, the responsibility or even the culpability of BNF. Black could not completely escape from the role of judge and jury of BNF in this situation. In these circumstances, the normal procedures of interpreting and weighing scientific evidence, applicable when the possible conclusions have no legal aspects, may perhaps justifiably be modified, and forensic procedures adopted.

The inquiry's awareness of its forensic nature is shown by Sir Douglas's subsequent comment, that he found the case against BNF 'not proven'; this supports similar statements in the text, at 5.17, 6.2 and 6.12. The interpretation of 'not proven' as innocent is a perfect reflection of a forensic inquiry in the Anglo-Saxon judicial tradition. Also, it explains

Black's interpretation of the relation between the model and the phenomena: in spite of its failure to explain the leukeamia deaths, and of its leaving us in ignorance of the causes of those deaths, the model did, however imperfectly and weakly, point away from BNF. Unless it were to be quite drastically modified (overcoming the factor of 40 between its 'expected' .1 and the 'observed' 4 deaths in Seascale), it is the opposite of a 'proof beyond a reasonable doubt' which would be necessary to implicate BNF in the leukaemia deaths.

Sir Douglas seems to have recognised this aspect of the model, remarking later on how the 40 was a sort of 'safety factor' in an assessment of the likelihood of the ambient excess radiation (and hence BNF) being responsible for the deaths. But here we encounter a paradox, a sort of nonconformity between this forensic use, and the standard scientific interpretations of such a disproportionately large ratio between predictions and observations. Suppose for the sake of argument that there had not been 4 leukaemia deaths but 10 or 50; (and given the recognised imperfections of the epidemiological evidence we should recognise that the 'correct' number might not be 4). Given the same model, the 'safety factor' from this forensic point of view would be even greater, some 100 or 500; the 'reassurance' issued by Black could have been correspondingly stronger. Conversely, with fewer recorded deaths, the forensic case against BNF would be stronger. In other words, by Black's logic of the 'safety factor' the greater the number of leukaemia deaths locally, the

weaker the implication that BNF were responsible. Correspondingly, the fewer the number, the stronger. From a scientific point of view, the investment of credence in a model showing such minute or indeed negligible explanatory power, and afflicted with such paradoxes, would become distinctly odd, not to say bizarre. For a model which so patently fails to explain the phenomena, leaving us so completely in ignorance of the causes, eventually loses its credibility to serve any function within this particular domain.

Even within the forensic mode of inquiry, Black presents the reader with paradoxes. Accepting the inevitable implications of its work, Black also implicitly accepted a particular burden of proof: a verdict of 'not proven' was sufficient for the apparent exculpation of BNF from the implicit charge of causing the local leukaemias. In this, BNF was given the benefit of the doubt in the final conclusion: any scientific argument which entailed BNF's responsibility for the leukaemias would have to be 'proven' in some sense to be accepted (and, as we have seen, the actual case was quite the opposite). Then, we may ask, what is the appropriate procedure for interpreting and weighting evidence in this case? To balance the severe requirements on the proof, the evidence tending to affix blame must be given due weight by the inquiry, and not weakened or explained away. For if evidence is also interpreted to the 'benefit' of the suspected person or institution, then a proof 'beyond reasonable doubt' could hardly ever be achieved. The exculpation of BNF, and the

related 'reassurance' are then very difficult to avoid.

Yet, paradoxically, this is the procedure in Black. This appears most clearly in connection with three of the four 'remote possibilities' of para 4.85 mentioned previously, which were stated and dismissed together by Black. Examining these, we are led to the conclusion that Black was consistently interpreting evidence weakly, so as to force a negative assessment. And as we have observed these three points all tend in their implications towards the possibility of the ambient radiation being a cause of the Seascale leukaemias.

We have commented earlier on the third and fourth point of para 4.85 in the course of considering the radiobiological component of Black. The second deals with the possibility of earlier undetected discharges, similar to that of November 1983, the remote possibility that 'there have been undetected discharges that have given rise to doses to the public greatly different to those believed actually to have occurred'

This was no mere surmise on Black's part; the point is dealt with explicitly earlier on (para 4.75)

'We questioned all relevant government departments and BNFL closely on this, [whether there could have been undetected discharges in the past] and they told us that it was probable (underlined) that such an incident would have been detected in the past' (emphasis added).

Now, this was verbal testimony of employees and officials who could be expected, in virtue of their positions, to say just that. Even they

qualified their statement by 'probably'; and yet Black converted that to a finding of mere 'remote possibility'; accordingly this contingency found no place in the model of emissions and pathways. But the air of paradox about this assumption of unlikelihood cannot be dispelled. It was, after all, just such an 'unplanned emission' of liquids and contaminated objects, for which there was no recorded precedent, that was discovered by Greenpeace protestors in November 1983. To consider any previous such emissions as a 'remote possibility' is to imagine the incredibly bad luck of BNF, that after some tens of thousands of accident-free days, they found Greenpeace at the end of the pipe the first time it happened. Of course, further scientific study could help to resolve the issue; for example, study of the patterns of radiation given off by collected objects could determine whether any of them were older than November 1983 [9]. (Later in the report Black seems to have had second thoughts on the issue, saying that "one cannot completely exclude the possibility" of such undetected discharges (6.10)).

In the body of the Report, Black had a comment on the emission, which illustrates his consistent tendency in the interpretation of evidence. We read (para 4.74)

'the consequences with regard to exposure of the publlic from this (the November 1983) incident are believed to be small, and to relate mainly to the risk of a skin dose from skin contact with abnormally contaminated debris picked up from the beach and held over a significant period of time ..... In the context of our invesetigation this hazard is not relevant since it is not believed to have resulted in a significant bone ,arrow dose likely to affect leukaemia incidence rates'.

Moreover, the deeming of one particular emission as negligible in health terms, is seemingly taken as the basis for an inductive inference of a reassuring cast.

Having reflected on the latter three of the four 'remote possibilities' mentioned by Black in para 4.85, the first, that there might be '....an unusual concentration of unusually susceptible children in the Seascale area' also warrants some consideration. As we have suggested, this tends to weaken any theory that the local leukaemias are caused by BNF.

However, if (by Black's forensic standards) the leukaemias are not caused by radiation from Sellafield; and if (by Black's scientific standards) they are only remotely possibly caused by anything else; then our ignorance is very profound indeed. The possible basis for the final 'reassurance' to the people of Cumbria is now only for the non-susceptible majority, by whatever unknowable criteria they are defined.

The policy component of Black

Our exploration of Black through its 'scientific' and 'forensic' aspects seems to have led us mainly to paradox and puzzle. But perhaps both these aspects are, after all, subordinate to 'policy'. Here, at last, we may hope to find coherence of argument and conclusion.

We recall that the 'policy' dimension of an inquiry such as this one, is fully as weighty as the 'scientific' and 'forensic'. The credibility of the nuclear power industry, and of its regulatory agencies, is bound up with Black's conclusions; major industrial investments and political commitments are involved in the industry. All these considerations lay a very heavy responsibility indeed on any individual or report which would even by implication accuse BNF of having caused the deaths of children in its vicinity.

Hence there is a strong policy constraint on an inquiry such as Black, not to cause public alarm except when absolutely unavoidable. Sir Douglas seemed to have recognized this when he said in a recent article [7]:

'We have been taxed with attempting to reassure the Cumbrian public. If this is a crime, I am happy to plead guilty to it'

On the other hand, the inquiry should not appear to be a whitewash, lest it be discredited and alarm arise again by default; nor indeed should it be (underlined) a whitewash, lest some real problems be obscured and continue uncorrected. Balancing such considerations is obviously a task of some delicacy; how is it to be accomplished?

Such a complex problem calls for equally complex means. For the preservation of calm and stability, the 'forensic' dimension is crucial. The implicit case against BNF were best argued in such a fashion that

BNF's neighbours, and the nation, can be given an honest 'reassurance'. On the other hand, in the policy domain the report must not be seen to be denying all problems; hence the list of urgent tasks for further research, relating to the 'qualified' character of the reassurance that Black could offer.

In brief, the recommendations call for (a) more refined case-controlled epidemiological work, more thorough analysis of appropriate health records and more exhaustive and up-to-date small area census statistical analysis (b) better co-ordination of small area statistics around major installations producing potentially carcinogenic or mutagenic effects (c) whole body monitoring of concentrations of radiation in individuals, and human tissue samples from post mortem examinations (d) more work on dose-response models used to estimate the effect of the uptake by man of radioactive contaminants (e) studies on children to investigate the existence of unknown critical pathways (f) a review of the official discharge authorisation for Sellafield, including consideration of the need for Sellafield to discharge alpha aswell as beta and gamma emitters (g) more formal consultation between authorising departments, advisory organisations and health departments, and clearer definition of their respective responsibilities.

Though doubts have been expressed about the utility of some of these recommendations, and the omission of other possible avenues of

investigation, it is possible that the proposed research projects could serve further severe qualifications on Black's 'reassuarance'. It is noteworthy that the report gives no indication as to what would have to turn up in the course of implementation of the recommendations to make any difference to the key message of reassurance. However, should further epidemiological study produce more than 4 cases in Seascale then (notwithstanding the paradoxical 'safety factor' logic mentioned above) those who first exposed the leukaemia issue as a public concern would be given further vindication. Or, improved models could make larger the parameters measuring throughputs and sensitivities. It seems hard to imagine ways in which further study could strengthen the scientific reassurance which is the policy outcome of Black.

The uncertainty and ambiguity portrayed above is characteristically reflected in the report. In its crucial final sections, Black repeatedly gives and takes away. There is a reassurance, but it is qualified. Critical research is strongly recommended, but it is of uncertain and unstated import. What Black appears to have given, for peace and continuity in the management of nuclear power, he nearly takes away with his caveats and qualifications. Any comfort that might have been derived from the models whose possible shortcomings are dismissed as only 'remotely possible' is taken away by his strong recommendation for their improvement through better monitoring and data. It is small wonder that the press could interpret it all the way from complacency to alarmism.

Perhaps more importantly, an immediate damaging confrontation of aggrieved sections of the public with BNF has been averted; on the other hand, BNF and the monitoring agencies have been warned; in future their operations will be cleaner; and a number of crucial new research studies have been set in train.

The ambiguities identified above cover deeper confusions. With all its impenetrable technicality, Black, as we have suggested, appears to be a scientific investigation; but its methodology is not that of research science. It concludes with a 'reassurance', presumably one of the two available options in the discharge of its main function; but its formal remit included only investigation of the evidence and recommendations for research. The task of examining and reforming BNF was actually undertaken by other agencies; the HSE and more recently the criminal courts. So there was no need for Black to pass judgement on the ambient radiation and hence (implicitly) BNF. But if the inquiry had not done that, who else could have reassured so plausibly, if somewhat obscurely?

The cultural context of Black

Such confusions are perhaps inherent in, or even essential to, the avuncular style of governing of which Black is a prominent example. (Sir Douglas is personally quite an anti-Establishment senior Civil Servant; for many that will serve to lend him even greater authenticity and

credibility). In his inquiry he had to cope with an alarming (though still small) number of deaths, in a community divided in many ways by loyalties and personal commitments involving BNF [10]. Most of the oral 'testimony' came from concerned individuals and environmentalist groups; there is little trace of this in the report. As we have seen, the only vulnerable witnesses are those who said that there was 'probably' no precedent for the 'Greenpeace' discharge; by the time they gave evidence, they were aware of an impending criminal case against BNF. So the whole inquiry could be run, at least in its retrospective report, as a piece of science which, with all its puzzles, did at least enable a reassuring conclusion to be drawn, for the peace of mind and stability of the local communities.

Close parallels to the Black inquiry might be the Flixborough and Windscale inquiries [11, 12], both chaired by the same distinguished lawyer, Mr Justice Parker. Both perhaps suffered in their image because of his lively adversarial style in the proceedings, and his frankly personal style in his reports. Black, by contrast, is very much the unassuming scientist, concerned only with the 'facts' of the case and such (qualified) reassurances as he could draw from them. Although the local community was not noticeably soothed by the report, neither was it noticeably agitated; and there were no more occasions for media scares. All this would naturally constitute a sort of success for those who commissioned the inquiry. And by his caveats, criticisms and urgent

recommendations for research, Black has laid the foundations for a possible eventual revaluation of data and models, perhaps even to a revision of that 1/40 or 20%, which led to the present reassurance.

Such a style of mixed, apparently muddled components, of science which proves less than it seems, of uncritical acceptance of testimony from vulnerable witnesses; of implicit burdens-of-proof leading to a focus on one question and a suppression of others; of a failed scientific explanation turned into a forensic proof; of reassurances hedged about with qualifications; and with criticisms and research recommendations that could some day re-open the whole issue - all this is a very English phenomenon.

In a culture more given to litigation and formality of procedure, as in the United States, such an amicable muddle would be greeted by hoots of derision while everyone reached for their lawyer. But here, the presumed impartiality, benevolence and competence of the judicious, eminent figures who conduct such inquiries, should serve to reassure participants and the public on all issues, including the conclusions of the inquiry as well as its conduct. What sort of inquiry, with what rules of procedure, evidence and inference, are not to be inquired into too closely. It should not matter whether it is offering a scientific explanation achieved by scientific methods and standards; or conducting a forensic investigation of responsibility and guilt, with its appropriate

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burden of proof and standards of interpreting testimony; or participating in a complex operation of simultaneous reassurance and reform. A bit of all three, perhaps; there is, as we have seen, genuinely something for everybody, not too clearly sorted out. Any disquiet over the resulting confusion should be eased by the undoubted and unchallenged wisdom and integrity of the chairman. It is a style that has survived in the past; and will doubtless continue to survive, though to be given legitimacy it is crucially dependent on public trust in the Establishment of which it is a part.

In the absence of such trust, scientific reassurance for concerned local communities can become very difficult indeed. Typically, the phenomena are small-scale, of dubious significance, and the reporting of them is partly or even wholly anecdotal. The relevant scientific disciplines are likely to be immature and weak, and quite inadequate for either proving or disproving locally suspected causal links. Where suspicion falls on some local installation, the inevitable assignment of the burden of proof to the accusers will totally swamp any possible scientific evidence on the complainants' side. And the general policy commitment to reassurance, in cases where there is any doubt, finally ensures that complaints and suspicions will be reasoned out of legitimate existence. Where the authorities are operating in ignorance, the decisive consideration is who needs protection most - a community from its still hypothetical hazard, or an institution from the real threats of panic or hysteria.

The logical trap of 'merely anecdotal' evidence, which can be scientifically deemed not even worth following up (as in early concerns over 245T), can leave a community in a state of total frustration and increasing rage. They may then begin to wonder just what sort of evidence would be adequate for convincing experts and civil servants that their local environment is not as tidily controlled as the reactions in an experimental laboratory. Must they eventually produce a body-count of some impressive size? In such circumstances, the scientific arguments come to be seen as merely rhetorical devices, ultimately a very dangerous situation for politics and for science.

Such a crisis was avoided in the Black inquiry; although criticisms continued to rumble about the selection and weighing of epidemiological data, the commitment to further research was clear and decisive. Viewed in such a perspective, the achievements of Black for the local community are considerable. The leukaemia cases claimed by the television journalists were confirmed; and the (qualified) reassurance of the report's conclusion was set in an array of urgent recommendations for research which might well alter the leukaemia statistics or the explanatory model. It is difficult to see how an inquiry operating within such constraints of resources, style and policy could have come to a significantly more rigorous and critical conclusion.

Conclusion

The apparent strengths and weaknesses, and the paradoxical properties of the Black report can thus be seen in terms of its very complex nature. It needed to incorporate elements of science, forensic procedures, and policy considerations; audiences and perhaps even participants were not fully aware of the complex nature of the exercise.

In these terms we can understand how a failed scientific explanation, based on a very vulnerable theoretical model, interpreted through a highly paradoxical 'safety factor' of 40 could serve for a 'no proven' answer to the only question chosen for analysis, and thereby could yield a 'reassurance' that was promptly encircled by caveats, qualifications and urgent recommendations for potentially destabilising research.

It succeeded in removing the issues from wide public attention while the real work of finding out what did happen could perhaps eventually begin, relatively unencumbered by partisanships and controversy. There might be doubts about whether the set of recommendations are the most appropriate

for advancing scientific understanding of the phenomenon and prevention of future harmful effects but such doubts seem hardly sufficient to leave the Black Inquiry as nothing but a complicated ritual.

As a scientific study, the Black Inquiry displays some characteristic problems of science entering the policy arena. In providing public reassurance, it necessarily softens the sharp edge of clarity and criticism operating in research communities; becoming more like other public institutions, depending on consensus, credibility and trust. Of course, in that role it depends on the strength of the institutions by which it is being deployed; and it remains an open question whether, in the long run, the very different sorts of roles and images of science can be kept in harmony.

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