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LONG TERM ENGINEERING REQUIREMENTS IN WASTE DISPOSAL AND SITE REMEDIATION

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INTRODUCTION

Laws governing waste disposal and remediation of old waste dumps mandate long design lives for disposal facilities. Ethical and moral considerations demand that the engineer do all that is reasonable and conscionable to provide a waste facility that will be stable and protect human health and the environment for as long as possible.

Standard engineering practice is to design according to cost benefit methods for design lives that are consistent with normal life spans and the behavior of synthetic materials. The twenty five to one hundred year design lives that result from these approaches are not long enough for waste disposal facilities that contain waste that will be toxic or hazardous for much greater periods.

New, revised, and different philosophical and technical approaches must be adopted by engineers and those involved in waste disposal facility design and remediation if they are to meet the legal and ethical demands to protect present and future generations. Accordingly, this paper discusses proposed technical and philosophical approaches to designing long-term, stable waste disposal facilities.

REGULATORY BACKGROUND

The Superfund Amendment and Reauthorization Act of 1986 directs the President to select and utilize permanent solutions for hazardous waste disposal and remediation. The Uranium Mill Tailings Radiation and Control Act calls for remedial action plans that have a design life of 1,000 years to the extent reasonably achievable, and at any rate for 200 years. Low-level radioactive waste disposal facilities should have a design life of at least 500 years. The 30 year design life so often quoted for waste disposal facilities governed by the Resource Conservation and Recovery Act, is in effect, not a design life. The legal reality is that 30 years is the monitoring period, and if the facility is not performing satisfactorily at the end of the 30 years, remediation or continued monitoring may be required.

Stripped of the legal wording, the core demands that come from these and other relevant and appropriate regulations may be stated as design criteria:

- Provide, to the extent reasonable, a permanent solution.
- Do not rely on long-term maintenance.
- Cost/benefit approaches should not be a significant design factor.
- Temporary control of contaminant migration is not acceptable.
- Some contaminant release is inevitable; to deal with this, select sites that are not environmentally sensitive and show that the inevitable contaminant releases will not adversely affect human health and the environment.

PHILOSOPHICAL ASPECTS

Waste middens in arid climates have remained in place for long periods. The expert and amateur geologist can easily locate numerous geomorphically stable landscapes that have remained essentially unchanged since the end of the ice ages some 10,000 years ago. Archeological evidence and natural analogues for the long-term stability of earthern structures and forms abound. It is not stretching credibility too far to postulate that present day engineers can duplicate these archaeological and natural successes.

We have to conceed that the engineer can, however, hold back the forces of nature for only a limited period, and not forever. Future generations will have to deal with the waste we create today. People as far removed in the future from us as we are removed from those who signed the Magna Carta will have to deal anew with the waste of today and tomorrow. It is technologically impractical to provide longer term assurance for common wastes; high level nuclear wastes can and do demand the assurance of safe disposal for 10,000 years and more.

Some may argue that it is indeed technically possible to secure common wastes for periods longer than 1,000 years, but the reality of economics forces us to conceed that there is probably not enough money around to secure our waste disposal facilities for such long periods or longer periods. Society has to make and does make hard decisions about allocation of financial resources devoted to waste disposal and facility remediation. A long-term societal perspective forces us to conclude that, potentially, the cheapest long-term waste remedial scheme is avoidance of waste generation. As much as that is desirable and necessary, the issues it raises are beyond the scope of this essay. We work with the problem of remediation of current waste disposal facilities, not the elimination of future ones.

We believe that some release of contaminants in the long-term is inevitable and unavoidable. The money and the technology simply do not exist to prevent all contaminant release for extremely long periods. The core components of the engineering philosophy and ethic, when faced with design of secure, long-term waste disposal facilities, must be that:

- Both the letter and the spirit of waste disposal laws and regulations, which encapsulate societal choice, must be observed.
- Everything that is technically and economically feasible should be done to secure the wastes.
- Sites and designs that minimize the consequences of inevitable contaminant releases should be selected.
- Technical and societal peer review must be secured.

ETHICAL AND PROFESSIONAL CONSIDERATIONS

It is easy to state, but difficult to achieve: use the site that minimizes the consequences of inevitable long-term contaminant releases. It is easy to state because few will be found who disagree with the nobility and correctness of the sentiment. It is difficult to achieve for the sad reasons that when wastes are to be moved from one place to the next, one or more, and probably all, of these objections will be heard:

- You cannot leave the waste at its current unsuitable locations.
- Don't transport the waste through or past my neighborhood.

- Don't place the waste in my backyard.

- If you place the waste at that new site how can you be sure you will not contaminate that environment (particularly given your admission of the inevitability of some long-term contaminant release)?

- Even if the law does allow you to invoke alternate concentration limits for groundwater contamination (i.e., contaminant loadings greater than the maximum concentration limits that are commonly accepted not to negatively impact human health and the environment), you should not choose a site that needs alternate concentration limits to be workable.

Each of these objections is perfectly reasonable from the perspective of the person raising the objection. But the engineer is faced with the ethical question: what is the absolute truth and, hence, the correct professional approach? I believe, at least from my limited perspective, that there is no absolute in such a case. Like the ultimate of physics, the ultimate in waste disposal is all relative. For that reason the professional engineering approach is to honestly represent the best interests of the client, and to accept that in the field of waste disposal, society has established an elaborate system of checks and balances to ensure that only the socially acceptable waste disposal solutions are implemented.

An interesting question is: what is the long term liability of the company or legal group with which the engineer who designs the long-term waste disposal facility is associated? Could that group be liable for a failure of the facility 500 years in the future, assuming the company is fortunate enough to survive that long? Probably, only current peer review acceptance of the design will be adequate defence 500 years from now.

TECHNICAL APPROACHES

Many documents have and may be written on the technical approach to designing and constructing long-term, secure waste disposal facilities. All we need do here is abstract the essence of the many approaches.

Regardless of the political realities of relocation, I believe we should seeks sites that are:

- Geologically and geomorphologically stable.

- Not located in flood plains, including the probable maximum flood plain.

- Close to or on watershed divides.

- Not in drainage channels.

In designing, we should select and arrange the components of the disposal cell and its surrounding elements, such as swales and diversion channels, according to these interlinking approaches:

- Use redundant control and protective components: i.e., incorporate two or more different materials that, in whole or in part, perform the same function. An example is using two low-permeability layers to impede infiltration.

- Provide multiple lines of defence against instability. If the failure of one component results in the failure of the whole facility, provide alternative defence mechanisms. An example is to place both a rock mulch and vegetation to prevent surface erosion.

- Seek to exploit the synergistic effects of complementary design elements. Arrange components to augment or reinforce the performance of other components. For example, one very low permeability layer may lead to partial saturation and, hence, low flow through a second layer.

- Adopt very conservative factors of safety. Thus, the factor of safety for a drain may be well in excess of fifty.

- Design for extreme events, to the extent economically feasible. For example, provide for the maximum probable precipitation. This does not mean that the facility must be designed to suffer no ill effects from so extreme an event; it does imply that the engineer consider what could happen if the extreme event occurs and should make an conscious decision that the consequences are unavoidable and acceptable.

In designing for the long-term, we are currently faced with many interesting debates about appropriate technical and engineering details. Here are some of them with a brief discussion of the issues.

- Natural versus synthetic materials. Uranium mill tailings piles do not conventionally incorporate geomembranes; most hazardous waste disposal cells do. The uncertainties of the response of soils to hazardous waste chemicals and the aggressive marketing of geomembrane manufacturers are at least two of many reasons for using synthetics. The long design-life requirements for uranium mill tailings piles has, to date, precluded their use. The NRC has recently stated that they will not give full approval of geomembranes, but will accept their use if they are used to augment natural materials.

- Rock versus vegetation to control erosion. Rock riprap on a waste disposal cell is a certain defence against erosion. Good quality rock may be unavailable or expensive or a tempting target for thieves, and so vegetation is offered as a good alternative. My belief is that we should be allowed to take into account the erosion resistance afforded by vegetation for evaluating stability against the probable maximum precipitation, but that we should ignore the benefits of vegetation in controlling erosion for the 100 year and similar event. I base this on the various probabilities of occurrence of the different events and the extremes of design to which other approaches lead us.

- Performance assessment models. Computer experts debate the merits of models with names like HELP and CREAMS as ways to quantify infiltration to disposal cells. Such models are, in my opinion, an invaluable aid to understanding and judgement, but they cannot represent the complexity and randomness of 1,000 years of nature. One number from one computer run cannot be used as "the" design value. Therefore, I propose that we must evaluate the impact of a reasonable range of influxes to the pile. The range must account for extremes of rainfall, material properties, and potential variable design responses. This is an exciting area for argument and the application of probability theories.

PRACTICAL APPROACH

"Be practical" is the normal response to the ideas discussed above. The response is that most are practical and are currently being implemented on numerous sites. Engineers are selecting alternative sites, considerable sums are being paid to relocate wastes, and cells are being constructed with natural materials and are designed to avoid routine maintenance. Extreme floods, precipitation, and earthquakes are used as design parameters.

Regulations try to avoid an appearance of acceptance of cost/benefit justification, but at the heart of alternate concentration limits is the implicit assumption that costs cannot be excessive.

What are the alternatives to long-term, secure waste disposal facilities? The first we have already mentioned: avoid the generation of waste. Others are well canvased in the literature and are in practice. They include: waste minimization, short-term designs with active maintenance, and the use of regional and national waste disposal facilities. I have even heard talk of national sacrifice zones for waste disposal.

CONCLUSIONS

Society will generated waste. Wastes are a concomitant of the safe, healthy, material existence we choose. The more wealth a society posses, they more waste it generates. Hopefully, in the future we will see wealthy societies constructively use that wealth to reduce the waste volumes. But, we must also assume that the richer a society, the better its waste disposal practices. So we must not allow our waste control practices to impoverish our society.

The engineer will then continue to be needed in the foreseeable future to design long-term, secure, but economical facilities. The ideas presented here merely scratch the surface of the problems the engineer will face and, as in the past, successfully solve.