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Aquifer remediation in Australia — current regulatory guidelines, evaluation of treatment technologies, and future directions (panel discussion)

Aquifer remediation is becoming increasingly important in Australia owing to the tightening up of environmental and health standards, and increasing stresses on groundwater resources. A panel discussion at the conference 'Aquifers at Risk' focussed on current regulatory guidelines for remediation in Australia, the evaluation of treatment technologies, and on likely future directions. Current issues were highlighted and comparisons drawn with the situation in the United States.

Introduction

A panel discussion on Aquifer Remediation in Australia was held at the 'Aquifers at Risk' conference, in Canberra, in February 1993. The panel was chaired by Dr John Ferguson (Consultant), and the panellists were Dr Marlene Bennett (BHP Research), Dr Greg Davis (CSIRO Division of Water Resources), and Mr Rod Harwood (Groundwater Technology Inc.). The discussion followed presentation of a background paper by Harwood (this issue), and addressed the topics of the current regulatory guidelines for aquifer remediation in Australia, the evaluation of treatment technologies, and future directions.

Current regulatory guidelines

Lucy LYTTON (Department of Water Resources, New South Wales):

My question relates to air stripping, soil venting and air sparging. I understand that air is discharged into the atmosphere in the cleanup process. Are there any EPA guidelines in any of our States which place any control over such discharge?

Rod HARWOOD:

That is correct. We are seeing a lot of applications in remediation, and production of vapour phase organics goes untreated. Certainly in the case of air stripping, it is a mass transfer from liquid phase to gaseous phase, and also for ventilation.

In a lot of sites it requires carbon treatment to polish the air streams. With the chemicals themselves you might need to go to catalytic converters, which are a destructive technology, or thermal oxidisers or converters which are also destructive. Therefore, they do not cause a potential problem to the environment.

Many remedial systems used in Australia today have not gone through the same level of stringent permitting. One method is to use a coarse air diffusion model. Given a certain height of tower, you can get sufficient diffusion in the air carbon to render that system safe.

Also there are a large number of sites throughout Australia where the regulated and permissible emissions are much greater than a lot of our remedial systems. You can look at vent stacks from service stations and similar areas just as an example of where it has been decided and regulated that a 6 m emission is quite suitable for VACs through a vent pipe at a service station. It is worth putting all the remedial strategies in context, but the question that was asked is valid.

Chris JEWELL (C.M. Jewell & Associates):

Remediation standards are likely to be risk-driven. It has been my experience over a couple of years that the EPA in New South Wales is going in that direction, and presumably that is also the case in other States. Do you see the need for risk assessment guidelines to be issued by the regulators in this country? Do you think it is practical, for example, to adopt the Superfund risk assessment guidelines, or do you think that it would be counter-productive to adopt guidelines such as RAGS [Remedial Action Guideline Systems] which have been widely criticised in the United States simply because they are so rigid?

Rod HARWOOD:

It is true that RAGS has been criticised. But it is also true that it is still in place and is still used to determine risks on a lot of the sites overseas. I would like to see us move strongly towards environmental risk-assessment guidelines just as much as toxicological ones.

My experience of the situation in the United States is that I believe they have gone a long way down the toxicological human health risk profile, but perhaps not far enough in looking at the environmental risks. I would like to see us looking a lot more closely at the environmental side rather than human health. I don't see that the guidelines in the environmental area are as clearcut as IRIS [Integrated Risk Information System], RAGS and all the things that are appearing at the moment. If there were a change, I would like to see us look more at the environmental area.

I believe the RAGS approach and the IRIS approach are highly conservative but still valid. It is amazing that the soil guidelines are based on one naked human eating so many milligrams of soil a day throughout a lifetime. And built into that analysis there is added conservatism. It is easy to understand how we can become cynical about risk assessment approaches. But I don't see that we have a great alternative, unless we go down the environmental path.

Chris JEWELL:

Do you think we need to develop our own system?

Rod HARWOOD:

My perception is that in our environment, with the chemicals that we use, the soil permeabilities are similar

to those elsewhere in the world.

Chris JEWELL:

But the ecosystems aren't!

Rod HARWOOD:

From my perspective looking at soil and groundwater I do not see any major differences.

Chris JEWELL:

There are Australian water quality guidelines, but they don't cover the range of things one comes up with.

Rod HARWOOD:

Correct. As scientists we want a number: ''Please give me a number that I can feel comfortable with!'' But is that the real answer? Sites are different.

Chris JEWELL:

Is there not work taking place into lowest observable toxicity levels?

Chris BARBER (CSIRO Division of Water Resources):

A lot of people will develop the argument, ''Where is the real health risk data?'' We have four or five chemical compounds that we know about, but we can identify human carcinogonesis. Everything else is based on rats and anecdotal information in laboratory studies and observed data. It is a real ''red herring'' area and a difficult one, but somehow we have got to try to grapple with it.

I think we are looking at starting with the soil quality guidelines, to become a framework or point of reference. Then if we find major problems with those at a particular site we could start considering risk-driven strategies. I think that might be the way we will end up heading.

Marlene BENNETT:

It is important in setting our priorities that we put our resources into those areas of highest risk. I think we are in the kindergarten in the area of risk evaluation methodologies. It is all very subjective at the moment. I agree that there need to be some guidelines, but we have to be careful how we go down this path from the kindergarten into a more advanced stage.

There is a lot of inadequate understanding around. The example of how many milligrams of soil a person consumes a day assumes that a 2-year old is able to climb over a 2 m fence and stays the weight of a 2-year old for 70 years! There are a lot of assumptions in these models that are not understood.

I think the important element is that if we are to move ahead with remediation and proper environmental control, we need to have the community participating in the process. To explain some of these risk evaluation concepts to the public and the concerned communities is a major task ahead of us as professionals in this area. I would like to put that into our thinking process.

Rod BANYARD (Water Authority of Western Australia):

In terms of risk assessment, if we are talking about target levels or cleanup requirements relating to the site, there are commercial advantages and disadvantages for people who come to an area after high value water resources have been developed. It is a matter that some companies would take issue with.

Are we dealing with existing sites, or are we also proposing risk assessment for anybody who causes pollution in the future? If there is a mandatory cleanup for new pollution, there is a very good incentive for companies to be responsible about avoiding contamination in the first place. A mandatory cleanup requirement for future pollution could be a very powerful policy tool.

Greg DAVIS:

A mandatory requirement for pollution sounds a little risky. It seems to me that these risk-based assessments, and assessments in general, are becoming much more site specific. It is at that level that you deem whether there is potential risk for some of these contaminants. If we take the dissolved plume that we saw earlier (Davis & others, this issue), the risk is to completely pump those sorts of concentrations out of the ground and perhaps for somebody to use it as drinking water if there are no domestic supply wells in the area. But you have very high levels of benzine and those numbers are a worry. As for a mandatory requirement to clean up that contaminant, you would need to assess that against the dollars that you are charging society for that cleanup.

Rod BANYARD:

I was thinking more of the service station pollution occurring tomorrow rather than an historical case where possibly the rules have changed. How do you make a service station behave, and how will you accept that the pollution will not continue?

Rod HARWOOD:

I think you have had direct experience of this in Western Australia in your groundwater protection zones. The statement by the EPA in regard to looking at secondary containment of underground tanks in that particular area is one approach. I think we need to be aware that when considering the leaks and losses from service stations we could probably account for 20% or less from tanks. You will have to enclose all the lines and fill points. You can have A1 protection, you can put in protection monitoring wells... I do not know that putting potential hazards into a cotton wool ball is the right long-term approach. I think that it is important to put adequate monitoring and detection in place.

The USEPA uses a very simple model. Assuming an aerobic environment, they use the model to determine the degradation rate of benzine and other contaminants off the site once the source has been removed. On the basis of that simple model, the USEPA has cleared various sites for closure and the remediation doesn't need to go forward.

I think that it is fairly dangerous to put in these mandatory requirements when there may not be a risk. We know that petroleum and organics are hazardous, but unless we have an exposure pathway that gets to a receptor, there is no real risk to it. You may need to do soil column studies, but as long as you can demonstrate degradation, perhaps you don't need to go to cleanup. That is the way I would like to see it happen.

Greg DAVIS:

The best polluter-pays principle I know is to have what was spoken of earlier — the double line tanks and so on. If you do that first up, it is a lot cheaper than trying to clean up at the end of the day.

Rod HARWOOD:

In fact, risk assessment is used overseas, before the event, as a proactive tool to determine what needs to go into place. Given the volume of contaminants on the site, the potential for leakage and the overall risk characterisation of my site, then that defines my monitoring program. The risk assessment process is integrated into that early planning in a lot of sites in the United States and Europe. I think that you can use risk assessment before the event and not after the event.

Marlene BENNETT:

I would add that it not just overseas. This is a key part of management strategy — to look at response strategies and at prevention strategies. The same applies to waste management in that you are looking at waste minimisation — not just at the end of the pipe but farther up the pipe. That is a key part of the overall picture we are discussing. We don't want to be left with the mess in the aquifer and just looking at that risk.

Evaluation of treatment technologies

Chris BARBER:

I would like to introduce the question of data uncertainty when you are dealing with monitoring and evaluation of any alleviation exercise. To evaluate a site properly or to get a statistically significant result you probably have to take out the whole site to a depth of some 20 to 30 m to be sure you know exactly what is there. You will always have the problem of uncertainty and whether you have got down to a particular cleanup level; whether you are talking about a risk assessment approach or whether it is just a straight standard.

Rod Harwood emphasised the need for more long-term monitoring of a particular site, and maybe a second look at some stage to ensure that the site is as clean as originally intended. Perhaps he would like to comment further.

Rod HARWOOD:

I agree and would add to what you have said about data uncertainty. That is the science ... or the art! All our cleanup programs have to be statistically valid or documented to be true. There is no question that it is a statistical exercise. No practitioner would be game enough to say "This particular site is totally clean!" You need to base your observations, correlations and final cleanup options on the statistical database published in the literature.

The USEPA under the Solid Waste Manual 846 goes into great detail in terms of that ongoing monitoring and the statistical database that is required to give you a 90–95% confidence level in the data. It will even indicate to you, using the Nebraska model, how many more data points you might need to get to the confidence level to close the site. It is very much a statistical science. Maybe we need to bring another professional group, the statisticians, into this environmental field to help us do it better.

Greg DAVIS:

It is quite a difficult task to prove up a site statistically. You need 30 replicas of the same site for a statistician to be happy that you have done a good job. I am not sure whether that was the point Chris Barber was getting at when he said that you need to dig the whole site out to be sure that you have done some good. Certainly, you need some reliable monitoring. I am not sure where the actual level is, but I am a bit sceptical on this point. Certainly, a statistician would require an awful lot of information to prove up a site, and that might be a bit hard to deliver.

Marlene BENNETT:

There have to be some guidelines in this area!

Rod HARWOOD:

There are!

Marlene BENNETT:

Crucial issues are involved! How do you know that you have a contaminant, and at what point of compliance have you exceeded that value? That can be a condition of a permit to operate. Often that is a trigger for remedial action. Therefore, you have to be certain. You do not want to be caught arguing whether you have triggered. You want to be able to get on and do something if it needs to be done. The next thing is to be clear that you have cleaned up — defining cleanup standards in ways that include references to the appropriate methodology, both for sampling and for analytical purposes. It is amazing the different answers you can get as to how to go about doing it.

Tom HOWES (Department of Primary Industries & Energy, ACT):

We have heard a lot about the technical options for remedial work. Do you see any scope for changing land-use practices in terms of remedial technology?

Rod HARWOOD:

That is a good point, and I think the question is related to whether we can come up with different closure goals or remedial strategies, depending on whether we are aiming at residential, commercial or industrial end-use on a site. I don't think that we in Australia have grappled with that issue at anywhere near the confidence that we need. The ANZECC guidelines appear to be focussing on the residential end-use. When we go to less sensitive end-uses, risk assessment as a process has got much more validity.

There are a whole range of sites where the consultant or regulatory body have to sit with the EPA and discuss, under an industrial end-use scenario, what are the exposure pathways, who are the end-users of the groundwater, who will touch the soil, can we landscape the soil, can we cap it, can we contain it? We are developing a lot more flexibility and creativity in the remedial process. I don't know that ANZECC has grappled with that in enough detail.

Tom HOWES:

I was thinking chiefly of the rural areas where you have

more land options and are dealing with changing crop types or feedlots, and change your land-use practices to meet those things.

Rod HARWOOD:

I don't have a lot of involvement with the feedlots. Are you saying it is impractical or should be put into the documentation to say "Thou shalt not do this in future at this site?" I am not sure what you are saying.

Tom HOWES:

We have looked at cheap as well as at expensive technical options. Rather than just technical options, there is the chance of varying land use.

Rod HARWOOD:

Maybe that is important, particularly when there are so many sites throughout the country where they are documenting major dramas. It would appear that the cost of cleanup of all those feedlots would be an horrific burden to the taxpayer.

Marlene BENNETT:

I can't comment on the rural scene, but I think that some management options are cut off if you do not allow some change in land use. Containment is one classic case where if you want to properly contain material on site, you will have to restrict land use to ensure proper capping and containment.

Richard EVANS (Rural Water Corporation, Victoria):

I have a question for Rod Harwood who quoted the "Wall Street Journal" earlier. The impression we have had from groundwater editorials over the past couple of years is that cleaning up DNAPL (dense non-aqueous phase liquid) sites is absolutely useless, that it has rarely worked, and that it is a great waste of money. You said in your presentation that the Australian ethic was to give it a go, implying that you think it will work. Have you much hard evidence that, with all the money being spent, it will work?

Rod HARWOOD:

That's a good question. I think that we need to subdivide the DNAPLs in terms of whether they are volatile, chlorinated VOCs, or whether they are coal tars, which appear to be the two main types that we deal with in Australia.

You are talking of non-aqueous phase, of free liquid DNAPLs. The recovery of chlorinated solvents in a DNAPL phase under the aquifer has had good results — not in the Australian context, because we haven't done any, but in the United States they have had very good recovery of DNAPLs. They have used a dual pump system which operates differently from the LNAPL (light non-aqueous phase liquid) pump system where you have a water pump on the base and the product pump on top. When you take the water off, you release the pressure and the DNAPL flows into the recovery well. I don't expect you to be totally convinced by what I am saying, so I will give you some test cases that we have been involved in where that has been successful.

In one of our air sparging jobs in the United States the focus was chlorinated solvent. It sparged very well in the ground, with a cleanup within 60 days of elevated chlorinated solvents.

However, the coal tars are a difficult area. They are trying to develop heated systems to increase the viscosity of the material. In research studies they are using radio antennae in a recovery well to transmit radio beams and to do whatever they can to get the stuff to migrate. I think that the coal tars are very hard to clean up.

Marlene BENNETT:

Perhaps I may add to that. Rod has rightly commented on some of the difficulties in cleaning up DNAPLs, but one of the main difficulties is finding them, because they are distributed in such a complex way in the subsurface.

We are doing some research in this area and proving methods on the surface of locating some of these things. If you can locate them, identify the plumes and remove the free phase, your problems with the dissolved DNAPL continuing in the aquifer will be reduced.

Future directions

Ian ACWORTH (Water Research Laboratory, University of New South Wales):

What is the potential for destructive technologies?

Rod HARWOOD:

I think the potential for destructive technologies is very good long term. For the water phase, I think advance oxidation has a real place to play in future, either on its own or with peroxide. I believe thermal desorption has a big part to play for soils, although it will have trouble getting permitting. It will be good for the light volatile organics in soil, and we probably should use it. If you can roast the soils and destroy them, you have taken care of the problem on site. You don't have to sit down and say, "We don't know whether we can get the closure, we are not sure whether we will clean it up with bioremediation within that four-month period." It's a quick fix!

Destructive technology will obviously have a place to play in the future. It goes back to Lucy Lytton's comments earlier about the permitting, which is a real issue. Even bioremediation in a classical engineer treatment cell had permitting problems in the early days, because carbon dioxide was coming out. That is now acceptable! Thermal desorption, high temperature incinerators have more and more problems associated with their off-gas. Considering the number of contaminated sites around the world, I think all the destructive technologies will have a real place to play. My opinion is that a lot more work should be put into the actual off-gas treatment.

CHAIR:

How much effort has been put into chelating techniques? I am aware of some very good techniques that have been employed. Provided it is in solution, you can almost design your own protein in a high surface area and extract metals very successfully — among other things, cyanide, which is a fairly expensive commodity in treating gold.

Rod HARWOOD:

Cyanide would work well with the oxidation process.

CHAIR:

Has much been done in remediation with chelating techniques?

Rod HARWOOD:

The standard answer is ''Oh, they are metals, they're easy!'', but I am sure that is a way of avoiding the real issue. A lot of process technology has come out of heat leaching in mining, and that is used in metal remediation, but I think that we have a long way to go. I admit that we as a company have a fair way to go. My perception is, that we tend to say, ''Well stabilise it and we'll throw some lime in or some cement material or stabiliser!'' I think that the metals area is a huge one for development. We have to extract the knowledge that is in the mining industry and apply it to contaminated sites much more effectively.

Perc WYLES (Sydney Water Board):

A matter that has not been discussed very much is the cost of doing these things, and that if you cannot do them at the right price, nothing will happen. You could have a stepladder clause to the effect that ''This site has horrendous problems, but you can change the land use to another if you improve it by such and such an amount''. You could then improve the site progressively, in steps, whereas the cost would otherwise make it prohibitive to have a go at it. The cost doesn't seem to have been valued as a deterrent as much as it should be. A lot of people will not go near a certain piece of real estate if it is to involve them in great cost and they know about it beforehand.

Marlene BENNETT:

Do you mean take a number of steps progressively? Is that what you had in mind?

Perc WYLES:

I think that every time land changes ownership, or every time the owner wants to change the use of the land from a small service station to one of these massive ones you see on expressways, then he has to put in so much effort that will bring it closer to the desired or acceptable standard. It might go through three owners or through different land uses in the same ownership — who knows?

Marlene BENNETT:

I think that one has to be a little careful about that. There are a number of ways in which you can make some improvement, depending on your measure of quality, and then make the next step harder. If you strip the volatiles out of a material by fairly easy and cost effective methods, then you reduce the total, say, hydrocarbon load on the system, but are left with the more intractable waste — the heavier material, with changes in viscosity and everything else that make it harder to handle. In some cases that may be an appropriate strategy, but I wouldn't like to see it as a remedy to be applied broadly.

Ian ACWORTH:

In terms of future directions, is there any move via legislation to put further restrictions on, say, building new petrol stations or new plants to try to stop things such as we have been discussing?

Greg DAVIS:

I would instance the Western Australian situation where the Water Authority has brought in restrictions for the building of service stations on priority areas and groundwater resource areas.

Ian ACWORTH:

You mean they just will not let them build there?

Greg DAVIS:

Not in those priority areas. I guess there are different levels of restriction on some of those other areas.

Rod HARWOOD:

Industry does a lot on its own as well. In a lot of ways the oil industry is pushing a long way forward, ahead of any regulations in Australia. We could say they are all good citizens, that's why they do it, and that could be the reason. But it is also because they are part of major multinational companies with parent companies in the USA where these regulations have been in force for some time.

We are seeing a lot of industry-driven changes in the building of service stations. We are now seeing fibreglass tanks and lines going in. They are now putting in overfill protection boxes. If someone puts 50 000 litres into a 20 000 litre tank, then there is the facility for that product to be redirected down to another tank, and so on. There is cathodic protection on all the steel tanks. The industry is embarking on hazard rankings of their sites to determine which are more susceptible to problems. They are testing sites where the tanks are of a certain age, so that they can avoid the high environmental costs of any problem.

There is definitely a very strong industry group that is also leading the way with good detection systems and monitoring wells, not just in tank pits, not just into the groundwater system, but into the lines that feed the product from the tanks. It is all part of a much more integrated storage systems management approach that industry is driving.

I reckon the future is good. Obviously in Perth where there is the Gnangara Mound and other features that have got to be protected, perhaps they should be a little more stringent. But industry is doing a lot.

Greg DAVIS:

The only cautionary note on that one is that most of the storage tanks are privately owned. Perhaps the bigger companies are being reasonable corporate citizens nowadays in trying to limit their liability by cleaning up or perhaps reducing the number of service stations they have, but a lot of storage facilities certainly need consideration.

Rod HARWOOD:

One point to bear in mind is that even though there are a lot of sites that are not owned by the major oil

companies, but by freeholders, the oil companies still supply the tanks with their fuel. The oil companies have a responsibility to the tanks and part of that responsibility involves the cleanup of any problems that have been caused.

Marlene BENNETT:

In the case of wastes, of course, it is clear that the philosophy is that the fact you have passed it on to somebody else doesn't remove that liability. You have a responsibility to ensure that what is happening down the line is according to the best standards and appropriate guidelines.

I would like to add to Rod's point about changes in industry practice. It is not only in the area of engineering controls, but also very much in the area of training. A lot of things that go wrong are due to human error. A lot of effort is going into better procedures and better training in organisations. It is changing the whole culture. Just as we are changing the whole culture in the community in recycling, we have to do the same for employees in these sorts of industries.

Chris BARBER (CSIRO Division of Water Resources):

The USEPA last year got together a number of industrialists who had cleanup problems. They identified that the single biggest cost item in cleanup was the monitoring and the evaluation rather than the treatment method. They put a plea to the EPA to develop more efficient methods for monitoring and evaluation. Perhaps the Panel would like to comment on that.

Greg DAVIS:

I have to agree!

Rod HARWOOD:

It surprises me that they would be spending more on monitoring than on cleanup. If you include operation and maintenance of a cleanup system in the cleanup, then I have a few problems with that. In terms of detection systems for leaks from tanks and lines of hazardous chemicals, petroleum or whatever, then I think that technology does have a long way to go. In Canberra for a while, continuous monitoring systems were put into the tank pits.

As a company we marketed our own continuous monitoring systems several years ago. We had a vapour detection unit and a liquid detection unit. I would say that in 1993, the technology is still not 100%. False alarms are the major problem. A lot of these detection systems have been hooked up with telemetry. An engineer or plant operator has a board in his office with about 15 lights, and when there is a vapour reading or liquid reading, the thing alarms. Often it is turned off because of algal problems, the bacteria, slimes and everything else. Overseas, the variability of climate, with snow and ice in the vapour phase detection units, is more of a problem.

A lot of companies are going forward with this technology at the moment, but I personally think that the technology has not got to where it should be.

Summation — current regulatory guidelines

CHAIR:

At this point I will ask Marlene Bennett to comment or sum up our discussion on regulatory guidelines.

Marlene BENNETT:

I offer just a few personal comments on things that impact on this area. One of the important ones is having a system that enables us, as communities, as institutions and as a country, to set reasonable priorities.

There are two important areas that we have to consider. In setting our priorities we cannot just take just one part of the environment. We have to look at ongoing input, and source reduction has to be one of our high priority strategies. If there is an ongoing input, turning off the tap is the first thing to do, unless an urgent response is needed through some effect where you have to assign that priority. But there are situations in which you really give priority to something else other than turning off the tap.

It is important to look at spill response, spill prevention and waste minimisation, and these should not be given some lower priority because certain issues have blown out of perspective. If we still have a leaking underground storage tank, the last thing we want to do is just pump and treat the groundwater. That doesn't make sense technically, nor is it a good use of resources.

The other area is that of past legacies of pollution. Clearly in the past we had waste disposal practices that are no longer acceptable today. I think industry and the community are coming to terms with domestic landfills. Coming to terms with looking at past waste disposal practices may perhaps give us problems, and we shall have to look at them. The first thing to do is to assess them.

Then, knowing what is there, we have to see what the risk is. I think that this is a three-step process. It is not straight into the process, ''Yes, we did this, therefore it is a problem!'' or ''There was a certain industry or practice, and it is a problem!'' Certainly, it can highlight an area for assessment. What is there, and is it a problem in the light of the factors we have been discussing?

We want to make sure that our expenditure in this area will give maximum results for what I hope is the mutually agreed aim of protection of human health and the environment. That is what we should all be committed to, and working towards.

We also have to remember that while soil and water are very important, they are only part of the exercise. We also have to consider air pollution. We have in the past cleaned up soil and groundwater by putting it into the air, and we have got to consider all the media. We have to set our priorities about air pollution sources versus some of the other environmental issues.

The other point I wish to make, which I think is relevant to this guidelines issue, is the problem of the moving

goalposts. I think that this is a major deterrent to moving ahead to cleanup, and to coming to grips with the problem in this country. We have to have remedial action objectives upfront and clear. I have been involved in some international operations, not under Australian regulations, where very considerable resources, in time and in money, have gone into assessing problems, carrying out feasibility studies, and clarifying the way we want to go. And then we have to put in a document for approval, without really knowing what the guidelines are, and whether any consideration will be made of land use or aquifer class. It is trying to shoot at a totally unknown target. We are lucky in Australia, and I hope we will continue to have an arrangement where we can work together to negotiate what are appropriate criteria to set up, so that we can help to choose the technology. Without knowing the goalposts, you can't make a good choice of technology. You can't even have a feasible, workable technology, let alone an economically viable one.

I think that the other problem with guidelines is the whole liability issue. While we don't want to get caught in the litigative atmosphere that applies in countries such as the USA, we have got to sort out some of these legal and liability issues, otherwise we will not be able to move forward constructively.

Summation — evaluation of treatment technologies

Rod HARWOOD:

We shouldn't be defeatist! We should be proactive! We should look at the good things that we can do, and look at the evidence for a new cleanup technology to solve our problems. At the same time we should not eliminate technology just because it is old and classical and proven to be effective in the past. New doesn't necessarily mean better! We shouldn't be reinventing the wheel in terms of cleanup technology.

I wish to reinforce one thing. If we can sit down at a site and establish closure goals or an end point, we will be a lot further ahead than are our counterparts overseas. Marlene Bennett brought out the very strong point that you don't move the goalposts. We should try to establish what should be, with the best judgement, with the best tools, with guidelines, with risk assessment, with transport modelling. We have to establish the goals, set the objectives, and then allow the cleanup to go forward. Don't go midway through a program and then change your mind as a regulator or as a client. That's not good enough. We have to have the courage of our convictions!

Summation — future directions

Greg DAVIS:

It is obvious that there are lots of new technologies. Some are *in situ* and some are *ex situ*. In some cases sites have been excavated to try to deal with the problem above ground. I still think that there is a need for infill validation. That is to some extent what we are trying to do with the trial bioremediation exercise.

I am sure that there is a lot going on in this area in the USEPA. They now have active programs where they have gone back and seen that a lot of the remediation exercises were not successful or as successful as they would have liked. They have had to go back and re-remediate or reassess sites. I think that this will be another part of our future directions.

Another focus for future work will be the source — looking at the source and cleaning it up. You have the dissolved plumes and perhaps other features — perhaps a gas phase that for some reason is polluted. At issue is certainly the source, and perhaps an absorbed phase. You may have material that is totally stuck on to the aquifer matrix or soil material. Therefore, I think the focus in future will be very much the source, finding it and remediating it.

In terms of LNAPLs, we are probably talking about quite a thin zone of residual material as a source, and how do you deal with a thin zone where you are dealing with a range of weight fractions from zero up to about 26% by weight? This is a problem that you cannot pull out of the ground by just pumping. You have got a source there that you will have to deal with. Certainly you can dig it; you can try to remediate *in situ* with some of these new technologies. But there is still the issue of targeting this thin zone.

To move on to trying to determine whether you are doing any good, if you are targeting this thin zone then you will need some better, more efficient, monitoring tools. At the moment perhaps you have to do it less often or to use certain techniques that are expensive. You will need monitoring tools from which you can take readings more often and perhaps at less expense.

Let me give one example. We have put in place in our remediation exercise continuous dissolved and gaseous oxygen readings. We have oxygen sensors in place in diffusion cells at many different levels. This gives us continuous readout of oxygen levels, so we know how oxic or not our groundwater is at all times. You perhaps need more devices or techniques to monitor situations of that sort. The USEPA is monitoring these sorts of things and carbon dioxide levels to see whether they are being effective.

Rod HARWOOD:

It is not just overseas. It is being done in Australia too with gas phase monitoring.

Greg DAVIS:

What I am saying is that this is not just the gas phase above groundwater. It is actually monitoring the dissolved oxygen levels as well, which are notoriously difficult to get.

With regard to DNAPLs, it is not so much remediation that is difficult but finding a source. If we are to be targeting a source in future, LNAPLs are a little easier. At least you know you can look down to the water table. With DNAPLs it is notoriously difficult to find where the source is. This has been overseas experience, and even in Australia. Steve Appleyard gave an example yesterday of one that was found by accident, in terms of a dissolved plume (Appleyard, this issue). But source is still an issue. We have narrowed it down somewhat as to how to define the source and where the free phase is in the system, if at all.

I think soil gas sampling has some role to play, but with DNAPLs you have things moving much deeper into aquifer systems, so it is less useful perhaps than with the LNAPLs.

There is a need for new techniques, but more now in terms of trying to characterise where the things are in the system. If you are to try remediation, you need to be able to monitor these things, but I think there is still need for techniques to actually find them and map them in the subsurface.

CHAIR:

It has been a pleasure for me to chair this Panel discussion. Like the panellists, I also am involved in the bioremediation field. I think the standard of people involved in this field in Australia is very high indeed. I think we can look forward to learning a lot from other countries, particularly the USA which has gone a bit further down the track then we have. They have made their mistakes and we can learn from those.

I am fairly optimistic about where we are at as a country. On your behalf I would like to thank the Panel and people who have volunteered questions here this afternoon.