INTERACTIONS BETWEEN SCIENCE AND CURRENT GUIDELINES - CONFLICTS, WINS AND LOSSES

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Abstract

What do we call science? Several definitions can be found of the term "science" but they all emphasise the same aspects. For example:

> *Science: A branch of study which is concerned with either a connected body of demonstrated truths or with observed facts systematically classified and more or less colligated by being brought under general laws, and which includes trustworthy methods for the discovery of new truth within its own domain*[1].

What are the characteristic elements of guidelines? They have a purpose, means of achieving this and an origin of necessity, which has sparked an institutional initiative.

Purpose: to assist the public with routine activities in common situations which they may not fully understand; unusual conditions not covered.

Methods and means: simple technical instructions, simplified explanations, easily understood; scientific and factual backing to avoid challenges; usage of "must" and "shall" where instructions are mandatory, otherwise "may" and "should"; innovative solutions to problems permitted if ultimate goals will be achieved.

Institutional initiative: The perceived need. May include baggage such as authors' prejudices or misunderstandings and institutional political programs and biases.

There should not be conflict between science and guidelines, but for the baggage. Good science looks for integrity and objectivity and profound understanding. Politics operates on different premises. It seeks power to enforce its views. Good science can inspire and facilitate the development of new, reliable guidelines. For the purpose of this paper we may consider this a win when this happens. Where there is no scientific backing for guidelines we speak of a loss.

I will list a few examples taken from the area of on-site domestic effluent treatment and disposal.

1 Does Science Inform the Guidelines?

1.1 Using science to develop sizing methods for various means of effluent disposal

In Victoria, the sizing of effluent absorption trenches is based on the painstaking research of Dr Joost Brouwer at La Trobe University during the period from 1978-82. Brouwer (1982) monitored 13 operating septic tank systems located in a wide arc around northern and western Melbourne, covering widely different soil types and rainfall regimes with annual rainfall ranging from 460 mm to 1100 mm. He determined the water balances of the disposal areas in

[1] The Oxford English Dictionary

relation to site factors, such as soil type, soil permeability, etc., local site rainfalls and pan evaporation for the nearest meteorological station, and measured inputs into the septic system exactly. In cases where the septic system treated only toilet wastes, the cisterns were fitted with electronic flush counters. The ponding level of effluent in all absorption trenches was recorded to know the area of the infiltration surface, and the soil moisture suction in the surrounding soil at different depths, and beneath the trench bottom was measured. These measurements were carried out frequently throughout the year, initially at three sites daily, and from this data the long-term absorption rate (LTAR) was calculated.

Finally, the soil permeability, Ksat, of the soil within the disposal area was measured with the Talsma & Hallam (1980) constant head method with the formula modified by Reynolds et al. (1983):

$$Ksat = 1.65\ Q\{\sinh^{-1}(H/r) - 1\}/2\pi H^2$$

Here *Q* is the stable volume of water infiltrating per unit time into the soil around the test hole, *H* is the constant depth of water in the hole and *r* is the radius of the hole. At the time the sizing system was developed, *H* was set at 15 cm and *r* at 5 cm.

The linear plot LTAR and Ksat showed there was a rough relationship. By drawing a line below the plot one can select a design relationship between Ksat and LTAR at a greenfield site. This is how the design curve in the 1990 Code of Practice came to be. Clearly this is an excellent win, since septic tank effluent disposal systems had been installed without any demonstrated sizing method for many decades. Often, as in NSW, they were simply determined by the size of the available area in the backyard.

1.2 What informed the sizing guidelines of AS/NZS 1547: 2000?

Tables 4.2A1, 4.2A2, 4.2A3 and 4.2A4 contain the design loading rates and design irrigation rates for a range of soil conditions, expressed as soil categories, but defined on the basis of soil texture, soil structure, and "indicative permeabilities". Whilst these tables and the design loading rates were discussed *ad infinitum* during the meetings of Standards Committee WS/13/1, to the best of my knowledge, having served twice on AS Committee WS13, there is no documented experimental basis to these numbers. They seem to be based on consensus and negotiation.

A loss for science and not necessarily a win for the guidelines.

2 What has Science to Say about Phosphorus and Environmental Damage?

The contribution of nutrients to the environment, and especially to groundwater and water in streams, has been of acute concern to the authorities in WA for at least 2 decades. The large areas of urban development on the Perth coastal plain that were not sewered seemed to have ideal soils for on-site systems: they were very sandy and had very high permeabilities. However, Perth obtains much of its potable water from the aquifer underlying the sandy coastal plain. In reality, the soils are part of the problem.

A major study was commissioned in the early eighties and carried out by a large consulting firm, Connell Wagner, on the performance of on-site systems and their impact on groundwater. CSIRO carried out some studies on the movement and dispersal of nutrients below these unsewered areas and their impact on stream water quality in small catchments (Gerritse, 1995a,b; 1996).

The results of these studies caused several WA government departments to commission the main author of these studies to carry out a special study of the movement of phosphate in soils and groundwater with a view of developing environmental policy based on good data. The study was carried out for the WA Department of Health, the Water and Rivers Commission, Department of Environment Protection, and the Department of Planning and Infrastructure by Gerritse and published in 2002.

An illustration of the effect of the phosphate retention index (PRI) on travel time is given below in Gerritse's Figure 4. The effect of the reaction parameter b2 is shown in the next Figure. This reaction parameter decreases with increasing particle size.

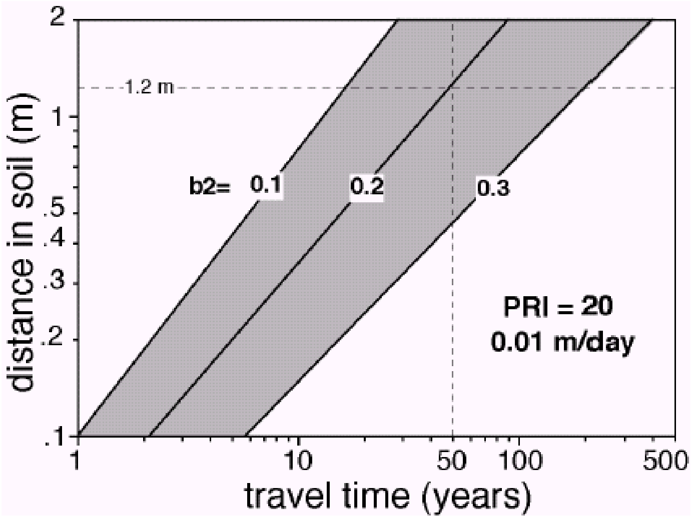

Figure 4 Times for distances travelled by phosphate in domestic wastewater leached at a rate of 0.01 m/day into a soil with a PRI of 20, adsorption parameter b1 of 0.35 and reaction parameters b2 of 0.1, 0.2 and 0.3 (Equation 5). A constant phosphate concentration of 10 mg/L P in the influent is assumed.

Thus, with a PRI = 20, adsorption parameter b1=0.35 (average value for WA soils) and reaction parameter b2 = 0.2 and an effluent infiltration rate of 0.01 m/day, it takes 50 years for the phosphate to move 1.2 m away from the source. This raises the question "What will be a suitable time horizon for environmental planning and environmental protection?"

The study contains several interesting conclusions.

- The velocity of P movement in soil and groundwater depends only on the phosphorus fixing (adsorption) abilities (PRI) of the soils and soil materials in contact with groundwater;
- Increasing the vertical clearance to the groundwater below a leach drain from 1.2 to 2 m can be expected to double the travel time of P to the groundwater;
- Increasing the infiltration area of a constant flow of wastewater has the effect of proportionally decreasing the leaching rate, and hence increasing travel time;
- Phosphate leaching from a septic tank system through soils with a PRI of 20 can be expected to move about 1.2 m in 50 years for an infiltration rate of wastewater of 0.01 m/day;
- At densities of septic tanks below 5/ha (i.e. 2000 m^2 lot sizes), inputs of nutrients can become dominated by other sources such as fertilizers, domestic pets, poultry and particularly horses.

Note that most clay soils, especially acidic clay soils, will have significant concentrations of extractable aluminium and iron and that the more of these are present, the more that phosphate will be retained. In the WA example these were known. The above now offers a scientific method of estimating PRI for soils other than the ones from WA as shown in the next figure simply by measuring extractable Fe and Al in the laboratory. This methodology of calculating travel times makes it easier and more objective to determine vertical and horizontal buffer distances for effluent systems to groundwater and to nearby streams.

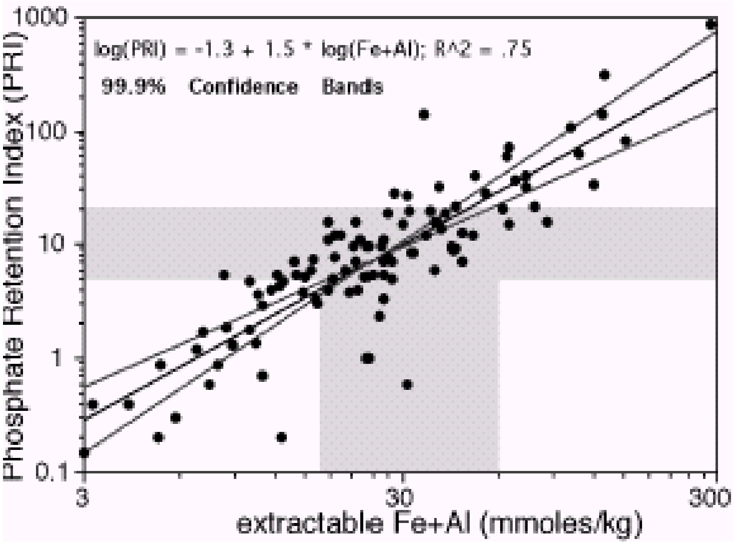

Figure 10 **Plot of PRIs against the sum of Fe and Al, extracted in 0.3 M ammonium oxalate at pH=3.5 for soils in cereal cropping areas of Western Australia.**

To the best of my understanding, Gerritse's conclusions are being adopted to develop policy in that State. An excellent win for science, especially considering the opprobrium that phosphorus enjoys in environmental mythology.

It reminds one of the multi-million dollar study commissioned by the USEPA in the late seventies and carried out by the University of Wisconsin under the title "Management of Small Waste Flows", published by the USEPA in 1978. This subsequently became the basis of the Design Manual – Onsite Wastewater Treatment and Disposal Systems. Because of this background, it would be hard to quarrel with the Manual.

The above raises the question why in Australia other regulating authorities do not commission more studies in areas where currently the guidelines are merely guessing. More wins are there for the taking. It will take some courage to abandon "common sense" and traditional views.

3 How Much Science is there in Site Assessments, or so-called Land Capability Assessments?

Site assessments aim at interpreting the suitability of a site from measurements and characterisations of site features and factors that are understood to have a limiting influence. These include depth to bedrock, depth to episodic/seasonal high water table, volume % of coarse particles such as stones or gravel, terrain slope, soil salinity, soil sodicity, etc.

Site assessments are typically an area where many operators have inadequate training and simply follow a cookery book procedure. Even site assessors with a university education, who should be able to follow a more critical approach, often follow a routine and do not ask themselves where the effluent will go after it has been discharged in a trench or other disposal system.

At the same time, Environmental Health Officers, Planners or State Government personnel often merely use, what they perceive to be common sense, to make judgements on the suitability of an area for on-site disposal.

These may not be well qualified to make a judgement on the work of the professional (?) site assessors where the issue is more complicated.

There is plenty scope here for disagreement between science and guidelines.

3.1 The effect of shallow perched water tables or seasonal water tables

One issue that frequently appears is that of the effect of temporary, short-lived, or longer seasonal perched water tables on the ability of a disposal area to function.

There is experimental evidence that absorption trench systems can continue to function if they are large enough and the perched water tables are not continuous for more than 3 months. By definition, a perched watertable has unsaturated soil below the saturated upper layer(s) and hence there is a hydraulic gradient and continuing vertical drainage, which, over time, will remove the saturation. Brouwer (1982) showed that episodic waterlogging of the upper soil did not cause an absorption trench system to fail if it had been sized appropriately and if the waterlogging did not continue for more than 3 months or so. His observations included periods with very high rainfall, equal to or higher than the 90% high monthly rainfall. Van de Graaff and Brouwer (1999) highlighted this in the 1999 Proceedings of the Armidale On-Site Conference.

Brouwer's results are a win for science as they elucidate the processes at work. The combination of two unrelated kinds of water tables in a single assessment criterion in a guideline is a major loss for science. It perpetuates erroneous thinking in a vital area of on-site effluent disposal.

3.2 Effects of soil salinity and soil sodicity

In these soil features one can discern a major defeat of science in NSW and Victoria.

Both the Victorian EPA Information Bulletin #746 "Land capability assessment for onsite domestic wastewater management" (2001(a)) and the NSW Environment & Health Protection Guidelines "On-site Sewage Management for Single Households" (1998) contain criteria for salinity and sodicity. The former states:

> *"Sodicity describes the sodium content of the soil. The higher the natural sodium content of the soil, the less stable the individual aggregates, and the lower the capacity of soils to take and treat domestic wastewater."*

The salinity criterion in Bulletin #746 is not explained, but in the NSW guidelines defend the use of the soil salinity criterion on the grounds of its impact on plant growth and that of sodicity on soil structure.

Sodicity should be defined as the degree to which exchangeable sodium occupies the soil's cation exchange complex and it is expressed in terms of the exchangeable sodium percentage (ESP), never the "sodium content". A saline soil may or may not be sodic. A highly saline soil, whether or not it has high sodicity, with a high "content" of sodium, has highly stable aggregates and good permeability. It is the combination of **low salinity** and **high sodicity** that ruins a soil for effluent disposal. More than half a century of experience with salinity and sodicity has bypassed this guideline.

However, if the criteria are compared, one could ask oneself the question of whether NSW and Victoria are located in the same country. Are plants in NSW up to five times as salt tolerant as plants in Victoria? Or are we suffering from an extreme case of provincialism?

State	**Criterion**	**Unit**					
Vic			Very good	Good	Fair	Poor	Very Poor
NSW			Minor limitation		Moderate limitation	Major limitation	
Vic	Salinity (Electrical Conductivity, EC*)	dS/m	<0.3	0.3-0.8	0.8-2.0	2.0-4.0	>4.0
NSW		dS/m	<4.0		4.0-8.0	>8.0	

**) The method of measurement of EC, whether in 1:5 or 1:1 mixture of soil to water, or in a saturated soil paste, which is vital to the outcome, is not given. Please yourself.*

A bad loss for science.

4 Is Science Evident in Guidelines?

Should guidelines facilitate or encourage the user to increase his or her understanding? Many guidelines contain scientific references, either at the end of the document, or even at the end of individual chapters. The USEPA publications mentioned before are excellent examples of this. Having these can only have the effect of increasing confidence that the conclusions are sound. A great win for science. Let's compare a few guidelines.

	NSW *On-Site Sewage Management*	**Vic *Code of Practice – Septic Tanks* 1996*)**	**Vic. EPA Bulletin #746**	**AS/NZS 1547:2000**
Total number of references	46	12	13	Nil as policy. References to other AS Standards scattered in text.
Scientific articles & technical handbooks	20	7	Nil	
Other guidelines from issuing organization	3	Nil	11	
National standards and guidelines, other general background	3	5	2	

*) References copied from 1990 Code of Practice.

EPA Information Bulletin 746 appears to say "Who on earth would want to check our guidelines for anything?" Or perhaps it is saying "Let's make it really hard for anyone to query and check any of the claims and assertions we present because we can't sustain them." Or "We make the law, you just do as you are told".

Strangely, the excellent scientific research in Victoria by Brouwer (1982) and Day[2] (1982) has never been acknowledged and used by the EPA. Science hasn't won this one yet.

[2] Day, K.J. (1982). On-site treatment and disposal of household wastewater with particular reference to sealed evaporation systems. MSc Thesis La Trobe University.

5 Common Sense and Science Versus Ideology

It is a good ecological and environmental principle not to waste any resources unnecessarily. Therefore, it could be argued that household effluent should be treated so that it can be used beneficially for watering the garden and feeding the plants with the nutrients. It can also be argued that at times when natural rainfall is adequate, the valuable treated effluent should be stored.

In NSW and in Victoria, the regulator recommends storage of treated effluent for irrigation when rainfall is deficient. Along the high rainfall east coast areas, this implies very large storage capacities, and then, once irrigation becomes possible, one needs also very large irrigation areas so as not to overload the irrigated land with water en nutrients. For example, in the greater Melbourne area, towards the Mornington Peninsula, the Victorian EPA guidelines (2001(b)) state that no irrigation is needed during 240 out of 365 days in the year. Thus, simple arithmetic dictates that for a 3-bedroom house with a daily effluent production of 1000 L of effluent, the storage should be 240,000 L. What this means is illustrated.

What this also means is that significant resources in terms of steel, concrete and energy – energy to create the concrete and the steel from raw materials and energy for the pumps - and land have to be sacrificed to serve one particular environmental objective. In my opinion, there is a lack of balance in these environmental sums. To insist on such a guideline is an issue of ideology, not science. Finally, it also means a lack of common sense. Tanks of these industrial sizes are extremely costly to build and costly to maintain. No common citizen with an environment-friendly disposition would have the financial resources to build one. Therefore, the government resources to develop these guidelines and to print them would seem to be another waste that cannot be justified.

6 Conclusion

There need be no conflicts between science and guidelines, but at times they do occur.

Science can only win through persuasion, open debate and with open minds; but prejudice and closed minds can appear to temporarily win some battles by sheer stubbornness, but they cannot win in the end. It has taken close to 400 years for the mighty Catholic Church to formally acknowledge that Galileo's views on the Earth revolving around the Sun were correct; never lose hope!

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