FORTY YEARS IN THE BLACK STUFF

"*Those who cannot remember the past are condemned to repeat it.*" (Santayana, 1905)

Evans, T. D.[1]
[1] TIM EVANS ENVIRONMENT
Tim Evans Tel. 01372 272 172 Email tim@timevansenvironment.com

Abstract

This paper is a retrospective of the last 40 years during which a lot has been learnt about the treatment and land application of biosolids and other organic resources. Starting with the statutory "Guidelines" (1976) through the Sludge Regs (1989), Quality Assurance (1989) and the Stakeholder Agreement (1998), controls have improved but the future depends on confidence and that is a house of cards. The stakeholder agreements were a milestone but do all parties apply their spirit all of the time? Is CATNAP (Cheapest Available Technology Narrowly Avoiding Prosecution) still a prevalent mentality? We have done a lot of science and have a good understanding of the risks and benefits and fate and behaviour of the constituents of biosolids and other organic resources. Phosphate has emerged as a prime sustainability criterion. We are exceeding the earth system boundary for phosphate by 5-times and for fixed reactive nitrogen by 6-times; this could be an opportunity. New treatment processes have been developed; some have disappeared again whilst others have proved their worth. The adage, *buy cheap, buy twice*, has been proved time and again. HACCP could have been a boon but has the lesson of "failure mode analysis" really been learnt? If something can go wrong it probably will. When the Engineer's Representative was asked (nearly 40 years ago) how much the first big London sludge to land contract was going to cost he replied "it will cost what it costs to do it right". We still brought the contract in on budget. Land application has a future if we remember the past and learn from it and if we spend what it costs to do it right but if the house of cards collapses, the alternative will be very much more expensive.

Keywords

branding; confidence; field trials; ground truth; HACCP; market research; odour; quality assurance; rheology; recovery; recycling; selling; stakeholders

Introduction

Soil Science was a wonderful grounding for a career in biosolids. My research progressed from the reasons phosphate availability is low in strongly weathered soils from Brazil, which are chemically relatively simple to the interfacial electrochemistry of synthetic hydrous iron oxide, an even simpler model system. The black stuff was a whole lot more complicated but the principles of Soil Science applied and helped explain what was happening.

I joined Thames Water Authority, Metropolitan Public Health Division (MPHD) in November 1975; it was a time of transition. The largest of the sludge-to-land works was Perry Oaks, the sludge treatment works for Mogden (2 million p.e.). It occupied the space between the runways at the western end of Heathrow Airport (Figure 1). At that time lagoon-thickened liquid digested sludge

was hauled to fields during an intensive summer campaign in sealed 8-wheel tippers that applied it directly about 20 cm deep; apparently this was a reduction on earlier practise.

Lagoons were operated on fill-settle-decant-refill over a cycle of at least 6 years and there was a 6-month locked-off final settlement before emptying was allowed to commence.

The farming was mainly vegetables for the London market. The soil was deep loam-textured brickearth over gravel. Remarkably the only lasting damage was deep compaction from the massive axel loadings.

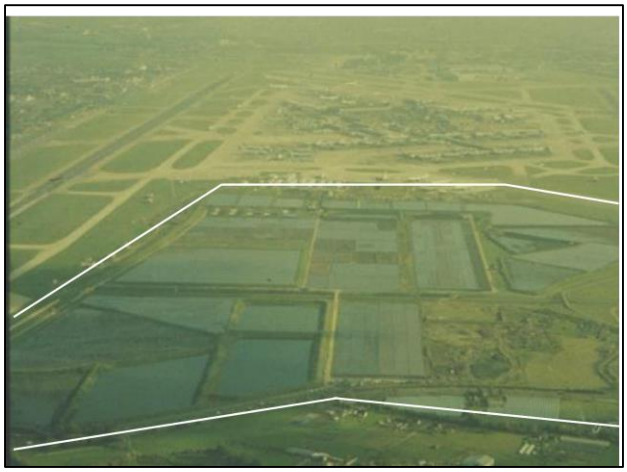

Figure 1: Perry Oaks in the foreground (outlined in white) with the drying beds in the centre, lagoons around the edge and the airport terminals in the background (looking east)

Figure 2: The old sludge application method (ended 1976)

No adverse health effects were found amongst farm families that ate produce from their farms (Sherlock, 1982) but other research had raised concerns about heavy metal accumulation in soils and the effects it could have on plant growth (Chumbley, 1971). The experimental design was flawed but set in train development of "The Guidelines" (DoE, 1976), the forerunner of the sludge directive (CEC, 1986) and regulations (Anon, 1989).

The question facing MPHD was "would The Guidelines spell the end of London's land application programme or could it adapt to them?"

Market research

Fortunately there had been quite a lot of monitoring of the biosolids, the soils and the crops. There had been no legal obligation to do monitoring, it was just defensive and because it was interesting scientifically. The data showed the soils in the historic distribution area exceeded the impending quality limits so if land application was going to continue, it was going to have to be on new land. I soil sampled along radial transects and found that over about 15 km from Perry Oaks the soil metals were very low.

There was no point talking to new farmers without some idea of the potential agronomic value. The biosolids monitoring data included ammoniacal and total nitrogen, phosphorus and potassium. The fate and behaviour of ammoniacal-N is the same as mineral fertiliser and the

organic-N undergoes mineralisation and nitrification just as 101 Soil Science taught; it was well stabilised so maybe 20% available in the first year and phosphate 50% available.

I cold-called farmers and interviewed them to find out what would be attractive to them, I now know this was qualitative market research. Farmers knew little about biosolids except that there had been stories about heavy metals and one area where stinking raw cake had been spread. They were interested in quick, controlled, even application, fertiliser and organic matter. We thought we could do that so wrote a fully itemised re-measured contract using ICE Conditions and recruited a team to manage it.

Selling & pricing

We had a large market to build and a lot of product to shift and decided that the price that would maximise volume was zero. The first head of sales was a very nice amiable raconteur but he did not appreciate that a salesperson has two ears and one mouth, which should be used in that proportion and he was incapable of closing a sale – he didn't get the ABC of selling - Always Be Closing. I ended up getting all of the orders so we got rid of the raconteur, I took over selling and eventually recruited Keith Panter to take half the area; what a relief!

There was no customer base so I decided that driving round the countryside armed with maps and cold calling on every farm that looked as if it had the potential to give a large order was going to be the best strategy. Fortunately nobody had told me cold calling was hard. It is easier to hang up on a telephone cold call than face-to-face. Actually farmers were quite welcoming. I got them to outline on the map the land they farmed and generally they were willing to refer me on to neighbours who would be likely prospects – "snowballing".

In 4 months from the start of the contract the fleet built up to twenty four 32 tonne tankers servicing six field 2-spreader teams and six 30 tonne tippers delivering cake to on-farm stockpiles. The remeasured contract included stoppage time which meant that failure to provide workable fields would have been a very visible KPI. The Specification included the livery.

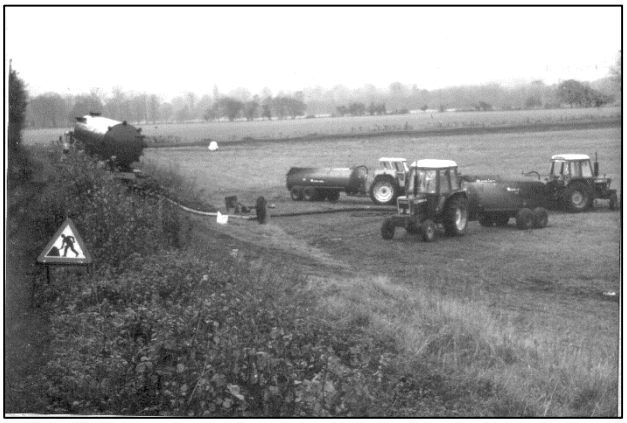

Figure 3: The first iteration of equipment, 1976

We learnt quite quickly that soil trafficability was key, farmers know their own fields but seldom if ever know how they compare with soil two counties away. We commissioned Soil Survey (now National Soil Resources Institute) to produce a map of five soil trafficability classes based on their soil database. Experience of this taught us there were some super trafficable soils which turned out to have a high gravel content as a common feature – class 0. The soil trafficability map overlaid with all the farm outlines became a very valuable strategic tool to target selling and manage haulage distance, which was another KPI because we paid by £/km.t hauled.

Equipment evolution

The advice to use 2-wheel drive tractors and tandem axel spreaders (Figure 3) soon proved inadequate for our scale of operation. The small diameter tyres developed high rolling resistance in soft soil and there was insufficient weight transfer to the tractor draw-bar so the wheels spun. After trialling many manufacturers' offerings and breaking some, we concluded that spreaders on large diameter super-single tyres with the axel set well back so that load was transferred to 4-wheel drive equal wheeled tractors (Figure 4) was the best combination to achieve a high work rate in all weathers and issued a Variation Order to the contractor to re-equip.

Figure 4: 4-WD equal wheel tractor

Even though the tankers had inclined barrels, the sludge was so viscous that they returned with 1t on board. The viscosity also meant that sludge was difficult to pump and did not flow readily in the lagoon where a difference of more than 1 m in the height of the surface developed between the location of the pumps and the opposite bank. The R&D laboratory of a cosmetics company locally very kindly let us test samples of sludge (which had been disturbed as little as possible) in their rotational viscometer. The undisturbed samples from the lagoon had a high yield value and then shear stress decreased with increasing shear rate (Figure 5), which demonstrated clearly that it was thixotropic and that stirring the sludge reduced its viscosity; this explained why manure pumps with external choppers worked better than ones that should have been more efficient. External consultants missed this entirely because they worked on two tanker-loads of sludge delivered to their laboratory; the process of loading the tankers thinned the thixotropy; if they had ground-truthed their rig results they would have seen they had not answered our problem. Standard pumping equipment became a submersible electric centrifugal pump and one or two submersible mixers to shear thin the sludge all mounted on a raft. This could pump 6 m^3/minute. The angle of repose was countered using a winched floating scraper that comprised two hulls with a hinged blade between them.

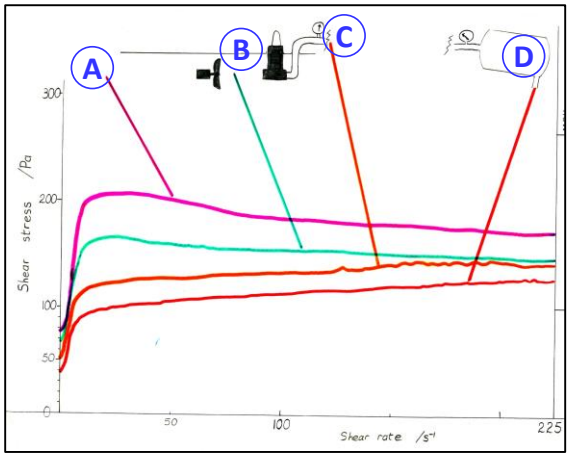

Figure 5: Rotational viscometer rheograms. A: undisturbed lagoon sample; B: between the mixer and the pump; C: after the pump; D: after 150 m of 150 mm pipe.

Having taken so long to decant water, adding water to lagoons was anathema and rainwater had to be removed before and during sludge pumping operations. We knew accumulated volume of sludge that had been pumped into a lagoon and the total volume of mass of sludge we had removed, we also knew the %DS and %VS but the masses did not balance. However we did get a perfect balance of the ash (i.e. the non-VS). During the course of lagoon consolidation there had been 15% VS reduction. No wonder it was stable and low odour but the climate change emissions (methane) must have been considerable.

With the second contract (1980-1983) we introduced self-propelled flotation tyred spreaders to the UK. These carried the load, which was even better than trailed. We also changed to sealed aluminium-bodied tippers that cleared their loads (Figure 6); use of Trakway to improve access, minimise soil damage and prevent mud on roads had been established during Contract 1.

Figure 6: The third iteration of equipment, 1980

Branding I

There are not many reputable people who run anonymous trucks. Branding is important for customer recognition, team cohesion and credibility. We chose Thames*gro organic soil treatment* as the brand. It gained a reputation for quality and service amongst the farming community. The name was later used for a topsoil business.

Knowing the product

In normal operations, biosolids were applied typically at 100 m^3/ha (10tDS/ha); the analysis was average 1000 mgCu/kgDS, 300 mgNi/kgDS, 1800 mgZn/kgDS and 60 mgCd/kgDS, very contaminated by today's standards. The routine soil sampling showed 62%, 47%, 47% and 19% recovery in subsequent soil samples of Cu, Ni, Zn and Cd respectively with 99% confidence by Student's t-test that the actual was different from the predicted (except for Ni which was 95% confidence). The fact that the recoveries of the elements differed showed that we were not just missing some sludge in the subsequent sample.

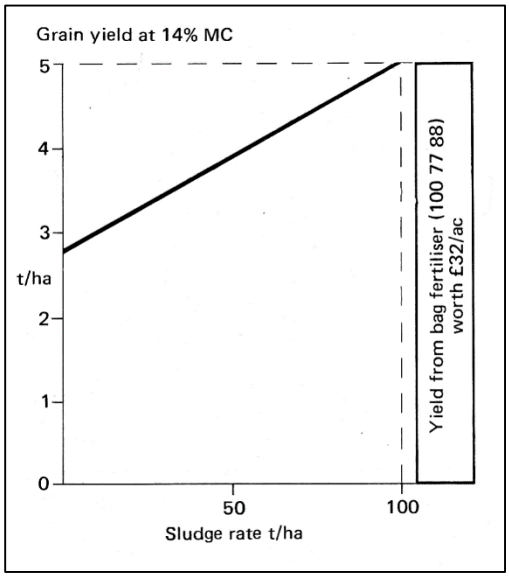

Figure 7: Field trial - Sonja winter barley 1979

A local farmer cooperated in field trials to assess the fertiliser replacement value of our biosolids (Figure 7). Yields look low compared with today's improved varieties but the trial showed fertiliser replacement worth £23/ha at 1979 fertiliser prices.

We also used the trial to assess effects on earthworm populations partly to test a hypothesis that it might be earthworms that were moving heavy metals around the soil profile so that we did not recover all of the previously applied metals in subsequent soil samples and partly because dead earthworms were often seen on the biosolids treated surface. The metal movement hypothesis was inconclusive but earthworms doubled in number and trebled in weight. Ammonia is a skin-absorbed toxin for worms so worms near the surface could be killed by ammonia in the biosolids but for those that were deeper in the soil, the biosolids became food. Biosolids don't kill earthworms; quite the reverse.

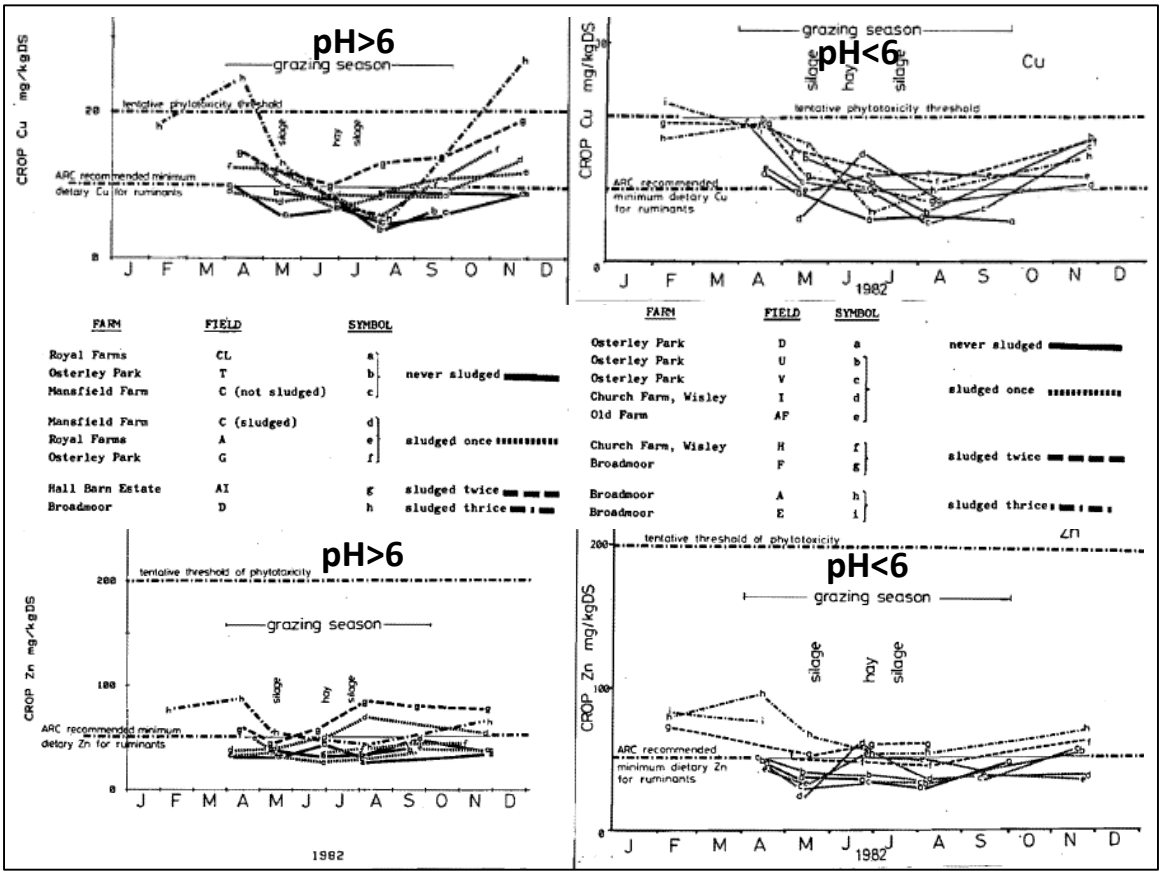

Figure 8: Analysis of herbage samples –addition had been 10 kgCu/ha.y and 1;8 kgZn/ha.y

Grass was sampled from fields treated operationally once, twice and thrice (never-treated field were the control,) and analysed for metals (Figure 8). The results show that time of year is critical, during the time of maximum growth the trace elements are diluted by plant dry matter. Grass from the control fields was frequently deficient in Cu and Zn for ruminant diets and some of the biosolids treated fields as well. Biosolids improved the dietary provision of Cu and Zn in the grass all samples. All were less than the phytotoxic limit for Zn and only thrice-treated fields exceeded phytotoxic Cu outside the growing season; not during it. This situation could not pertain with modern control and modern biosolids but it was interesting and reassuring to have the information.

We should have published the information and shared it but at that time I had not realised the importance of publishing so as to influence debate internationally. Also we were pretty busy keeping the trucks and spreaders rolling! Publishing is especially true in the Google-age.

Conclusions Phase 1

In 1982-83 we recycled 545,000 t/y biosolids (77,000 tDS/y at average 14.13%DS) at a cost (including our supervisory costs) of £31.90 /tDS. It was a lot of biosolids and we pushed the envelope but always within the Guidelines and the best practice internationally so that it was defensible. As Frank Truman, the Engineer's Representative, said when asked to forecast the outturn, "it will cost what it costs to do it right".

The Finance Department (which knew the price of everything and the value of nothing) decided we had created enough storage capacity and that it was not necessary to award a third contract. They did not think it mattered that our had-won market would wither.

Topsoil and Standards

A contractor had been blending air-dried biosolids and subsoil to make topsoil-substitute for some years and we decided to vertically integrate with this contractor, Thames and a landscaping contractor. The Thames*gro* name had recognition because it had been on many trucks and field equipment. Thames*gro* Land Management was Thames' first "enterprise" company. BS 3882:1984 "Specification for topsoil" only accepted natural topsoil and was so vague that landscape architects had their own pet specifications. I joined the BSI committee AW/20 to work on revising the standard and was soon chairing the drafting committee and eventually AW/20. BS3882:1994 and subsequent revisions has given equal recognition to manufactured and natural topsoils. This initial involvement with Standards led on to British and European standards committees for soil, growing media, soil improvers, fertilisers and sludges and was an access route to working with the European Commission on the technical background to legislation.

Biosolids resurrected 1989-1999

To make more space at Perry Oaks two more lagoons (450,000 and 500,000 m^3 capacities and 10 m deep) had been dug and the gravel sold. The plan had been to fill the site with lagoons, which given that the real estate value was similar to the City of London, was pretty crazy but it would have been business as usual for the local management. Heathrow Airport Ltd. (HAL) came to Thames and asked us to stop digging gravel out of the site and instead to empty it, at their expense, because they wanted to develop it into the fifth terminal so as to keep up with the traffic demand and keep Heathrow as the premier European hub airport. Winston Churchill had wanted to move West Middlesex Main Drainage and extend Heathrow's curtilage because he recognised that Croydon would not satisfy post-war air transport; WWII ended before he could do it under the war powers. Thames asked me to write the contract, recruit the team, liaise with HAL and manage the clearance. The offer was presented in a form that was hard to refuse "we might be able to find you another job if you really don't want to do it".

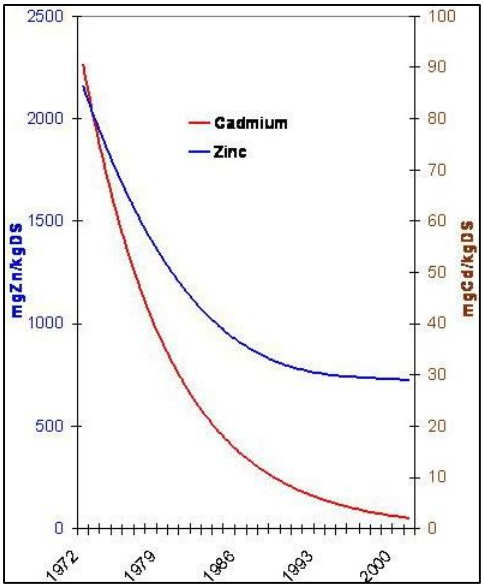

Figure 9: Modgen's feed to the lagoons

Phase 1 had been a good preparation. This time we were able to write a relational database to manage the contract and keep it on track instead of ledgers, pens and calculators. We could analyse progress more easily and present it more graphically. The contracts were completed on time and on budget.

The first 3-year contract looked similar to the second Phase I contract: Flygt pump and mixers, winched scraper, sealed tipping tankers, AgGator spreaders, Trakway, etc. There was the added adrenalin of being associated with controversial airport expansion and the potential scrutiny of the media looking to

make a scandal. HAL appreciated this and that every tonne of the oldest biosolids (25 mgCd/kgDS) out of the gate was important progress; we knew we would get to less contaminated sludge when we got to the newer lagoons (Figure 9). It was important to be squeaky clean.

At the time biosolids were being accused of having adverse effects on soil microorganisms, particularly nitrogen fixing rhizobia. HAL accepted the business case to get some pre-emptive information and after two false starts we established a field trial to measure yield response, effects on rhizobia and effect on the specific respiration quotient of the soil microbial biomass (Evans and Smith, 2012). The two false starts were because in the first two years we picked the wrong sites to hold the trials; the first site was infected with couch grass (Elymus repens) and the second had very high residual fertility following cabbages, both years we suffered from non-timely management because the research team tried to do the farming. Good results came when we sited the trials on the farm of a customer who specialised in running field trials (Figure 10). He did the farming, which he was on top of (being local) and very good at, and we did the experimental design; it was a superb team result.

Figure 10: The field trial; grass-clover on left and arable rotation on right.

Table 1: Fertiliser replacement factors derived from grass and arable field trial data

Time of application	August-October		November-February		Mar-Jul
Soil type	Sandy	Other Mineral	Sandy	Other Mineral	All Soils
$NH_{4\ surface}$	25%	70%	80%	80%	70%
$NH_{4\ injected}$	25%	70%	80%	85%	95%
N_{org}	10%	10%	10%	10%	10%
P_2O_5	35%	35%	35%	35%	35%
K_2O	90%	100%	100%	100%	100%
MgO	90%	90%	90%	90%	90%
SO_3	40%	50%	50%	60%	60%

The trial was operational scale (12 m wide plots) with triple replication and continued over 3 years. Lagooned liquid (which was older and had higher metals) and centrifuge dewatered cake (which contained polyelectrolyte conditioner) were used on different plots. The data enabled us to benchmark biosolids analysis into RB209 Fertiliser Recommendations and develop the availability model shown in Table 1. The results demonstrated that biosolids do not impair the nitrogen fixing ability of rhizobia, which we had also shown by ground-truth testing at a selection of field sites that had a spectrum of metal concentrations that should have shown effect had it been a general one. We had shown that rhizobia vary in their ability to fix nitrogen but that the variation was not related to biosolids history. Other countries inoculate legume seed with selected efficient strains of rhizobia but that is not common in the UK. The trial also showed that nothing in the biosolids (either single compounds or cocktails) stressed the soil microbial

biomass; this is the most sensitive test of adverse soil-mediated effect and it is non-specific, i.e. it would be triggered by anything. Indeed an approved selective herbicide and soil dryness both caused stress responses but biosolids did not.

Quality Assurance

In August 1989 Thames Water made the headlines because of little worms in the potable water supply. It transpired the sand in the filters had been skimmed for cleaning once too often and not replenished – the people who had been given early retirement knew all about it but it was not written down! Consultants with experience of the nuclear and aerospace industries were called in to advise how to prevent reoccurrence. Thames took their advice and implemented Quality Assurance for which we were early adopters. At the time most people in the industry thought it was a synonym for quality control. "Get it right first time and every time" was very appropriate for biosolids recycling. We built it into the management database that by now had a farming and quality module and a contract module that were interlinked. By 1995 it had become a distributed database with digital maps, which people had on their laptops and could update in the field with customers and then synchronise with everybody else when they got home or to an office.

Branding II

For boring internal company reasons (which demonstrated that senior management really did not understand brands) we were told to stop using the Thames*gro* brand so we created a new brand, TERRA *organic fertiliser,* for the Perry Oaks' lagooned liquid operation. The brand included our phone number on every truck, spreader and transfer tank so that if anybody had a complaint they could get it answered directly and quickly before emotion was magnified by frustration. Equally, if any potential customer wanted to find out about the service they knew where to phone.

Figure 11: Launching the TERRA organic fertiliser brand

Brand Stretching

The first addition to our portfolio was a new process, raw cake stabilised with potassium-rich alkaline cement kiln dust. We called it TERRA *lime-plus* and charged for it from the start. We pegged the price to agricultural lime, which we learnt subsequently was less than the market would bear because of the fertiliser benefits. We crept up the price but it would have been better if we had got it right in the first place. The second was raw cake composted with straw, which was handed over from R&D to us to manage. Naturally the name was TERRA *compost.* TERRA *soil-builder* covered land reclamation and landscaping.

As other operations came up to TERRA's quality standards they were brought into the brand and an umbrella brand was coined, TERRA ECO•SYSTEMS. It recycled 220,000 tDS [1.4 million m3/year] per year comprising every type of biosolids (apart from thermally dried) from 80 biosolids production sites in the most populous corner of the UK and treated 15,000 ha farmland per year, 200 ha land restoration per year all with 100% compliance with all legal obligations.

Income 1992

In 1992 a newly appointed Director gave us a target of achieving £100,000 income by 1995. TERRA *lime-plus* was just coming on stream but the income was less than £10,000 so £100,000 was a stretch target but we beat it (Figure 12).

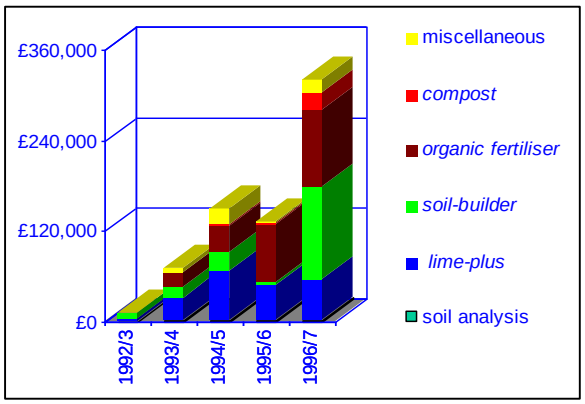

Figure 12: TERRA ECO•SYSTEMS' income growth

In August 1994 centrifuges were commissioned at Perry Oaks to cut off supply to the lagoons so that the lagoon clearance could be completed. To meet the income target I decided this new product was an opportunity and we would charge farmers for TERRA *cake* (Figure 13). There was push-back from a few farmers but most accepted it was still a very good deal, however paying customers were less tolerant of any service deficiencies. For new customers the price was supported by case studies written by an agricultural journalist in addition to the results of our field trials. The journalist, who wrote for Farmers Weekly and other magazines, managed to draw out from the farmers he interviewed the value of TERRA products to their farms' businesses. Several told him the cash value from increased yields and from reduced fertiliser, pesticide and seed costs.

Figure 13: TERRA *cake* application

There had never been an odour issue with the lagooned liquid but the cake was a very different matter. We started spreading in the week before the end of August and the stench ruined Bank Holiday barbeques etc. It transpired that stabilising the sludge had not been high on Production's priorities. If digester mixing or pumps broke, etc. the poorly digested sludge was still pumped down to Perry Oaks. In the past the lagoons had completed the stabilisation but high-speed centrifuges sheared open any poorly digested material and odorants formed, which were persistent and sorbed by fabrics. Other high-speed centrifuge conventional digested cakes also had odour issues though none as bad as that early Perry Oaks cake.

In September 1996 we launched a bagged multipurpose compost (MPC), growing bags and soil improver at the main trade exhibition (Evans and Rainbow, 1998). The principal objective was to demonstrate that members of the public were not faecally averse but would buy products based on "sewage cake composted with straw and other biomaterials" (as it said on the bags) to use in their gardens. I ran growing trials in my home greenhouse in 1994 and found a formulation that

performed as well as the brand leading MPC. Our director approved using consultants to progress to market.

Our waste management site licence was silent about the matured compost, i.e. it had ceased to be waste. Extensive monitoring showed that it conformed to the strictest requirements, which was the USEPA's Class A EQ and acceptable for unrestricted use including home gardeners. Alan Titchmarsh had used bags of TERRA *soil Improver* that I had delivered to him on Gardeners World TV programme. His water company's switchboard was inundated with callers asking where they could buy the products. When a delegation from the EA visited the site we had an adult conversation; they appreciated it was not necessary to restrict something that satisfied the most stringent standards internationally and had been used by "the nation's favourite gardener" on primetime TV.

Market research showed that gardeners liked the concept and would buy the product if it performed as well as their usual product but they would not accept inferior performance. It also gave pointers to elements of the bag designs that attracted customers. Gardeners would not pay a premium for recycled, peat-free, etc. but neither would they expect a discount. We sold to independent garden centres intentionally and in the first year had stockists in England, Scotland and Wales. Sales doubled year on year and by 2002 the venture was on track to achieve a profit over all costs including the composting. Most importantly it had proved its principal objective, people would buy biosolids to use in their gardens. Milorganite demonstrates the same thing in North America, it is a pity there is no such example in the UK any longer. The fast moving consumer goods market was very different from the bulk professional market that we had been used to.

A James Herriot moment

In about 1990 a farmer phoned to say calves grazing in a field we had treated were dying and his vet said it was lead poisoning from the biosolids. Sick calves had recovered when treated with an antidote for lead poisoning. The vet was from the Royal Veterinary College (RVC). The farmer had observed the 3-week no grazing limit. Analyses from our routine sampling (weekly composites) did not show abnormal lead in the biosolids that had gone to the farm and were 10-times less than the RVC's analyses. We advised the dairy company; milk analyses from that time were normal. Worryingly we had treated pastures at Windsor Castle that were grazed by the Queen's pedigree Jersey cows at the same time. It was not looking good. We sampled dung and biosolids from the field where the calves had died. Analysis of the biosolids was normal but the lead concentration in the dung was very high, however the concentrations of other metals in dung bore no relation to those in biosolids. The fencing was nice iron parkland fencing and the gateposts were 23 cm square timber painted white; there were some flakes on the ground and bare patches on the posts. The flakes analysed as lead oxide. The calves had been licking the gateposts. That was the cause of death. Unbelievably, the RVC had been using a very old colorimetric method and got the analysis wrong because of interference. Biosolids were innocent.

Stakeholders

In the mid-late 1990s the supermarkets (British Retail Consortium, BRC) were striving to address Campylobacter, Salmonella, Listeria, etc. and were looking at all the inputs to farming. Water UK organised meetings to discuss biosolids, the controls we operated and the crops we treated (no salads, strawberries, etc., contrary to the supermarkets' expectations). Incidentally

Campylobacter is back on the spotlight again. The BRC was satisfied that chemical risks were controlled but concerned that untreated sludge was permitted, albeit with injection or ploughing. The BRC Agreement was a milestone, it introduced conventional and enhanced treatment for sludge, HACCP, FACTS training and more. The BRC said they were happy with the new controls but if the biosolids producers screwed up or created a scandal they would have to sort it out, the BRC would step away.

At the same time the landowners were concerned that they were bearing the risk of some unknown or latent pollutant that could damage the value of their land, which many regard as being on loan from future generations. The Water and Sewerage Companies (WaSCs) refused to indemnify the landowners saying they could not get insurance and were not prepared to accept the risk themselves. Understandably some landowners refused to allow their land to be treated with biosolids.

Following the Agreement the question of what to do with the sludge from extended aeration was perplexing because the aerobic biomass would not dewater well so it would be difficult to compost or to lime stabilise and neither would it digest anaerobically. Umbilical injection had worked very well and with low odour but it would not count as “treated”.

Figure 14: TERRA *liquid* injection

Serendipitously Cambi called into my office to discuss their new thermal hydrolysis process (THP). At the time, Thames owned an equipment company, Simon-Hartley Ashbrook (SHA), Cambi wanted a partner to help expand, Thames Water Utilities Ltd (TWUL) needed an answer to its intractable untreated liquid, it seemed as if it could be the perfect match. THP looked too good to be true but I arranged party of representatives of the different interests to visit the first THP plant at HIAS in Norway and “kick the tyres” and find the weaknesses of the process. Nobody found any. SHA partnered with Cambi and TWUL bought a plant for Chertsey. This was going to be a very severe test; Chertsey had primary settlement, biological filters and 2 digesters, the objective was to treble the sludge treatment capability and treat extended aeration sludge from Esher and Leatherhead. Perhaps naively, I had anticipated that when buying a proprietary process SHA and TWUL would let Cambi engineer it but that proved not to be the case and consequently there were “teething problems”. Eventually Cambi was permitted to rescue the situation, refurbish the plant and operate it; it exceeds the original objective.

Defra promised to revise the Sludge Regulations (Anon, 1989) to incorporate the provisions of the voluntary agreement but it never happened because advice from parliamentary lawyers was that to do so and to include EA inspection fees would require debate in parliament which might result in unwelcome public exposure. Stakeholders have subsequently questioned whether all of the voluntary agreement has been applied by everybody all of the time. It has to be admitted, they have some justification (for example treating grass before silage, which is OK, but knowing that the aftermath will be grazed, which is not because it is in the same growing season). A more blatant example is the recent practice of contracting removal of cake to lime treatment and land

application when incinerators, etc. have broken down, however the treatment has merely been mixing lime and cake using a loading shovel, not the intimate mixing necessary for proper treatment. Much of this stinking product has been spread in southern Scotland which has resulted in so many odour complaints that the Scottish Parliament has launched an enquiry. Proper lime treatment is good (for example when plough-share mixers are used, possibly controlled action lime and electrical heating are used) but invariably cheap treatment stinks. A poorly positioned stockpile flowed and blocked the Carlisle to Newcastle railway line in October 2014. The biosolids producers do not operate the same oversight as they do with their "home" recycling. Maybe they think they have transferred their liability to a contractor but they have not.

Thomas Miller, a provider of insurance products for complex risks based in London, researched the issue and recruited a Risk Evaluation Panel which developed a protocol based on HACCP to contain the risks. The largest insurer in Europe was prepared to give 25 year strict-liability, latent-defect insurance for land treated with biosolids or other organic soil treatments – BOOST (Evans, 1999). I took early retirement from Thames and joined Atkins to sell BOOST but nobody was buying, however it was a useful transition to my own consultancy, which I established December 1999. BOOST would have given many benefits to the biosolids industry besides the insurance. For example, it would have required the rigorous application of HACCP to the whole process (from source control through to land application) which would have meant that proper "corrective actions" for "critical control points" going out of their "critical limits" would have been planned in advance instead of ad hoc actions such as the lime treatment discussed above.

Some food industry buyers have been ignoring the BRC Agreement and warning farmers off using biosolids; many farmers heed the threat. Unfortunately because some WaSCs do not follow the Agreement some of the time, the water industry is in a weak position to demand observance from the other parties.

TIM EVANS ENVIRONMENT consultancy

I have enjoyed a wide range of commissions from a wide range of clients, mainly in the UK and some overseas.

Urban Drainage

The Foundation for Water Research became one of my first clients when they invited me to be their wastewater specialist and technical secretary to the Wastewater Research & Industry Support Forum. This broadened my wastewater knowledge, especially facilitating workshops for WaPUG (now CIWEM UDG) on aspects of urban wastewater modelling and management and publishing the proceedings. There are so many missed opportunities for retrofitting sustainable drainage systems in our cities and reducing the amount and rate of surface water entering sewers (Evans, 2014).

HACCP analysis and training

Following on from BOOST I was well placed to provide HACCP analysis and training for waste treatment sites and for water companies (Evans 2001). When examining the hazards that needed to be managed, teams always agree that odour from land application and from treatment was the most public vulnerability. Odour has the largest outrage factor in perceived risk (Covello and Sandman, 2001). However companies have often compromised on odour, frequently because the production department has not bought into the objectives and constraints of the recycling department. HACCP had been introduced by the BRC because it was something with which they were familiar in the context of managing the safety of food and drink but rather than

applying it as the food industry does, the water industry compromised and developed its own insular interpretation; the CATNAP culture triumphed again.

One expert witness case would have been avoided had the designers used HACCP. The 6 km pipeline to the WwTW rose about 100 m from the main population centre. There was no attempt at septicity prevention. The WwTW design was extended aeration, the sludge was dewatered with a centrifuge and then dried in a drum dryer. There was no standby or contingency for downtime. To treat the make required a totally unrealistic 96% availability. When the dryer broke down (as assuredly it would) the operators spread the sloppy raw cake 15-30 cm deep on nearby land creating horrendous odour and polluting runoff that found its way through the field drains. HACCP would have forced them to consider these entirely predictable events and a redesign.

Technology and market evaluation

It has been fascinating to evaluate innovations. Sometimes people have failed to appreciate the crowded nature of the sector to which they hope to pitch their technology. They have seldom done any market research or identified the beachhead for invading the market (Moore, 1999). Wise innovators have appreciated the value of knowing these things at an early stage before too much money is burnt.

Food waste

There have been several projects on food waste: the viability of co-digestion; feasibility of AD for farms; outline design of an AD plant; impacts of food waste disposer (FWD) to sewer strategies.

In the 1990s, Denmark set a policy that biogas would be a major component of its energy supply; a consortium engaged me to investigate how it worked (Evans et al., 2002). A tiered market for co-digesting food and other wastes with manure or sewage sludge developed generally linked to the biogas potential of the waste. The unsolved issue was effective removal of physical contaminants, especially plastic. Regulations were enforced but they had a pragmatic basis. The financial incentive for biogas was slightly less generous than applied at that time in the UK but more importantly there were fewer regulatory blockers. In the early 2000s there seemed no reason why UK water companies should not emulate Denmark if they had adult-to-adult relations [rather than child-to-adult] with the regulators.

One of the largest contract farming companies commissioned me to look at the feasibility of co-digestion on the farms of some of their clients. Generally there was sufficient land to use the liquid digestate. The critical criterion, which most failed, was sourcing a sufficient quantity of clean food waste. Transport access and electricity export were generally adequate.

The FWD to sewer work has been very interesting. The public's willingness to participate in food waste diversion and the cost are two critical factors for local authorities. The global warming potentials of the options was a key social responsibility factor. The published science (including extensive CCTV) all shows that sewers will convey the output of FWD without any impairment provided they are fit to carry sanitary sewage. Examining the monitoring data from a WwTW showed that even with 50% of households using FWDs the load to secondary treatment did not increase but biogas increased by 50% (Evans, 2014). However some water company people have decided that, irrespective of the evidence, FWDs must be bad for sewers. The scientific and psychological aspects of this issue have both been interesting; akin to Darwinism versus creationism.

Recovering phosphate and ammonia rather than losing them

Digestate contains abundant dissolved and weakly sorbed ammoniacal-N and phosphate. They transfer to the dewatering liquor and need to be treated. The conventional approach is the convert the ammoniacal-N to nitrogen gas biologically (nitrification-denitrification; nitritation-denitritation; anammox) and to precipitate the phosphate into the biosolids. The "outside the box" approach is to recover phosphate as struvite and strip and recover ammonia physicochemically (Evans, 2006). Both have been practised for about 20 years but they are still at the "early-adopter" and "innovator" stage respectively. They have not "crossed the chasm" yet but they will. Steam stripping produces saturated ammonia solution which sells for a good price for NO_x reduction in combustion processes (Evans and Thompson, 2009). Struvite can be compounded with other fertiliser ingredients or sold [at a lower price] to phosphate refiners. We are exceeding the earth system boundary for fixed reactive nitrogen by 6 times and phosphate by 5 times so recovery is important and socially responsible.

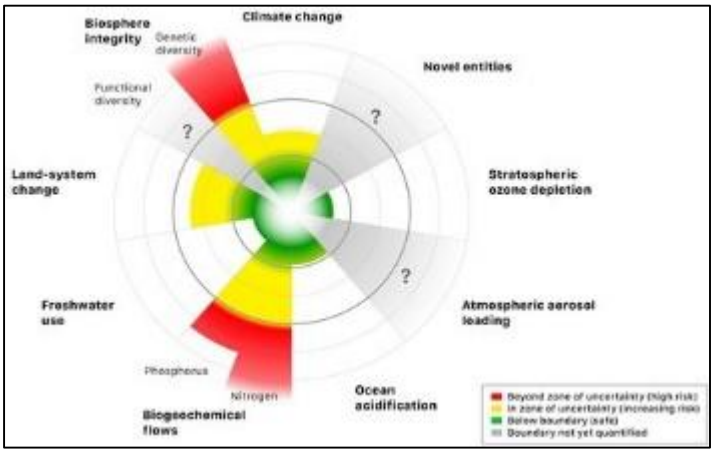

Figure 15 Earth system boundaries

Strategy and training for charging for biosolids

This was probably the first application of rigorous market research techniques to designing a biosolids recycling operation. United Utilities (UU) has a challenging area with a substantial population, multiple biosolids production centres many of which have very limited on-site storage, high precipitation and mountainous topography in some areas. UU decided to award a project to measure farmers' needs and wants regarding biosolids recycling so as to get it into a position where it could charge farmers for biosolids and to establish the optimum price. A combination of auditing the current situation (to recommend a strategy to smooth the peaks and troughs of production), training in agronomy and selling and qualitative interviews to frame on-line quantitative research, which was subjected to conjoint analysis was used to establish what mattered to farmers, what value-added features would be interesting and how much farmers were prepared to pay. The changes to effect the production strategy and the changes to the service package that would have given the optimum price would have been simple and inexpensive in principle but there were company politics such as "production" and "laboratories" buying into the objectives.

The application of market research to biosolids recycling proved very successful. Market research with conjoint analysis of the results has enabled us to recommend the optimum price and product-service package that will result in a secure and sustained market for biosolids in NW England. Even amongst biosolids users there is apprehension or worry about the possibilities of collateral adverse effects. Science tells us these fears are not justified but none the less they exist, which points to a gap in disseminating the evidence, which can be bridged by communication. There was also a gap in disseminating the importance of maintaining good nutrient status of potassium and sulphur. Farmers appreciated that biosolids are good sources of phosphate and nitrogen, including slow release nitrogen but were less convinced about the soil improvement benefits and also understood less about how organic matter acts to improve soil structure.

Lessons learnt

"*Do unto others as you would have them do unto you*" Jesus Christ in the Sermon on the Mount
and very occasionally
"*Do unto others before they do unto you*" Terry Pratchett

1) It should cost what it costs to do it right. This is especially true of recycling biosolids to land, which is the best practicable environmental option and the least expensive option. It is very foolish to save a few pence and jeopardise confidence in the process because any alternative will be hugely more expensive. It is important that everybody buys into the objectives.
2) Know your product. Investing in analysis and performance testing are crucial. Some testing is a legal requirement but other testing is necessary for due diligence and to support obtaining the optimum price. Without a sufficiency of analysis how can you know that the biosolids, topsoil, growing medium, etc. is going to be within the acceptable quality limits? Scrutinise results so that outliers can be questioned.
3) Know your market. What causes customers to buy? A strategic map is very valuable for recycling to farmland. Market research can be very valuable if done competently. We might think we know what customers will want but it is better to assess this skilfully, the alternative can lead to expensive mistakes.
4) Paracelsus said 500 years ago "the dose makes the poison". Many policy makers and influencers do not acknowledge the truth of this nor that for there to be a risk to a receptor requires a source [biosolids] and a pathway to deliver a harmful dose. They know what they believe and they do not want to be confused by facts. However, generally evidence generally trumps dogma eventually but we need to be active in the formulation of policy.
5) Ground-truthing (i.e. is the experimental observation replicated in the real world experience?) should be an essential part of experimental design but it is often omitted.
6) Applied correctly, HACCP deals with Murphy's Law [if something can go wrong it will] but the water industry did their own HACCP-lite instead of applying it to the whole process.
7) One-site storage, preferably covered, and preferably for at least 3 months of production should be the norm.
8) Quality Assurance is essential if you want everybody in a team to get it right first time and every time. If it is expensive, bureaucratic or constraining, it is wrong. I still meet operations where individuals do things their own ways and differently from each other.
9) The key to selling anything is that it should satisfy customers' needs or their wants though it might be possible to generate wants that they did not know they had. Market research can reveal those needs and wants. It can also test the most interesting product/service package that will enable the optimum price to be charged.
10) Selling is a skill that is often under-recognised. Some people are gifted, some are congenitally incapable and most can become more effective with the help of training. Being asked to sell can be intimidating for some people. It is kinder to the individual and better for the business to move people who cannot sell to another role.
11) Brands are important. A brand should encapsulate customers' experiences. A brand can give cohesion to a team. If you have got one, use it.
12) Competitor and market analysis can be invaluable. It is better to know whether your intended marketplace is already crowded, who the incumbents are and how a new technology or product might be received at an early stage before burning cash.
13) Publish and contribute to advancing the sum of human knowledge. Provided the results of research are not commercially sensitive it is best to publish them; if everybody does

that we shall all gain. If four competitors meet and each shares one new piece of information, everybody goes away with three things they did not know before. Science advances by building on prior knowledge. The trend today is "open access" because there is very little interaction with work published behind high pay-walls – it might just as well never have been done.

14) Always question. Is the conventional thinking about a subject correct? Even if the results come from a big reputation, are they correct? Might there be a better way?
15) Practice "management by walking about". It is better that you find out what is really happening (by looking and listening) rather than a critic. It avoids "filtering" by middle managers and supervisors and overcomes the "nodding donkey" syndrome that tells you everything is OK.
16) You get out of a contract what you put in. A good Specification combined with diligent monitoring and supervision can give a good result and you will get what you pay for. A smartphone app can replace "boots on the ground" by providing georeferenced, timed photographic evidence. If you try to put the risk on the contractor you will pay one way or another.
17) Haulage (logistics) is a skill and so is spreading albeit very different. They can be contracted but if you contract the selling, it is the contractor who has the relationships with the customers. The contractor is likely to filter any customer complaints. Customers are hugely valuable.

"It's easier to ask forgiveness than it is to get permission."
Rear Admiral [amazing] Grace Hopper (1986)

"We need to innovate, we need to change, dare to think the unthinkable"
Tony Wray retiring CEO Severn Trent (UDG 2013)

Conclusions

Recycling treated organic resources and biosolids to land to complete nutrient cycles and to help conserve soil organic matter is socially responsible but to remain socially acceptable it must be done properly and honestly. A strong, well-recognised brand might differentiate one programme from another but undoubtedly there will be some cross contamination, as for example happened when VW was found to have cheated the emissions tests and the share prices of other German auto-makers were also dragged down. Engineers love to engineer and scientists love to do science but is what they think important the same as what customers think is important? Market research can answer that question. The present "back door" recycling, the unwritten warnings of some commodity buyers and the enquiry of the Scottish Parliament are all reminiscent of the situation in the mid-1990s. If recycling to land falls over, the alternative will be much, much more expensive. I hope we don't go there.

Acknowledgements

I should like to thank those managers who gave me space (enough rope) to do what I thought was right and the many customers, clients and colleagues who have contributed to my experience. It has not been rocket science but it has been addictive, enthralling, fascinating and fun.

References

Anon, 1989; Statutory Instrument (1989) *The Sludge (Use in Agriculture) Regulations* SI 1263, as amended by The Sludge (Use in Agriculture) (Amendments) Regulations 1990, SI 880. HMSO, London.

DoE (1976) Report of the working party on the disposal of sewage sludge to land STC5. HMSO, London

CEC (1986) Commission of the European Communities (1986) Council Directive of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC). *Official Journal of the European Communities*, No L181/6-12.

Chumbley, C. G. (1971) Permissible levels of toxic metals in sewage used on agricultural land. Agricultural and Development Advisory Paper 10. MAFF, Pinner, UK.

Covello, V. and P. Sandman. "Risk communication: Evolution and Revolution," in Wolbarst A. (ed.) Solutions to an Environment in Peril. Baltimore, MD: John Hopkins University Press (2001): 164-178 (available at www.psandman.com)

Evans, T. and Rainbow, A. (1998). Wastewater biosolids to garden centre products via composting. *Acta Horticulturae* no 469, 157-168.

Evans, T.D. 1999 Do biomaterial recyclers need externally audited quality assurance and insurability? 4th European Biosolids and Organic Residuals Conference CIWEM/AquaEnviro

Evans, T.D. 2001 The potential benefits of applying HACCP to organic residuals recycling processes 6th CIWEM AquaEnviro European Biosolids & Organic Residuals Conference

Evans, T.D., Jepsen, S.-E., Panter, K. P. (2002) *A survey of anaerobic digestion in Denmark*. 7th CIWEM AquaEnviro European Biosolids & Organic Residuals Conference, 18-20 November 2002

Evans, T.D. (2006) Treating dewatering liquors – is physico-chemical better than biological? Can a problem be turned into an asset? 11th CIWEM AquaEnviro European Biosolids & Biowastes Conference.

Evans, T.D. and Thompson, A. (2009) Recovering ammonium fertiliser – an alternative to blowing it away. Proc. 14th European Biosolids and Organic Resources Conf., November 2009, Lowe P. (ed), Aqua Enviro

Evans, T.D. and Smith, S.R. (2012) *Bioassay of biosolids in an operational scale field trial*. Proc. 26th Water Environment Federation, Annual Residuals & Biosolids Conference, 25-28 March, Raleigh NC

Evans, T. D. (2014) Missed opportunities for rainwater management. The Environment (October) 30-32

Evans, T. D. (2014) *Is there a free lunch in food waste?* Proc. 19th European Biosolids & Organic Resources Conf. Aqua Enviro, Manchester, UK

Hallam, S.; Evans, T.D. and Mansfield, H. (2015) Application of market research to design sustainable biosolids recycling and set prices. SludgeTech 2015, University of Surrey, UK

Moore, Geoffrey, A. (1999) Crossing the chasm: Marketing and Selling Technology Products to Mainstream Customers. 2nd edition. Capstone Publishing Ltd. Oxford, England.

Sherlock, J.C. (1982) *The intake by man of cadmium from sludged land*. in “Environmental effects of organic and inorganic contaminants in sewage sludge” Reidel Publishing Co. 1983