Everything Circulates: Agricultural Chemistry and Recycling Theories in the Second Half of the Nineteenth Century

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ABSTRACT

This paper analyses the arguments in favour of recycling put forth by agricultural chemists in the mid nineteenth century. In this context the study emphasises how agricultural chemical theories, mainly developed by Justus Liebig, were connected to larger issues outside the scientific domain. The study also investigates how agricultural chemists argued for different kinds if recycling systems in a more practical way. By way of conclusion, some reasons for the ultimate abandonment of the recycling discourse at the end of the nineteenth century will be discussed.

KEY WORDS

Justus Liebig, agricultural chemistry, chemico-theology, recycling, sewage, Alexander Müller, nineteenth century

> Paris casts twenty-five millions yearly into the water. And this without metaphors. How, and in what manner? Day and night. With what object? With no object. With what intention? With no intention. Why? For no reason. By means of what organ? By means of its intestine. What is its intestine? The sewer.[1]

Thus begins an almost fifty-page-long description of the sewer system of Paris in Victor Hugo's *Les Misérables* (1862). It was human excrement, manure and other types of organic waste emanating from the city that made the contents of these sewers so valuable. Hugo claimed that 'A great city is the most mighty of dung-makers'. At the same time as expensive guano was being imported from

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'the South Pole', in France alone manure worth half a billion francs was literally going to waste. Hugo was not alone among his contemporaries in emphasising the economic potential of this 'filth' and the interdependence of town and countryside. Others labelled the night-soil from the cities a 'mine of wealth' or 'golden manure'.[2] Nor was only money at stake. To the question as to what it was that lay in the muck, cesspools and sewers that made it so valuable, he answered,

> They are the meadow in flower, the green grass, wild thyme, thyme and sage, they are game, they are cattle, they are the satisfied bellows of great oxen in the evening, they are perfumed hay, they are golden wheat, they are the bread on your table, they are the warm blood in your veins, they are health, they are joy, they are life.[3]

Thus sewer water also carried away the richness of the soil and 'the very substance of the people'. In Paris, a one-way sewage system had been constructed, which effectively deposited waste into the river. But Hugo maintained that 'From this spring two results, the land impoverished, and the water tainted. Hunger arising from the furrow, and disease from the stream.'[4] In England, where Hugo lived in exile when he wrote *Les Misérables*, several towns had constructed a double tubular apparatus, which functioned like 'the lungs of a man'. With this tubular system, fresh water was transported to the cities and the sewage brought back to the fields. Thereby, according to Hugo, a reciprocal interaction between town and countryside – a recycling system – was created.

The purpose of the present study is to analyse the arguments in favour of recycling put forth by agricultural chemists in the mid-nineteenth century. In the first section, theories mainly developed by the German chemist Justus von Liebig (to whom Hugo referred directly) will be examined. In this context the study will emphasise how these chemical theories were connected to larger issues outside the scientific domain. Questions about religion as well as social problems and health matters were discussed in relation to recycling. One crucial question concerned how societies could best be organised in order to improve themselves by living in concert with the laws of nature. Examples from different epochs and different geographic regions were offered to illustrate which societies were sustainable and which had declined and perished. Thus, these recycling theories were not only scientific theories, but also contained apocalyptic fears and utopian solutions for creating better societies.

The aim in the second section is to investigate how agricultural chemists argued for different kinds of recycling systems in a more practical way. A crucial issue for the agricultural chemist was to prove that night-soil and other kinds of city-waste could be transformed into fertiliser, so that the nutrients that had been transported from the countryside to the cities could be returned to the farmers and benefit them. In this section, the focus is placed on the German chemist Alexander Müller, who was active in both Sweden and Germany. Müller approached urban technical and sanitary problems from an agricultural perspective and argued in favour of recycling. By way of conclusion, some reasons for the ultimate abandonment of the recycling discourse at the end of the nineteenth century will be discussed.

METAMORPHOSIS AND CHEMICO-THEOLOGY

How, then, was the recycling idea described from a scientific point of view? An important concept in Liebig's theories was 'metamorphosis', which comprised the entire second part of his study *Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie* (1840). The concept originated from the Greek word for transformation and was introduced by German natural philosophers at the end of the eighteenth century.[5] Chemists influenced by Romanticism maintained that the chemical processes in organic and inorganic matter were fundamentally different. In living organisms, there was an inexplicable 'life-force' which both made organisms stay intact and caused chemical processes to occur in a specific way so that their life-bringing qualities could be inherited by new organisms. Recycling occurred only between plants and animals, while another, inorganic chemical process was operative in the mineral realm.

Liebig forcefully repudiated the Romantics' philosophy of nature, although he did not deny that a life-force existed. According to Liebig, it functioned in the same mechanical way as light, magnetism, electricity, heat and chemical force. When the life-bearing 'cause' stopped working, organic compounds remained intact only because of a inertia between the elements. Liebig asserted that according to the mechanical law of inertia, matter did not possess the power to transform itself. There must exist an active, external force or resistance to affect an immobilised atom. A mechanical motion or 'push' caused by air, rising temperatures or attraction to another chemical body could in other words easily alter the state of equilibrium and bring the individual atom into motion and decompose organic compounds.[6] Metamorphosis was consequently a purely chemical and mechanical process, which activated the atom and broke up the molecules, whereupon the chemical force formed new compounds in accordance with the weight and attraction of the elements. There was no vitalistic life-force that followed nature's circular processes and transmitted the life-bringing qualities from one generation of organisms to the next.

Jointly, metamorphoses created the circular processes in nature step-by-step. While the first part of *Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie* discusses how plants, absorbing nutrients from soil and air, consisted of complex organic compounds, the second part describes chemical reactions, such as fermentation, putrefaction and decay, which once more broke these compounds down into their most minute components. Thus Liebig's study followed nature's circular process. By showing in accordance with his 'mineral theory' that minerals were also absorbed by plants and animals, Liebig proved that the exchange of matter occurred both between plants and animals as well as between minerals. Consequently, one result of Liebig's theory was that the boundary between organic and inorganic nature was breached – the same natural laws applied everywhere.

A basic supposition of Liebig's chemical theory was that there existed a limited and constant quantity of matter. Thus, in order to be able to maintain every form of life and all the processes of nature, there needed to be a balance in the flow of matter and feedback in the system. According to modern atomistic theory, elements cannot change their status. However, metamorphosis made it possible for individual particles joined in unlimited ways with other elements to form chemical compounds, only to subsequently separate and become parts of other compounds. Consequently a few types of matter existing in a limited quantity gave rise to an infinite multiplicity of forms in nature.

During this era, scientific theory and theology were closely bound together. Chemistry was seen as a key to man's understanding of Creation; the English historian of science Christopher Hamlin has called this outlook 'chemico-theology'.[7] In contrast to the usual physico-theology of natural history, chemico-theology represented a higher level of abstraction. On the atomic and molecular level, nature's 'balance' and 'economy' become obvious, demonstrating the existence of God. The sublime in nature and the exterior aesthetics of the landscape were the result of their interior relationships and chemical laws. In reality, everything was chemistry and chemical metamorphosis.[8]

An agricultural chemist who clearly related chemical recycling theory to theology was the Scotsman James F. W. Johnston. In his essay 'The Circulation of Matter' (1853),[9] later reworked as a chapter in his study *Chemistry of Common Life* (1855), Johnston uses layman's terms to describe how water, coal, oxygen, nitrogen and minerals each followed their own chemical cycles and that these processes comprised a unified whole. Johnston saw creation and destruction as aspects of the same process. The elements not only followed the food chains, but the refuse generated by one organism was essential to subsistence of another. For example, the oxygen that plants emitted provided nutrient for mammals, while conversely, the carbon dioxide emitted by mammals was necessary for the survival of plant life.

A particle that one day was a part of a plant could be picked up the next by an animal and later be deposited in the currents of a river, finally being returned to the soil or the atmosphere before beginning another cycle. Thus matter was in constant motion and the terminus of one chemical cycle marked the beginning of the next one, like a *perpetuum mobile*. Johnston asserted that, like all other organisms, the human body was in permanent flux, maintained by a constant metabolism of chemical elements from the environment. One consequence of this metabolism was that the atoms that had been the building-blocks of a particular body at a given point in time would have been almost entirely replaced by new ones roughly each month, 'so that what is now part of the body of a Cæsar or a Venus may literally within a week become part of a turnip or of a potato',[10] Johnston wrote, alluding to *Hamlet*.

Johnston ended his essay with a rhetorical question: 'Why does this wheel turn?'[11] The principal answer to this question was, according to Johnston, that the whole of Creation was upheld by one eternal motion that simultaneously controlled all the other cycles. These various cycles were dependent on each other and followed a simple, beautiful and intelligent design. In other words, a Divine and omnipotent order sustained Creation. However, the Earth differed from the rest of the universe. While the same Divine driving force and physical laws that made the planets move in their orbits caused the Earth to move, too, only on Earth did chemical cycles exist. It was those cycles that created a living atmosphere and made organic life and civilisation possible.

> Earthly life, therefore, has no share in the general system of the universe. It is a little episode, so to speak, in the poem of creation. The Deity willed that this corner of his great work should be the theatre of new displays of wisdom, of consummate contrivance, of a wonderful fitting in of means to the accomplishment of beneficent ends and at last the seat of intellectual being, with capacity to study and comprehend, and admire His works to praise and love and serve Him.[12]

Thus, the Earth and mankind were unique in all Creation. In the same way as Isaac Newton asserted that God actively upheld the mechanism of the universe, Johnston claimed that God constantly maintained the chemical cycles. If not, then all life could immediately cease to exist 'by the simple turning of a screw'.[13]

THE METABOLISM OF THE CITY

How did the city fit into the order of nature and the chemical cycles? One long tradition views the city as something that exists outside nature, an artificial construction which goes against its order. On the other hand, there is another which considers the city an integrated part of nature's processes.[14] Metaphors like 'organism', 'body', 'heart', 'lungs', 'arteries', and 'veins' were commonly used to describe the city and its functions, since the city, in the same way as biological organisms, is also characterised by its metabolic relationship with the physical environment. In the nineteenth century, both those approaches were used to describe the changes that followed upon urbanisation and industrialisation. Filthy cities shrouded by smog and shot through with odorous and poisoned waterways seemed to be killing both people and the little nature that remained. Rivers like the Seine, the Spree and the Thames were depicted as gigantic sewer ditches from which cholera and other dreaded diseases emanated.

Influenced by Liebig, Edwin Chadwick, a prominent figure in the English sanitary movement, attempted to improve the fertility of the soil in the 1840s by combining sanitary goals with agrarian ones. In his *Report on the Sanitary*

Conditions of the Labouring Population of GT. Britain (1842), Chadwick pleaded that cities ought to introduce water-flushed sewage systems with pumps that could recycle organic material back to the soil. A commonly held notion, based on chemical research, was that nature possessed a purifying capacity. By using sewer water to irrigate the fields, the water would be effectively purified at the same time as the plants were fertilised. As sewage irrigated the fields it would be filtered, the plants could absorb nutrients from the water, and contact with the air would cause some substances to be transformed into gas. This was a rapid process which decomposed the organic compounds before they began fermenting or putrefying and before smells and diseases spread. At the furthest end of the irrigation fields, the water would be almost totally purified and could be returned to the nearest watercourse. In other words, if the matter followed the cycle of nature, organic compounds would decompose harmlessly.[15]

Furthermore, Chadwick was enthusiastic about the optimistic economic calculations that Liebig had made about the value of the sewage. Hence the recycling of sewer water could finance public sanitation and the construction of a water-flushed sewage systems in the cities of Europe.[16] In the following decades, this idea elicited a strong positive response from both spokesmen for the sanitary movement and agriculturists.[17] According to Chadwick's technical utopian approach, the city could be successfully integrated into the circular motion of matter, at the same time as these processes could be made more efficient with the aid of pipes, pumps and steam engines.[18] These technical recycling systems would adapt the cities to the laws of nature.

In the 1860s, both Liebig and English agricultural chemists were engaged in the discussion about London's sewage system. Liebig, who had a good understanding of the situation in England provided by his English students, wrote several articles on the subject.[19] In an essay addressed to the Lord Mayor of London, Liebig compared the content of nutrients in common provisions with human excrement, showing that a clear connection existed between the town and the country, or 'the place of consumption [and] that of production of food'.[20] Thus there was consequently a balance between access to nutrients and access to food, economising the limited quantity of matter. Moreover, sewer water and recycled refuse from the cities comprised an infinite resource in contrast to the imported guano.

> Thus it will be easily understood, that if a possibility is offered to the farmer to get back, as sewage, those matters which he has carried to the town in the form of corn, meat, and vegetables, and if he gives his field the same, both in quantity and quality, as he took from it, then its fertility may be assured for an endless number of years.[21]

The English anthropologist Mary Douglas claims that the binaries 'order/purity' and 'disorder/dirt' are defined through a collective and cultural process. 'Filth' is not an unambiguous concept. Its meaning varies depending on its historical and cultural context. Douglas defines filth as something that falls outside the given order or is situated in the 'wrong place'. In this case, organic matter and nutrients have remained within the confines of the cities instead of being recycled to the soil. Douglas also asserts that 'to do away with filth does not imply a negative action but rather a positive incentive to organise the environment. ... It is an affirmative action, an effort to merge form and function, to create harmony from the experience'.[22] Demands of purity thereby also coincide with claims about a certain social order, while dirt and disorder are seen as perils that threaten the survival of society.

Thus the recycling idea can be seen as a way to create order in a changeable society. According to Liebig's above-mentioned atomic theory, the limited quantity of matter could not change. But it could end up stranded in the 'wrong place' from a human perspective. Minerals in particular, which were static, could easily end up in the 'wrong place', outside their proper cycle. Minerals were crucial nutrients for plants and animals, according to Liebig's mineral theory; when they accumulated in the cities or were flushed into the watercourses, the soil from which they originated became slowly depleted. In other words, it was society and social practices that created an imbalance in nature's economy and diluted the soil. Thus demands for the introduction of recycling systems implied changes in society. The efforts of the agricultural chemists to redefine 'dirt' as 'golden manure' also reflect Douglas' theory. Night soil and other kinds of city waste were not 'dirt' from the outset; instead, they became it when one went against the order of nature. Dirt could therefore be transformed into a valuable resource if brought back to its 'right place'.

Matter which ended up in the 'wrong place' was also seen as a significant problem, especially the organic matter accumulating in the cities. By analogy with the human body, obstructions in the cycles of matter caused diseases and spread toxins. A healthy city was characterised by the free circulation of air and water, so that matter could be transported out of the city and safely decompose. The English urban historian Graeme Davidson states that during the nineteenth century, an anatomical perspective on the city emerged. The city was likened to the human body, a three-dimensional mechanical system governed by physical and chemical laws. Like surgeons, scientists and technicians should locate obstructions and malfunctions and fix them.[23] Stagnant water and putrefied organic matter were hindrances in the system that caused 'miasmas'.

What was it in these miasmas that caused disease? In Liebig's opinion, miasmas did not contain contagion that consisted of living, microscopic organisms. He claimed instead that the contagion was composed of 'ferments', i.e. invisible chemical particles that were generated when organic material containing ammonium came into contact with moisture and oxygen and started to putrefy, ferment and decay. These ferments acted as 'seeds of diseases', which initiated chemical reactions that decomposed organic compounds. These ferments could easily be transferred from the air to the blood via the lungs, where they multiplied and caused decomposable metamorphoses. Liebig asserted that in the blood, the chemical force and the life-force balanced so perfectly, that the smallest disturbance could cause the life-force to give up its 'struggle' against the chemical force, so that the body began decomposing.[24] In Liebig's footsteps, the zymotic theory developed (*zymosis*, Greek for fermentation), and diseases including cholera, typhus and measles were identified as 'zymotic diseases'. The zymotic theory was held sway until Louis Pasteur and Robert Koch proved in the 1880s that it was in fact bacteria that caused infection.[25]

Parallel to this, it was claimed that if the cycles of nature were not maintained, city-dwellers ran the risk of becoming morally ill. In Victorian society 'moral miasma' was greatly feared.[26] In the big cities rich and poor alike mingled, and women abandoned their traditional positions at home to become factory hands or prostitutes. In this chaotic situation it was hard to maintain the old social order and its traditional values. As mentioned above, Douglas argues that there is a connection between what is seen as unordered and filthy and what falls outside the social order.

Contemporary social sanitarians, agricultural chemists and social reformers also perceived a link between pollution and dirt on the one hand, and ill health, poverty, crime, prostitution and other immoral acts on the other.[27] These negative social phenomena had not been caused solely by self-inflicted adversity, laziness and criminal deposition, but also by filth, or to use a current term, by 'environmental problems'. By improving the physical environment people would become healthier, more hard-working and less inclined to commit crimes and start rebellions. Thus, the introduction of a recycling system was characterised as a way of solving a number of the most significant problems facing the society of the time.

IMPROVEMENT OR DECLINE?

To garner evidence to support his chemical theories, Liebig ventured into time and space. In the seventh edition of *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie* (1862), Liebig describes earlier societies that have followed one after the other in the 'cycle of culture and civilisation'.[28] Liebig paid the Roman Empire particularly close attention.[29] During the Enlightenment, when the idea of progress was established, it became evident that all ancient civilisations, in Mesopotamia, Egypt, Latin America and those situated on the shores of the Mediterranean, had degenerated and perished. Taking a cue from Edward Gibbon's *The History of the Decline and Fall of the Roman Empire* (1776), the fate of Rome was constantly reiterated as a warning.[30] Progress and civilisation seemed to be almost inexorably followed by 'decline' and 'fall' and the civilisation of the West could, if caution was not exercised, quickly be transformed into misery and anarchy.

The Empire, and especially the city of Rome, depended on a constant influx of food, taxes and soldiers, states Liebig. This dependency put Roman farmers and the soil itself under increasing strain. The Italian mainland alone could not cope with this burden. Instead, the Empire had to expand, plundering its colonies of both the richness of the soil and of slave labour. While enormous wealth was accumulated in the city of Rome, nothing was returned to the Italian fields or to the colonies. Instead, via the *cloaca maxima*, valuable nutrients poured into the Tiber. Rome's conspicuous luxury was a symptom of the Empire's approaching fall. At the same time the 'capitalists of Rome' carried out a profitable trade with cereals from the colonies that drove out the domestic market, resulting in the loss of the independence of the free Italian peasants. Thus, Liebig asserted, at the same time as nature was being destroyed, Roman civil spirit degenerated and the Empire lost its life-force.

The Roman Empire was an example of a civilisation that had lived off the benefits of a *Raubwirtschaft*, to use Liebig's term: a 'robbery system'. A robbery system was practised by a society that impoverished the soil by not returning the mineral nutrients that had been taken out of it. The principle that all nutrients had to be completed restored was inflexible, Liebig claimed, and the commercial farming system of contemporary Europe violated this principle. Modern agriculture was the last stage of the 'robbery system'. By exporting agricultural products from the countryside to the cities or to foreign countries, the mineral nutrients disappeared from the soil without being replaced. This exploitative 'self-destruction process' would have Malthusian consequences.

> For their self-preservation, nations will be compelled to slaughter and destroy each other in cruel wars in order to obtain balance, and if, God forbid, there are two years such as the starvation years of 1816 and 1817 then those who live through them will see hundreds of thousands perish in the streets. Add a war thereto and mothers, as during the Thirty Years' War, will drag home the bodies of the slain enemy in order to still with their flesh the hunger of their children; as in Silesia in 1847, the corpses of animals having died of diseases will be excavated in order to prolong the agony with the carcass. These are not vague and dark predictions, images of sick fantasy; for science does not prophesy, it calculates; not if, but when, is undecided.[31]

Though English agriculture had been the ideal of European agriculturists since the eighteenth century, it was instead a shocking example in this context. In Great Britain, exploitation of the soil was paid for with 'gold, iron and coal'. From all over the world nutrients, in the form of guano and crushed bone, were imported to English farmlands. However, the stock of guano was almost completely depleted. And yet valuable nutrients were allowed to flow out into the rivers and the sea via the water closets of its cities. The English farming system was thus ultimately based on finite resources, short-term economic gain and the exploitation of other lands.

> Great Britain deprives all countries of the conditions of their fertility. It has raked up the battle-fields of Leipsic, Waterloo, and the Crimea; it has consumed the bones of many generations accumulated in the catacombs of Sicily; and now annually destroys the food for future generation of three millions and a half of people. Like a vampire it hangs on the breast of Europe, and even the world, sucking its lifeblood without any real necessity or permanent gain for itself.[32]

In the same way as the Roman Empire had exploited its empire, Great Britain plundered Europe as well as its overseas colonies. Instead of recycling the nutrients already extant within its own borders, fertilisers were imported from all over the world and then poured out into Britain's own *cloche maxim*, the river Thames.

Many agricultural chemists saw East Asian farming as an ideal in contrast with European agriculture. One reason for their admiration was that the East Asian system was successful by definition because it seemed to have solved the Malthusian dilemma. The Chinese and Japanese civilisations had survived for thousands of years and at the same time the population had multiplied at an incredible rate. In spite of this, the soil had not been impoverished. What made Asian agriculture so successful? An extended answer can be found in an appendix on Japanese agriculture added to the seventh edition of Liebig's *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*. The appendix was the travelogue written by Dr. H. Maron from a Prussian East Asian expedition. Just as Liebig claimed, in Japanese agriculture the nutrients need not take a detour via animals in order to be turned into manure. Maron claimed that in accordance with the two dominant Japanese religious beliefs, Shintoism and Buddhism, it was forbidden to eat meat and therefore there was very little cattle. Instead, all available soil was intensively cultivated to produce food for human beings. Consequently, in Japan only people consumed food and they alone produced the manure.

Moreover, the Japanese appeared to have understood the principle that everything that was taken from the soil had to be compensated. Major efforts were invested in the collection of human excrement. Maron reported that not even in the poorest areas had he seen night-soil going to waste. Instead, the Japanese had ingeniously conceived earth-closets, where a receptacle in a pit under the closet collected the excrement. These receptacles were regularly emptied into a larger container before its contents were used in the fields. Even alongside roads and fields the peasants had placed barrels and pitchers everywhere, where travellers could relieve themselves without any nutrients being wasted.

There was also a balance between rural and urban environments. Each morning Maron witnessed how long lines of coolies from the countryside transported agrarian products to the cities. In the evening they returned each bearing two receptacles filled with faeces. Also thousands of boats spread 'the blessing deep into the country'.[33] Since there were no animals to consume, straw and other by-products from the farming composts were very common. Consequently these nutrients were recycled without any 'animalisation'. Furthermore, the Japanese not only recycled everything back to the soil, the supply exceeded the withdrawal, claimed Maron. Since a substantial part of the Japanese diet consisted of fish and seafood, nutrients from the sea raised the value of human excrement.

Thus, Maron saw Japanese agriculture as a consummate recycling system. He wrote, 'Then appears the great picture of a perfect circulation of the forces of nature; no link in the chain is missing, the links reach out for each other'.[34] Compared to the Japanese farming system, several 'links' in European agriculture were sorely missing. Maron's conclusion was that European agriculture was 'a sham culture and the fraud will sooner or later be exposed; Japanese agriculture by contrast is a real and genuine culture; the yield from the soil is the interest on her growing power'.[35] However, thanks to agricultural chemistry, the Europeans now knew why certain nations perished while others survived. Consequently, humankind held its own destiny its hands. Liebig wrote that 'they are responsible for all the misery, that their actions will cause their descendants'.[36]

ALEXANDER MÜLLER AND THE MANURE QUESTION

In 1856 the German chemist Alexander Müller (1823–1906) was instated as the first professional agricultural chemist at the Royal Swedish Academy of Agriculture. Müller had a doctoral degree in chemistry from the University of Leipzig. In 1853 he was employed by the technical and agricultural school in Chemnitz, where he also became head of its new experimental station.

From his arrival in Stockholm, a central task for Müller was the recycling of night-soil and city waste, as an imbalance was discerned between country and city. Since the production of manure in the cities far surpassed the consumption of manure in their hinterlands, it was of the utmost importance that night-soil could be made easy to transport. In this manner, it would be possible to recycle nutrients at the same rate as they were transported to the cities. Müller maintained that in this context, Stockholm was very fortunate, since its numerous waterways made it possible to reach a large area without difficulty.[37]

Müller's studies on recycling in Sweden resulted in several articles and the text *Gödselboken eller grunderna för gödselämnenas behandling i städer och på landet* [The manure book, or principles for the handling of nutrients in the cities and the countryside] (1860). This study clearly shows that Müller was familiar with chemical recycling theories and the chemico-theological outlook. He asserted that matter was indestructible and followed unlimited cycles, where everything in life, death and nature depended on how elements were combined or decomposed. 'It is granted to our time to have a clear understanding of the wonderful circulation of nature', Müller stated.[38]

It was the duty of agricultural chemists to counteract the mismanagement of nutrients, the lack of knowledge and the prejudices against excrement which were common in society. One example proving how little mankind understood the order of nature was that nitrogen in urine was preserved in a fresh form during the winter, when the plants could not assimilate nutrients. In that way, nature built up stocks for the new plant life which would emerge in the spring. However, mankind did not care for this 'storage', Müller maintained, and did everything to get rid of it.[39]

Müller was also made indignant by the fact that expensive guano was imported, while there was shortage of manure in the country and the population continued to grow. It was, however, possible to produce domestic guano featuring the same properties as the imported one, claimed Müller. Guano results from a concentration of the nitrogen and minerals in the food digested by animals, according to Müller. Consequently, 'nature everywhere on Earth, where animal digestion occurred, left materials for guano'.[40] Thus to Müller, guano was identical with animal excrement, irrespective of the animal that produced it. The difference in its quality depended on the digestion process and the kind of food the animal consumed. Since the human digestion process worked in the same way as other mammals, night-soil was thus guano.[41]

Moreover, climate played a decisive role in the formation of guano. On the islands off the coast of Peru where guano was accumulated in large deposits, the water evaporated in the warm, dry breeze. Conversely, in a more cold, moist and variable climate like Sweden's, putrefaction prevented the formation of guano. Müller's problem, in other words, was how to forestall this decay before the nutrients went to waste. The product also had to be economically viable and easy to transport and use. To dry the night-soil with artificial heat was too expensive, and the use of straw, mud or earth to absorb the moisture only reduced the quality of the product and made it bulkier. Müller's fundamental principle was that excrement had to be handled in a correct way from the very beginning, so as to facilitate its transformation into a pure and concentrated form.

Crucial to the attainment of this goal, Müller claimed, was that urine needed to be separated from solid excrement. This was more 'natural' and would facilitate the handling of the substances, answering different applications in agriculture. Previous failures by manure factories could be ascribed to the fact that these two substances were mixed together. That not only activated the putrefaction process that Müller wanted to avoid but also resulted in an infernal stench and the spread of disease. In many poudrette industries that Müller visited in Germany, excrement was no longer used as raw material, since the diluted and blended night-soil was too expensive to use. Instead, they had started using by-products from butcheries and industry.[42]

However, Müller expected 'Mr Marino's patented earth-closet' to solve the problem.[43] This was an earth-closet that separated solid excrement from urine in different containers, thereby preventing the onset of the putrefaction process. The urine, which contained nitrogen, was then rendered odourless by means of sulphuric acid. By mixing it with lime it became a high quality fertiliser. As a consequence the faeces were also easier to dry and concentrate in poudrette factories.

In accordance with this ambition to keep the excrement separate and concentrated, Müller strongly opposed the introduction of a sewer system and water closets. The sewers both destroyed and diluted the manure, causing substantial financial loss. Müller stated that 'Stockholm has still the advantage, that the waste of manure is enouraged neither by a sewage system nor water-pipes. Hurry up before it is too late, to make something substantial, to the glory and benefit of Sweden!'[44] Even if the flush toilets and sewers were connected to an irrigation system, the method had become too expensive and been abandoned in many areas, he claimed.[45] In contrast, Marino's closet was based on a collection system with barrels. In a later article, Müller asserted that they had already understood the advantages with such disposal system abroad:

> In Berlin the authorities have rejected the proposal of introduction of water closets and sewers to remove the filth from the city, as inconsistent with the public health service and the need of nutrients for agriculture, and instead decided on a collection system with barrels. Also in London, where the sewerage system with enormous costs have been most developed, they begin to see how unnatural this system is...[46].

URBAN TECHNOLOGY FROM AN AGRARIAN POINT OF VIEW

When Müller left his post at the Royal Swedish Academy of Agriculture in 1869 he moved to Berlin, where he continued investigating how night-soil and waste could be recycled. On Müller's initiative, the German Society of Agriculture set up a commission in February 1884 to investigate the utilisation of night-soil in cities, in which Müller himself participated.[47] In 1885, the members of the commission, including Müller, Eduard Heiden (agricultural chemist and super-intendent for the experimental station in Pommris) and Karl von Langsdorff (secretary of the Royal Saxonian Agricultural Society), published the survey *Die Verwerthung der Städtischen Fäcalien* [The Utilisation of Urban Faeces].

In the introduction, written by Müller, he questioned the definitions of the concepts 'waste' and 'filth'. Müller wrote that 'the concept of "waste" is wholly subjective'.[48] Everything that has been used once for a specific purpose can be seen as refuse; accordingly, something that can defined as waste can also be classified as a resource from another angle. Thus filth and night-soil can only be regarded as 'waste' in some quarters. In the universe, matter was not used only once for one purpose, but rather again and again through its various metamorphoses for infinite ends. It was this insight that distinguished the nineteenth-century 'Kulturstaaten', and the current generation in particular, from previous societies. Müller's conclusion was that all 'refuse' had to be used to the greatest possible advantage.

Müller wrote that the aim of the public sanitation was to remove and restore that which had become sticky, dusty and unpleasant to the human senses. This filth is produced in everyday life by human beings and other organisms which 'stand in the way' of man. Thus, filth was '"things" that have ended up in the wrong place'.[49] This argument is reminiscent of Mary Douglas' definition of filth and dirt mentioned above, i.e. that filth is something that has been misplaced and thereby violates what is regarded as ordered and natural. In contrast to Douglas, who claims that what is regarded as 'natural' is socially constructed, Müller claims that filth is something that is in the 'wrong place' in relation to the genuine order of nature. For Müller, man on one hand remains an agent who disturbs the natural order, and on the other is capable of adapting and maintaining this order.

By returning the waste of the city to the soil, the sanitation system could work hand-in-hand with agriculture. However, the problem, as always, was how to recycle this waste in practice so that it was easily accessible and cheap to process while maintaining its quality and minimising the danger of the spread of disease. In the preceding section concerning technological methods, the two main alternatives are described, namely latrines and the water-borne sewage system, '*abfuhr oder canalisierung*'. The collection of excrement could be achieved by means of a pit or barrel system. The advantage of the barrel system was that the barrels were mobile and that waste did not leak from them, polluting the surrounding soil. An essential effect of this collection system was that the waste was transformed into nutrients. This could be achieved by means of composting. The time-tested method of mixing it with lime, peat, and ashes was described, as were more modern methods. The commission's survey includes an account of how factories extracted faeces by means of vacuum and high temperatures so that the waste was totally disinfected and prepared for manure powder.[50]

A water-borne sewage system was the second main alternative for removing dirt from the cities. As mentioned several times, this system could be interlinked with sewage farms, where the self-cleansing capacity of the soil or, in the words of the commission, 'the molecular cleansing force' (*die moleculare Reinigungskraft*), cleansed the sewage water.[51] However, since there was a risk that poisonous parasites might be spread, the sewage water needed to be filtered. The mud from filtration could nevertheless be dried and thereafter used as a means to improve the soil.

As a third technical solution, the separation system was proposed, i.e. constructing separate sewers for rain water and household water, respectively. Here the '*Differenzirsystem*' of Dutch engineer Charles T. Liernur (1828-1893) was specifically mentioned by the three authors. Liernur used the recycling theory as the starting-point of his system, the object of which was to use separate sewage systems for rain water, households and industry. Thereby different kinds of waste could be separated at the very point of origin and be cleansed in a way appropriated to each. Specific to household waste was that water would not be used to transport excrement but rather pneumatic pressure. Via pipes from each household leading to a central pump station, excrement was sucked from the whole city and gathered in one place. From there the faeces could be sold directly to the farmers, be composted or be industrially processed for manure powder.[52]

How widespread was the use of these various systems? The commission's survey gives us a general idea of their distribution at the time in some fifty north-western European cities (mainly in Germany). The cities are divided into categories, depending on the methods that were used, i.e. removal or sewage, with or without irrigation fields. The category of '*Abfuhrstädte*' comprised thirty-five German cities, the Scandinavian cities of Copenhagen, Stockholm, Christiania (Oslo) and Bergen, and Manchester, Rochdale and Glasgow in Great Britain.[53]

The second category consists of '*Städte mit Schwemmcanalisation*'.[54] This group included Bunzlau in Silesia, Mailand, Hamburg, Frankfurt am Main, Danzig, Berlin and Paris. All these cities except for Hamburg and Frankfurt had irrigation systems. A special chapter was devoted to London and the remaining cities and towns of Great Britain where water-borne sewage systems were furthest evolved.[55]

The third category of cities, '*Städte mit pneumatische Canalisation*', used Liernur's differentiation system. The use of pneumatic sewage removal had been put into practice on a large scale, according to the survey, only in the Dutch cities of Amsterdam, Dordrecht and Leiden.[56]

In the conclusion of the investigation by Heiden, von Langsdorff and Müller, it is apparent that the authors were critical of water-borne sewage systems since valuable nutrients were lost. The employment of irrigation fields was also rejected, since they were too expensive and the necessary sanitary requirements had not been met. A well-organised removal system with favourable means of communication was beneficial to city-dwellers and farmers alike. The importance of processing excrement in faeces factories was emphasised. In that way they were transformed into a dry, easily distributed product that was easy to transport, possible to store and marketable.[57]

The authors were also positive in their assessment of Liemur's pneumatic system. If this system were to be connected to a modern manure industry, it would make it convenient for its users to rid their homes of waste, while at the same time as the recycling process was rational and all sanitary requirements had been met. It would also prove to be an inexpensive system, claimed the authors. At the same time as systems for gas and water pipes were being built, the cost for constructing a pneumatic pipeline system would not be high and, after some time, it would prove cheaper than the barrel system. All the links in the chain between the individual urban dweller, via the manure industry, to the individual farmer, would then be automatic and effective. The authors discerned a historical turning point where 'the long disputed question, which is of interest both for the population of the cities and the country-side, has been brought to a final solution'.[58]

CONCLUDING REMARKS

In the short run, these expectations were to some extent fulfilled. In the early twentieth century, industrial recycling techniques were developed by means of mechanisation, chemical treatment and improved communications. However, agricultural chemists were no longer a driving force in their implementation. Instead, engineers, technicians and private entrepreneurs took over the initiative. Their purpose was chiefly to solve the sanitary problems of the cities, and recycling was a way of financing the disposal of waste. Arguments for recycling based on ideas about a balance between the country and the city or preserving the fertility of the soil were of secondary importance.

Why did interest in recycling decline among the agricultural chemists? First, there was a gap between the theory of recycling and its practice and available technology. The great financial and social expectations for recycling in the 1860s never came true. From the 1870s onwards, the discussion about recycling instead concerned technological, sanitary and economic problems.[59] Secondly, the development of new mineral and nitrogenous fertilisers at the turn of the century was very significant. For the first time in history, the problem of the constant shortage of nutrients seemed to have been solved.

At the same time, the recycling idea itself came into question. Physicians and advocates of the sanitary movement in particular started propagating for building flush toilets connected to sewers, foregoing any recycling. The advantage offered by water closets was that they rapidly removed the waste from households and the urban environment before any stench or bacteria could be disseminated, without anyone having come into contact with the disgusting fluid mass. The critique that nutrients crucial for agriculture were thus wasted was rejected since there was an abundance of night-soil based powdered fertilisers that had been difficult to sell, and its preparation incurred large economic losses.[60] However, the recycling idea was still present to some extent, as were, paradoxically, arguments against it. According to the idea of nature's purifying capacity, it was asserted that water also possessed such a capacity. As long the sewer water was poured into streaming water-courses, the filth would be diluted and purified. Some sanitatrians even claimed that sewer water would fertilise the seas, and consequently the nutrients could be recycled, not via farming, but through commercial fishery.[61]

Important for this development was, thus, the new understanding of the significance of micro-organisms and bacteria for transmitting diseases. However, the bacteriological breakthrough becomes contradictory when comparing the hygienic movement with agricultural science. In agriculture, bacteria were mainly seen as 'beneficial'. Microbes fix nitrogen from the air, are crucial constituents in fertile soil, and are important in dairy production. However, the dominant conception of bacteria established at this time saw bacteria are dangerous, since they transmitted diseases. Thus, the sanitary movement made 'evil' bacteria visible, which gave it a strong position in society.[62] These dangerous microbes were also associated with filth and immorality, which should not be allowed to exist in a healthy society. There was no place for any kind of filth in a modern society, and an increasing scepticism towards the use of human excrement as fertiliser grew. The sanitarians could therefore use their arguments about microbes to sanction the building of water closets and sewage systems.

Finally, crucial to decreasing interest in recycling among agricultural chemists was the abandonment of the chemico-theological outlook, in which both the absorption of nutrients by plants as well as the appearance of diseases in cities were characterised by interconnected chemical processes. The chemico-theological outlook was rejected with the emergence of modern bacteriology and because of the disappointing financial rewards of recycling. When the recycling discourse was discarded, so were efforts to create an interdependence between the cities and the countryside and agrarian and sanitary interests, which had been emphasised in the mid-nineteenth century. With the rejection of the chemico-theological idea, the connection between recycling, wealth and the survival of society as a whole disappeared. The disposal of night-soil and refuse was thereby reduced to an economical and technological issue on the municipal level.

The recycling idea did not, however, totally fade away. Outside established agricultural science, the recycling idea has been crucial to the organic movement, for example.[63] In the last decades, recycling has enjoyed something of a renaissance, and the idea of an interdependence between the urban and rural life has been added to the political agenda in efforts to create a sustainable society.

NOTES

[1] Victor Hugo, *Les Misérables* (1862), English translation by Isabel F. Hapgood 1984. The page number refers to the Swedish edition 1862, fifth part, 114.
[2] Nicholas Goddard, '"A mine of wealth"?: The Victorians and the Agricultural Value of Sewage', *Journal of Historical Geography* 22 (1996): 274–90; Ola Wetterberg and Gunilla Axelsson, *Smutsguld & dödligt hot: Renhållning och återvinning i Göteborg 1864–1930* (Göteborg: Göteborgs renhållningsverk, 1995) [Golden Waste and Mortal Threats: Waste Disposal and Recycling in Gothenburg 1864–1930].
[3] Hugo, *Les Misérables*, 115.
[4] Hugo, *Les Misérables*, 116.
[5] Pat Munday, 'Liebig's Metamorphosis: From Organic Chemistry to the Chemistry of Agriculture', *Ambix* 38 (1991): 135–54. Cf. William H. Brock, *Justus von Liebig: The Chemical Gatekeeper* (Cambridge: Cambridge University Press, 1997), and Ursula Schling-Brodersen, *Entwicklung und Institutionalisierung der Agrikulturchemie in 19. Jahrhundert: Liebig und Die Landwirtschaftlichen Versuchsstationen* (Braunschweig, 1989).
[6] Justus von Liebig, *Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie* (Braunschweig, 1840). The page number refers to the Swedish edition translated from the fifth German edition (Stockholm, 1846): 240–5 and 346–7.
[7] Christopher Hamlin, 'Providence and Putrefaction: Victorian Sanitarians and the Natural Theology of Health and Disease', *Victorian Studies* 28 (Spring 1985), and Christopher Hamlin, 'Robert Warington and the Moral Economy of the Aquarium', *Journal of the History of Biology* 19 (Spring 1986): 134–41.
[8] Trevor H. Levere, 'The Rich Economy of Nature: Chemistry in the Nineteenth Century', in *Nature and the Victorian Imagination,* ed. U. C. Knoepflmacher and G. B. Tennyson (Berkeley, Los Angeles and London: University of California Press, 1977): 191.
[9] James F.W. Johnston, 'The Circulation of Matter', *Blackwood's Edinburgh Magazine* 73 (May 1853): 550–60.
[10] Johnston, 'The Circulation of Matter', 556.
[11] Johnston, 'The Circulation of Matter', 559.
[12] Johnston, 'The Circulation of Matter', 560.
[13] Johnston, 'The Circulation of Matter', 560.
[14] Graeme Davison, 'The City as a Natural System: Theories of Urban Society in Early Nineteenth-Century Britain', in *The Pursuit of Urban History*, ed. Derek Fraser and Anthony Sutcliffe (London: Edward Arnold, 1983): 349–70. Cf. Susanne Hauser, '"Reinlichkeit, Ordnung und Schönheit": Zur Diskussion über Kanalisation im 19.Jahrhundert', *Die Alte Stadt* 14 (1992): 310–12; Martin V. Melosi, 'The Place of the City in Environmental History', *Environmental History Review* 19 (Spring 1993): 5–11; and Marina Fischer-Kowalski, 'Society's Metabolism: The Intellectual History of Material Flow Analysis, Part I, 1860–1970', *Journal of Industrial Ecology* 2 (1998): 61–78.
[15] Hamlin, 'Providence and Putrefaction', 391–2, and Engelbert Schramm, *Im Namen des Kreislaufs: Ideengeschichte der Modelle vom ökologischen Kreislauf* (Frankfurt am Main: Verlag für Interkulturelle Kommunikation, 1997): 230–1.
[16] Edwin Chadwick, *Report on the Sanitary Conditions of the Labouring Population of GT. Britain* (1842), new edition, ed. M. W. Flinn (Edinburgh, 1965): 118–24.

[17] Cf. *Das Management von Fäkalien und Flüssigabfällen aus Haushalten – historische Perspektive auf ein Problem der Gegenwart: Referate und Thesenpapiere der Arbeitstagung vom 20.–23. 10. 96 in Frankfurt am Main*, unpubl. report from Institut für sozial-ökologische Forschung (ISOE) (Frankfurt am Main, 1996).
[18] Schramm, *Im Namen des Kreislaufs*, 226–31.
[19] Brock, *Justus von Liebig*, 254–7.
[20] Justus von Liebig, *Letters on the Subject of the Utilization of the Metropolitan Sewage, Addressed to the Lord Mayor* (London, 1865): 20.
[21] Liebig, *Letters on the Subject of the Utilization of the Metropolitan Sewage*, 20.
[22] Mary Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo* (1966), Swe. trans. (Nora, 1997): 10–11.
[23] Davison, 'The City as a Natural System', 357–8.
[24] Liebig, *Chemien tillämpad på jordbruk och fysiologi*, 314–47.
[25] Brock, *Justus von Liebig*, 208–9, and Christopher Hamlin, *A Science of Impurity: Water Analysis in Nineteenth Century Britain* (Berkeley and Los Angeles: University of California Press, 1990): 129–40.
[26] Elizabeth Wilson, *The Sphinx in the City: Urban life, the Control of Disorder, and Women* (Berkeley, Los Angeles and Oxford: University of California Press, 1991): 26–46. Cf. Donald Reid, *Paris Sewers and Sewermen: Realities and Representations* (Cambridge, MA and London: Harvard University Press, 1991).
[27] Chadwick, *Report on the Sanitary Conditions of the Labouring Population of GT. Britain*, 424–5.
[28] Justus von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*, 2 vols. (Braunschweig, 1862). The page number refers to the abridged and translated Swedish edition, *Naturlagarna för åkerbruket* (Örebro, 1864): 65.
[29] von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*, 64–70.
[30] Cf. Clarence J. Glacken, 'Changing Ideas of the Habitable World', in *Man's Role in Changing the Face of the Earth*, ed. William L. Thomas jr., *et al.* (Chicago: University of Chicago Press, 1956); Kenneth Robert Olwig, 'Historical Geography and Society/Nature "Problematic": The Perspectives of J. F. Schouw, G. P. Marsh and E. Reclus', *Journal of Historical Geography* 6 (1980): 31–6, and 70–88; Theodore S. Feldman, 'The Ancient Climate in the Eithteenth and Early Nineteenth Century', in *Science and Nature: Essays in the History of Environmental Sciences*, ed. Michael Shortland (Oxford, 1993): 23–40; Gottfried Zirnstein, *Ökologie und Umwelt in der Geschichte* (Marburg: Metropolis-Verlag, 1996): 155–6; and Marcus Hall, 'Restoring the Countryside: George Perkins Marsh and the Italian Land Ethic (1861–1882)', *Environment and History* 4 (1998): 91–103.
[31] von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*, 86. Translation cf. Wolfgang Krohn och Wolf Schäfer, 'The Origins and Structure of Agricultural Chemistry', in *Perspectives on the Emergence of Scientific Disciplines*, eds. Gerard Lemaine *et al.* (The Hague, 1976): 31.
[32] von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*, 91. Translation cf. Brock, *Justus von Liebig*, 178.
[33] H. Maron, 'Tillägget G, Japanska åkerbruket', in von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie t*, 403.
[34] Maron, 'Tillägget G, Japanska åkerbruket', 404.
[35] Maron, 'Tillägget G, Japanska åkerbruket', 405.
[36] von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie*, 76.

[37] Alexander Müller, *Gödselboken eller grunderna för gödselämnenas behandling i städer och på landet* (Stockholm, 1860): 45.
[38] Müller, *Gödselboken*, 2.
[39] Müller, *Gödselboken*, 19.
[40] Müller, *Gödselboken*, 7.
[41] Müller, *Gödselboken*, 7–12.
[42] Müller, *Gödselboken*, 47, and 49.
[43] Müller, *Gödselboken*, 11–12, and 14–17.
[44] Müller, *Gödselboken*, 55.
[45] Müller, 'Anteckningar under en resa i Holland och England', *KSLAT* (1864): 154.
[46] Müller, 'Berättelse om Agrikulturkemins framsteg', *KSLAT* (1865): 61–2.
[47] Eduard Heiden, Alexander Müller and Karl von Langsdorff, *Die Verwerthung der Städtischen Fäcalien* (Hannover: Verlag von Philipp Cohen, 1885): 417.
[48] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 4.
[49] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 5.
[50] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 79–82.
[51] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 105.
[52] Cf. Henk van Zon, 'Liernur Gegen den Storm', in *Das Management von Fäkalien und Flüssigabfällen aus Haushalten – historische Perspektive auf ein Problem der Gegenwart: Referate und Thesenpapiere der Arbeitstagung vom 20.–23. 10. 96 in Frankfurt am Main*, unpubl. rapport from Institut für sozial-ökologische Forschung (ISOE) (Frankfurt am Main, 1996), and Wetterberg and Axelsson, *Smutsguld & dödligt hot*, 72–5.
[53] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 179–291.
[54] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 292–383.
[55] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 384–403.
[56] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 404–14.
[57] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 454–64.
[58] Heiden, Müller and von Langsdorff, *Die Verwerthung der Städtischen Fäcalien*, 464.
[59] Ola Wetterberg, 'Great Expectations: Some Remarks on the Economy of Solid Waste Removal and Recycling in Gothenburg 1860–1930', paper presentated by the Second European Social Science History Conference, 5–7 Marsh 1998, Amsterdam.
[60] Lars Lundgren, *Vattenförorening: Debatten i Sverige 1890–1921* (Lund: Gleerups, 1974): 40–5.
[61] Hamlin, 'Providence and Putrefaction', 409.
[62] Bruno Latour, *The Pasteurization of France* (1984), English translation. (Cambridge, MA and London: Harvard University Press, 1988): 13–58.
[63] Cf. Anna Bramwell, *Ecology in the 20th Century: A History* (New Haven and London: Yale University Press, 1989); Barton Blum, 'Composting and the Roots of Sustainable Agriculture', *Agricultural History* 66 (1992): 171–88; and Philip Conford, 'The Alchemy of Waste: The Impact of Asian Farming on the British Organic Movement', *Rural History* 6 (1995): 103–14.