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Risk perception and assessment of a Brownfield Site

L'évaluation du danger posé par une ancienne zone industrielle

R W Sarsby
RIATec, Department of Civil Engineering, Wolverhampton University, UK
Rama Sarma Karri
Department of Civil Engineering, Birmingham University, UK

ABSTRACT
There is an increasing need to redevelop brownfield sites, particularly for housing, because of continuing rise in the demand for residential properties and the need to preserve greenfield sites. However, brownfield sites commonly contain substances and materials, from previous industrial activity, which can be hazardous to human health. This paper concerns the risk assessment of a real brownfield site. The site and the land adjacent to its boundaries formed part of a former industrial area which had been occupied by an abattoir, a milk depot, a plant hire company and an engineering works. As a result of undertaking the hazard identification and hazard assessment stages of the risk assessment process it was determined that the site did not pose a hazard to the proposed end users and this outcome could be demonstrated definitively to members of the public.

RÉSUMÉ
En Angleterre il faut réutiliser d'anciennes zones industrielles, surtout pour créer des lotissements, afin de conserver la campagne et le terrain agricole. Cependant, la terre à ces zones contient souvent des substances et des produits chimiques qui peuvent abîmer la santé humaine. Cet article-ci concerne l'évaluation des dangers d'un chantier actuel. Ce chantier et ses environs ont été occupés autrefois par: un abattoir, un dépôt pour les produits laitiers, un loueur d'équipement de construction et un atelier de construction mécanique. L'identification des hazards et des risques associés avec la contamination du sol prouva qu'on pouurait créer sans danger un lotissement sur ce chantier.

1 INTRODUCTION

In the UK there is increasing need to redevelop brownfield sites (areas of land previously used for industrial purposes), in particular for housing, due to the need to conserve existing greenfield sites and the greenbelt areas surrounding cities. Such requirements are expressed in recent government targets, e.g. 60% of new housing has to be built on brownfield sites (Environment Agency, 2000). However, residential development is the most sensitive end-use of such land because of its potential to affect the health and finances of the occupants and also the socio-economic well-being of the community.

In the UK it is common practice to adopt a risk-based approach that aims to identify and manage the risks posed by the site. This involves defining the hazards, quantifying the levels of risk that they pose and taking steps to reduce the risks to an acceptable level (Petts et al, 1997). This is typically a four-stage process which aims to 1) identify the hazard, 2) assess the nature of the hazard using a Source-Pathway-Target model, 3) estimate the risks posed to the 'Target' by the hazard in a site-specific analysis, and 4) to evaluate whether the level of risk posed is acceptable. The risk management approach also provides for reduction of hazards to an acceptable level where necessary.

Risk assessment of brownfield sites is usually undertaken by specialist environmental companies but other site stakeholders (the general public, residents, etc) also perform undertake a psychological process of risk perception. In making their assessment the public rely on a variety of sources of information relating to their everyday experiences and are most likely to rely on intuitive risk judgements, i.e. risk perceptions, (Slovic, 1987). The outcome unfortunately is that the 'public' perception of the risks associated with brownfield sites often does not correspond to the levels of risk determined to exist by 'experts'.

2 PUBLIC RISK PERCEPTION

The primary factors which control risk perception by the general public are:

- Cognitive bias - the person threatened assesses the scale of the problem by reference to previous experiences concerning similar events or situations. The less familiar that a person is with the risk and the less control that they exercise over their exposure the greater is the perceived risk (SNIFFER, 1999). The 'experts' themselves are also subject to cognitive influences and their judgements are prone to many of the same biases as those of the general public (Slovic, 1987).
- Sociological influence - the person at risk will be influenced by the opinions of others on the type of information that is available on the nature of a hazard. The opinions of friends, work colleagues and family are the most important sources of influence when gathering information on the nature of a hazard (Petts et al, 1997).
- Credibility of decision-makers - the public place most trust in management strategies which recognise and identify risks, and which provide for rapid response and implementation of corrective action. There is a general lack of trust in; industry (their approach to safety and the environment), regulatory agencies and industry (effective monitoring of facilities), risk assessments (concerns over reliability and validity), effective environmental action (lack of coordination between authorities).
- Protection of personal interests - people will always try to maintain the status quo where it appears that doing so will provide protection of their personal assets.

3 RISK ASSESSMENT

During the hazard identification stage a conceptual 'picture' of the site is developed using information gathered through the desk study, zoning and reconnaissance phases. The 'picture' can then be used to determine all plausible contaminants (previous land-use), possible pathways (understanding of geology, hydrogeology and use of site) and receptors (workers on site and proposed end use and users of the site) within a Source-Pathway-Receptor model. The underlying principle of this is that, regardless of the presence and nature of contaminants, if there is no plausible pathway to existing receptors or there are no receptors that can be affected by the presence of the contaminant, then the contaminant poses no risk.

There are three stages to determining whether actual risks are presented to the named receptors via the linkages described;

- Completion of a detailed ground investigation using sampling strategies to aid determination of the nature and location of samples required.
- Analysis of selected samples to determine nature (e.g. soluble, bioavailable, leachable) and concentration of contaminants.
- Comparison of results with standard guideline values and/or use of professional judgement to determine whether the risks posed are acceptable. The risk estimation process comprises the use of two main models, one (exposure assessment) concerned with the movement of contaminants in the pathways of concern and the transfer between media, and the other (toxicity assessment) concerned with the effect of a contaminant of concern on the receptor.

3.1 Site description

The site is approximately 80m by 60m and is located about 3km east of a medium-sized town. The area is elevated between 2 and 5m above the level of surrounding land. The only watercourse in the immediate area is a small stream just over 300m to the south-west of the site, flowing in a south-westerly direction.

In 1877 the Ordnance Survey Map showed the north-east region of the current site to be occupied by a gravel pit. The rest of the site was recorded as unmarked open field, as was the land to the North and East. Directly south-west of the site lay the town sewage outfall works and beyond this there were areas of marshy ground and open undeveloped fields. For the next 80 years there were no recorded changes in land use for the site although extraction of gravel from the site ceased and the 1961 Ordnance Survey Map records the whole site area as open land. The only significant change of land use in the area was the extension of the sewage works to the east and south thereby occupying previously open fields and marshland.

During the 1960's significant development took place within and adjacent to the site boundary. A slaughterhouse (abattoir) was built on the site and plant hire and milk transport depots were established to the North. The sewage works also underwent further development and part of the main works was demolished and converted into a refuse tip. In the 1970's and 1980's there was further development of the abattoir in an easterly direction and an oil depot was established to the north-east of the site, but otherwise no other major construction work was undertaken on or adjacent to the site.

The abattoir was demolished in the late 1990's and there is now no evidence of this former land-use on the site. The site generally comprises levelled made ground of demolition rubble, soil, bricks, etc with a patchy cover of grass, weeds and shrubs. Recently completed residential developments (houses and blocks of 3 storey flats) are now located to the east and west of the site. There are no active landfill sites in the vicinity and no official records of pollution incidents occurring on or within 250m of the site.

On the basis of the foregoing information a conceptual model of the site (Figure 1) was established for undertaking the risk assessment.

3.2 Ground conditions

The geology immediately beneath the site comprises river sands and gravels of Quaternary age, underlain by mottled red brown clays and silty sandy clays. These materials overlie the Upper and Middle Chalk which dip very gently to the south. The approximate depth of the water table is 6m below ground level across the site and the hydraulic gradient is in a south-easterly direction. Groundwater levels in the chalk are approximately 4m lower than in the river gravels but at a similar level to the local stream. There is thus a flat lying water table which suggests good hydraulic connection between the chalk aquifer below the site and the stream to the south of the site. Whilst there is a downward vertical hydraulic gradient from the river gravels to the chalk there is no evidence of any significant hydraulic connection between the two aquifers.

The river sands and gravels comprise a minor aquifer. The materials of this aquifer are classified as coarse-textured, permeable soils which readily transmit a wide range of pollutants because of their rapid drainage and low attenuation potential. There is licensed groundwater abstraction from the river gravels 1km to the south-west of the site for industrial processes and dust suppression. The Upper Chalk is a major aquifer and the most important one in the region. Water is taken from the chalk by two public-supply pumping stations – one 4km to the west and the other 3km north of the site.

3.3 Environmental concerns

Since the site had been formerly used as an abattoir there was the possibility of biological contamination of the ground.

There was also the possibility of hydrocarbon contamination from an active oil depot adjacent to the site. Elevated levels of diesel-range hydrocarbons had been detected within the river gravels during construction work to the north of the site, adjacent to the oil depot. At this location there was a diesel storage tank which had an estimated capacity of 45,000 litres. The tank had been in existence about 40 years. Examination of this facility showed that the tank was located within a lined brick bund that contained a large crack. An adjacent tank was found to contain 1,500 litres of waste engine oil. Trial pits and boreholes were dug in the vicinity of the tanks and hydrocarbon contamination was measured and compared with a target action level for Total Petroleum Hydrocarbons (TPH) - soils containing concentrations exceeding this level were removed from the site. A total of 435m^3 of contaminated soil was identified, and removed from the areas surrounding the previous location of the storage tanks. A 6-month programme of bioventing was also undertaken to remediate the contaminated area and the quality of the groundwater was monitored for 2 years. A major concern of the environmental authorities was the potential for movement of contaminated surface water from land immediately adjacent to the abattoir site and the creation of migration pathways into the underlying Chalk. Such pathways could be formed by boreholes sunk as part of the site investigation or by the use of piled foundations which extended down to the Chalk.

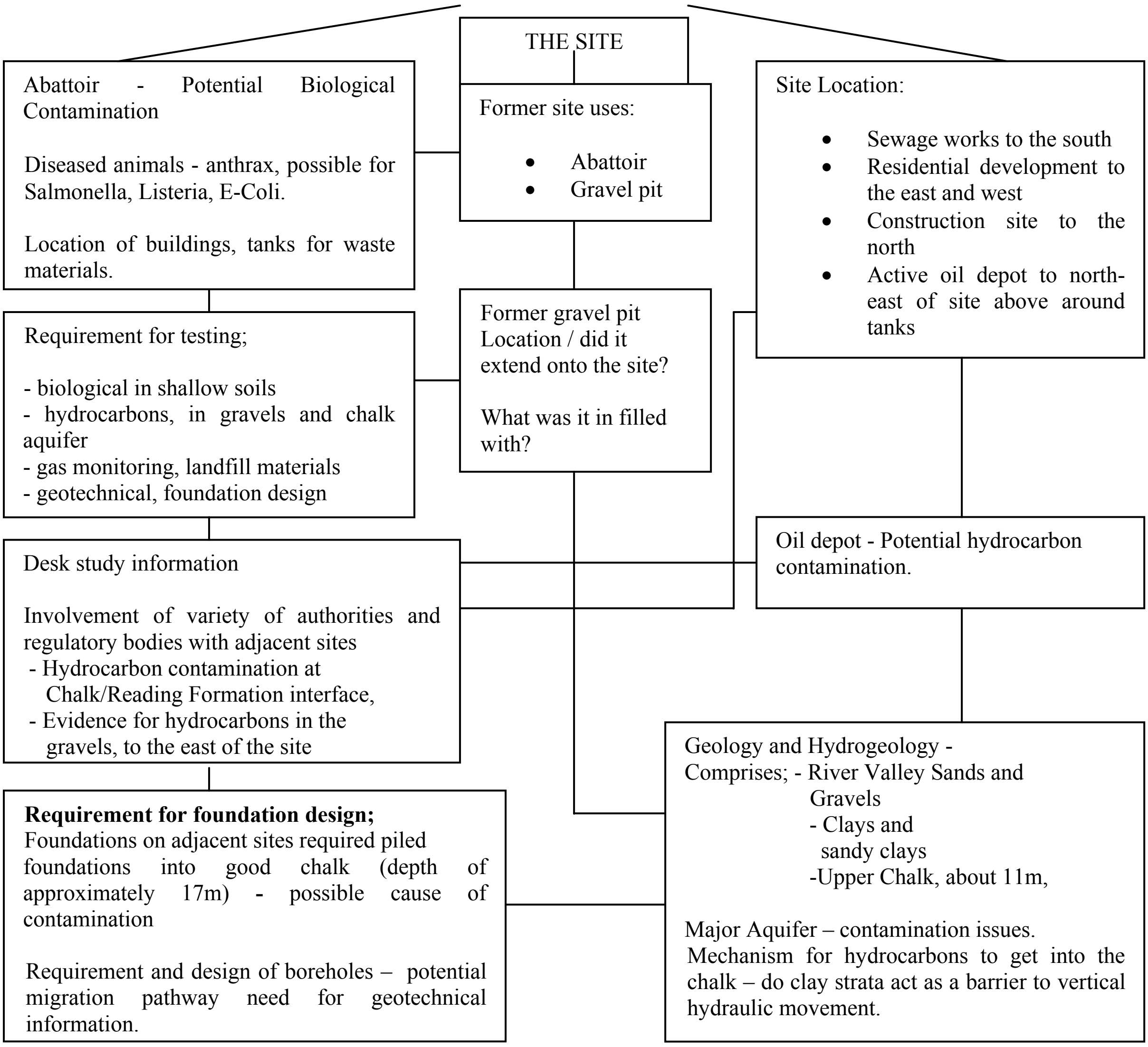

Figure 1. Conceptual Model of the Site

3.4 Ground investigation

A total of 13 trial pits and 9 boreholes were sunk;

- along the north and eastern perimeter of the site - to detect any hydrocarbon migration (from adjacent areas) in the river gravels and/or Upper Chalk,
- in the north eastern area of the site - to locate the former gravel pit and determine the presence of fill materials,
- across the centre of the site (around the approximate location of the former abattoir buildings) to sample for biological and chemical contamination.

Trial pits were excavated to a depth of 3m using a 'backacter'. Boreholes were drilled to a depth of approximately 10m into good chalk to provide geotechnical information that would assist in the design of suitable foundations.

Seven of the 9 boreholes were used to monitor groundwater levels and condition. Great care had to be taken not to create a potential migration pathway between the upper and lower aquifers and the remaining two deep boreholes were backfilled with bentonite pellets. Monitoring of the groundwater in the chalk was not considered necessary at four boreholes and they were therefore fitted with single standpipes into the river gravels.

Dual installations comprising two separate standpipes of different length were installed in three boreholes. The intention was to provide monitoring information firstly from the upper water bearing strata to a depth of 10m below ground level and secondly from the underlying chalk strata at depths greater than 11m from the same borehole. The deep standpipe comprised slotted HDPE pipe through the chalk and plain pipe above the junction of the chalk with the clay strata. The short standpipe comprised slotted pipe through the gravels and plain pipe through both the clay strata and made ground. It was separated and sealed from the deep standpipe within the same borehole by a 2m deep bentonite seal at the interface of the chalk and the clay strata.

3.5 Sampling results

Because of the past usage of the site biological testing was undertaken as follows:

- *Salmonella bacilli* (Salmonella) – nothing significant detected.
- *Listeria* sp - samples from two Trial Pits (at 0.2m and 0.3m depth) were identified as containing a form of listeria, which, due to its nature and quantity, would not cause any

harm or risk to the proposed end users of the site.

- *Escherichia coli* (E Coli) – nothing significant detected.
- Total Viable Count (TVC) of bacteria - the type of bacteria detected and their extent was typical for the soil type at the site soil and would not pose any risk to residents of the redeveloped site.
- *Faecal Streptococci* – nothing significant detected.
- *Bacillus anthracis* (Anthrax) – nothing significant detected.

At the time of undertaking the risk assessment the methodology utilised ICRCL (Interdepartmental Committee on the Redevelopment of Contaminated Land) trigger concentration values (ICRCL, 1987). Thus the chemical testing focused on the standard ICRCL suites of contaminants. Testing for the presence of inorganic toxic and phytotoxic materials gave the following results:

- *Arsenic* – very slightly elevated concentrations were detected in five locations at depths between 0.3 and 0.4m, i.e. three values of 11mg/kg, one value of 12mg/kg, one value of 13mg/kg (as compared to a threshold trigger value of 10mg/kg).
- *Cadmium, Chromium, Lead, Mercury, Selenium* – nothing significant detected.
- *Boron, Copper, Nickel* – nothing significant detected.
- *Zinc* – only one excessive value was recorded, i.e. a moderately elevated concentration of 590mg/kg as opposed to the threshold value of 300mg/kg. Zinc is phytotoxic but not normally hazardous to human health and the contaminated sample was taken from a depth of 0.3m. Futhermore, at the time of the site assessment it was not know whether this contamination would fall beneath a house footprint or garden area. Since a veneer of clean topsoil would be imported to provide a growing medium for the gardens, it was decided this concentration of zinc could remain on site without causing a risk to human health.

Guideline values for TPH are not included in the ICRCL guidance but concentrations above 2000mg/kg are widely considered to represent elevated soil concentrations. The ICRCL guideline trigger value for Poly Aromatic Hydrocarbons (PAH) for land with a domestic end use is 50mg/kg. Speciated TPH and PAH were undertaken on samples in the vicinity of any predicted or encountered hydrocarbon contamination. Several occurrences of hydrocarbon odours were recorded during the trial pit and borehole investigations. Representative samples were scheduled for chemical analysis:

- A value of 2100mg/kg for total TPH range was recorded in one Trial Pit at a depth of 2.5m. The majority of the hydrocarbons corresponded to the range found in diesel. No corresponding elevated PAH concentration was recorded. Given that the measured concentrations only marginally exceeded the trigger level and that the contamination was located at significant depth, no remedial measures were recommended at this locality.
- During the drilling of one borehole olfactory and visual evidence of hydrocarbons was noted at the interface of the clay strata and the chalk at a depth of approximately 11m. TPH values in excess of 5000mg/kg were measured, with most of the hydrocarbons (around 4500mg/kg) belonging to the diesel range. No corresponding elevated PAH concentration was recorded. The results indicated slight to moderate contamination of the soils in this area but this was not considered to pose a significant direct risk to the development because the pollution was located so deeply and so remedial measures were not considered necessary.

Water samples collected from monitoring standpipes were tested for speciated TPH and PAH and were found to contain no significant evidence of contamination.

4. SUMMARY AND CONCLUSIONS

No evidence of widespread or pervasive contamination was encountered during the ground investigations undertaken at this site. However, some evidence of hydrocarbon contamination was encountered at the interface of the clay strata and the chalk. The likely source of the hydrocarbons was off-site to the north/north-east. However, there was no cost-effective method of preventing this migration onto the site. Furthermore the contamination was located so far below the ground surface that it was not considered to pose a risk to the residential development, human health or the environment at this site.

Because of the foregoing contamination, it was anticipated that during the development of the site hydrocarbon odours and perhaps visual evidence of hydrocarbons would be encountered. Such areas should then be investigated to decide whether the material could remain on site or whether a localised area had to be removed and taken to a suitably licensed landfill facility.

Under normal circumstances, there was no mechanism for free-phase contaminants to enter the chalk aquifer via vertical movement through the clay strata. This was due to the less dense nature of free-phase product compared with water. Free phase contamination could enter the chalk by introduction via deep boring or piling, but only where groundwater levels in the chalk were lower than those in the gravels and below the base of the confining clay strata.

The hazard identification and hazard assessment stages of the risk assessment process indicated that the site did not pose a hazard to the proposed end users. However, as a result of the public perception of the site there was significant local interest in the future of this plot of land. The area of the site is remembered as a former industrial area and local residents were concerned about development of the site. Therefore it was decided that, henceforth, the general public would be involved in the decision-making process about this site and that communication would be maintained between all parties to minimise the public concern. At the present time this site still remains undeveloped.

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