**Aly Karam & Nathan Venter**

# Affordable housing on contaminated land in Johannesburg

*Peer reviewed*


## Abstract

The intention of this article is to look at radon contamination; the various housing design solutions that may be implemented to overcome the problem; as well as the possibility that private developers will buy into this form of development. It is not sufficient to have designs and a population willing to live on this land if private developers are not willing to take a risk and develop these sites (Simons *et al*., 2006). By addressing these issues, three questions shall be answered:

1. What are the potential complications in building housing on mining dumps?
2. What are the practical solutions for dealing with housing in such areas?
3. Are private developers willing to develop contaminated land?

The actual cost of construction on the sites although important to the overall feasibility of development shall not be discussed. This component certainly needs further research in order to sufficiently grasp the willingness to develop on behalf of the developers. From the onset of this research, the developers showed some ignorance towards the issues of radon contamination. They did show willingness to develop certain types of designs, but the recommendation of the research is the need for education to facilitate the use of this contaminated sites.


Keywords: Johannesburg, contaminated land, radon, building with radon

Dr Aly Karam, School of Architecture and Town Planning, Private Bag 3, Wits University, 2050 Tel: (011) 717 7707, Fax: (011) 717 7739, Email: aly.karam@.wits.ac.za

Nathan Venter, Student in Urban and Regional Planning Program, Wits University, Mobile: 082 967 2196, Email: njv@mweb.co.za

## Abstrak

Die bedoeling van hierdie artikel is om na radon besmette terreine te kyk; die verskillende huis ontwerp oplossings wat geïmplimenteer kan word om die probleem te oorkom; asook die moontlikheid van privaat ontwikkelaars wat in hierdie tipe ontwikkeling sal wil belê. Dit is nie genoeg om ontwerpe en 'n populasie gewillig om op hierdie grond te bly te hê indien privaat ontwikkelaars nie bereid is om 'n risiko te neem en in hierdie terreine belê nie (Simons *et al.*, 2006). Deur hierdie sake aan te spreek sal drie vrae beantwoord word:

1. Wat is die potensiele komplikasies om huise op ou mynhope te bou?
2. Wat is die praktiese oplossings wanneer met huise in hierdie areas gewerk word?
3. Is privaat ontwikkelaars gewillig om hierdie besmette terreine te ontwikkel?

Die werklike konstruksiekoste van hierdie terreine alhoewel belangrik tot die oorhoofse lewensvatbaarheid van ontwikkeling sal nie bespreek word nie. Hierdie komponent vereis verdere navorsing om die bereidheid van ontwikkeling namens die ontwikkelaars genoegsaam aan te spreek. Uit die navorsing blyk dit dat ontwikkelaars die sake oor radon besmette terreine grootliks ignoreer. Ontwikkelaars het wel bereidwilligheid getoon om sekere tipes ontwerpe te ontwikkel. Die aanbeveling is dat daar 'n behoefte bestaan vir inligting rondom hoe om die gebruik van besmette land te fasiliteer.

Sleutelwoorde: Johannesburg, besmette bou-terreine, radon, bou met radon

## 1. Introduction

The history of housing developments for the majority of the population in Johannesburg and indeed the rest of South Africa have predominantly been lacking in tangible physical, social and economic success (Bond & Tait, 1997). The reasons unfortunately cannot be attributed to, or rather restricted to one cause. There is a multiplicity of factors that include poorly constructed top structures, insufficient quantity, as well as the lack of surrounding amenities and services. However the prevailing problem, and most significant, in many cases with these developments has been their location (Bond & Tait, 1997; Behrens & Wilkinson, 2003). The peripheral location of most new housing developments compounds the inherent problems associated with apartheid planning and its intention of racial segregation. The *Gauteng Housing Annual Report* for 2001/2002 supports this assertion and states that "The location of the majority of new housing projects since 1994 has not had a positive impact on changing the apartheid structure of the cities – in most instances; the poorest communities of Gauteng remain increasingly marginalized" (Gauteng Housing Department, 2000). However, there are solutions that are able to rectify the current situation provided they are not overlooked.

Housing does offer the opportunity to integrate cityscapes as it constitutes a large percentage of the land use in the urban area. This coupled with Johannesburg's insatiable requirement for affordable and moderate priced housing will make it one of the integration tools as the city continues to develop and the need for housing continues to grow. However, there are limitations to the ability of this mechanism to integrate, namely its location. This calls for the pursuit of alternative ideas for well located underutilised land in order to create viable communities from both a social and economic standpoint.

The former mine dumps in the South and South western areas of Johannesburg (see figure -1) provide a partial solution (Sihlongonyane & Karam, 2003). The land is largely owned by iPROP, which is a private company, holding land previously owned by the Rand mines in Johannesburg and Ekurhleni. This land remains to a large degree underutilized despite its good location in terms of proximity to job opportunities and bulk infrastructure. The land forms part of the mining belt that extends about 80 km east-west and 3 or 4 km north-south, as such it is a large parcel of land. Some of the dumps are currently undergoing re-cycling and some of the dumps are being cleared (figure – 2). A majority of this land is locationally suitable for development. The research identified this area for the research as it is close to several existing developments and is a natural extension for ties with the city centre and several southern neighbourhoods. The dumps in these areas are earmarked for clearing in the near future and development is contemplated by the owners of the land.

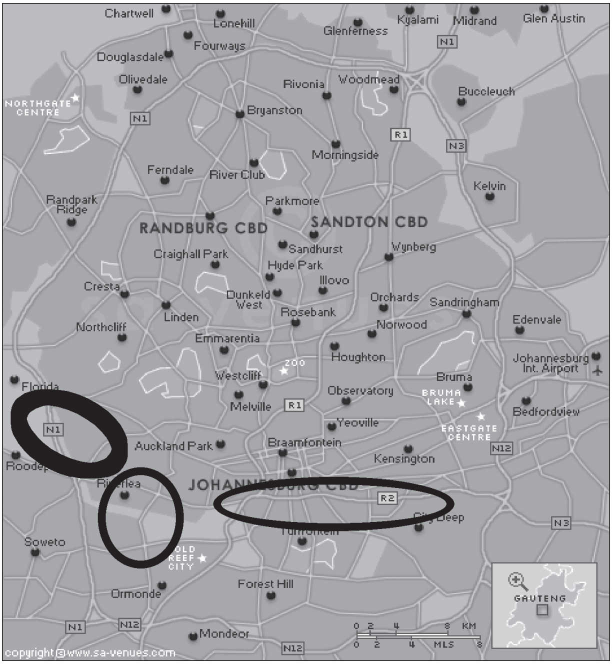



Figure 1: Location of mining lands in relation to Johannesburg CBD and Soweto.
Source: South Africa explored, 2007: online

Figure 2: Part of reclaiming mining dumps in south of Fortsburg, Johannesburg, for use as storage area
Source: Karam, 2007: own picture

However, there are prevalent complications with the land as a result of the previous gold mining activity. These complications do not prevent development but rather pose difficulties and limitations to developing the land. In most gold mining areas, the land is contaminated with a radioactive gas known as radon (CCOHS, 2005: online). Radon is an odourless, tasteless and naturally occurring radioactive gas. It occurs as a result of the decay of Uranium; a heavy metal that accompanies gold in some mining areas (CCOHS, 2005: online). However, under certain conditions radon can prove to be hazardous to human health (CCOHS, 2005: online). Therefore, it is important to plan and design in accordance with radon gas as this contaminant cannot be entirely removed. Despite this, development should not be prevented from occurring. There are several developments around the world that have utilised radon contaminated sites for the purpose of housing.

Due to contamination, the design aspects of development are fundamentally important to the long term success, future and indeed health of the communities that shall occupy the sites. If carelessness is shown with regard to the conception of design solutions, one may find that the radon gas accumulates and aids in the development cancer, more especially lung cancer, within the population.

Currently there are several developments that although inhabited by people display levels of radon contamination that are detrimental to the health of its occupants (Colgan & Gutiérrez, 1996). In addition, the building materials used have acted as a catalyst in increasing the levels of radon within the houses. (Rydock *et al*., 2001). These two circumstances may not prevail if the afore mentioned objective of sustainable human settlements is to be realised. This in turn makes the design component exponentially more important to the overall success of the future development of the former mine tailings.

The need and demand for the development of affordable housing in Johannesburg is growing and the complications with the land have been identified. On the housing side, between 2001 and 2004 the households living in formal housing increased by 0.01 percent while the annual growth in population during the same period was 2.5 percent (Cities Network, 2006: online). This leads to an increase in the households living in informal housing by 16.21 percent during the period 2001 and 2004 (Cities Network, 2006: online). Simons *et al*. (2006) studied the benefit-cost of such a project with the expenses of the land remediation and some of the discounted rates on the housing. Simons *et al*. (2006) concluded also that people are willing to live in such location given a certain discount to the price of the units. One party that has not been consulted on whether they would be willing to take the risk of building in such land, are the developers. This article deals only with the developers' perspective but acknowledges that the city has developed some parcels for commercial use and could involve itself in residential developments on the sites discussed. Another reason for concentrating on private developers is the fact that the land is in private ownership.

In this article the concentration is on the review of some appropriate designs for radon contaminated land and survey seven developers in the Johannesburg area involved in producing different types of housing. The basic question was whether they would be willing to produce one or more of these types of housing in these locations. This study should be treated as exploratory as there are no other studies on types of designs likeability in Johannesburg to assist in determining from a developer's perspective the suitable type.

The intention of this article is to look at radon contamination; the various housing design solutions that may be implemented to overcome the problem; as well as the possibility that private developers will buy into this form of development. The latter will give an opinion regarding whether private developers are willing to actually develop these sites. It is not sufficient to have designs and a population willing to live on this land (Simons *et al.*, 2006) if private developers are not willing to take a risk and develop these sites. By addressing these issues three questions shall be answered namely:

1. What are the potential complications in building housing on mining dumps?
2. What are the practical solutions for dealing with housing in such areas?
3. Are private developers willing to develop contaminated land?

The actual cost of construction on the sites although important to the overall feasibility of development shall not be discussed. This component certainly needs further research in order to sufficiently grasp the willingness to develop on behalf of the developers; neither will the moral nor ethical issues arising from health problems related to living in previously contaminated land. Therefore the recommendation is to utilise this article as a platform from which further studies and research can be launched.

The United Nations Stockholm Declaration on the Human Environment in 1972 declared that protection of human health is the most important aspect when building in sites with potential hazards to human health. Accordingly, this research acknowledges the importance of this issue, but does not discuss the ethical or moral issues associated with building on hazardous sites. The research concentrates mainly on technical aspects rather that the important for mentioned issues. Having mentioned these issues, it is important to note that there have been several developments in other countries around the world on Radon contaminated sites, mainly in Norway and the United Kingdom (Denman *et al.*, 2000).

## 2. Radon: the Contaminant

Uranium, the source element of Radon gas is associated with gold mining in Johannesburg. This radioactive gas arises as a result of the natural decay of Uranium-238 and radium-222 which can be found in soil, rocks, and water as well as gold deposits in many parts of the world (Denman, *et al.*, 2000). It is an odorless, tasteless radioactive gas that does have the potential to cause cancer (Kreswki *et al*., 2005). Despite this however it remains harmless when outdoors due to its rapid dissipation.

The acceptable level for radon exposure according to the National Nuclear Regulator is around 0.4pCi/L (Strydom *et al*., 2002). However when confined to smaller areas and allowed to accumulate and inhaled continuously for over 20 years, the risk of contracting cancer is increased substantially. It is important to keep in mind that radon levels, whether outdoors or indoors are subject to seasonal and daily fluctuations, which have been known to increase in the evenings and decrease during the day (Rydock *et.al.*, 2001; Strydom *et al.*, 2002). It is interesting to notice that the World Health Organization (2005) acceptable safety threshold are at levels between 2 – 4 pCi/L putting the possibility deaths from lifetime exposure at between 2 – 7 deaths per thousand population, which is significantly higher than the National Nuclear Regulator. Naturally, deaths will be less if exposure is less than a lifetime. Due to lack of information on the health implications of radon in South Africa, American research shall be utilised in order to grasp some understanding of the link between radon exposure and cancer as well as relating it to other situations (table – 1).

It is important to move toward discussing the relationship that exists between radon and mining practices in Johannesburg. The city has a long history of gold mining south of the CBD and north of the southern suburbs and as a result a by-product, as well as their various implications, namely radon contamination occupy valuable space that is in close proximity to bulk infrastructure, work opportunities, recreation and shopping. This contamination may be attributed to the alluvial heavy minerals, namely gold and uranium, which are found together in some mine areas in the city. These areas, particularly those that have heavy metal mining, have naturally high levels of radon (Simons *et al*., 2006).

The implication of this higher rate of contamination and subsequent exposure to those living there requires an intervention to make the areas safe for human occupation. Therefore the design of housing projects constructed on the mine dumps becomes exponentially more important and relevant.

Table 1: Radon risk if a person has never smoked

| *Radon Level* | *If 1,000 people who never smoked were exposed to this level over a lifetime*...* | *The risk of cancer from radon exposure compares to**...* | *WHAT TO DO:* |
|---|---|---|---|
| 20 pCi/L | About 36 people could get lung cancer | 35 times the risk of drowning | Fix your home |
| 10 pCi/L | About 18 people could get lung cancer | 20 times the risk of dying in a home fire | Fix your home |
| 8 pCi/L | About 15 people could get lung cancer | 4 times the risk of dying in a fall | Fix your home |
| 4 pCi/L | About 7 people could get lung cancer | The risk of dying in a car crash | Fix your home |
| 2 pCi/L | About 4 persons could get lung cancer | The risk of dying from poison | Consider fixing between 2 and 4 pCi/L |
| 1.3 pCi/L | About 2 people could get lung cancer | (Average indoor radon level) | |
| 0.4 pCi/L | | (Average outdoor radon level) | |
| Note: If you are a former smoker, your risk may be higher.<br>* Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003). USA data<br>** Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports. | | | |

Source: Environmental Protection Agency, 2006: online.

According to Ellis (2005), the National Nuclear Regulatory allows workers in mines to be exposed to the internationally accepted levels of Radon of 20mSv/a. The NNR still uses the old measurement of the dose but it is equivalent to the internationally acceptable standards.

## 3. Housing Designs for Contaminated sites

The introduction illustrated a need to develop good quality, well located and affordable housing, therefore this section uncovers the resistance techniques and design elements that will enable this form of residential property to be constructed on the contaminated sites. The list below indicates the ways in which radon enters the house and will subsequently aid in the explanation of the resistance techniques implemented (Environmental Protection Agency, 2006):

- Cracks in solid floors;
- Construction joints;
- Cracks in walls;
- Gaps in suspended floors;
- Gaps around service pipes;
- Cavities inside walls; and
- The water supply

It is important to keep in mind that radon dissipates in the air and if the ground floor is kept ventilated, it will decrease, almost to nothing, the radon infiltrating to the first floor over the ground floor which as will be discuss could be used for parking or commercial.  Figure 3 shows the list.

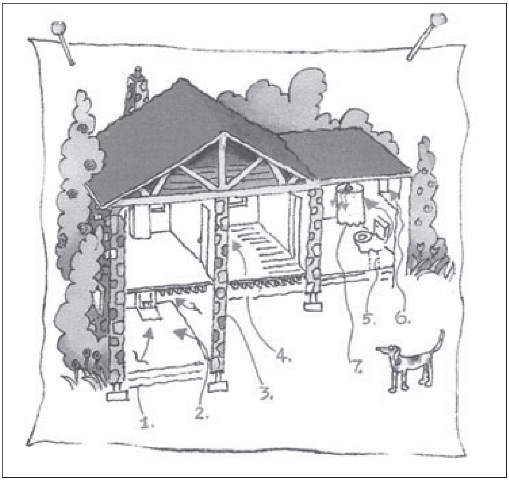



Figure 3: Ways in Which Radon can enter the House
Source: Environmental Protection Agency, 2005: online

### 3.1 Resistance Techniques to Aid in the Dissipation of the Gas

In order to stop radon from entering into a dwelling unit, there are resistance techniques that may be utilised. The first is a gas permeable layer which allows the free flow of the gas beneath the home. It comprises of a ten centimetre layer of clean gravel and is utilised in basement or ground level homes. (Office of Air and Radiation, 2003: online). Plastic sheeting is then placed on top of the gas permeable layer on ground floor units and acts as a blanket preventing the gas in the soil from entering the house.

The second technique is sealing the cracks and other openings in the slab or foundation. Sealing these cracks limits the flow of radon gas into the house thereby lowering the possibility of cancer development (Office of Air and Radiation, 2005: online). However this technique should not be used in isolation and must incorporate other reduction and resistance techniques such as active or passive sub-slab suction. Sealing has the advantage of allowing more cost efficiency as well as effective dissipation of radon.

Natural ventilation exists in all homes through windows, doors and vents. This forms the third technique, although not the most effective, of alleviating the build up of radon (Office of Air and Radiation, 2005: online). This technique should be regarded as a temporary solution because once these openings have been closed the radon levels will return to normal within 12 hours. Accordingly, it is important to monitor the levels of radon in the units to ensure it does not rise to dangerous levels and stays within the required approved limits.

Preventing the build up of the gas is important in new and existing homes and allows for people to live far healthier lifestyles. However, this only forms a component of the construction of the housing. The designs proposed, with the exception of ground level housing, all have elements that are there to dissipate the gas without the need to solely rely on preventative and reductionist techniques. The following is a list of the proposed designs. Each shall be investigated individually and explored in detail:

- Normal single-stand ground floor house;
- Normal single stand house with a crawl space;
- Commercial use on the ground floor with housing above it;
- Cluster developments with parking on the ground floor;
- Town houses with parking on the ground floor; and
- Single stand development with parking on the ground floor

### 3.2 A normal single floor house with or without a crawl space

Both of these design typologies pose considerable challenges in terms of development on contaminated land because of their inability to dissipate the radon gas. Consequently, they require the greatest number of mechanisms to make the houses safe for occupation. The first of these, which is the least effective, is using normal ventilation through open doors and windows. This method may help only if employed with other techniques.

The second of these is utilising Active Sub-slab Suction under the structure. This entails placing a suction pipe beneath the floor slab into a bed of crushed rock or alternatively the pipe is inserted under the slab from outside the dwelling. More than one pipe may be employed depending on the extent of radon gas build up and the size of the building. Once this has occurred a suction fan is placed on the pipe and subsequently draws the gas from below the slab and dissipates it into the air.

The other mechanism is using Passive Sub-slab Suction which is similar to active suction however it does not employ a fan and rather relies on the natural air pressure differentials and air currents that exist to dissipate the gas. This technique although simpler and easier to maintain is not as effective as the more mechanical option. A mechanism specific to crawlspace developments in conjunction with the resistance techniques discussed previously is making use of active or passive crawlspace ventilation. Firstly active ventilation relies on a fan to blow the gas from below the structure. This is the most effective but not necessarily the most cost efficient because of the need to maintain the fan. Secondly is passive ventilation which, rather than a fan, exploits the natural circulation of air within the crawlspace.

Preceding any implementation of a particular technique or mechanism is the need to know the level of radon in the area. Failure to do so may result in either the technique being superfluous or ineffective in coping with the gas.  It is important to add that single story dwellings are the least cost-effective in terms of building cost and land cost, so this type of building might not be as effective when considering affordable housing options.

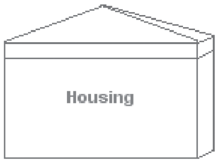



Figure 1: Single stand construction on the ground floor without crawlspace

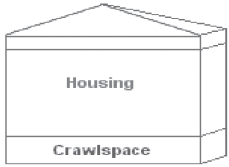



Figure 2: Single stand construction on the ground floor with crawlspace

## 3.3 Commercial or parking use on the ground floor with residential above

Commercial use on contaminated land is not new in Johannesburg. It has been developed successfully on several sites south of the CBD, such as City Deep. It is an economically attractive form of development because the cost of development may be recovered through rent and other commercial activity.

This form of development does not require the mechanisms implemented in the previous two design typologies, unless the levels are high. The reasons for this is with commercial use people are not constantly inhaling the gas as they would be with residential use (figure 3). The addition of the residential component is not only advantageous in terms providing affordable housing it also creates a vibrancy that is lacking in so much of Johannesburg's and indeed South Africa's housing developments. Therefore by ensuring a good land use and density mix, the prevention of inward looking, mono focused and private car oriented neighborhoods may be achieved.

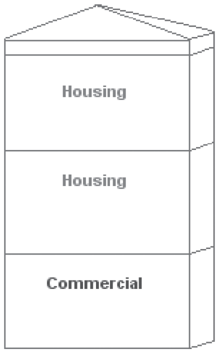



Figure 3: Three storey residential construction with commercial or parking on the ground floor

## 3.4 Parking on the ground floor with residential above

The fourth design typology utilises the ground floor as parking and the floors above it as residential. The proposal is that the building go no higher than the third floor or that it be mixed density however these are subject to the requirements of the private developers as well as what the market is able to bare. This design may take various forms as is illustrated in the following figures however it still retains the basic design elements.

This fourth design is effective in dissipating the gas because it does not implement a use on the ground floor. This in turn aids in preventing a gas build up and therefore allows it to disperse. Research conducted by Simons *et al*. (2006) indicates that about 87 percent of their respondents indicated willingness to live in apartments. Due to the contamination and the simplicity of this form (requires no prevention techniques or mechanical dissipation measures) of construction this would be a good alternative.

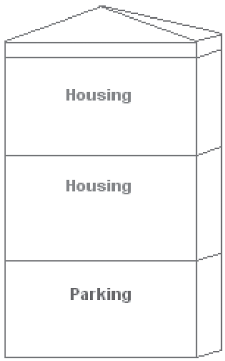



Figure 4: Ground floor as parking and the floors above it as residential

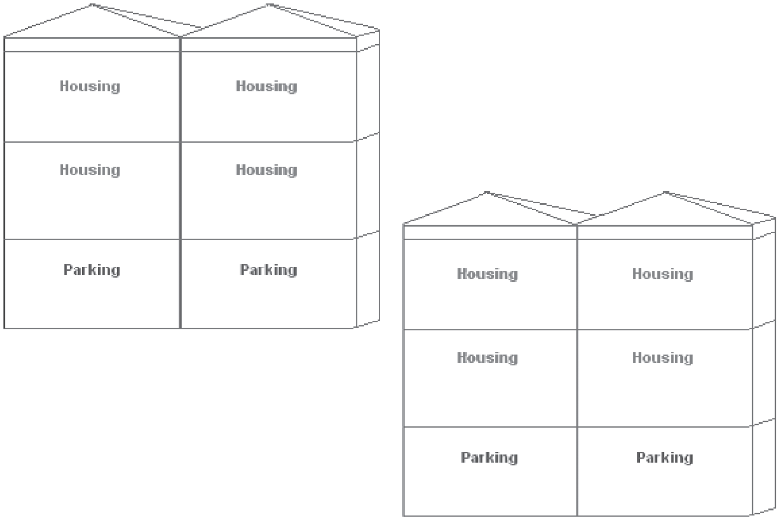



Figure 5: Three storey cluster developments with parking bay on the ground floor This design will have island developments in the sense that the two structures will share a common wall.

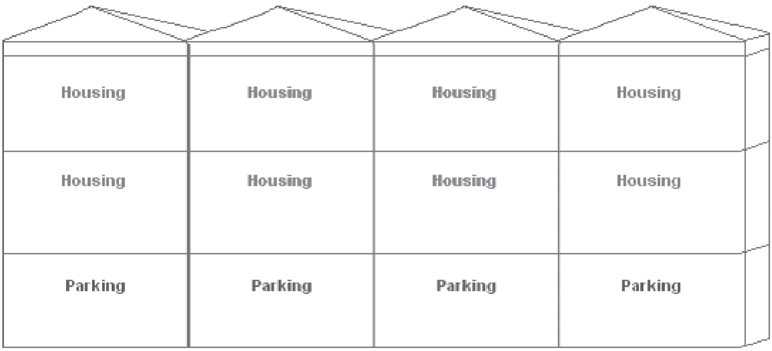



Figure 6: Three storey town house development that shares a common wall and has parking bay on the ground floor

This type might be the most economical in terms of cost and land usage but it then depends on the market whether this type would be acceptable. Having open parking underneath helps in dissipates radon and protects the above housing.

It is clear that houses remain fundamentally porous to radon infiltration, if resistance techniques are not employed. However if these techniques are incorporated into the design typologies discussed previously it becomes apparent that contamination levels may be significantly reduced and controlled.

The intention of this section was to highlight the various resistance techniques as well and design typologies necessary in order to allow for the development of the former mine tailings into successful and sustainable human settlements that would not endanger human life.

## 4. The Opinions of Private Developers

The following section is from seven interviews conducted with a range of private developers and one banking institution from Johannesburg. The interviewees' involvement in residential development was a key motivating factor for the purpose of this research as too was the size of the operations and projects undertaken. Therefore, smaller lesser known developers and large better known developers were also pursued. These were important elements that allowed the collection of the differing opinions on developing the sites as well as the different design proposals that would best suit their needs.

The interviews were conducted in person on a one on one basis in order to obtain more specific information as well as to provide an excellent platform from which the opinions of the developers could be collected. The questions regarding the most desirable design typologies were closed questions. However questions around the perceptions of the effects of contamination and overcoming these perception as well as Radon were left open to allow free conversation.

### 4.1 Awareness of Radon

The responses to the surveys by private property developers in Johannesburg showed some interesting results with regard to radon as well as its subsequent health implications associated with exposure. Firstly of those surveyed only 28 % were aware of radon. The reason for the lack of awareness can be attributed to a shortfall of availability of information with regard to this type of contaminant especially within the housing developers. Accordingly, all those surveyed were unaware of the health implications of prolonged exposure to the gas. This can be attributed to the fact that all except one of the developers surveyed have ever worked on contaminated land. In that case the developer was not responsible for clearing the contaminated land; rather he received the land ready for development. Knowledge of the land is important if it is going to be developing it.

## 4.2 Responses to the Different Design Typologies

In the survey, developers were asked to give their opinion on the design typology they found to be most attractive for the contaminated sites. A rating system was utilised in order to gauge their responses with 1 being the most attractive, 3 being middle attractiveness and 5 being the least attractive. The following results were obtained.

The **first and second** design typologies (with one story residential, figures 1 and 2) proved to be the most unpopular with the developers, scoring a four (not attractive) and three (middle attractiveness) respectively, despite the technology that exists to allow construction. This may be ascribed to the number of techniques required to enable development such as active and passive sub-slab suction as well as the gas permeable layer and in the case of the crawlspace design, active or passive ventilation. The perception is that these measures will inflate construction costs, drive down profit margins and create a barrier to development.

Another significant weakness is the low density of this form of housing. Amongst those surveyed there was unanimity in the need for the highest allowable density. The motivation behind this response is that construction costs will be lowered and greater number of people will be housed on a smaller area therefore reducing the acquisition of land.

The **third design** (two story residential above commercial, figure 3) obtained a three rating (middle attractiveness). This design requires no specific techniques to dissipate the gas unless the levels are high, in which case active or passive sub-slab suction could be utilised. This design got varied responses from the developers and therefore showed the greatest inconsistency. Despite the average rating being three, it is not an accurate representation of the overall opinions of the developers.

The range of responses is surprising considering the opportunity to place commercial features on the ground floor without having to implement any specific design techniques. This typology affords developers the opportunity to recover costs by renting to tenants and thus allowing a constant flow of income. This design requires greater more in depth studies in order to ascertain the reason for the discrepancies and be looked at on an individual basis.

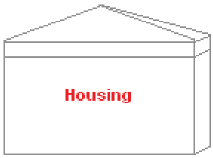
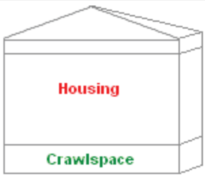
The fourth, fifth and sixth design possibilities are part of the third design, they all utilize similar characteristics in that they have parking on the ground floor with housing above it and do not have to employ any specific techniques to dissipate the gas. The air differentials that exist allow the gas to be dispersed naturally.

The **fourth design** (residential with parking underneath, figure 4) that proposed detached cluster units received an average rating of 2.4. There was only one developer that gave it a rating of five otherwise the rest were constant. It does not receive high ratings but better than middle attractiveness.

The **fifth design** (three story cluster with parking underneath, figure 5) proved to be the most popular for the developers. It received an average rating of 1.7. This design advocated town house developments, which shared a common wall. The ratings given by the developers were very consistent which illustrates the attractiveness of this form of development.

The **sixth design** (three storey town house development that shares a common wall and parking underneath, figure 6) was the second most popular for the developers. The design is a semi detached housing development. The scope of responses was very narrow, its average rating was 2.1, indicating great reliability in the opinions of the developers.

Table 2: Summary of the designs and the ratings

| *Design* | | *Rating* |
|---|---|---|
|  | Design 1 | 4.0 |
|  | Design 2 | 3.0 |

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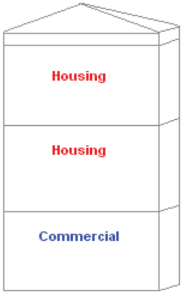
<tr><td>
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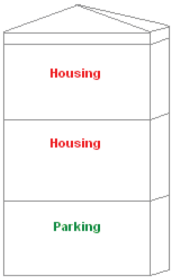
<tr><td>
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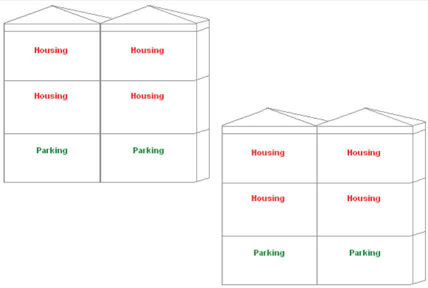
<tr><td>
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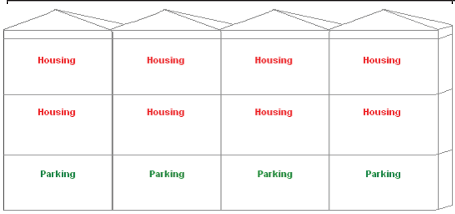
<tr><td>
</td><td>Design 6</td><td>2.1</td></tr>
</table>

The popularity of the basic components of these designs answers the research question conclusively. Although there were discrepancies between the three proposals within this design in terms of their popularity with the developers, they were still the best received. The fifth design that utilises a common wall proved to be the most popular of the designs and therefore by logical deduction would most likely be constructed.

A mixed density development utilising any one of the last three designs was suggested by one developer which seems to be the most appropriate for the site. It will break the monotony of a single height development and allow a range of different housing styles and sizes. For example bachelor flats, loft apartments, 2 bedroom flats or 1 bedroom flats. This creates greater flexibility for the consumer as well as the developer.

## 4.3 Findings from Developers

First, the lack of awareness of both radon and the resulting health implications can be attributed to a shortage of available information and more importantly a lack of a drive to develop this land. Once there is a drive to utilise the land, developers will have to improve their knowledge regarding the radon gas and its remediation techniques. However, the general consensus amongst the developers was that the land could be developed, and more significantly for residential purposes.

Second, and most importantly, negative perception is a factor that may determine whether or not private developers are willing to develop the sites under investigation. Despite the land being safe for occupation, provided the appropriate measures are taken, the mere notion of contamination is enough to create enough bad sentiment amongst potential tenants that they will not occupy the property. This makes it necessary for greater marketing of the land in order to educate the public on the possible health risks but more importantly to make them aware that occupation of the sites is both safe and indeed possible.

Finally, the design typology that fulfils the requirements for overcoming contamination and makes the sites viable for development was the fourth design. This design utilises a vacant ground floor that will be used for parking and shares a common wall with the other townhouses. The reason for its popularity can be attributed to three things:

- The simplicity of construction, because it requires no specific dissipation techniques unlike the first and second design;
- It fulfils the goal of achieving a healthy environment for the tenants that shall live there; and
- The density requirement of developers is fulfilled with this typology because it supports multi storey construction.

Coincidentally the developers' preference is compatible with the design typology that is easiest to maintain, in respect to resistance techniques, and subsequently consistently maintains the lowest levels of Radon contamination.

## 5. Recommendations

From the previous research the following are recommendations for a shared responsibility between government, developers, in some cases banks, and possibly the NNR. As mentioned earlier the benefits from locating residential use on such land is far reaching and could not be overlooked, but naturally the risk on human life is also very important and cannot be underestimated.

- There is a need to educate the public as well as developers on the risks of developing and living on contaminated land. This education has to be in simple non-technical terms and widely available. The demand for development of the sites is currently, not high but as the city expands it is likely to become increasingly attractive. Therefore the education process can begin so that a gradual shift of perceptions is achievable.
- The negative perception associated with contamination may prevent any form of development occurring. However with the improved education, advocated in the above point, as well as the promotion and marketing of the former mine dumps as an investment, this can be overcome.
- It is important that the sites are developed for residential purposes and not solely for commercial or industrial applications. At present the city has a tremendous population living on the periphery, which makes it difficult for them to access jobs and basic amenities, such as water and sewerage. By allowing these people the opportunity to live and work in the city they have a better quality and standard of life. There is enough commercial space in the inner city to satisfy demand and in order to allow the creation of job opportunities. If the former mine tailings were also developed for these purposes, there would be a tremendous oversupply.

## 6. Conclusion

The housing developments constructed by private developers thus far have been ineffective in targeting the affordable market; they usually target the middle class and mostly located on the periphery of the city (Beavon, 2004). The most prominent problem contributing to the inadequacy of these developments can be attributed to poor location in terms of closeness to infrastructure, jobs and amenities.

However this article has identified candidate sites for development that are well located in terms of basic services, work, recreation and shopping.

In spite of this good location there is one substantial weakness, namely radon contamination that has occurred due to the gold mining that has taken place there. This contaminant poses two significant challenges that must be overcome or managed to make the sites safe for occupation. The first of these is that it can lead to some serious health problems such as cancer if measures are not introduced to manage the obstacle. The radioactivity cannot simply be cleaned and the problem disappears like many other forms of contamination. The second is the negative perception or stigma attached to development on contaminated land. Despite all the designs proposed being able to overcome this problem successfully there is no guarantee people will buy the property. Therefore marketing strategies will have to be formulated in order to educate the public on the type of contamination, the health risks as well as the safeness of the sites once development has been concluded.  It is important now to move toward answering the questions posed in the introduction in order to conclude the article.

There are a range of complications that exist with regard to the construction of affordable housing on the former mine tailings. The most substantial of these is contamination, more specifically the radioactive gas radon. This gas, when confined to a small area and at a higher than normal concentration does pose a health hazard to humans. However through appropriate housing design this risk is narrowed considerably.

In terms of practical solutions for dealing with housing in such areas, the aforementioned housing design typologies in association with the resistance techniques advocated, such as sealing floor slab cracks, creating a gas permeable layer and allowing for natural ventilation, form the practical solution to managing the contaminated sites. These sites cannot be cleared of the contaminant so the best solution is to create an environment that manages the situation

The willingness to develop the land is currently not forthcoming on behalf of the private developers. The abundance of sites that do not pose the environmental and economic challenges that the former mine tailings do, negates the need for its development. However as the city continues to expand and these opportunities become less plentiful other prospects will be pursued. Currently land is available that offers fewer complications thus affording easier construction. This in turn extends to the motivation of these three developers in regard to residential usage for the land. If land is abundant and more attractive alternatives exist then the need to utilise such sites is negated.

The development of the mine dumps is important in providing the market with greater diversity and offering new home owners or people wanting to leave the low income areas an opportunity to do so. The contaminated areas can undercut the market and could potentially fill a niche.

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